AASCTF PENANG SMART MOBILITY MICRO-SIMULATION MODEL DEVELOPMENT

TRIAL AREA MODEL CALIBRATION REPORT

JUNE 2022

ASEAN
AUSTRALIA
SMART CITIES
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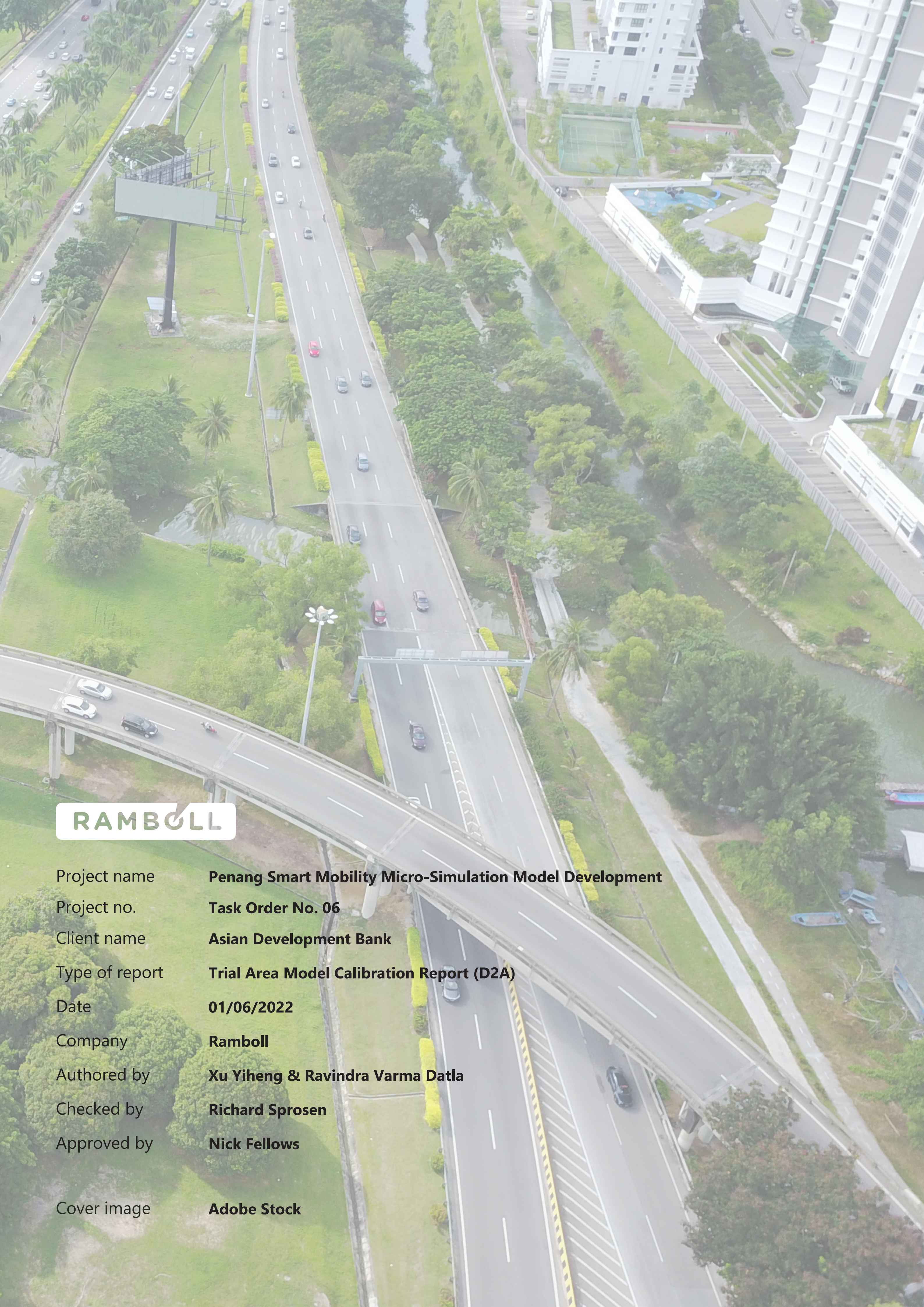
ADB



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Company	**Ramboll**
Authored by	**Xu Yiheng & Ravindra Varma Datla**
Checked by	**Richard Sprosen**
Approved by	**Nick Fellows**
Cover image	**Adobe Stock**

CONTENTS

TABLES

FIGURES

INTRODUCTION

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1.1 BACKGROUND

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

This Pilot Project will involve 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.

This report presents the calibrated Vissim micro-simulation model results. 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 ORGANIZATION OF THE CALIBRATION REPORT

Following this introduction, the report is structured as follows:

- Section 2 provides a description of trial study area, the existing traffic condition, and the provision of the surrounding transportation network and study methodology.
- Section 3 provides the model parameters used in developing Vissim model and the demand inputs used in it.
- Section 4 summarizes the model calibration results.
- Section 5 provides a description of the model results.
- Section 6 presents the next steps of this study.

STUDY AREA

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2.1 STUDY AREA AND BOUNDARY

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.

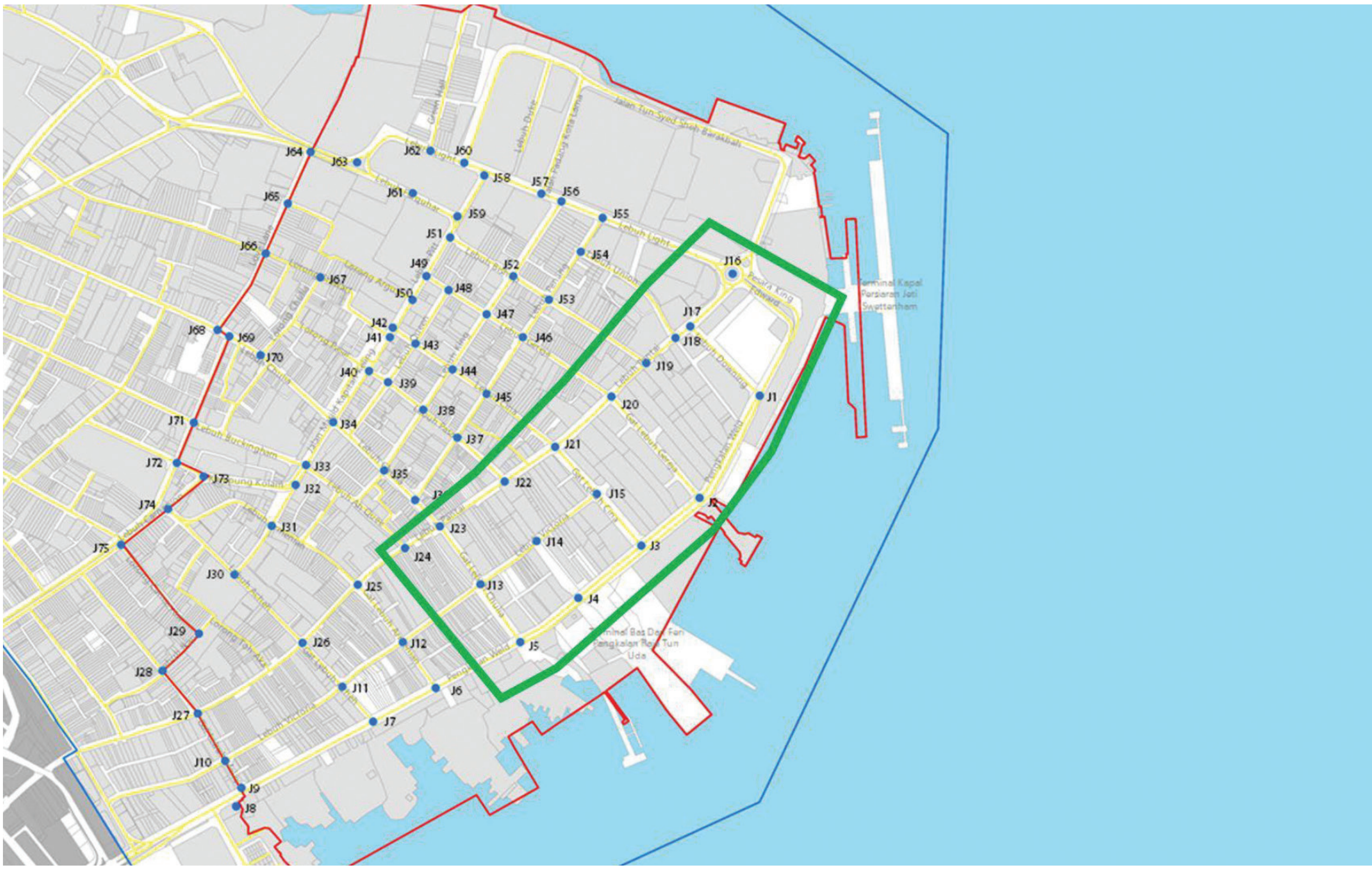


Figure 2.1 Model Area

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.

2.2 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.

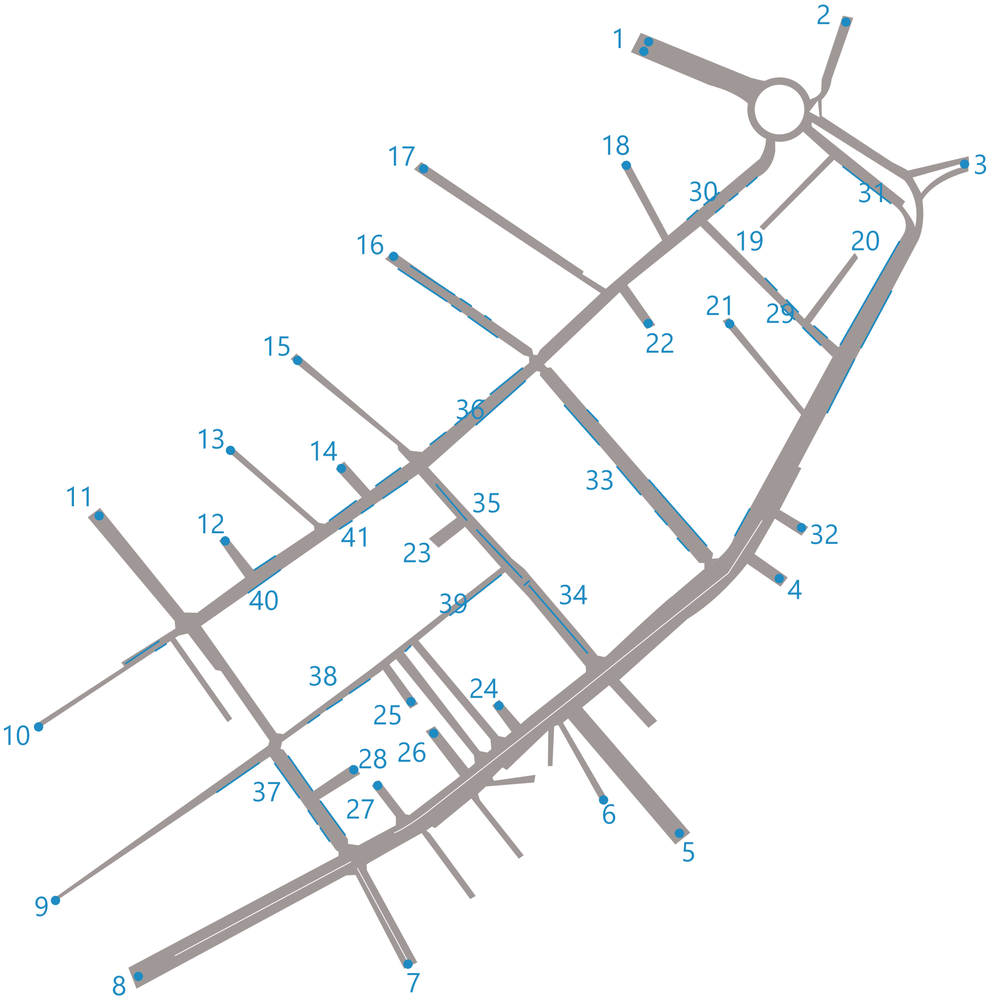


Figure 2.2 Zoning System

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 2-1 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	Pa rking 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
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			

2.3 MODEL TRAFFIC SURVEY INPUT

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 trial 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
- Junction13: Lebuh Victoria/ Gat Lebuh Chulia
- Junction14: Lebuh Victoria/ Gat Lebuh Pasar
- Junction15: Lebuh Victoria/ Gat Lebuh China
- Junction16: Lebuh Pantai/ Pesara King Edward
- Junction17: Lebuh Pantai/ Lebuh Downing
- Junction18: Beach Street/ Lebuh Union
- Junction19: Beach Street/ Bishop Street
- Junction20: Beach Street/ Gat Lebuh Gereja
- Junction21: Beach Street/ Gat Lebuh China
- Junction22: Beach Street/ Gat Lebuh Pasar
- Junction23: Beach Street/ Gat Lebuh Chulia

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

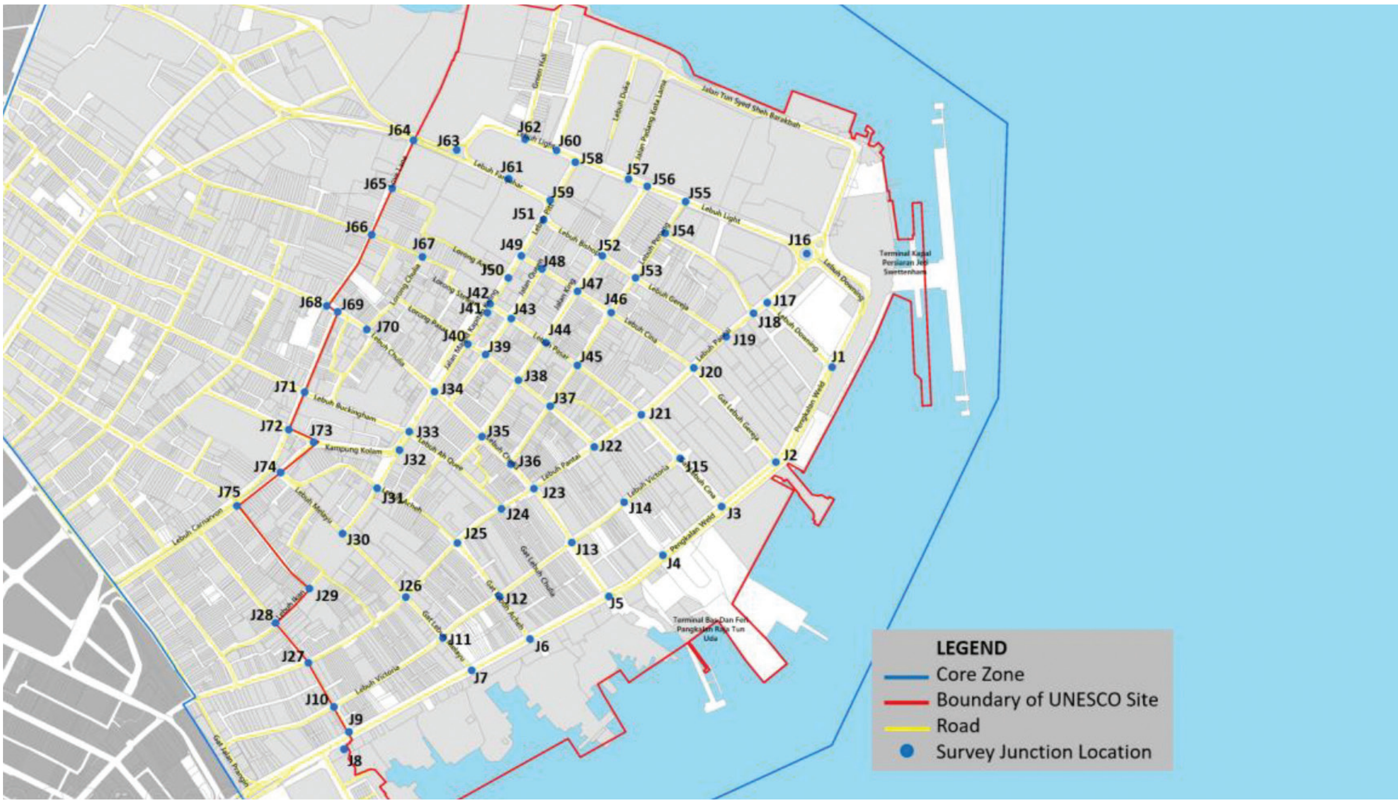


Figure 2.3 Existing Junctions Surveyed in Study Area

Traffic counts results were analysed 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 2-2 Survey Peak Hour

	Surveyed Time	Peak Hour Traffic
Weekday AM	07:00 to 10:00	08:15 to 09:15 (Traffic flows shown in Figure 2.4 to 2.8)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (Traffic flows shown in Figure 2.9 to 2.13)

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.

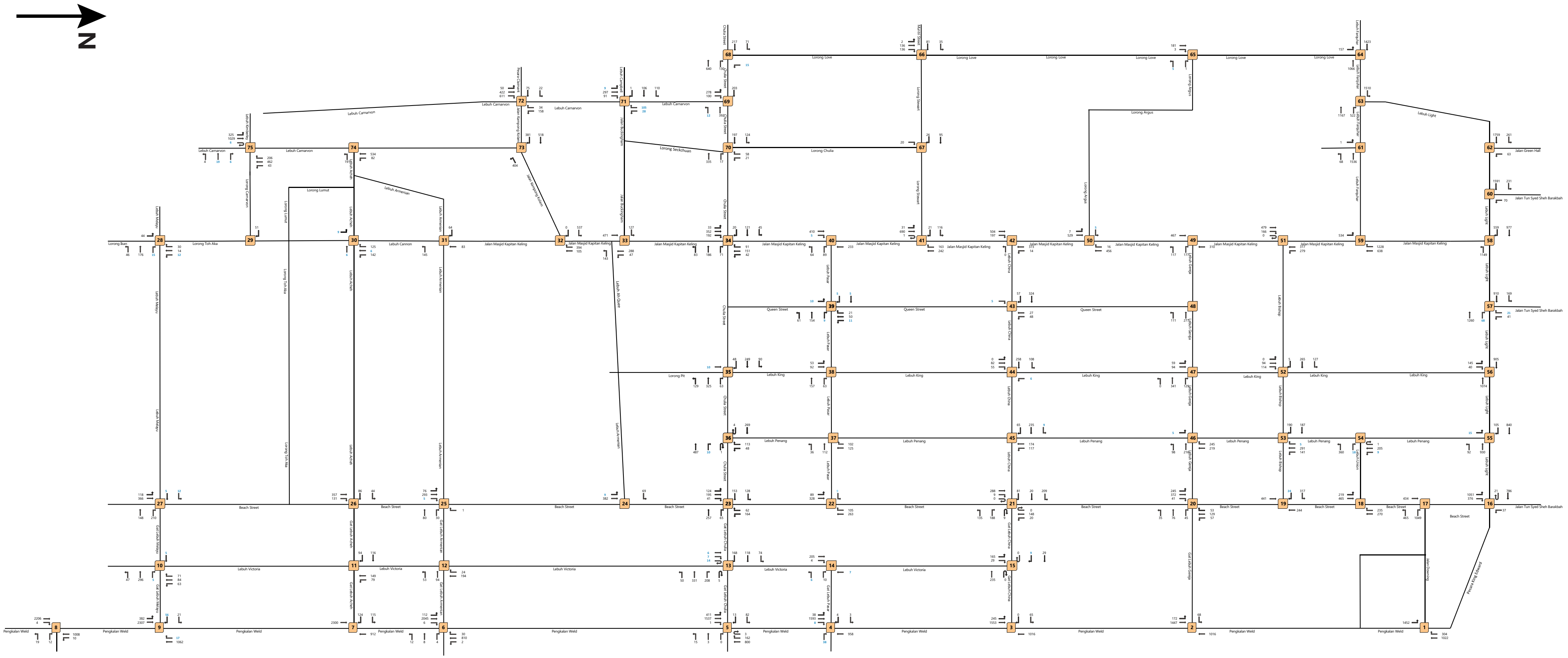


Figure 2.4 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Full

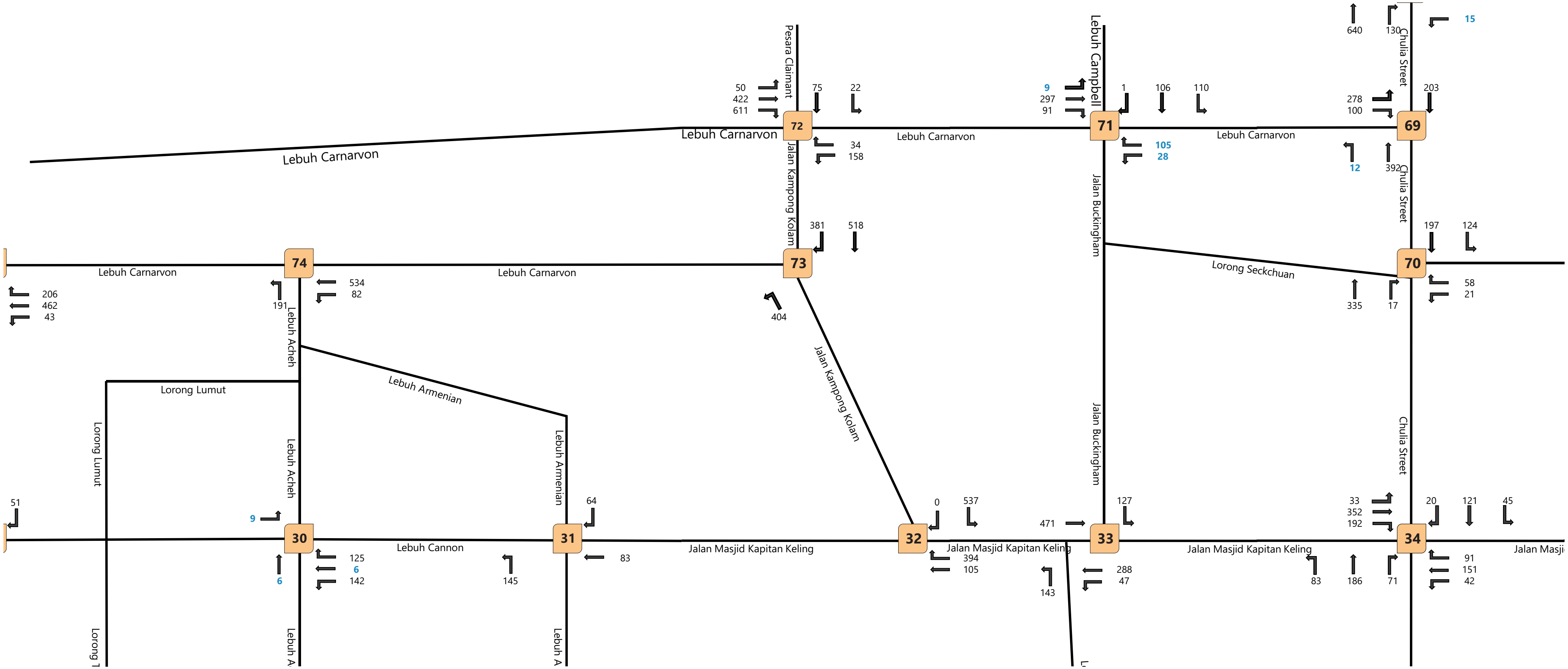


Figure 2.5 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northwest Section

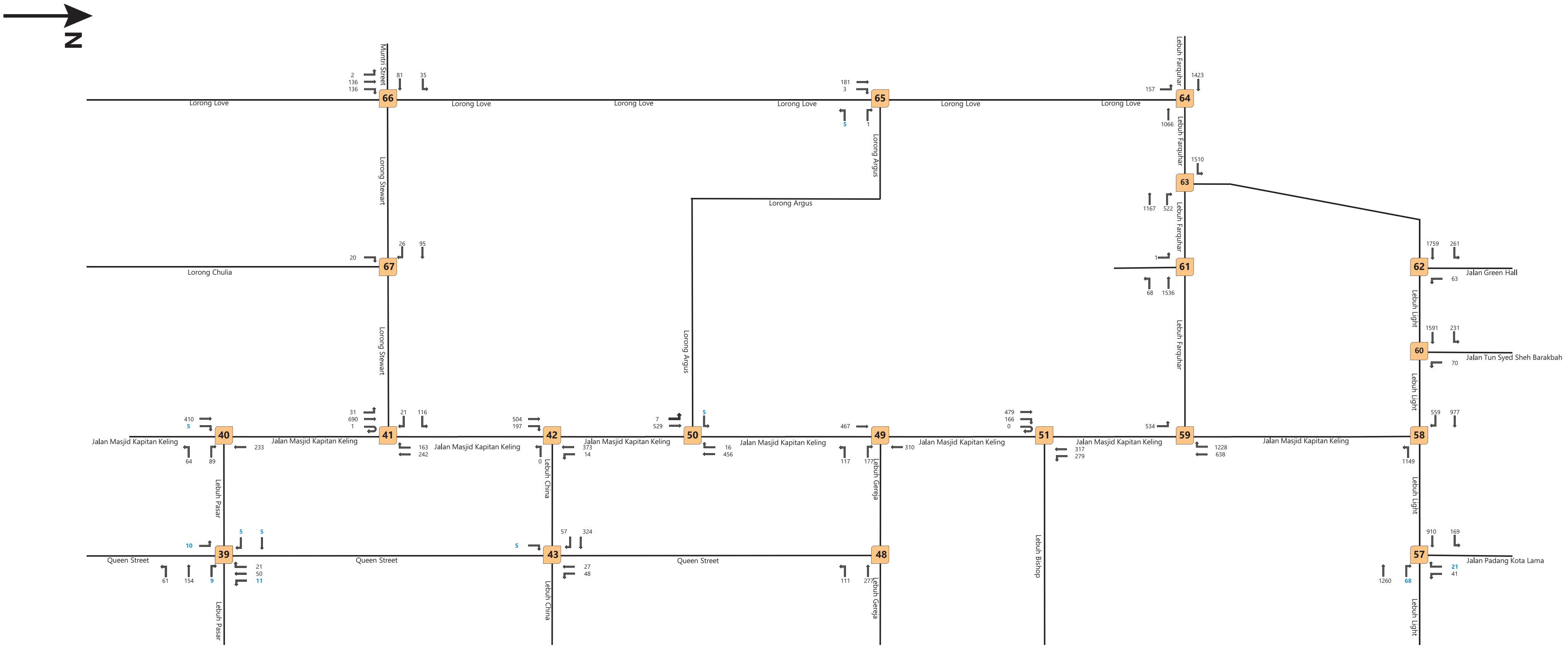


Figure 2.6 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northeast Section

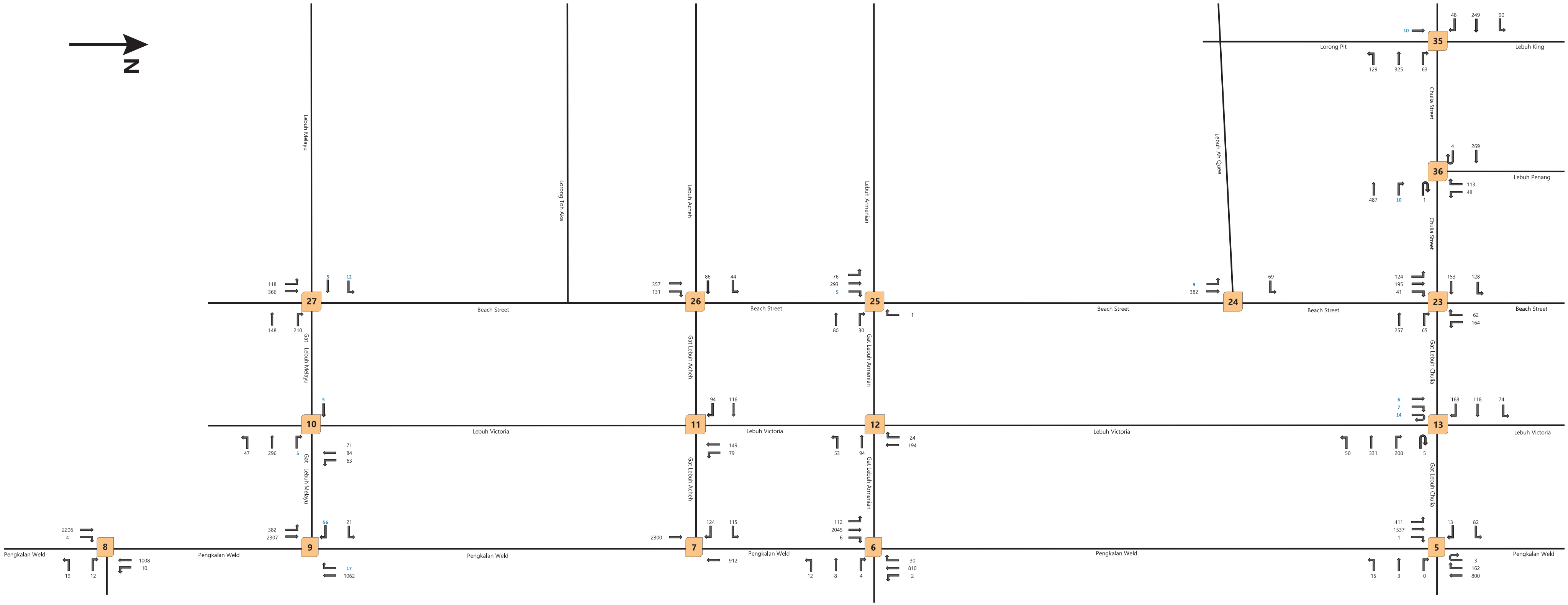


Figure 2.7 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southwest Section

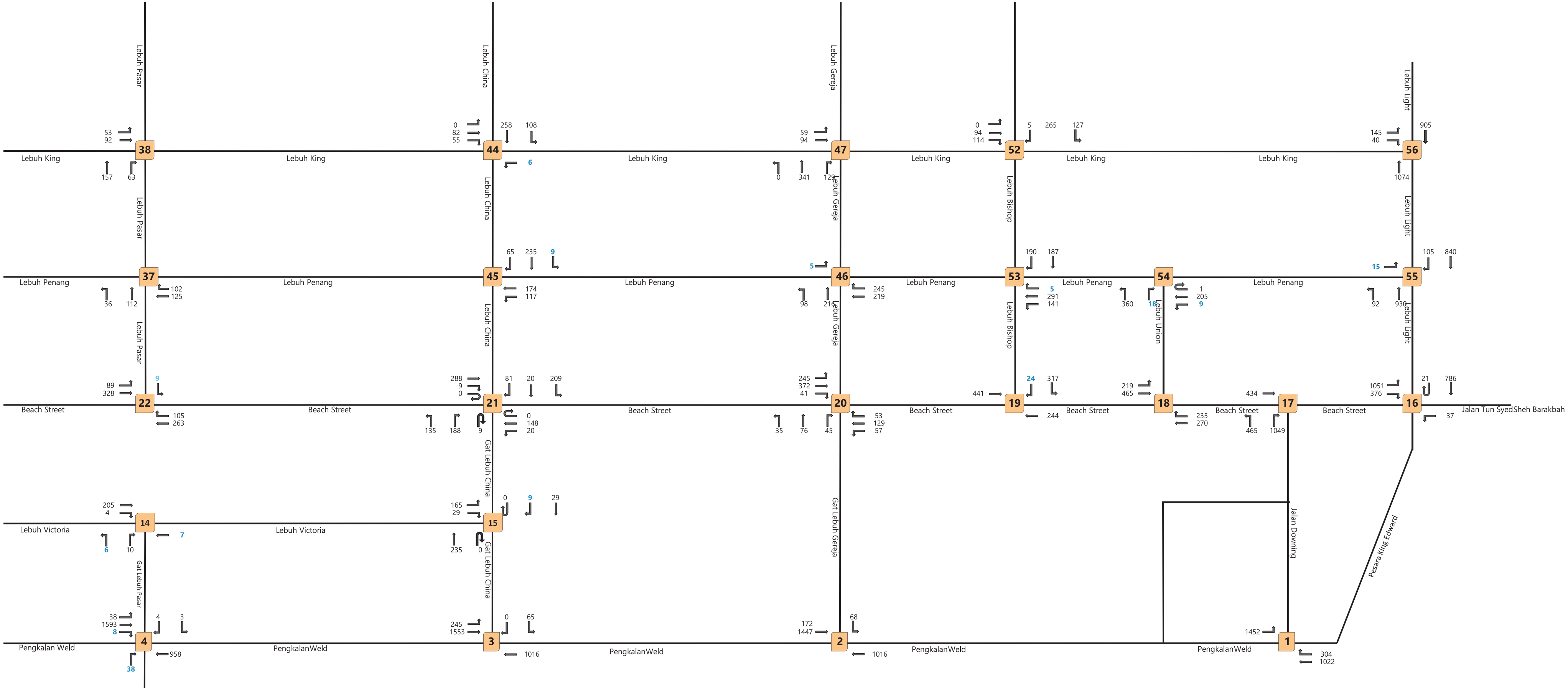


Figure 2.8 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southeast Section

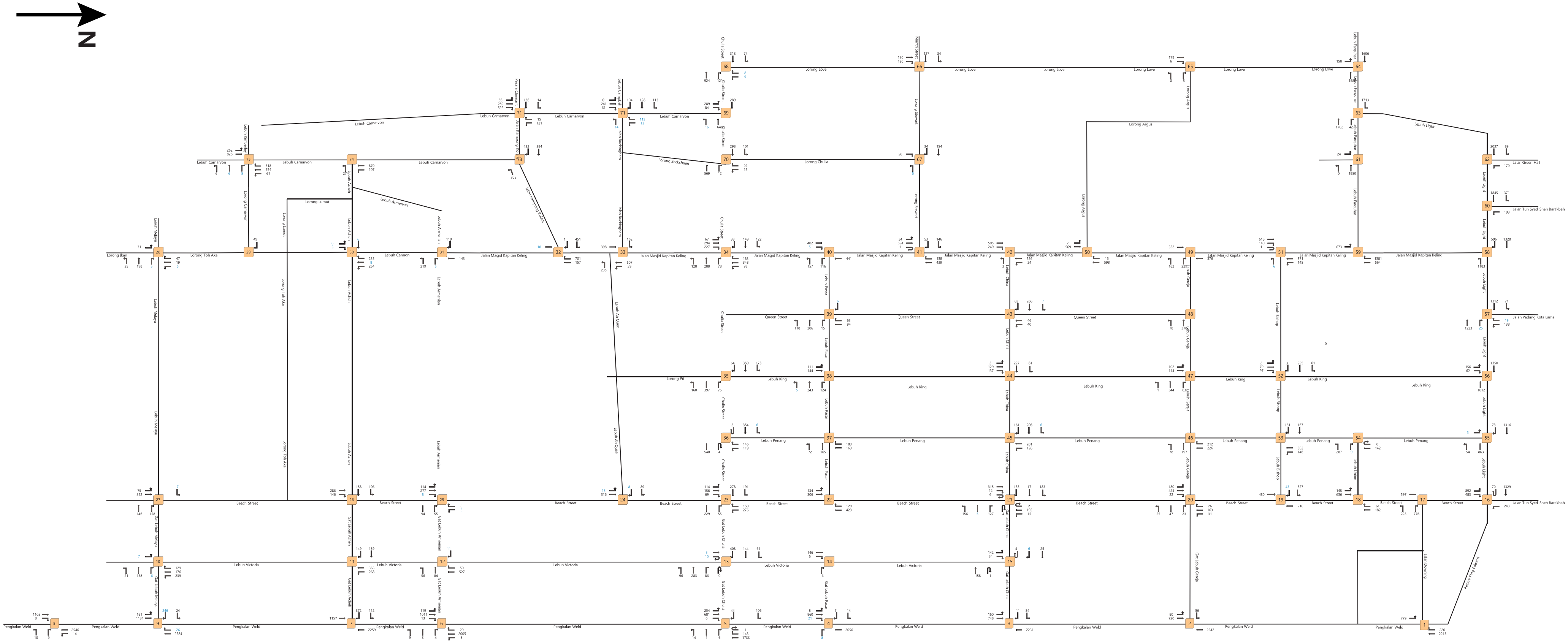


Figure 2.9 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Full

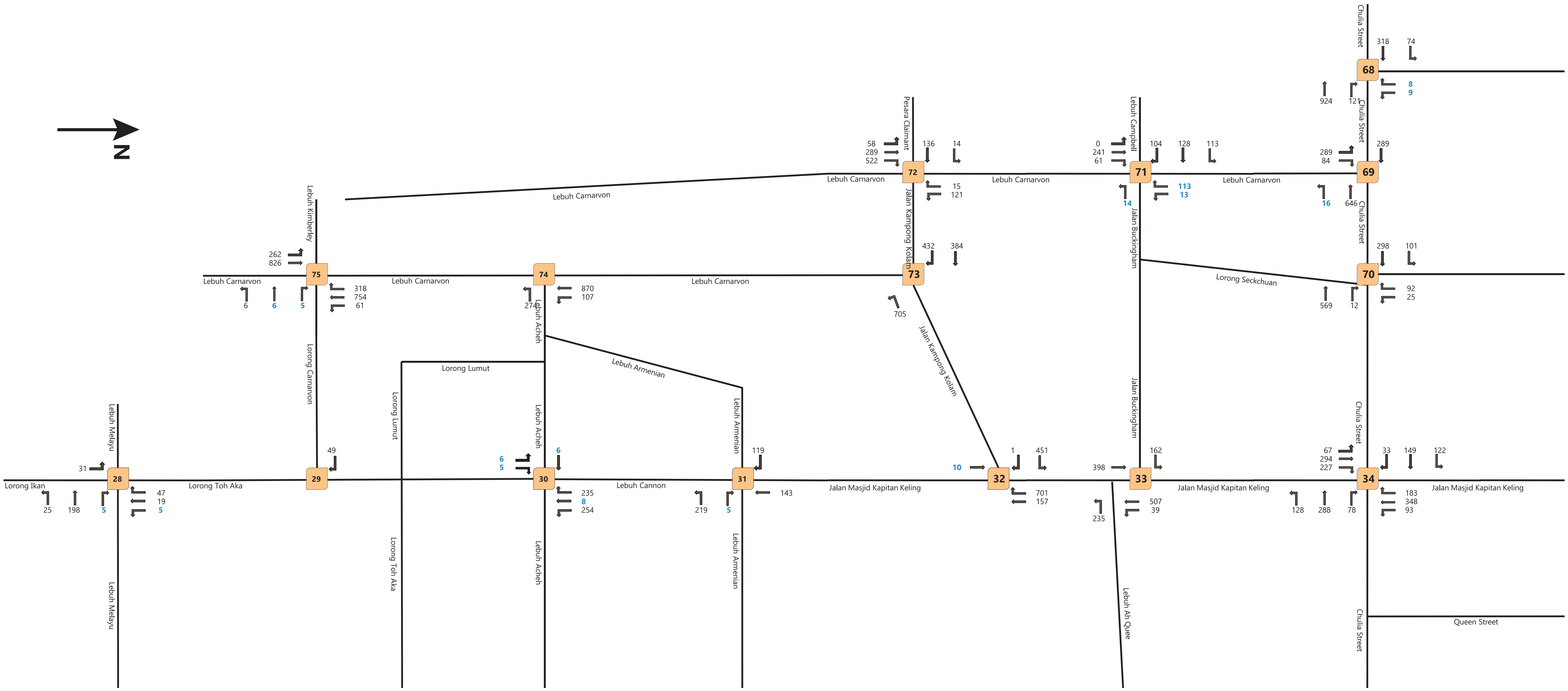


Figure 2.10 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northwest Section

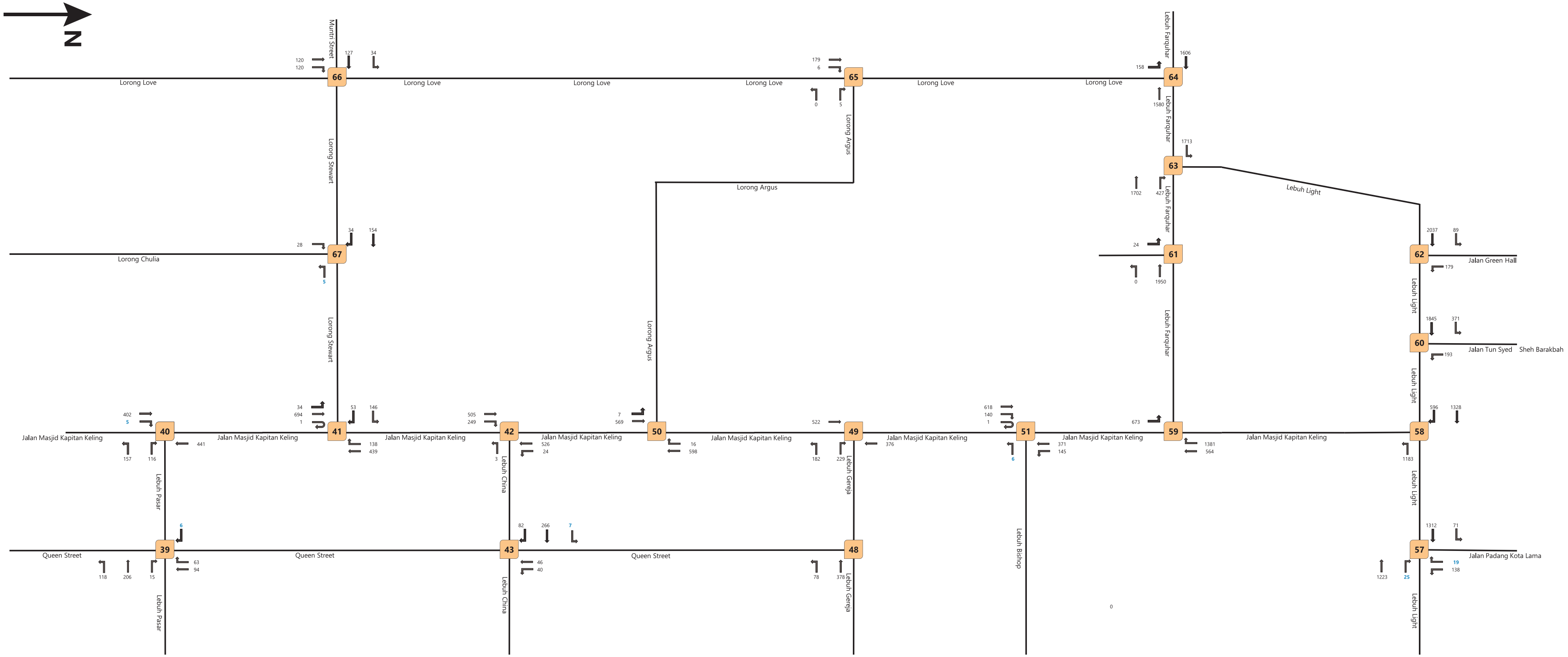


Figure 2.11 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northeast Section

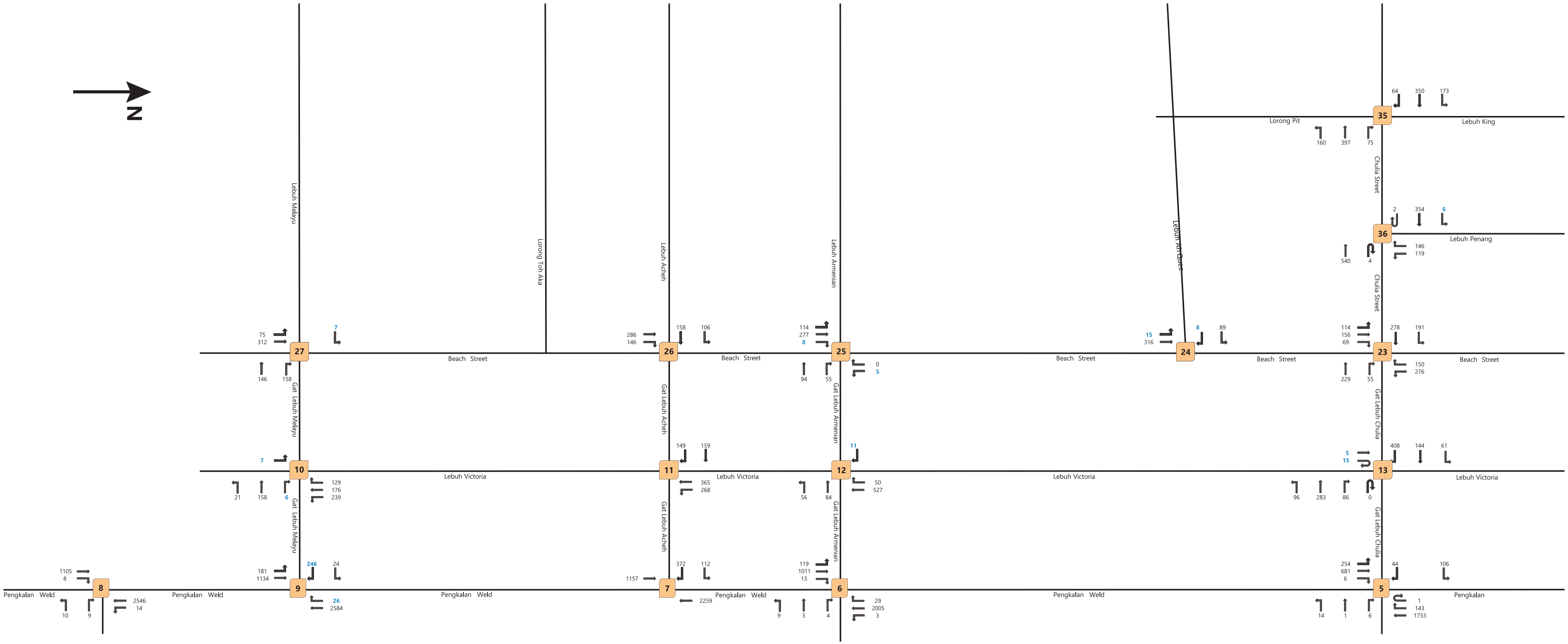


Figure 2.12 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southwest Section

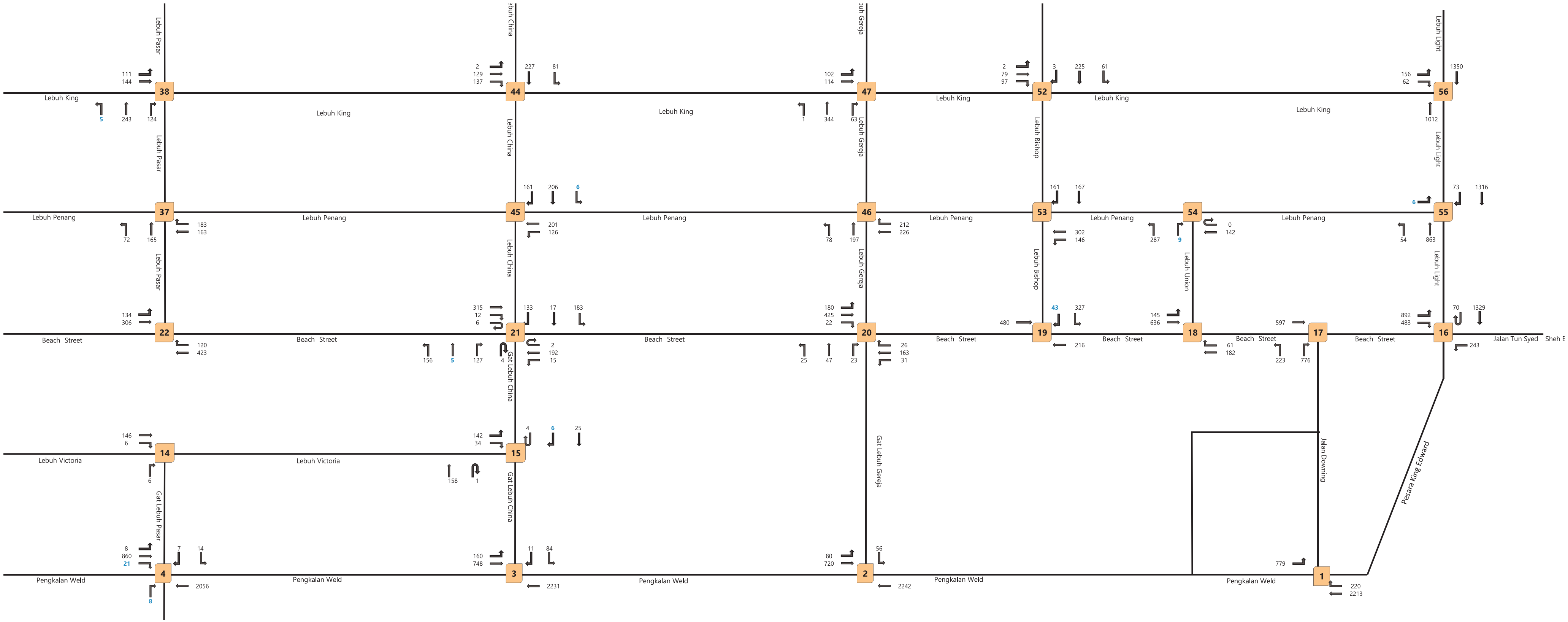


Figure 2.13 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southeast Section

2.4 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.

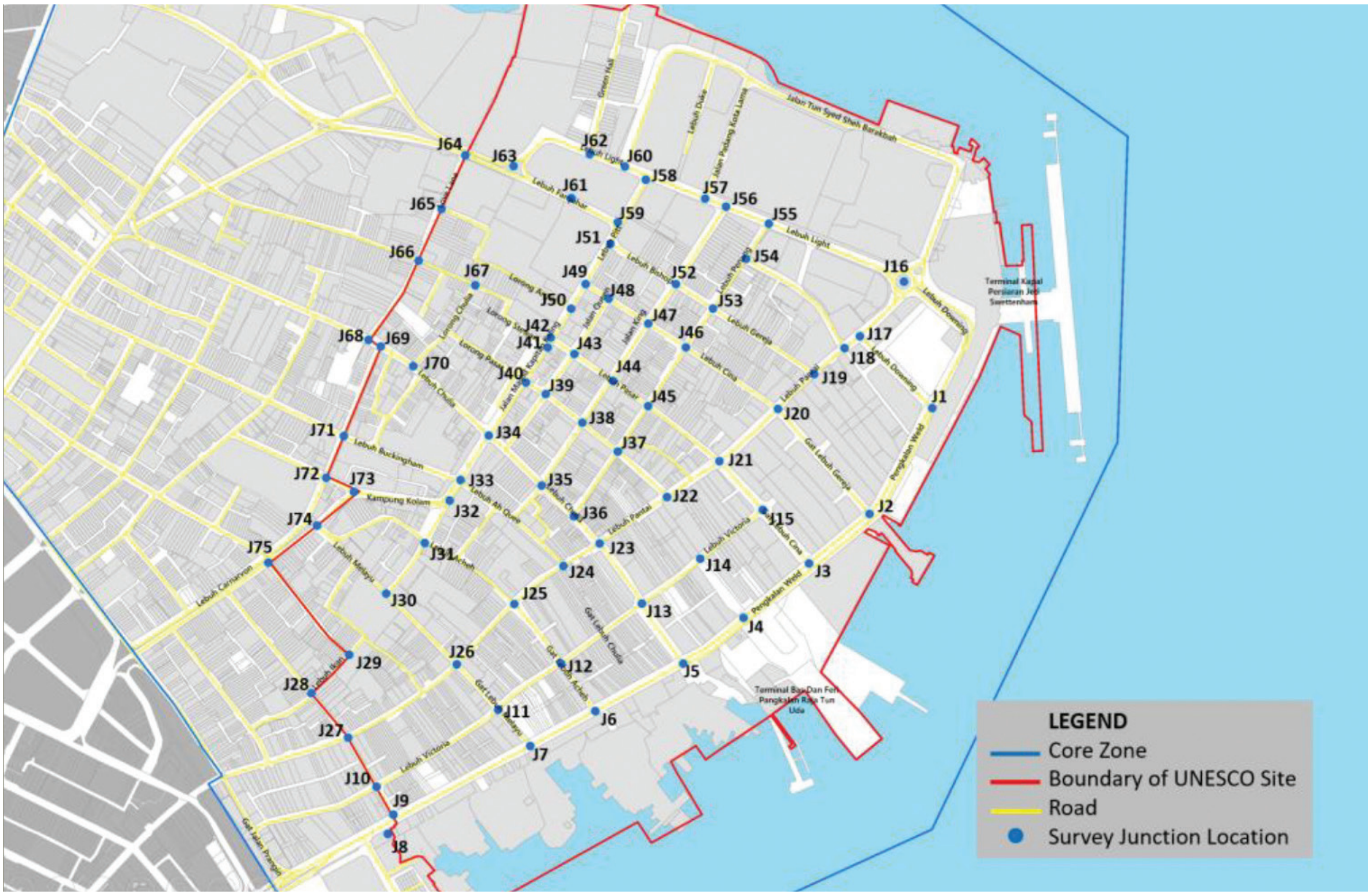


Figure 2.14 Existing Pedestrian/Cyclist Crossings Surveyed in Study Area

Pedestrian / cyclists counts results were analysed 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 2 3 Survey Peak Hour (Pedestrian/Cyclist)

	Surveyed Time	Peak Hour Pedestrian/Cyclists
Weekday AM	07:00 to 10:00	08:15 to 09:15 (flows shown in Figure 2.15 to 2.19)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (flows shown in Figure 2.20 to 2.24)

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.

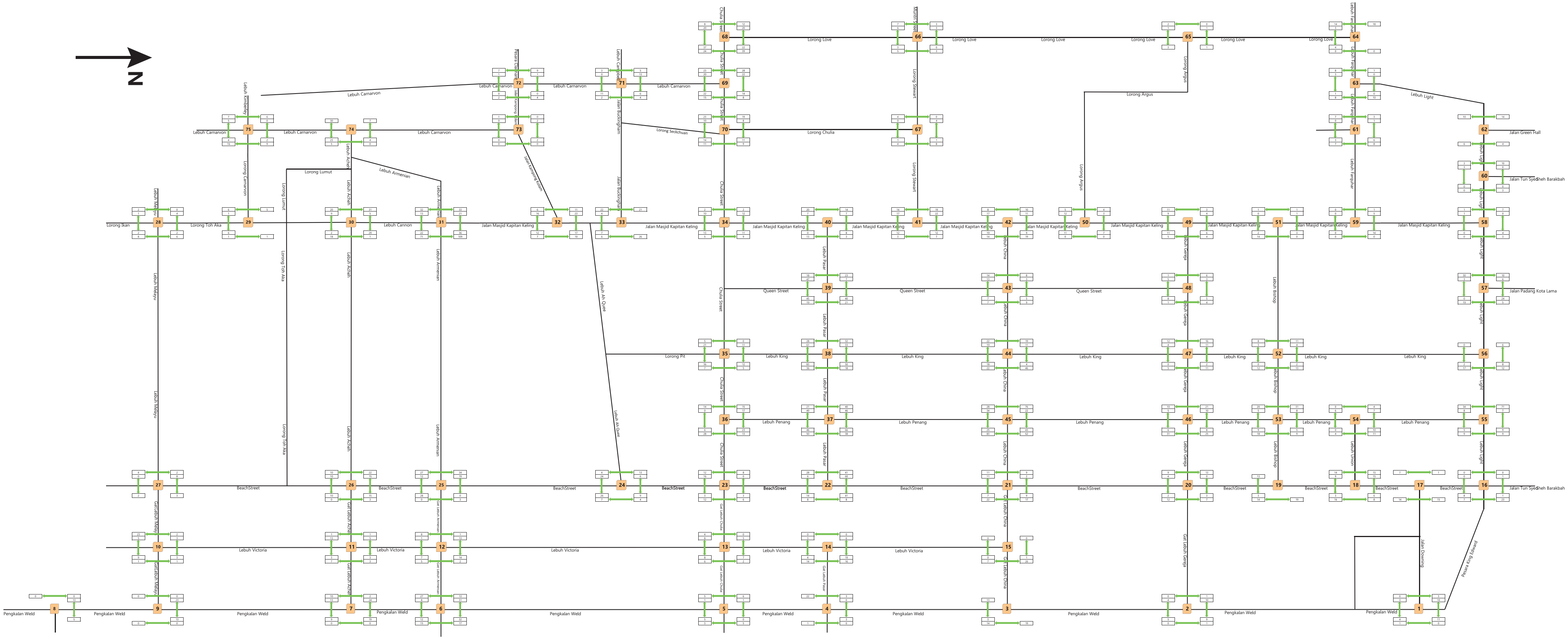


Figure 2.15 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Full

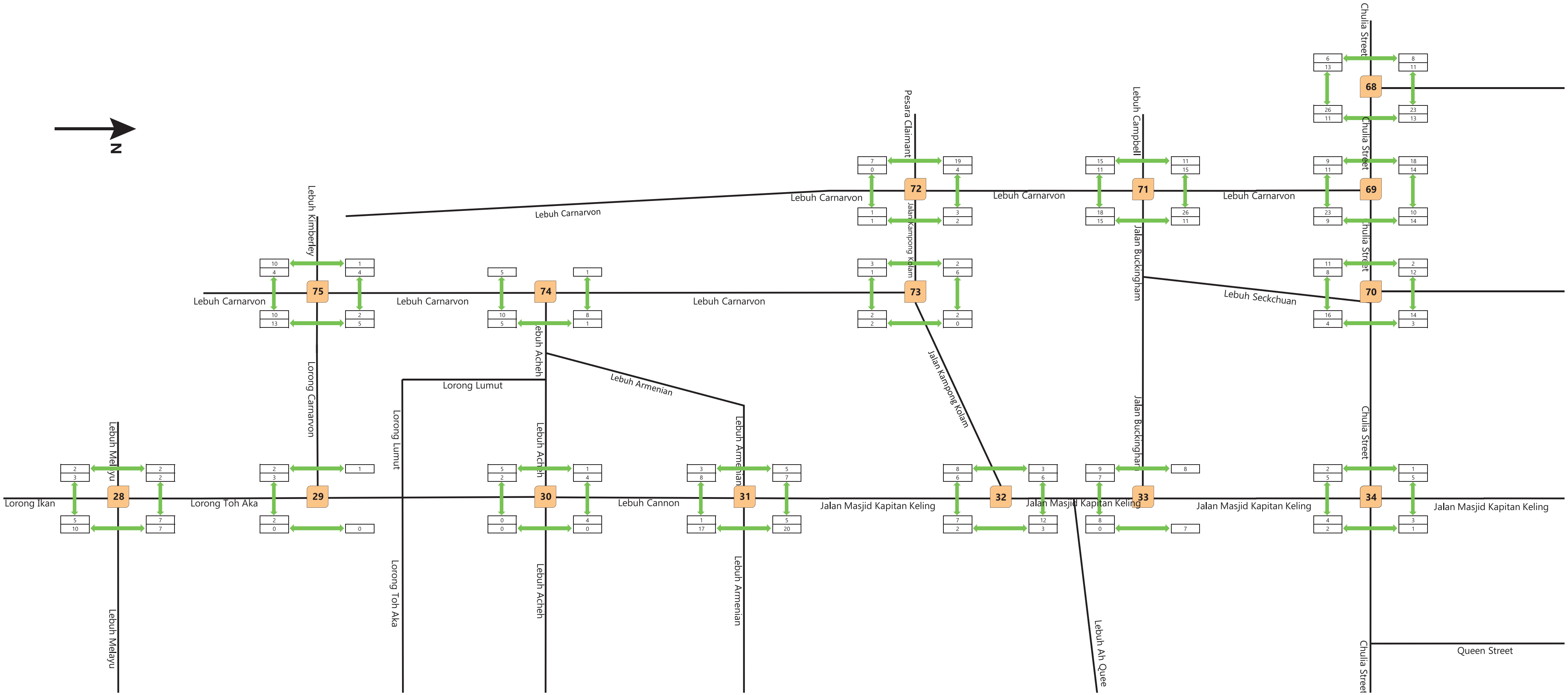


Figure 2.16 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northwest Section

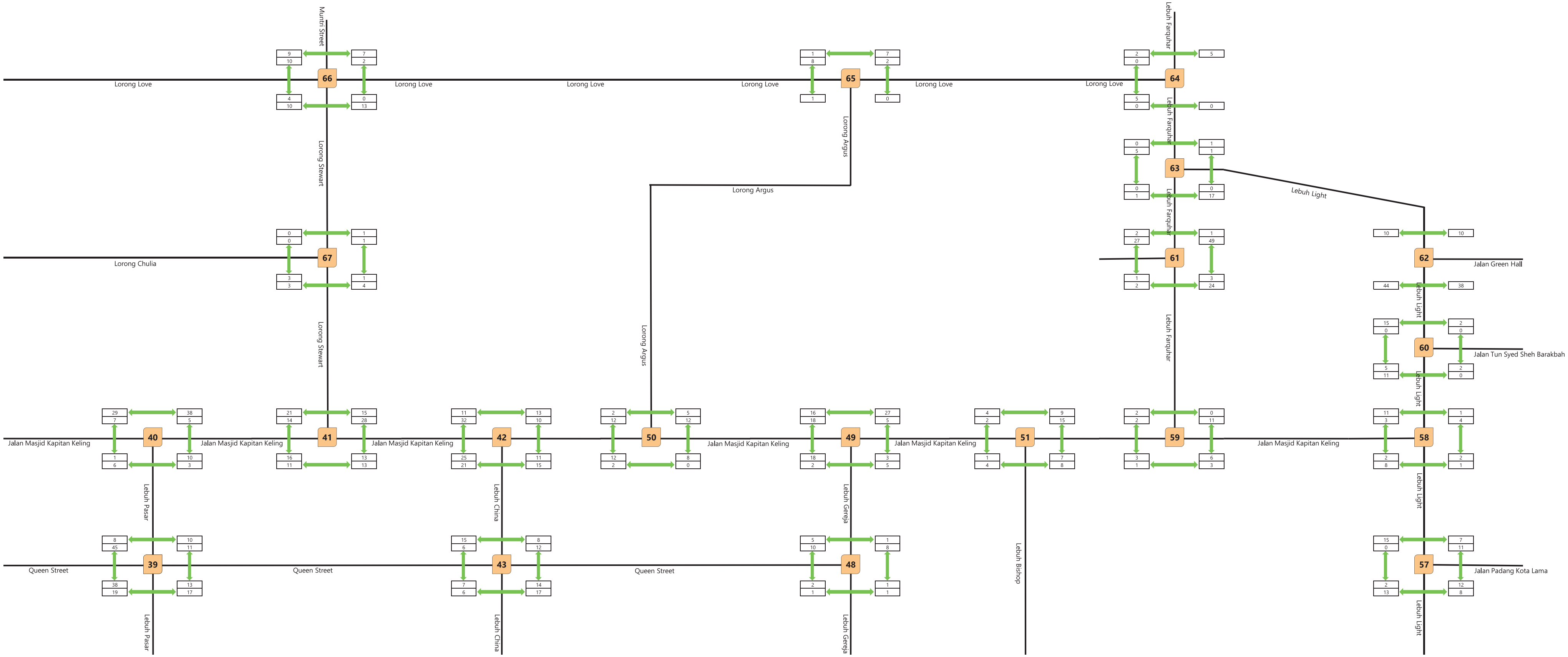


Figure 2.17 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northeast Section

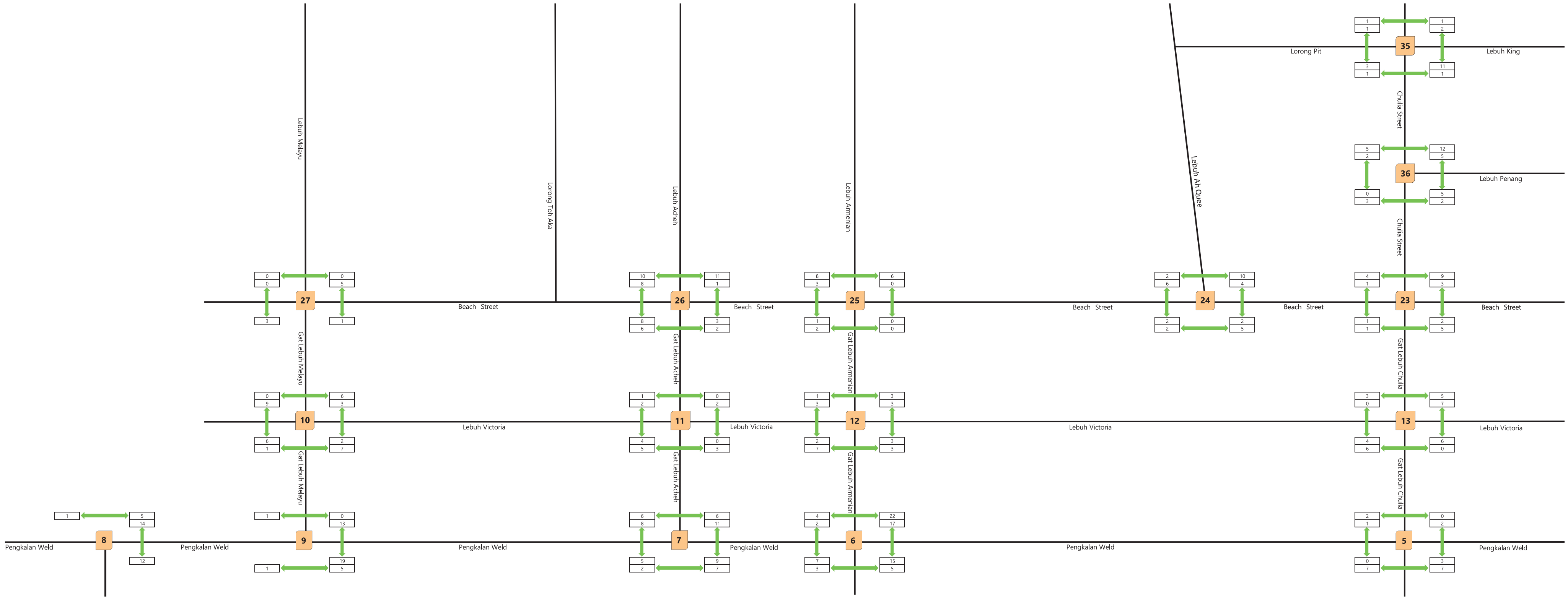


Figure 2.18 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southwest Section

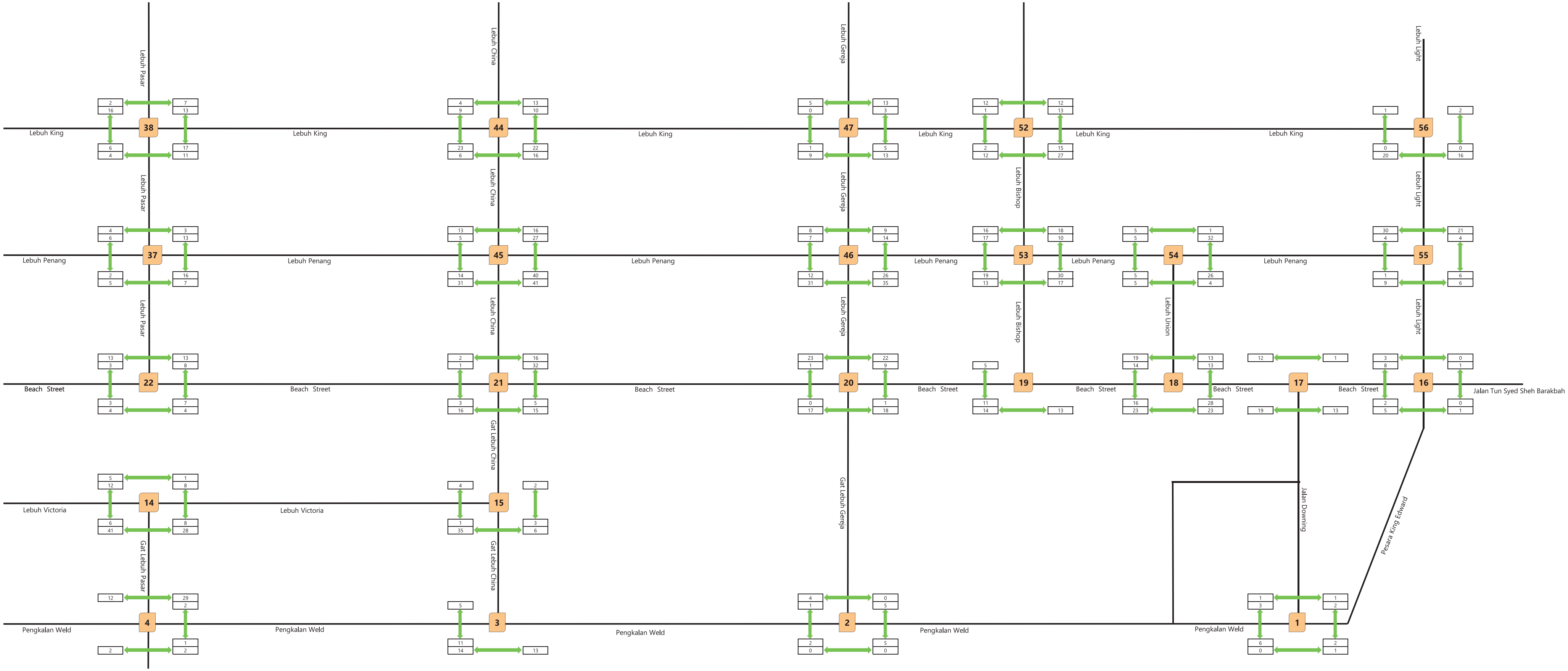


Figure 2.19 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southeast Section

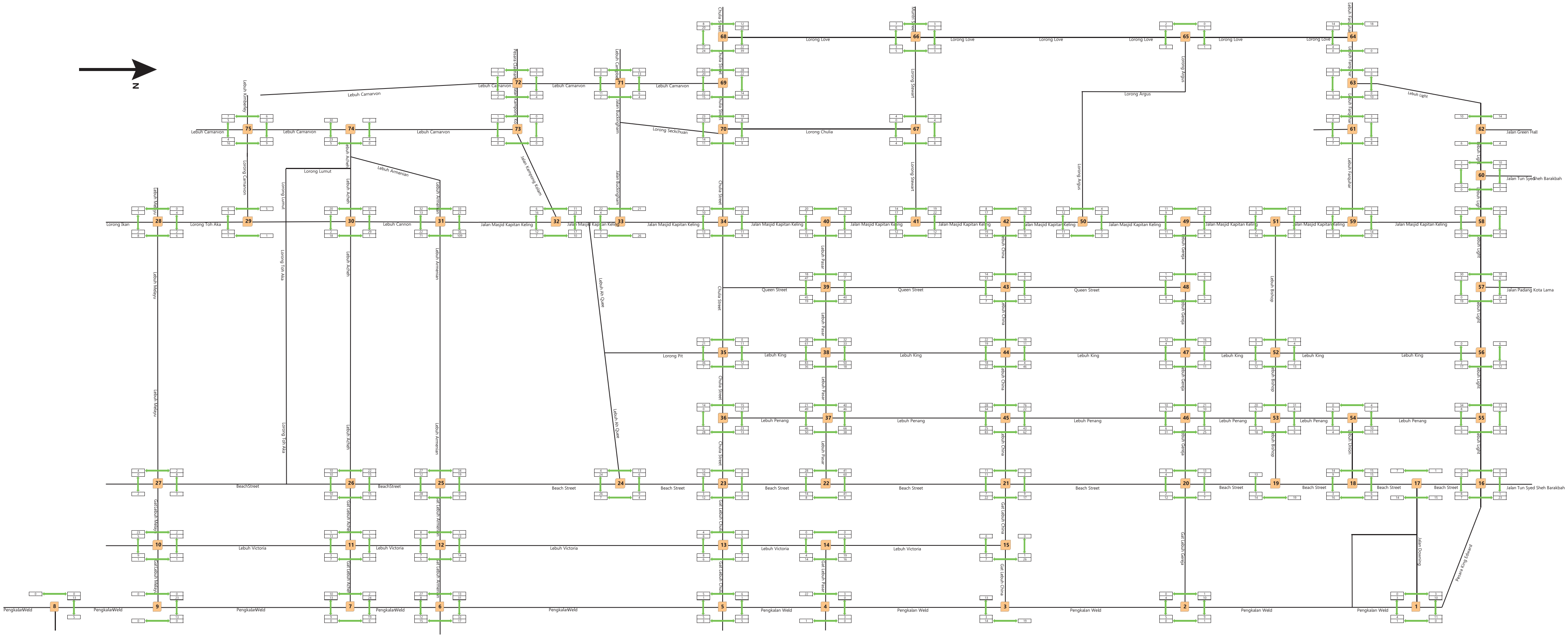


Figure 2.20 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Full

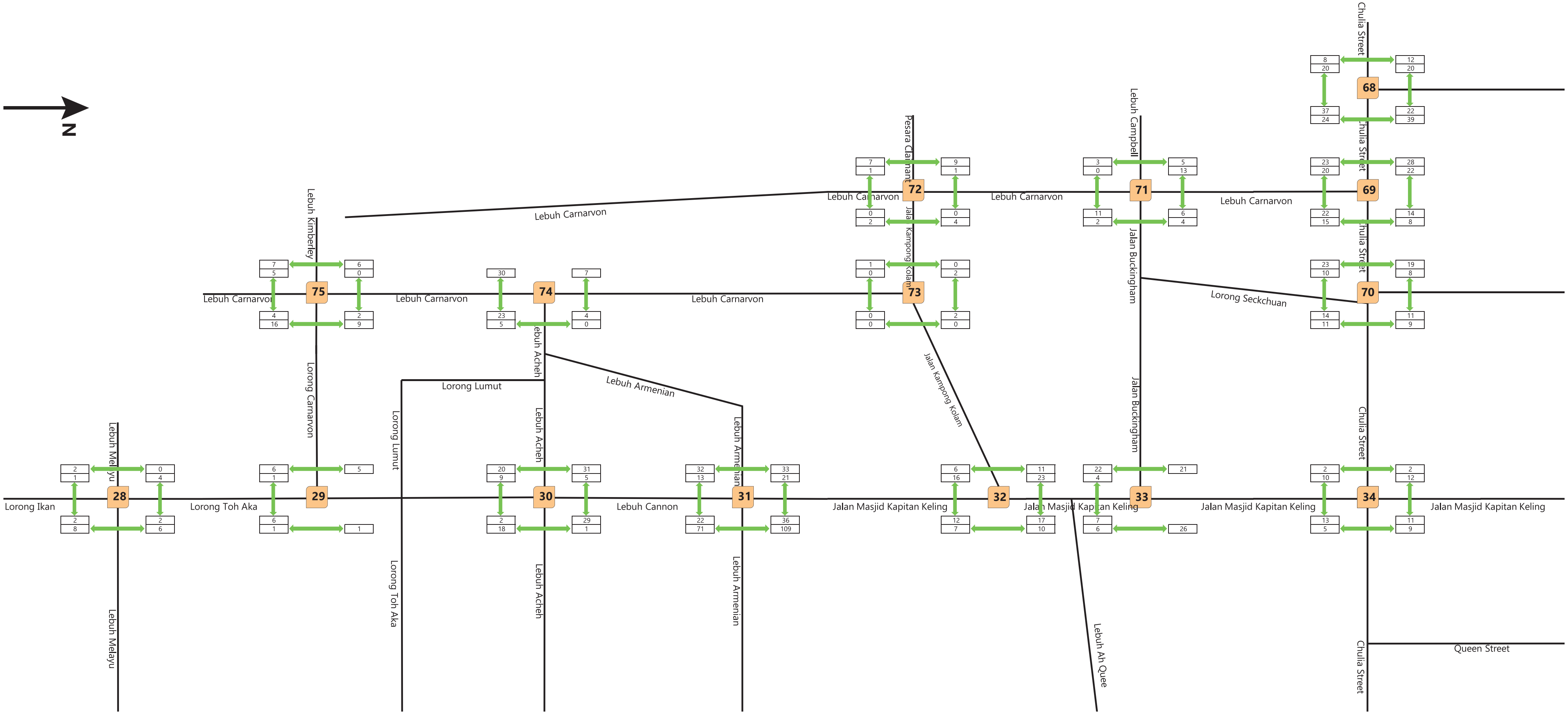


Figure 2.21 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northwest Section

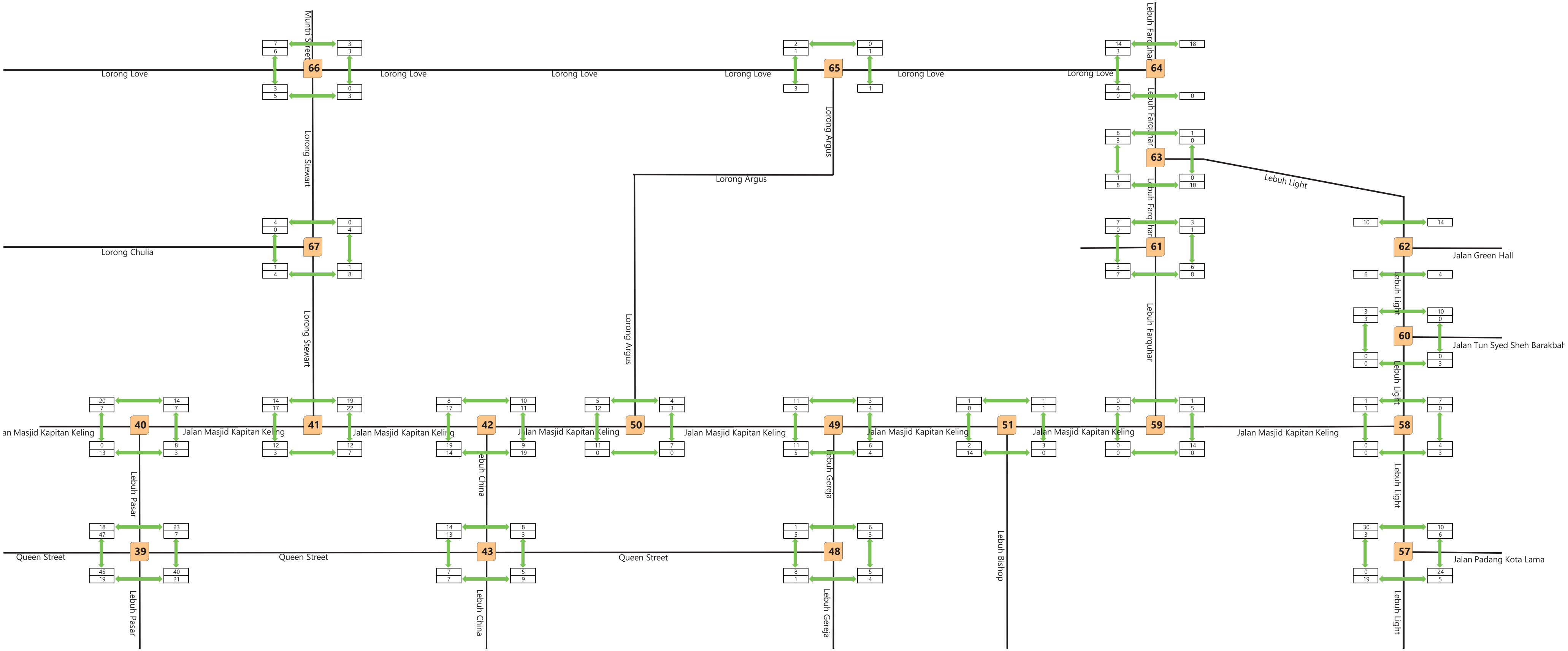


Figure 2.22 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northeast Section

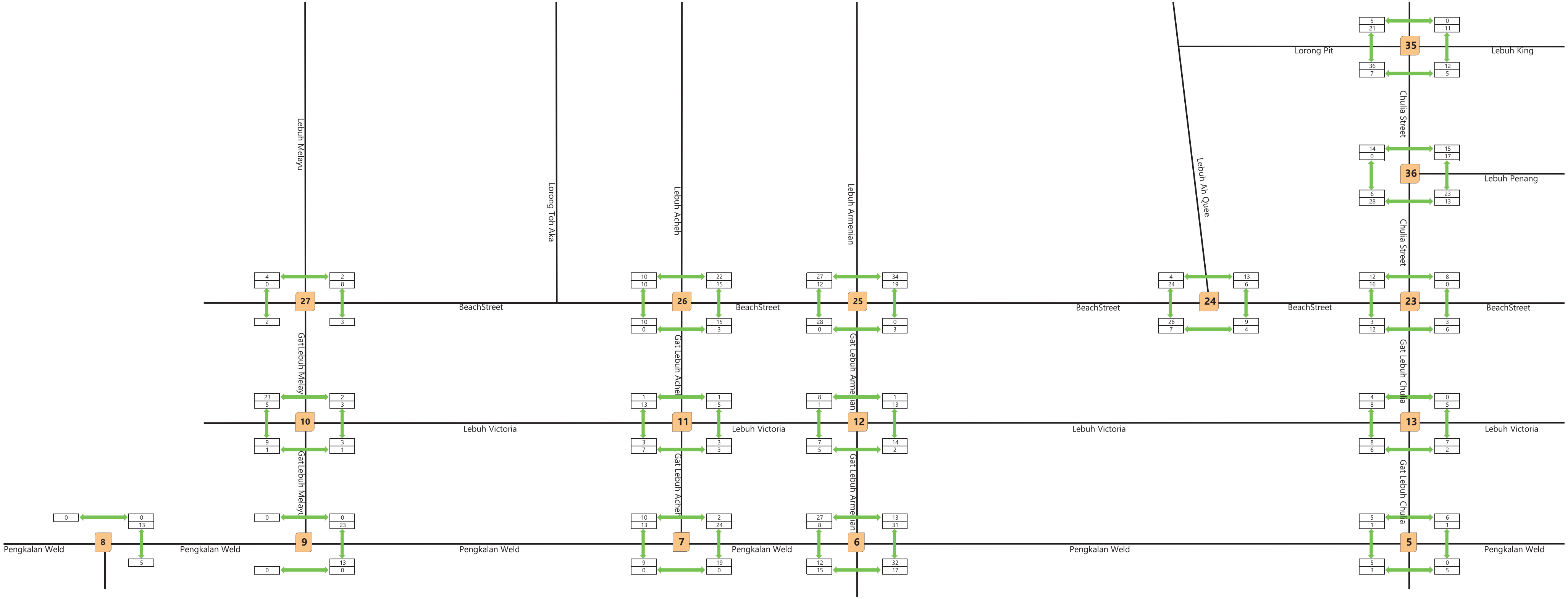


Figure 2.23 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southwest Section

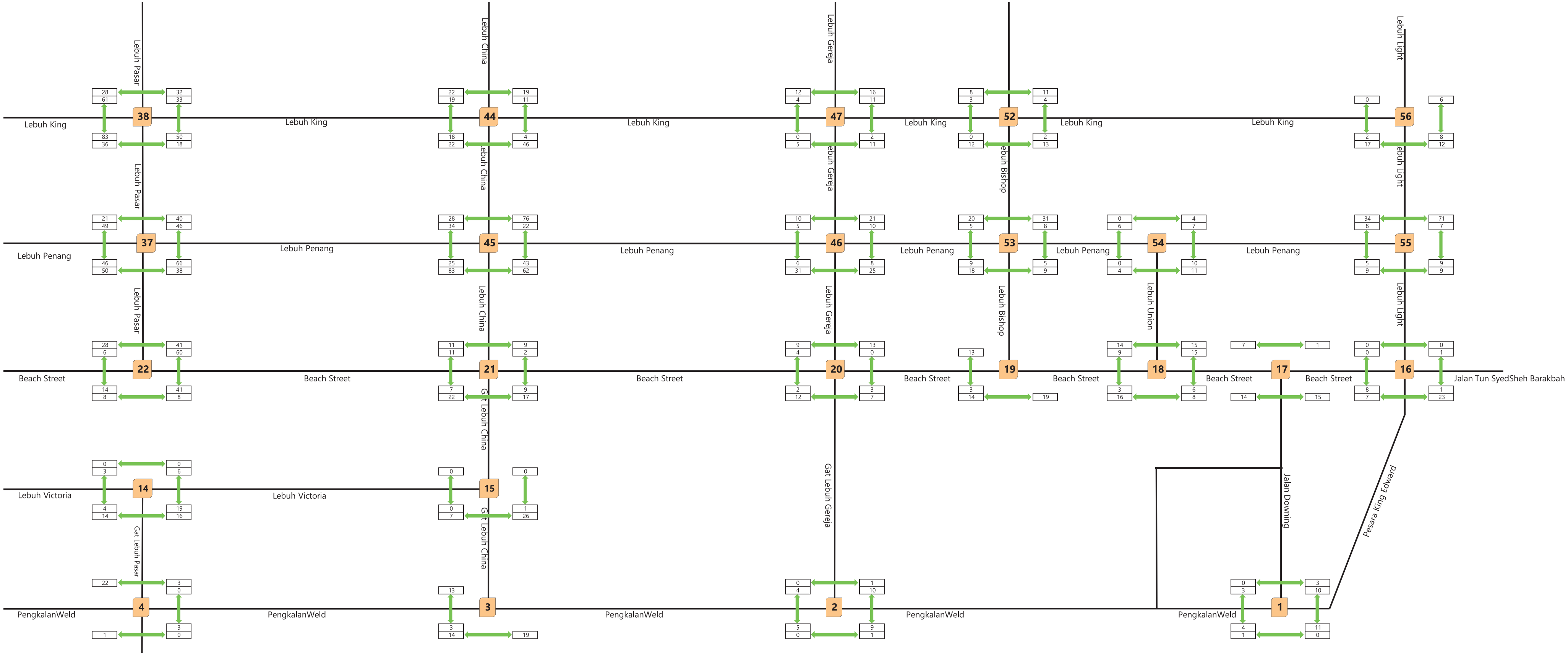


Figure 2.24 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southeast Section

2.5 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 2.25 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.

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 2-4 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 2-5 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
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

2.6 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 utilising the on-street parking. This provides an insight into the behaviour 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 2.26 Parking Dwell Time Survey Locations

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

Table 2 6 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**

2.7 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.

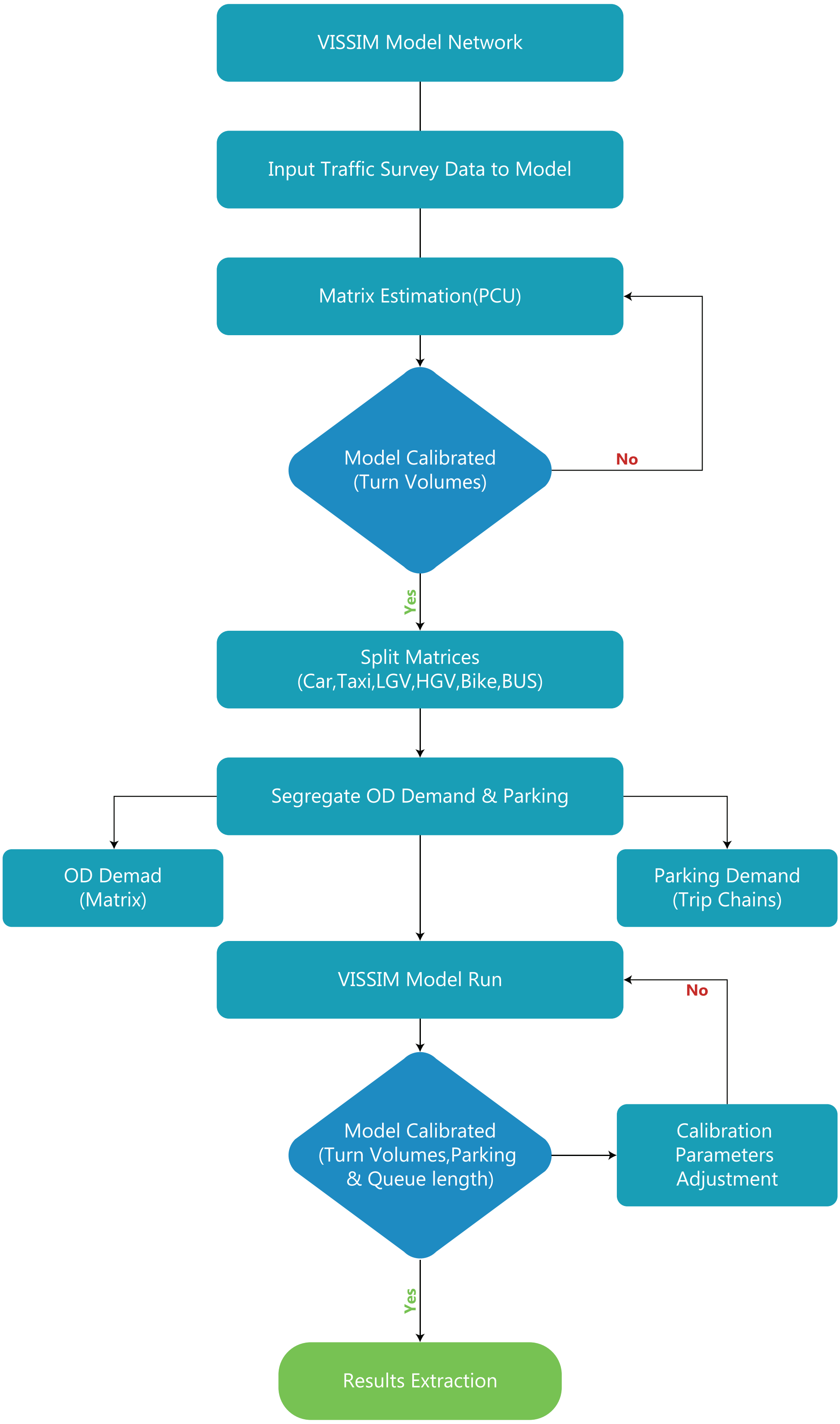


Figure 2.27 Study Methodology

2.7.1 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 2-7 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
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

2.7.1 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.

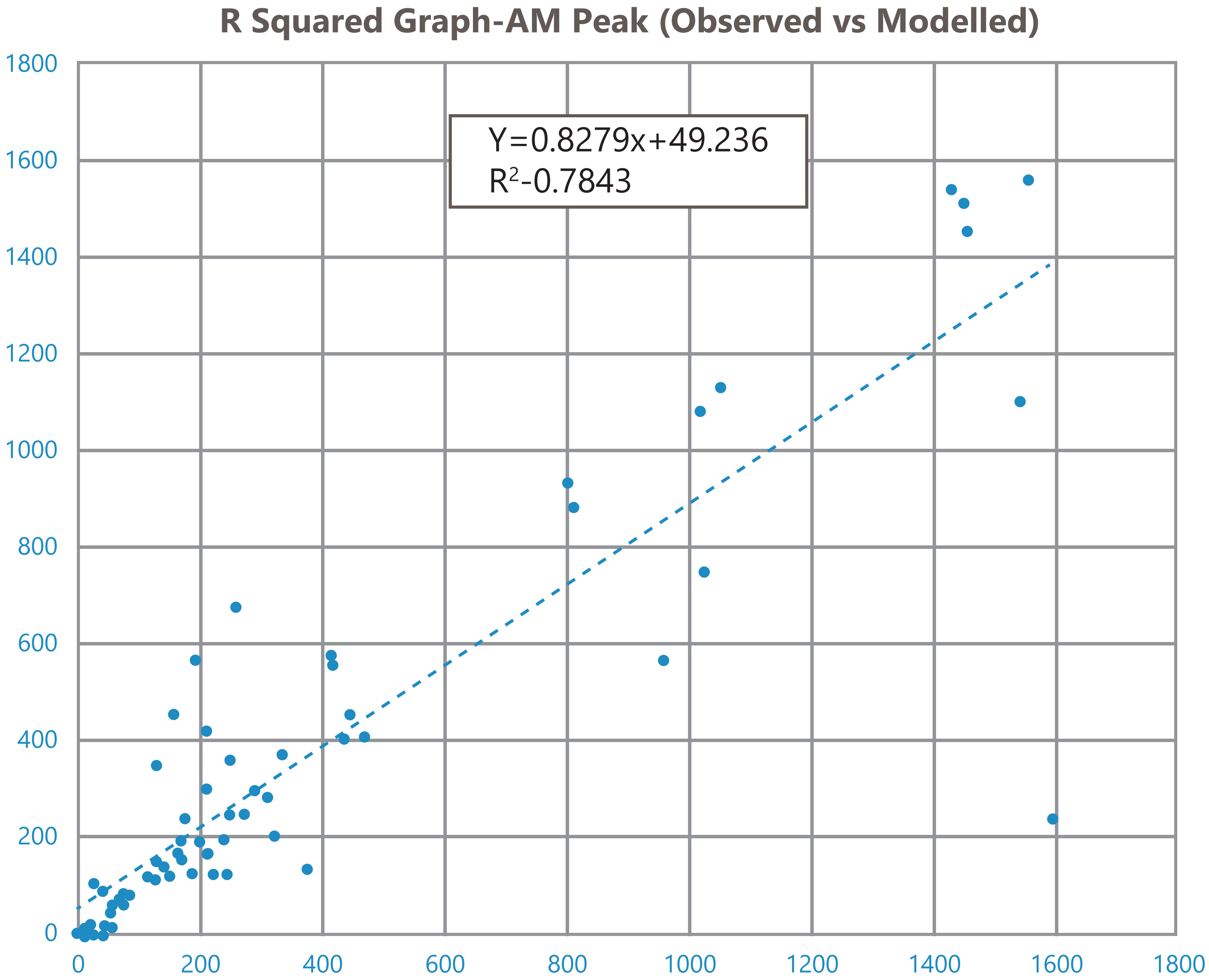


Figure 2.28 Example R-Squared Graph before Turn Volume Calibration

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.

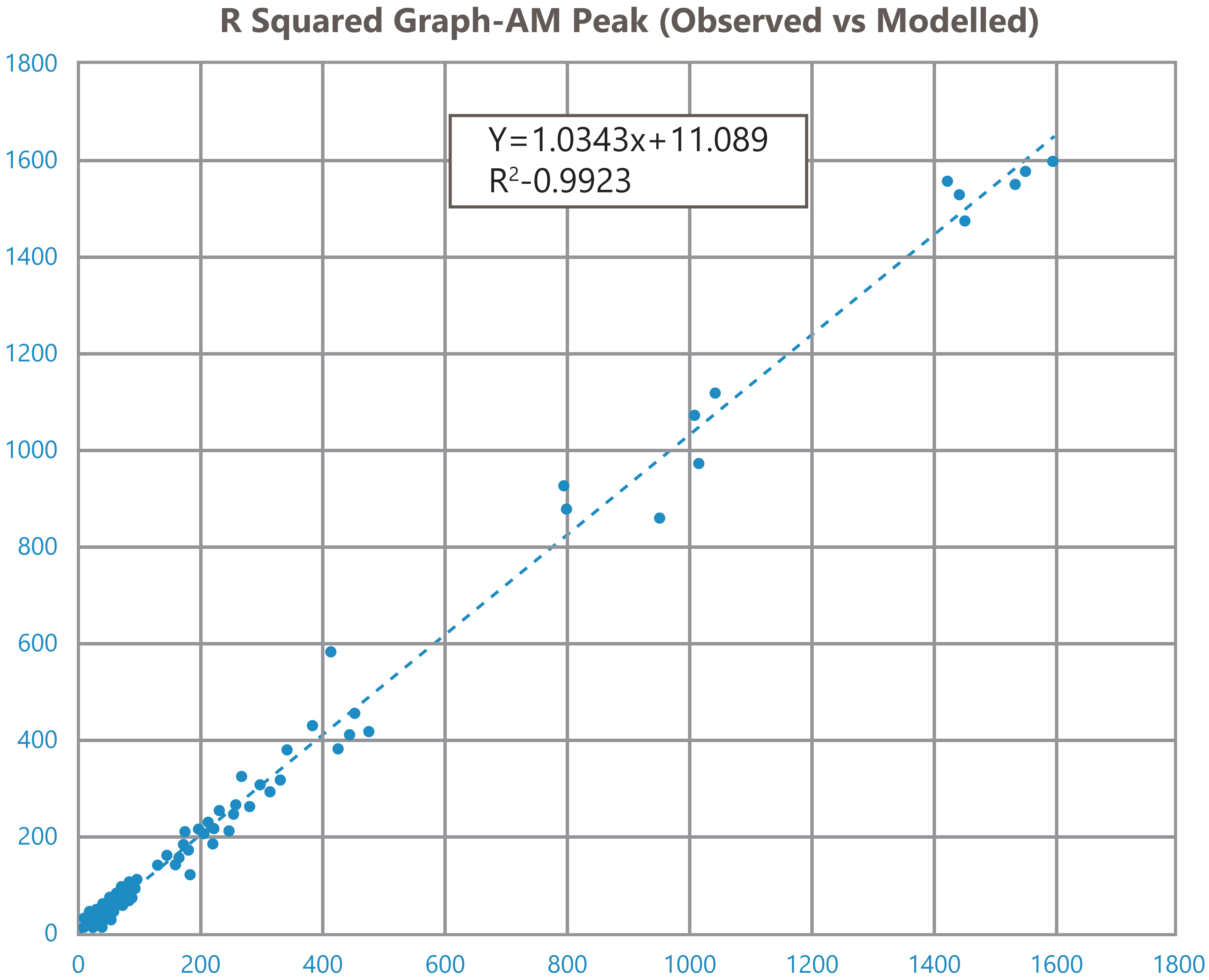


Figure 2.29 Example R-Squared Graph after Turn Volume Calibration

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).

2.7.3 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 2-10 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	2649.75
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	1919.25
Total	88688	1058	6577.5	159	7968	36744.5
Proportion	62.8%	0.7%	4.7%	0.1%	5.6%	26.0%

2.7.4 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 1Home to Work/Shopping/recreation
- Activity 2Work/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 in Figure 2.2 and Table 2.1. 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 shown in Table 2 11 and Figure 2.30 below.

Table 2-11 Trip Chain example

Vehicle	Vehicle type	Origin	Departure	Destination	Coordinates	Activity	Minimum dwell time	Departure	Destination	Coordinates	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.

-

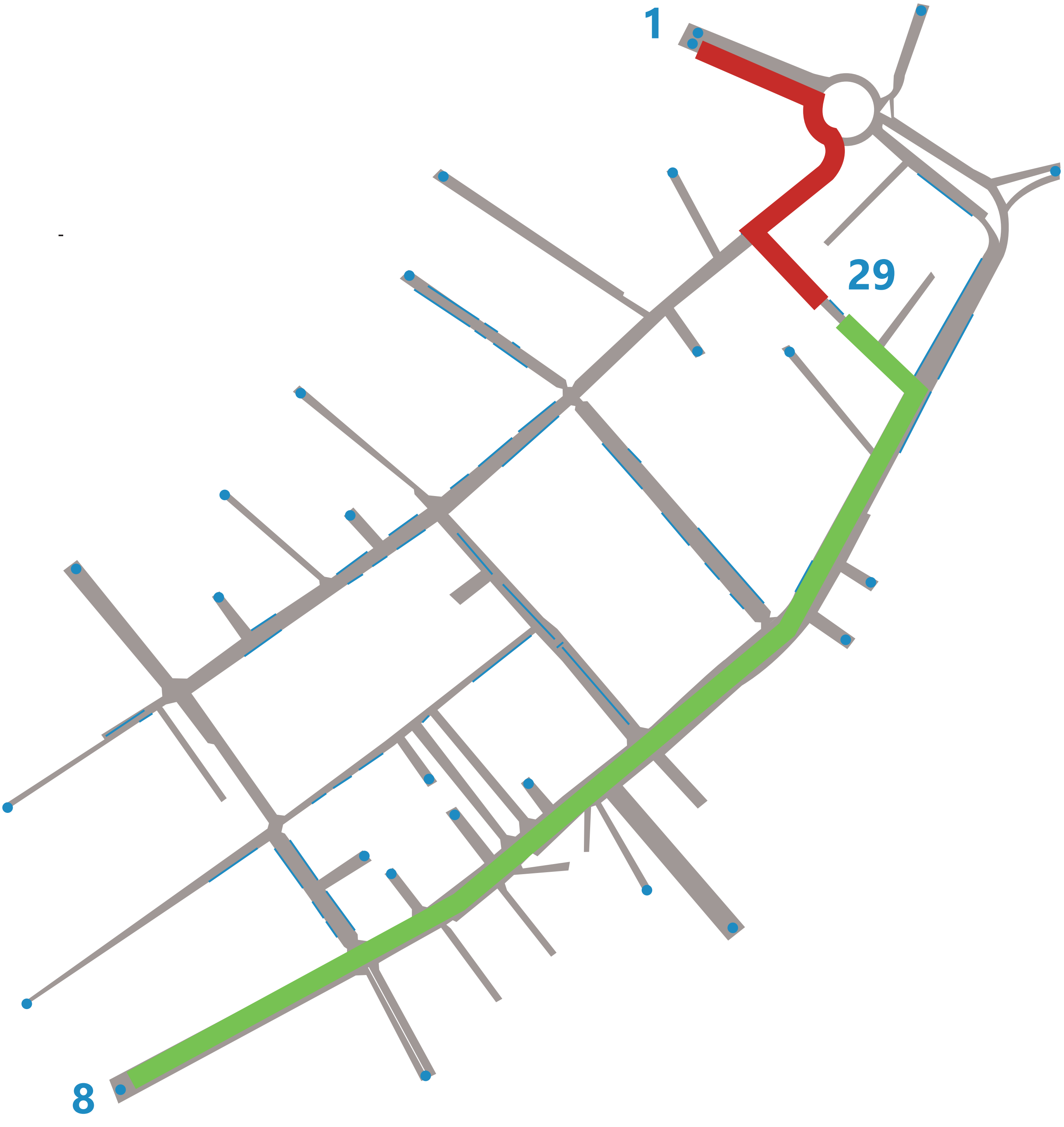


Figure 2.30 Travel Pattern in Trip Chain

2.7.5 Model Calibration with Queues

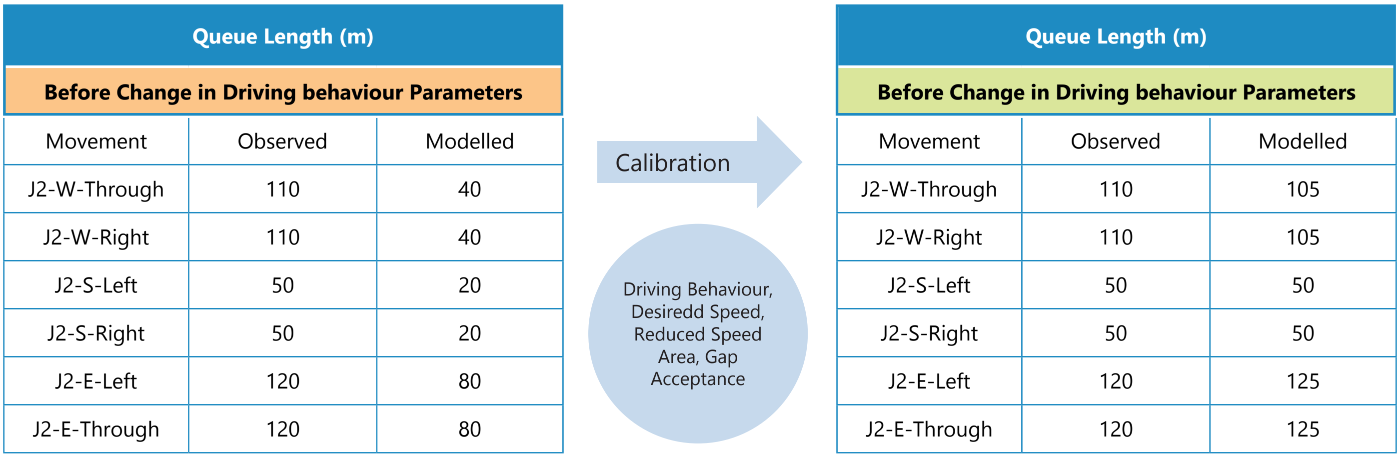
After all the steps above, the model is further calibrated with queue length data recorded from the on-site traffic survey.

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)		
Before 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 2.31 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.

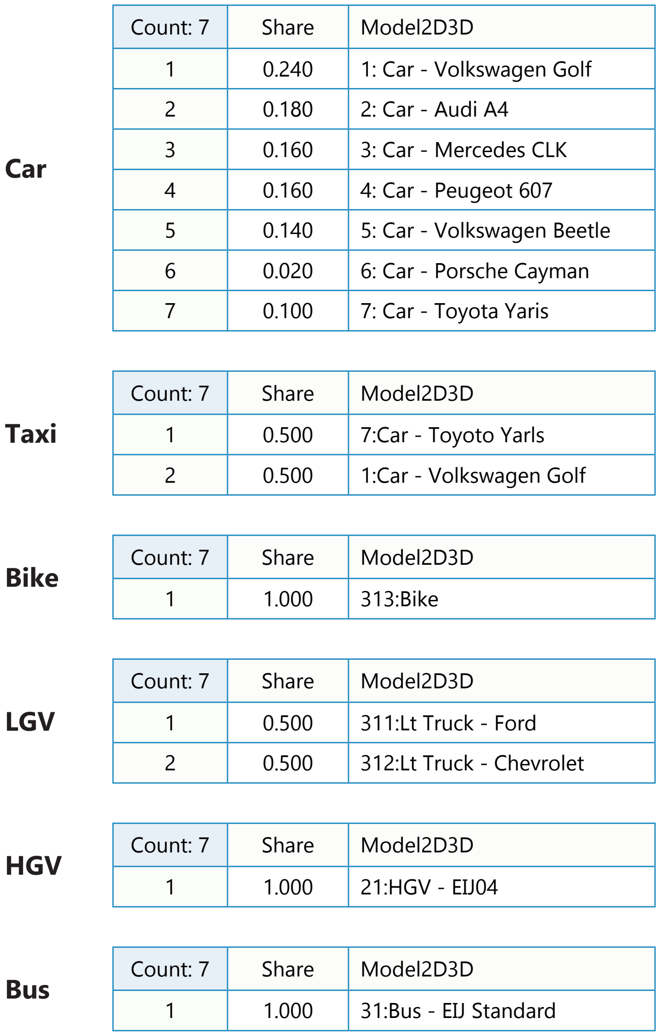
MODEL VERIFICATION

Photo: Adobe Stock

3.1 NETWORK MODEL

3.1.1 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 Toyato 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 Beetle
6	0.020	6: Car - Porsche Cayman
7	0.100	7: Car - Toyota Yaris

Taxi

Count: 7	Share	Model2D3D
1	0.500	7:Car - Toyoto Yarls
2	0.500	1:Car - Volkswagen Golf

Bike

Count: 7	Share	Model2D3D
1	1.000	313:Bike

LGV

Count: 7	Share	Model2D3D
1	0.500	311:Lt Truck - Ford
2	0.500	312:Lt Truck - Chevrolet

HGV

Count: 7	Share	Model2D3D
1	1.000	21:HGV - EIJ04

Bus

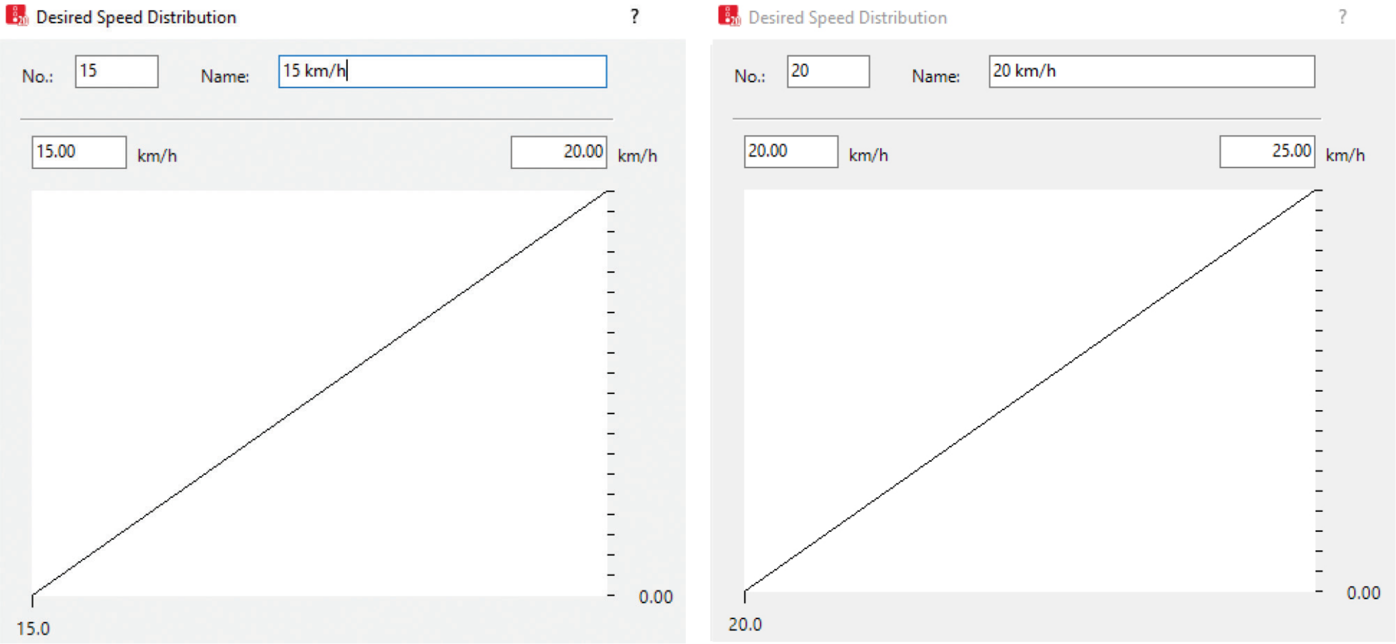
Count: 7	Share	Model2D3D
1	1.000	31:Bus - EIJ Standard

- **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.

3.1.2 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.



Desired Speed Distribution

No.: 15 Name: 15 km/h

15.00 km/h 20.00 km/h

Desired Speed Distribution

No.: 20 Name: 20 km/h

20.00 km/h 25.00 km/h

Figure 3.1 Speed Distribution at Turn Movements

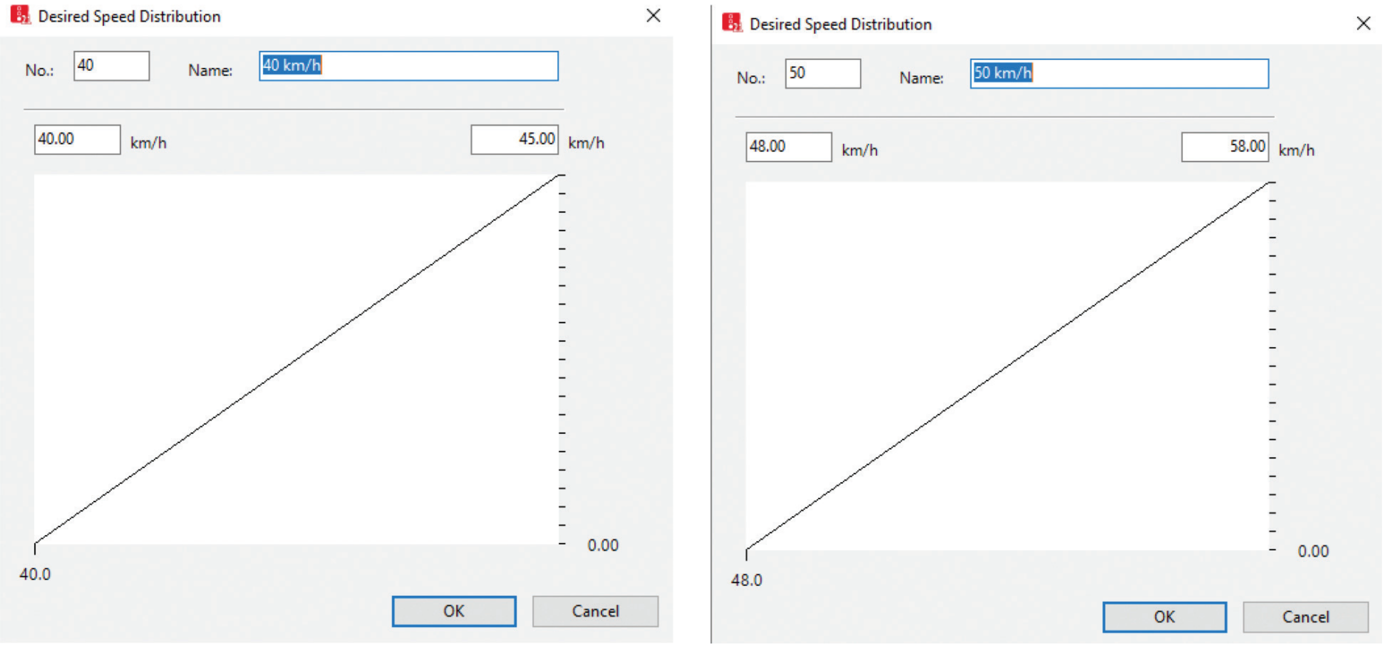
The figure above shows a linear distribution of speed between the lower limit and upper limit.
For example, the speed distribution of 15 km/h shows a uniformly distributed speed between 15 km/h and 20 km/h. While the speed distribution of 20 km/h shows a uniformly distributed speed between 20 km/h and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

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

3.1.3 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.



Desired Speed Distribution
No.: 40
Name: 40 km/h
40.00 km/h
45.00 km/h

Desired Speed Distribution
No.: 50
Name: 50 km/h
48.00 km/h
58.00 km/h

Figure 3.2 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.

3.1.4 Driving Behaviour

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:

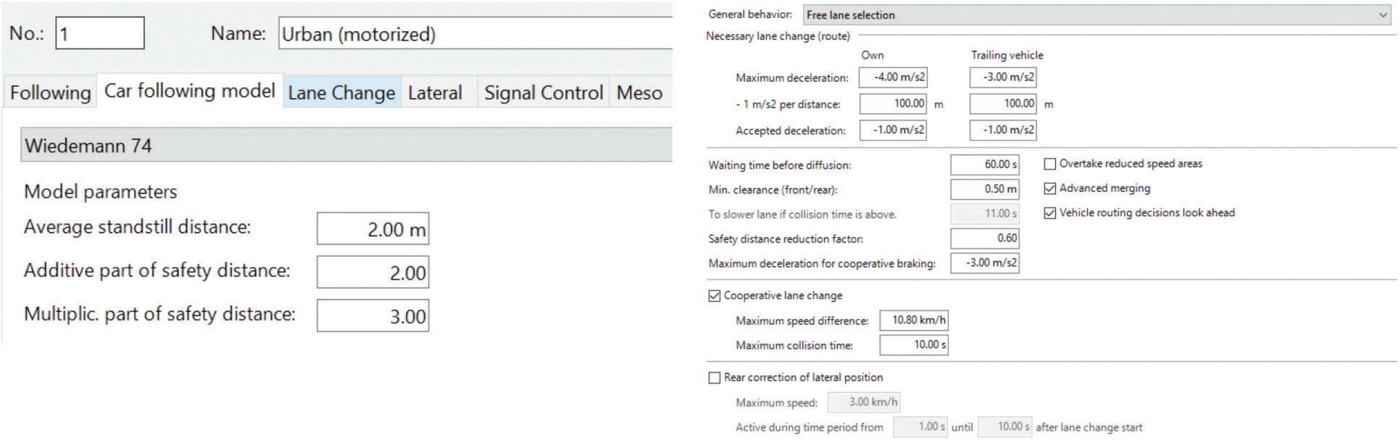
- Vehicles are not running at fixed assignment with uniformed speed – this is not just a video
- Vehicles are reacting to other vehicles in the model consistently
- When put in origin and destination of traffic, route need to be selected by the model for vehicles

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 bahavior of 1 Urban (motorized). As the Penang model is based on urban settings, the default driving behavior



No.: 1

Name: Urban (motorized)

Wiedemann 74

Model parameters

Average standstill distance: 2.00 m

Additive part of safety distance: 2.00

Multiplic. part of safety distance: 3.00

General behavior: Free lane selection

Necessary lane change (route)

	Own		Trailing vehicle	
Maximum deceleration:	-4.00 m/s2		-3.00 m/s2	
- 1 m/s2 per distance:	100.00	m	100.00	m
Accepted deceleration:	-1.00 m/s2		-1.00 m/s2	

Waiting time before diffusion: 60.00 s

Min. clearance (front/rear): 0.50 m

To slower lane if collision time is above. 11.00 s

Safety distance reduction factor: 0.60

Maximum deceleration for cooperative braking: -3.00 m/s2

☐ Overtake reduced speed areas

☑ Advanced merging

☑ Vehicle routing decisions look ahead

☑ Cooperative lane change

Maximum speed difference: 10.80 km/h

Maximum collision time: 10.00 s

☐ Rear correction of lateral position

Maximum speed: 3.00 km/h

Active during time period from 1.00 s until 10.00 s after lane change start

Figure 3.3 Default Car Following and Lane Change Behavior

MODEL CALIBRATION

Photo: Adobe Stock

4.1 TURN VOLUME CALIBRATION

3.1.1 Model Parameter Settings

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:

(1) Hourly Flows (Model Versus Observed)
- Turning movement Flows
    a. 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.

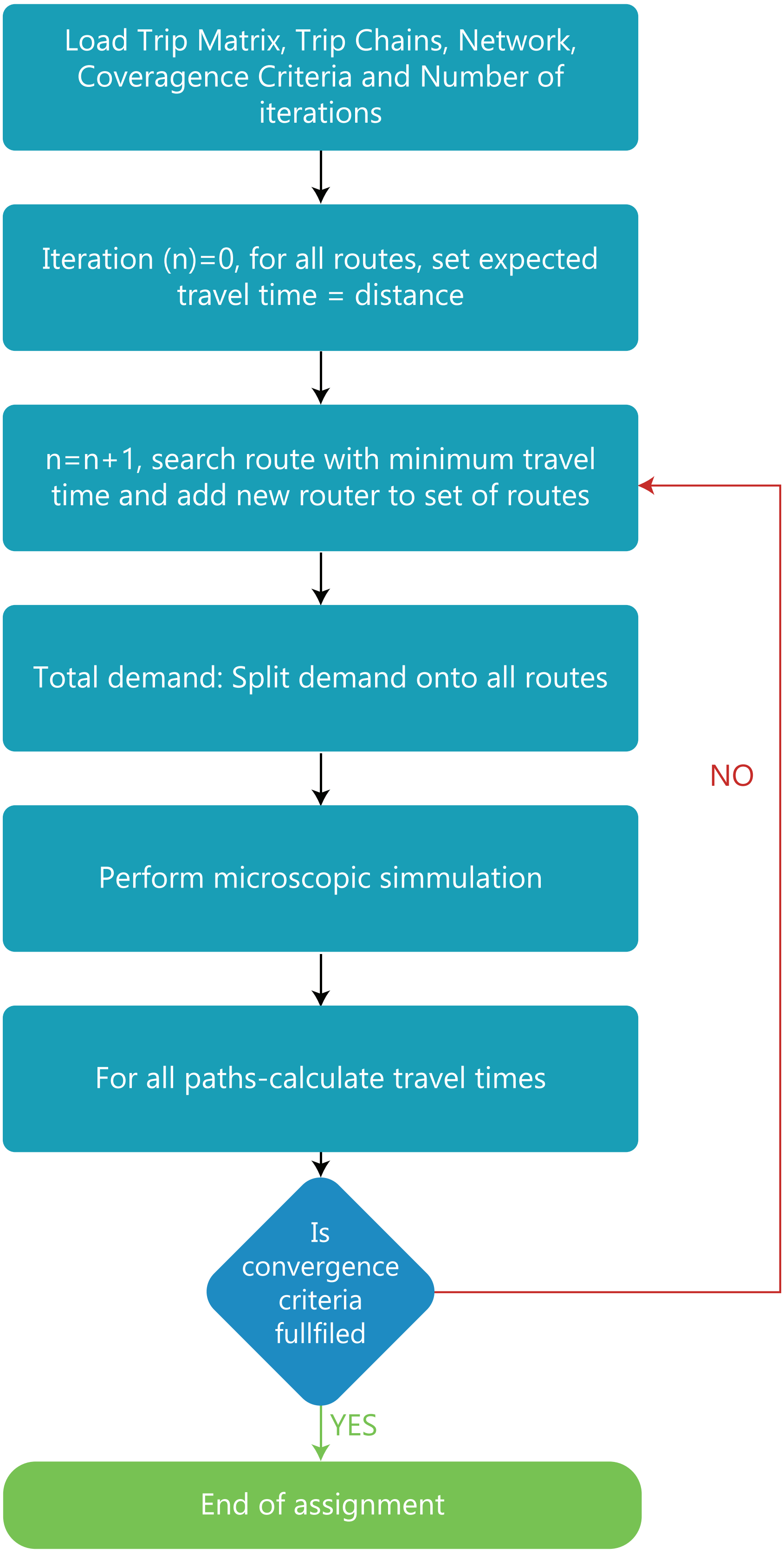


Figure 3.4 Dynamic Assignment Process

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 (Random seed definition is defined in Section 3.1.1).

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 3-1 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
	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
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
	13-S-Right	208	164	3.21	YES
14	14-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
	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

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
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
	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-E-Left	20	0	6.32	NO
	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

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
23	J22-W-Left	124	115	0.87	YES
	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-N-Left	128	140	1.05	YES
	J22-N-Through	153	131	1.86	YES
Proportion of Turns with GEH<5					**92%**

Table 3-2 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
	J13-S-Through	283	246	2	YES
	J13-S-Right	86	55	4	YES

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
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
	15-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	216	1	YES
20	J20-W-Left	180	172	1	YES
	J20-W-Through	425	450	1	YES
	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
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

Junction	Approach	Base Volume	Modelled Volume	GEH	GEH<5
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
	J22-E-Left	276	256	1	YES
	22-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 told 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.

4.1.1 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.

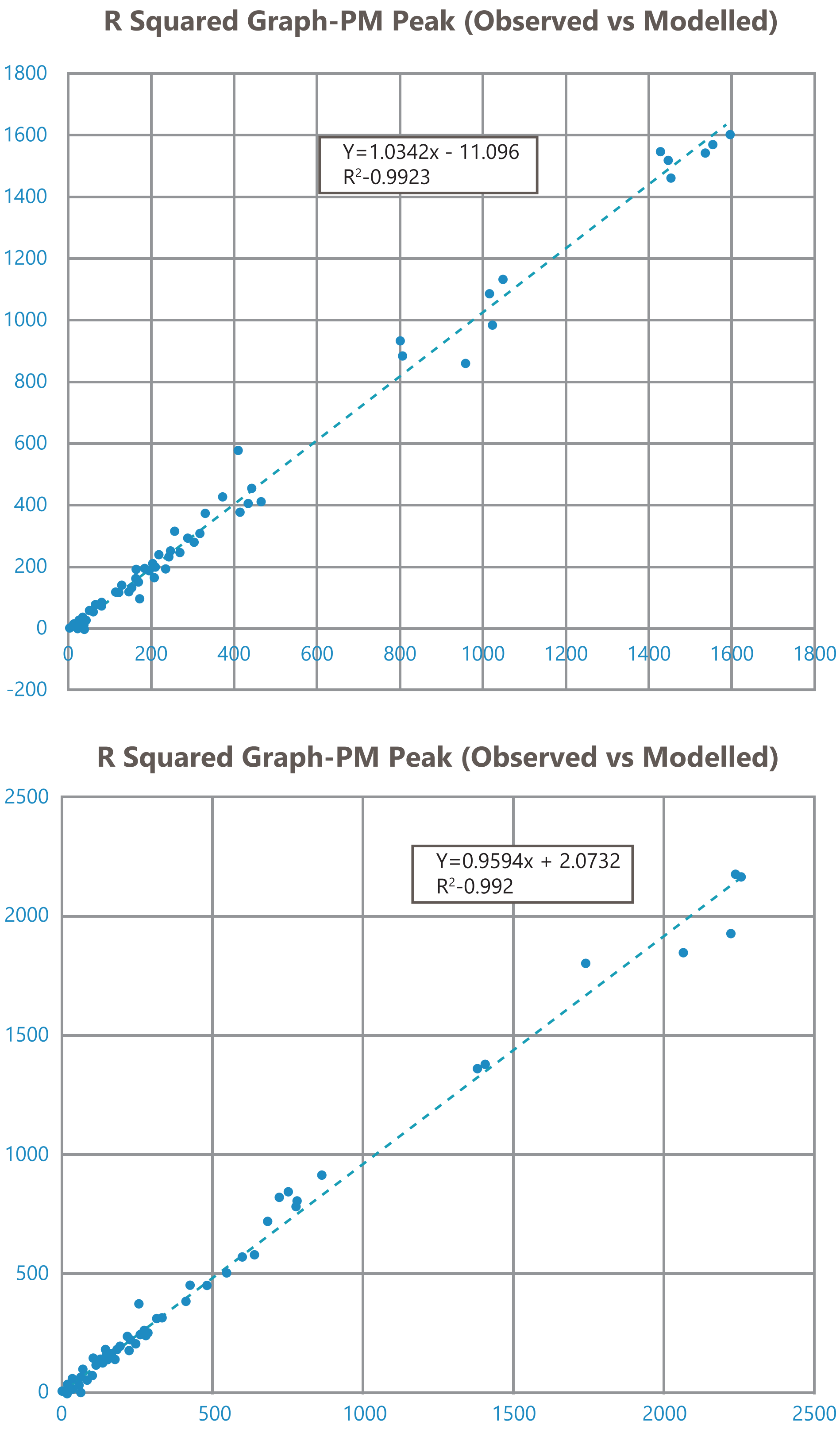


Figure 3.5: Observed Vs Modelled Volume-Graph-Base

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.

4.2 QUEUE LENGTH COMPARISON

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

Table 3-3 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
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
13-S-Right	1	15		J21-W-Right	0	0

Movement	Queue (m)		Junction	Movement	Queue (m)	
	Modelled	Observed			Modelled	Observed
J1-E-Right	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 3-4 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

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

MODEL ASSESSMENT

Photo: Adobe Stock

5.1 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.

5.1.1 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 3.6 LOS Criteria

5.2 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 3-5 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-Through	263	2	A
	J2-W-Left	103	1	A		J18-W-Left	251	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	Total	**879**	**4**	**A**		J21-W-Right	10	2	A
14	J14-S-Right	0	0	A		J21-W-Through	311	2	A
	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	178	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 3-6 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-Through	3	1	A
	J2-W-Left	822	0	A		J18-W-Left	183	0	A
	J2-W-Through	72	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
	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.

NEXT STEPS

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6.1 NEXT MODEL STAGES

With the Stage 1 micro-simulation model calibrated, the scenario testing will commence as the next step of the project. The Stage 1 scenario testing report will contain information on the process and result from scenario testing.

Upon the acceptance of the Stage 1 micro-simulation model report, Stage 2 will commence which will include simulation of a wider area of Georgetown encompassing the full UNESCO World Heritage area.

On completion of Stage 2, Ramboll will conduct a PTV accredited training courses on the use of VISSIM software for MBPP and Digital Penang in order for the micro-simulation model to be used for ongoing testing of changes to transport within Georgetown beyond the conclusion of this Pilot Project.

6.2 Next Deliverable Stages

With the above model stages, the following deliverables will be produced and submitted as part of this project.

Table 6-1 Deliverable Stages

Deliverable	Contents
Model Inception and Trial Model Report (D1A)	Project inception, background information review, scenario development and simulation modelling methodology
Survey Report (D1B)	Interim Technical Deliverable - Results of on-site surveys including traffic counts, parking and signal timing. Survey information is used as the input parameters into the model development to ensure the model is representative of real world conditions.
Stage 1 Base Model Calibration Report (D2A)	Interim Technical Deliverable – This report documents the model development and calibration and is a formal documentation of the models accuracy and reflectiveness of real world conditions
Stage 1 Scenario Testing Report (D2B)	Stage 1 Final Deliverable – This report documents the simulation of the scenario testing and comparison of the base calibrated (real world) model to the future proposed interventions to evaluate their improvement.
Stage 2 Base Model Calibration Report (D3A)	Interim Technical Deliverable (Stage 2) – This report documents the model development and calibration and is a formal documentation of the models accuracy and reflectiveness of real world conditions for the larger Stage 2 area
Stage 2 Scenario Testing Report (D3B)	Stage 2 Final Deliverable – This report documents the simulation of the scenario testing for Stage 2 and comparison of the base calibrated (real world) model to the future proposed interventions to evaluate their improvement.
Final Report (D4) and Project Evaluation (D5)	Compilation of Stage 1 and Stage 2 work above

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.

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