PENANG SMART MOBILITY MICRO-SIMULATION MODEL DEVELOPMENT

FULL AREA MODEL CALIBRATION REPORT

DECEMBER 2023

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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.

This project involves the development and calibration of a micro-simulation model using PTV Vissim software and testing of a limited set of potential future interventions for Georgetown, as well as training of MBPP staff in the use of PTV Vissim.

This report presents the calibrated Vissim micro-simulation model results for the full study area as defined for Stage 2 of the study. 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 full 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; and
- Section 6 presents the next steps of this study.

2. STUDY AREA

2.1 Study Area and Boundary

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.

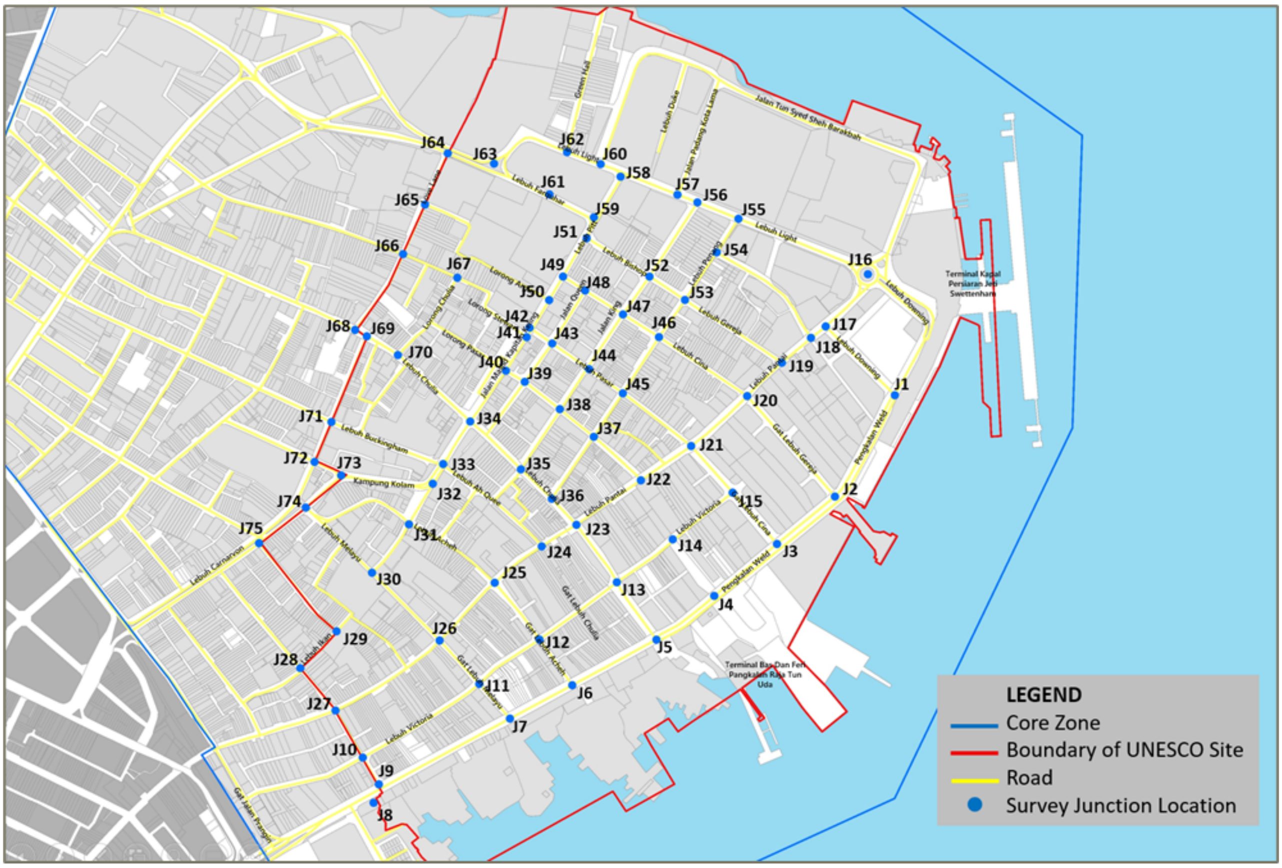

Figure 2-1 Model Area

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.

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	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
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
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	Lehub 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
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
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
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
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			

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 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
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- 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
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- 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.

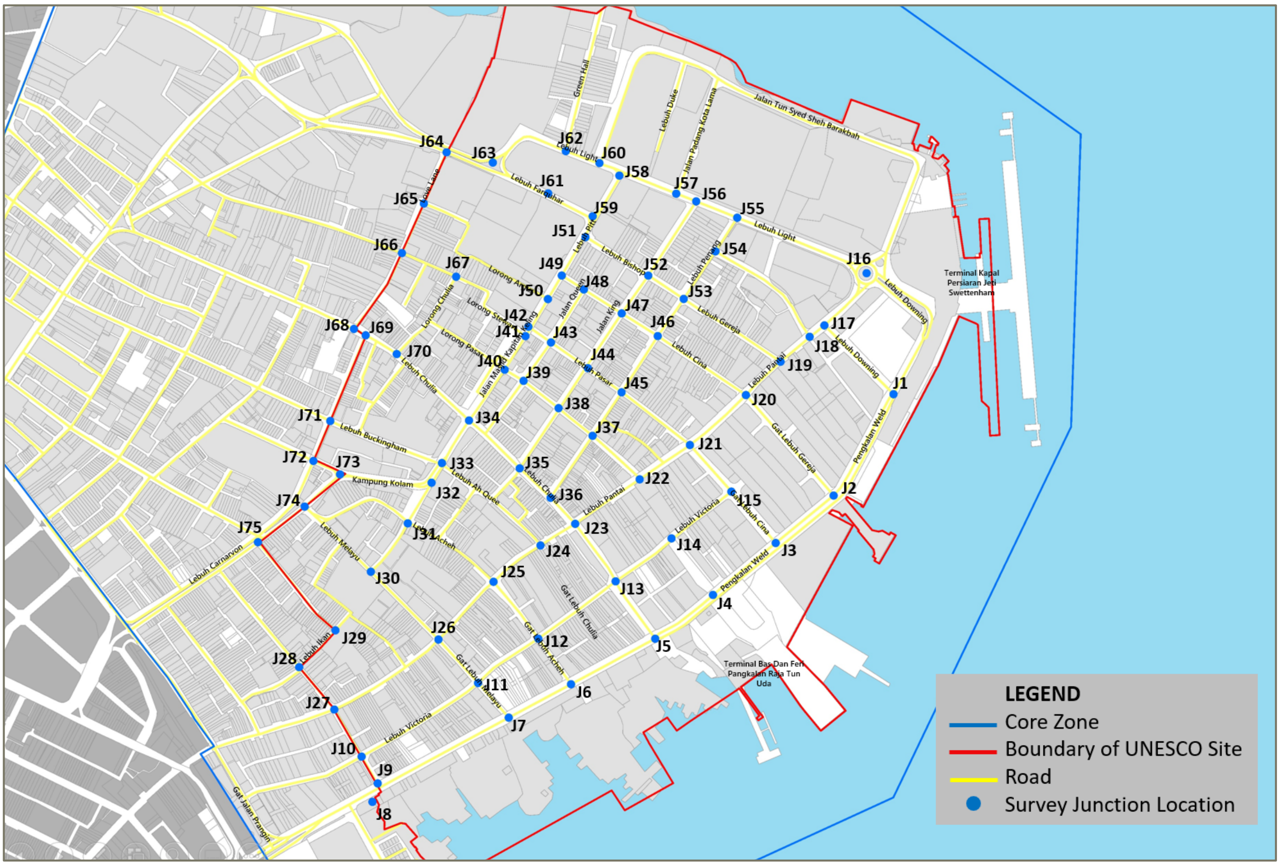

Figure 2-3 Existing Junctions Surveyed in Study Area

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 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 3.2 to 3.6)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (Traffic flows shown in Figure 3.7 to 3.11)

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 2-3 11 Junctions Survey Volume Comparison

		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.

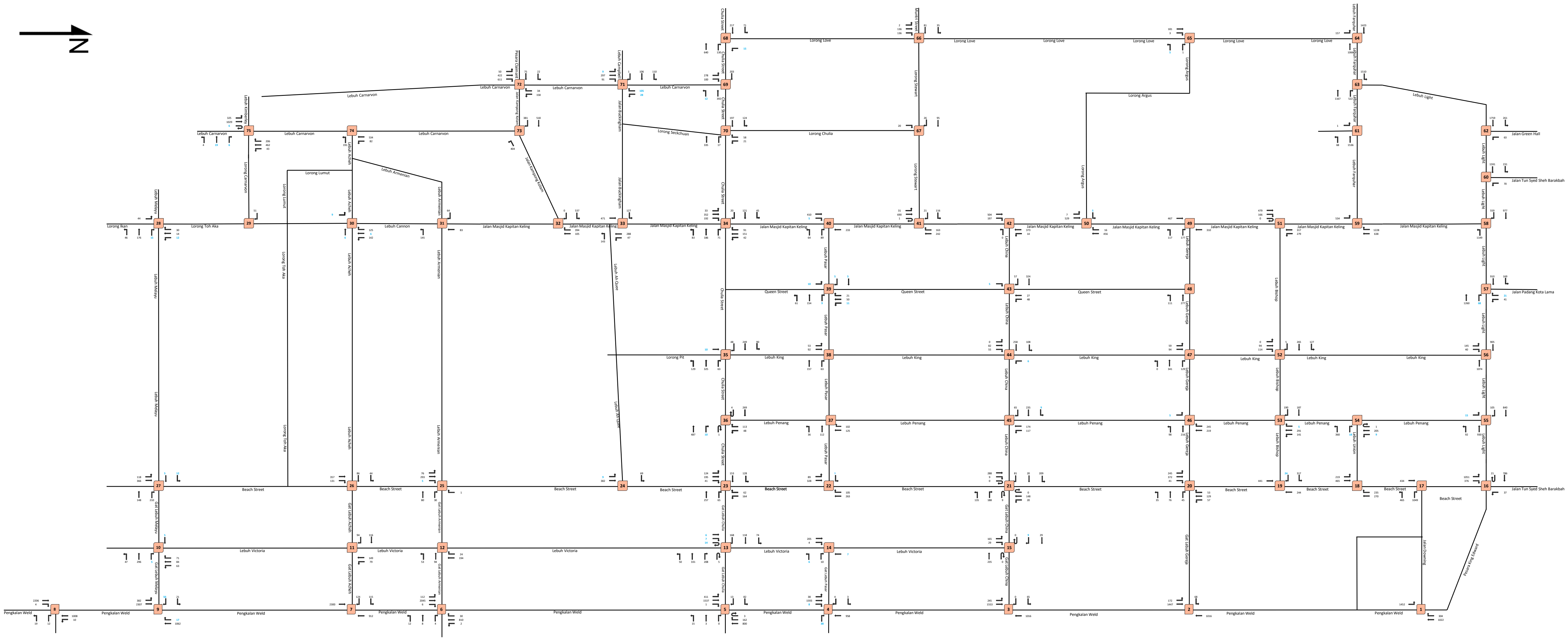

Figure 2-4 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Full

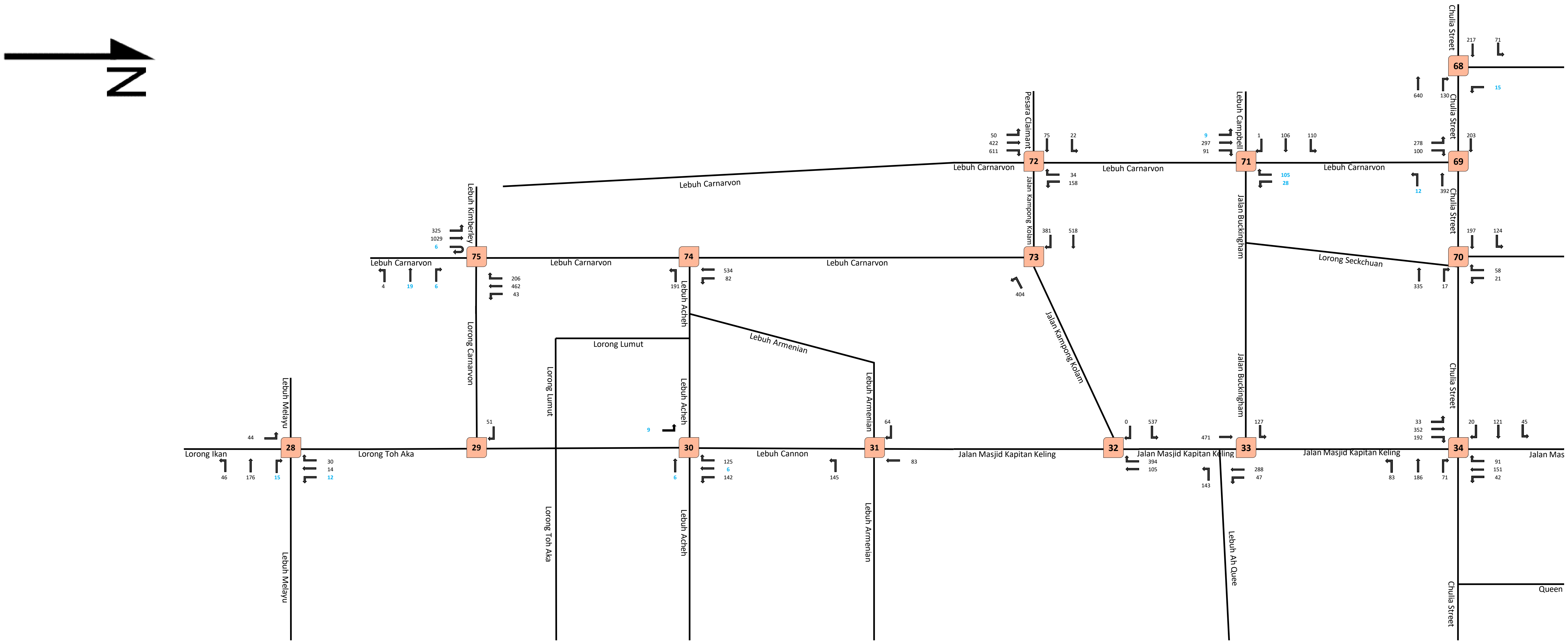

Figure 2-5 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northwest Section

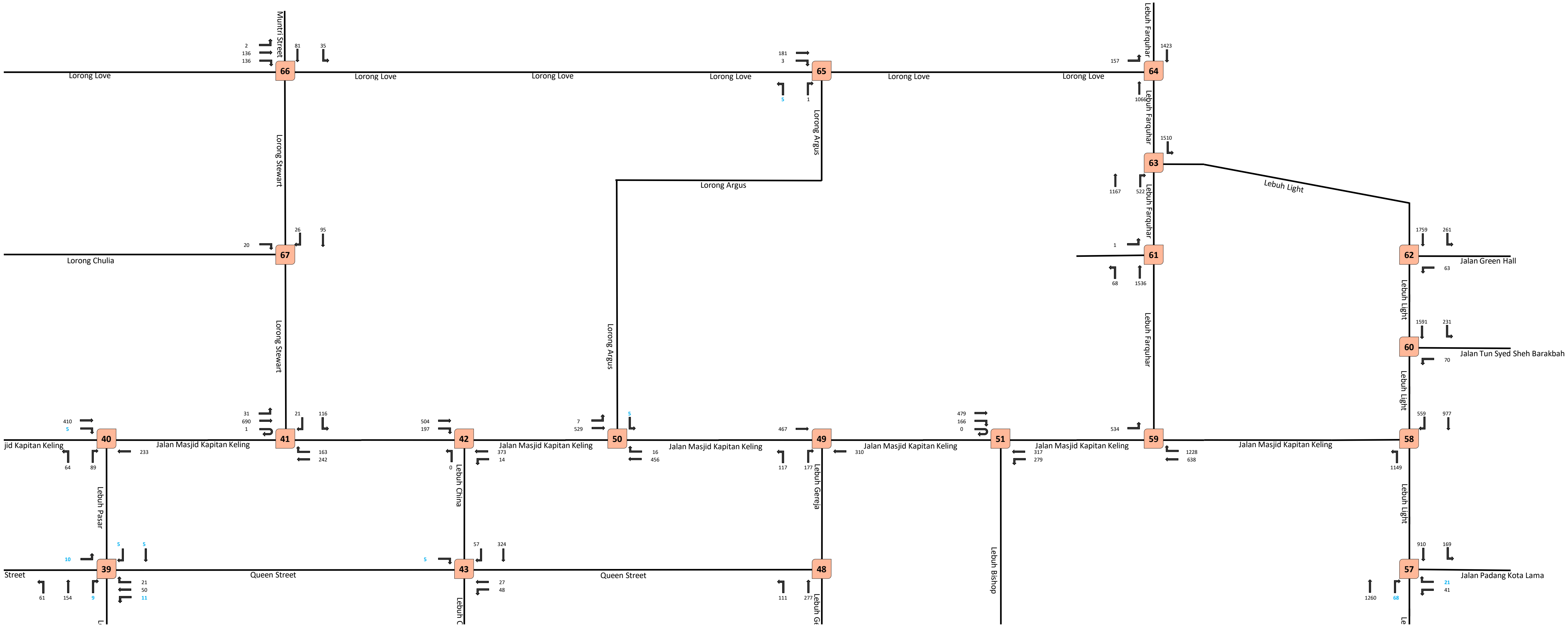

Figure 2-6 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Northeast Section

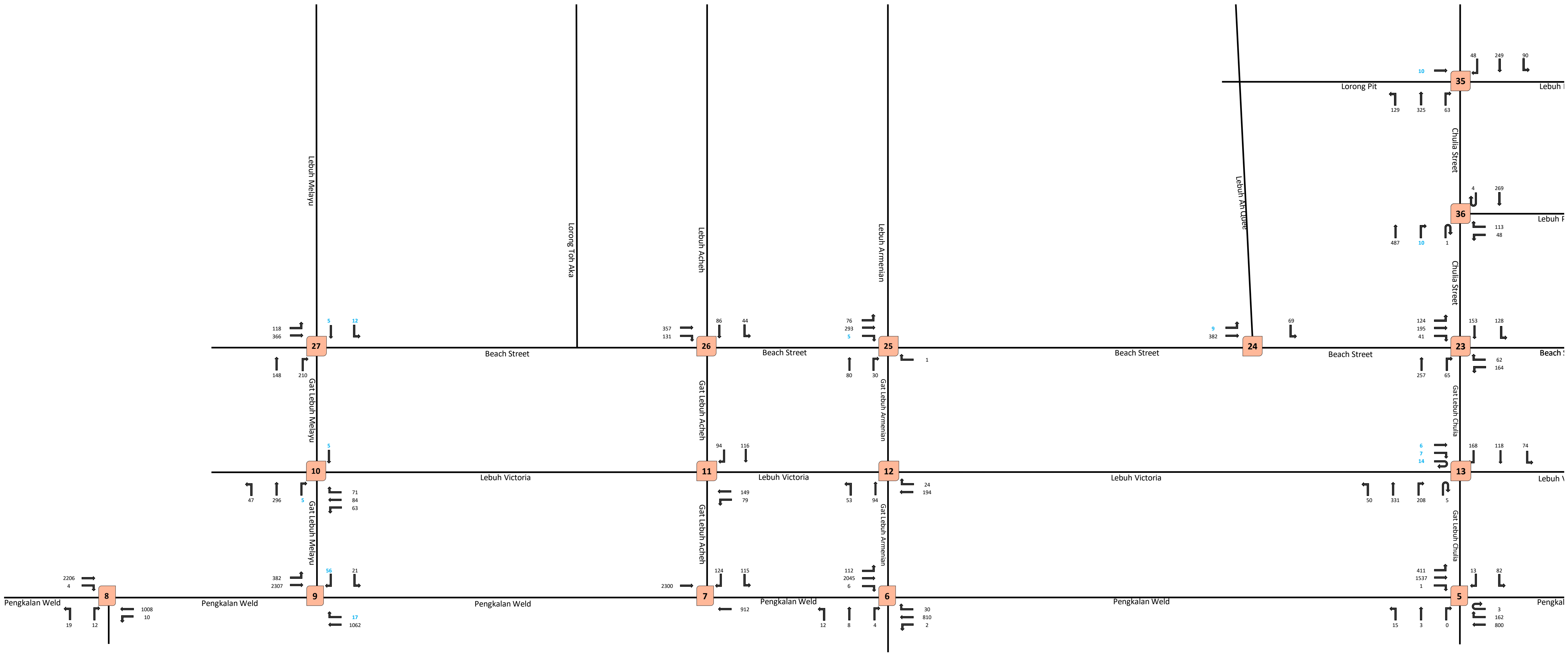

Figure 2-7 2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southwest Section

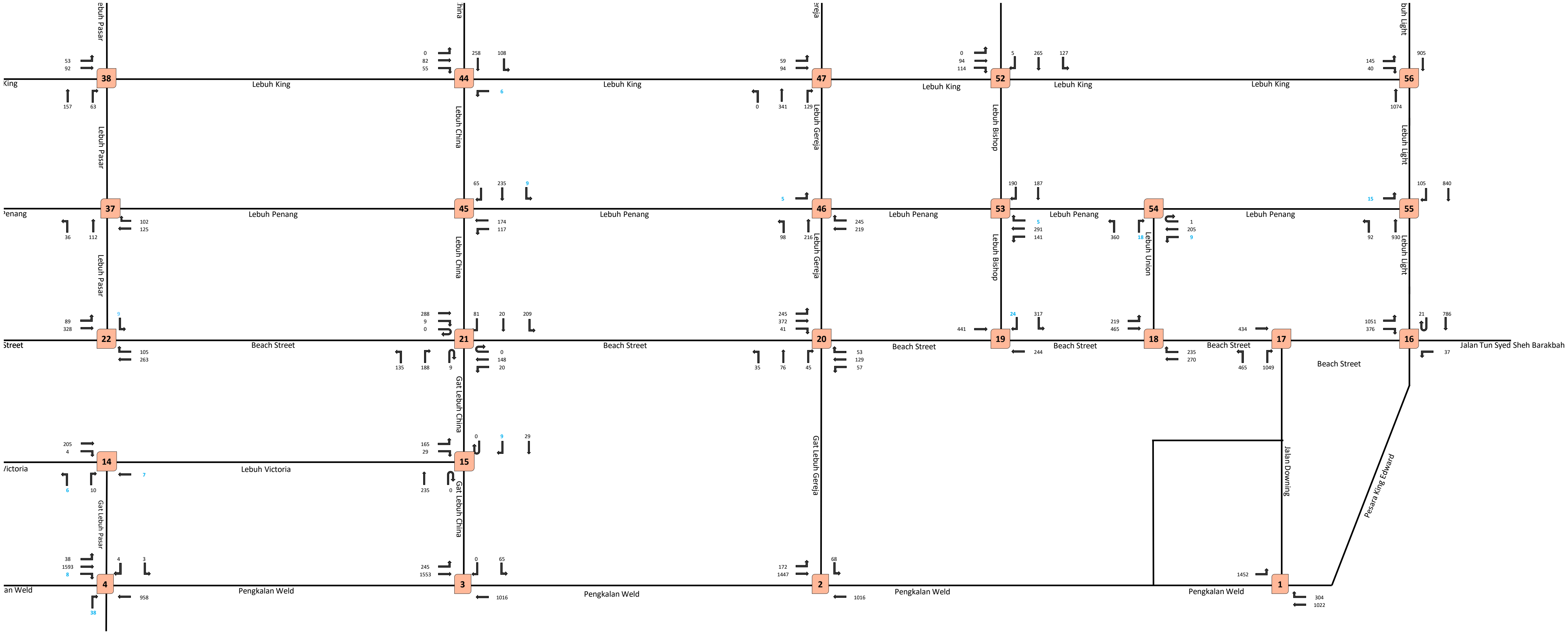

Figure 2-8 **2021 Existing Traffic Flows (PCUs/Hr) AM Peak – Southeast Section**

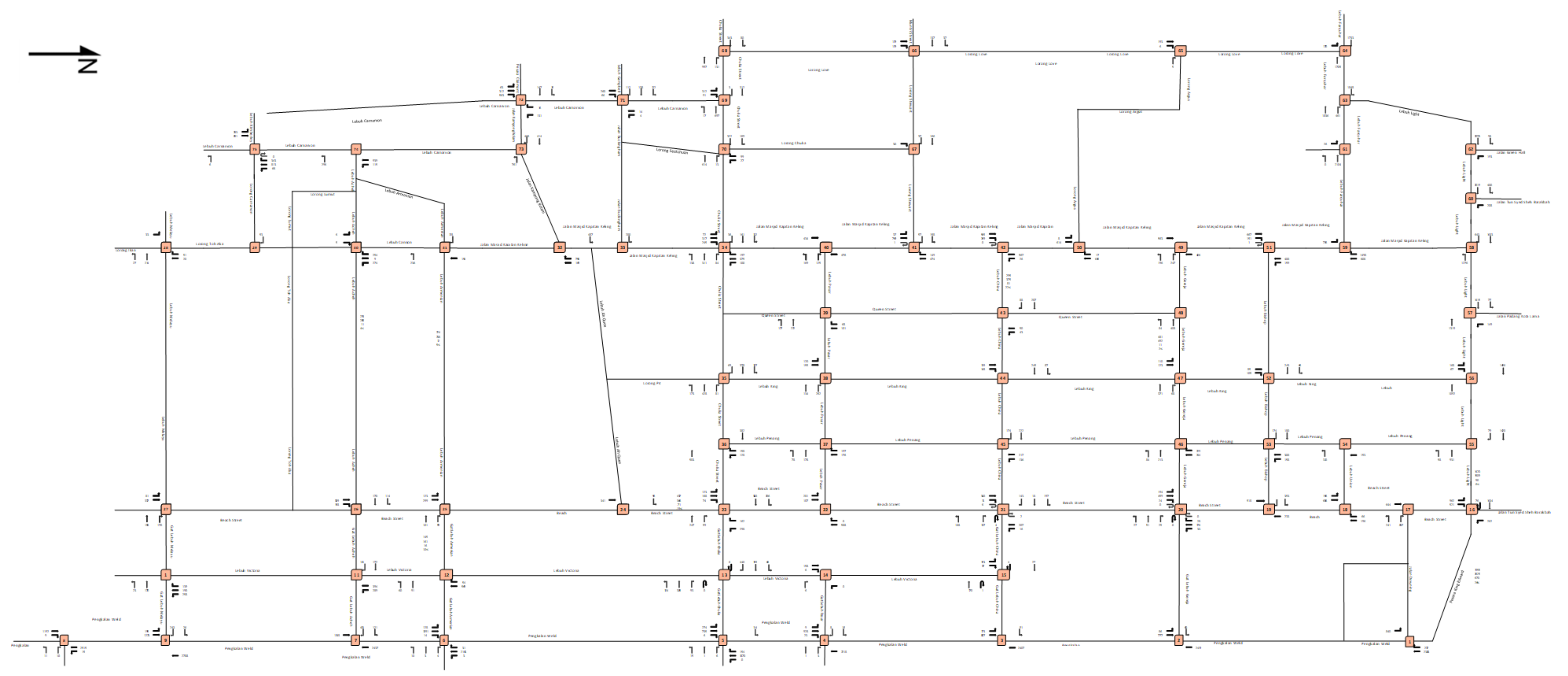

Figure 2-9 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Full

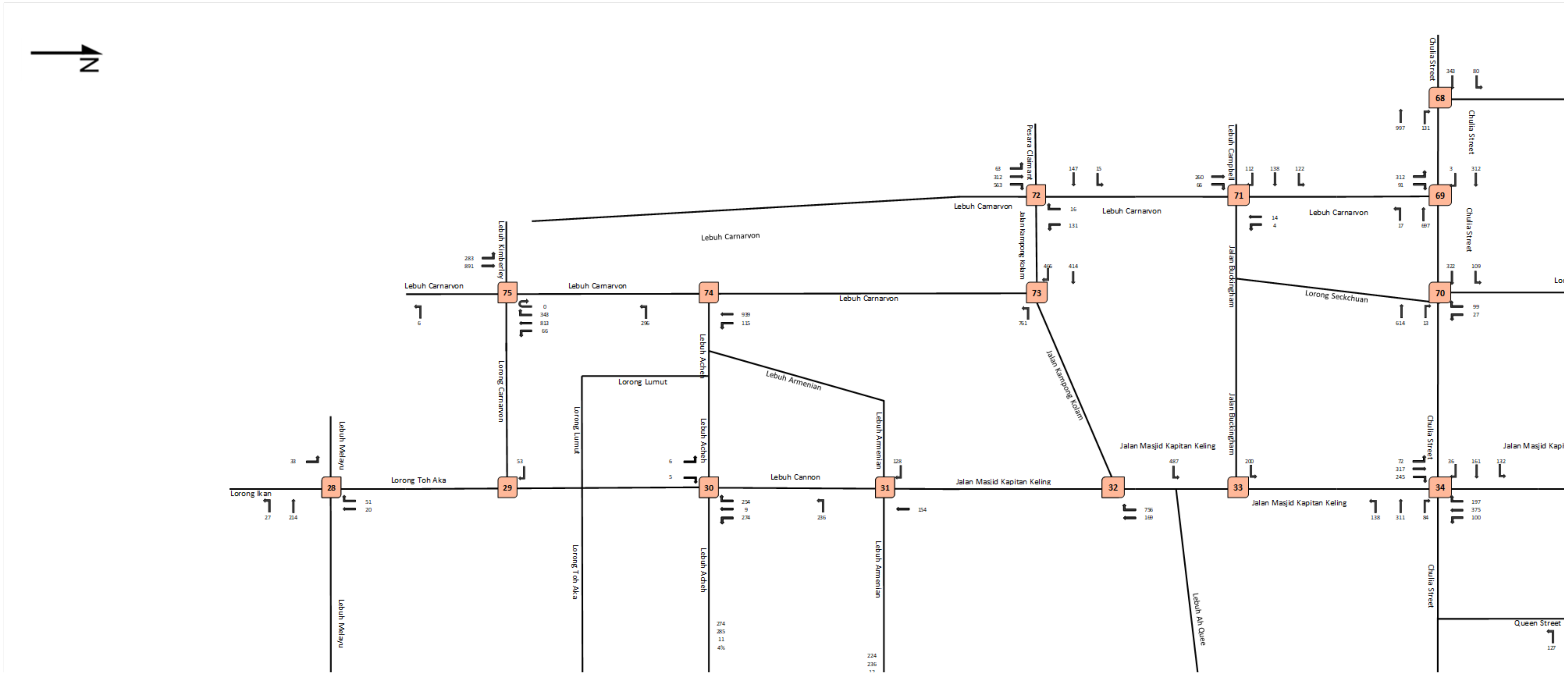

Figure 2-10 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northwest Section

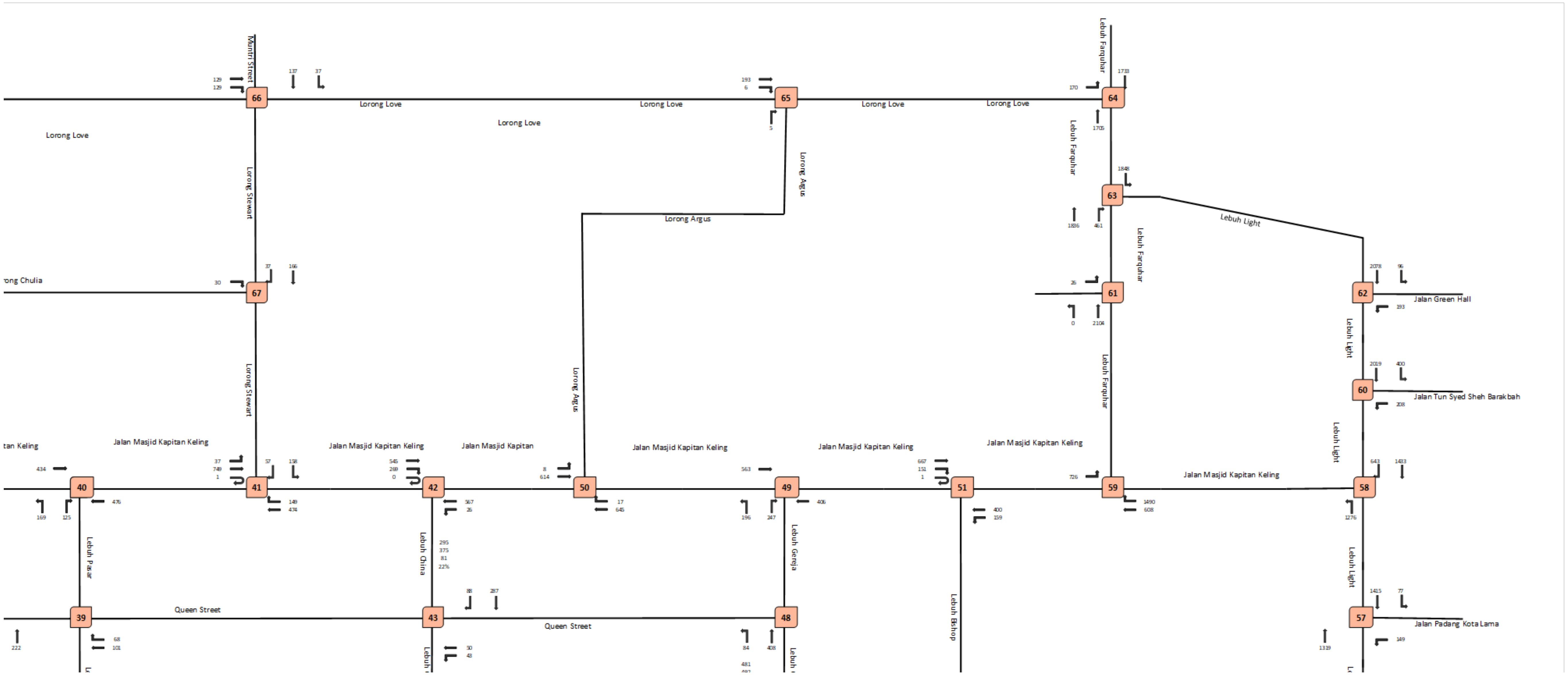

Figure 2-11 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Northeast Section

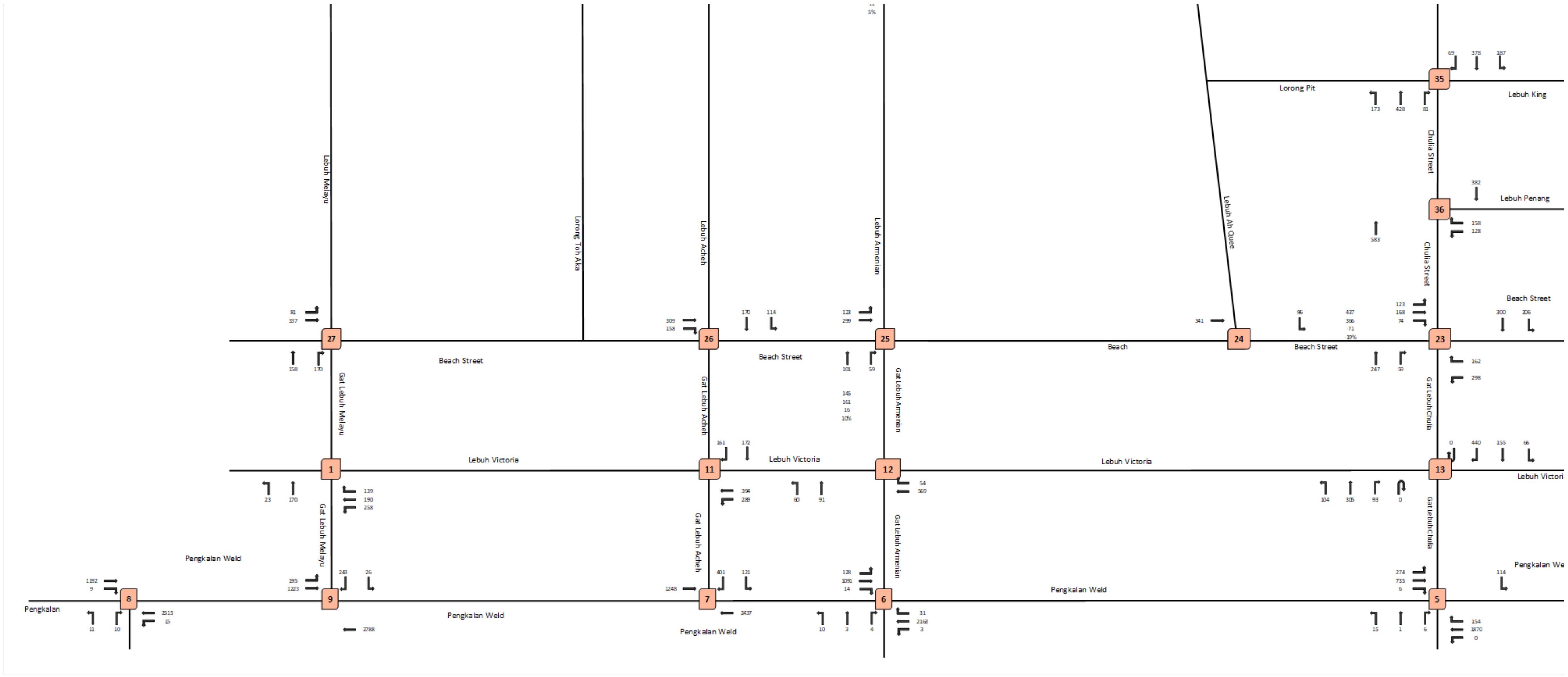

Figure 2-12 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southwest Section

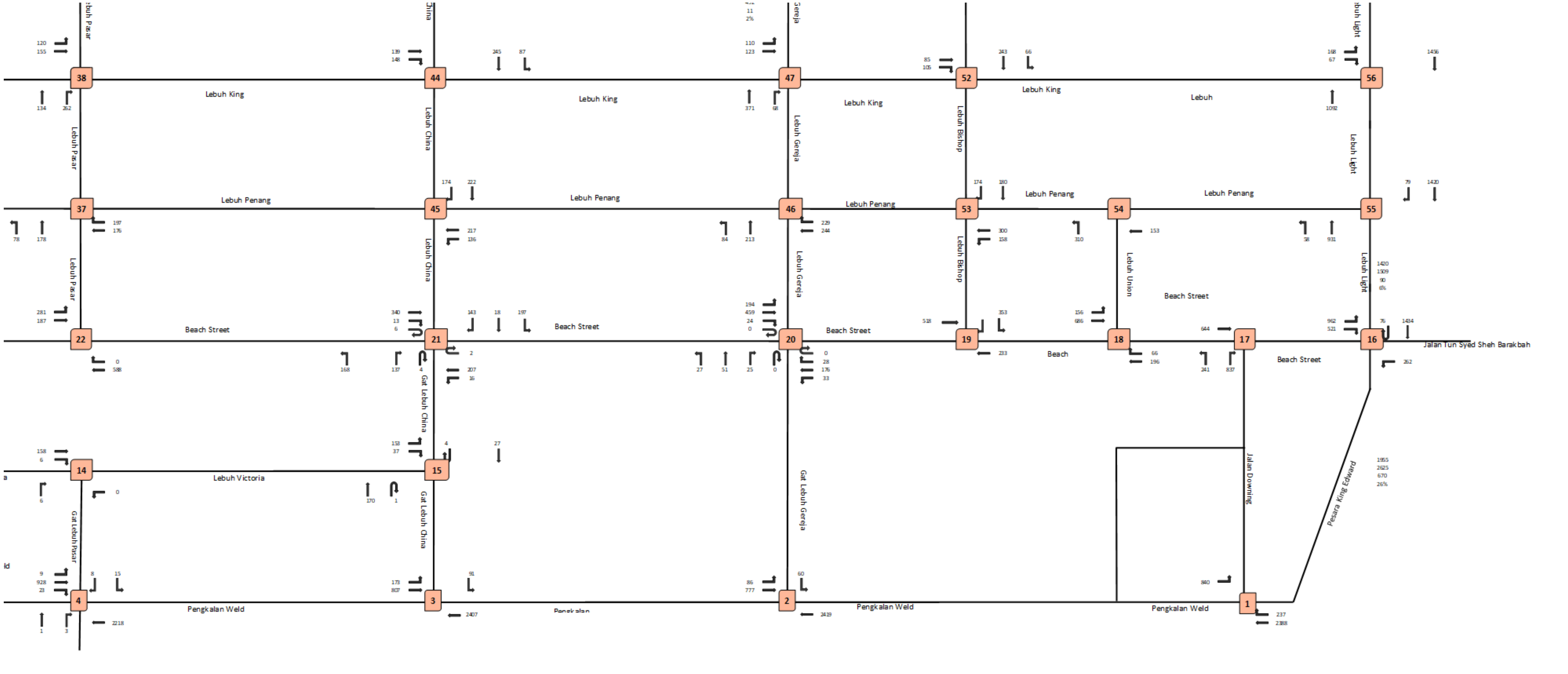

Figure 2-13 2021 Existing Traffic Flows (PCUs/Hr) PM Peak – Southeast Section

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.

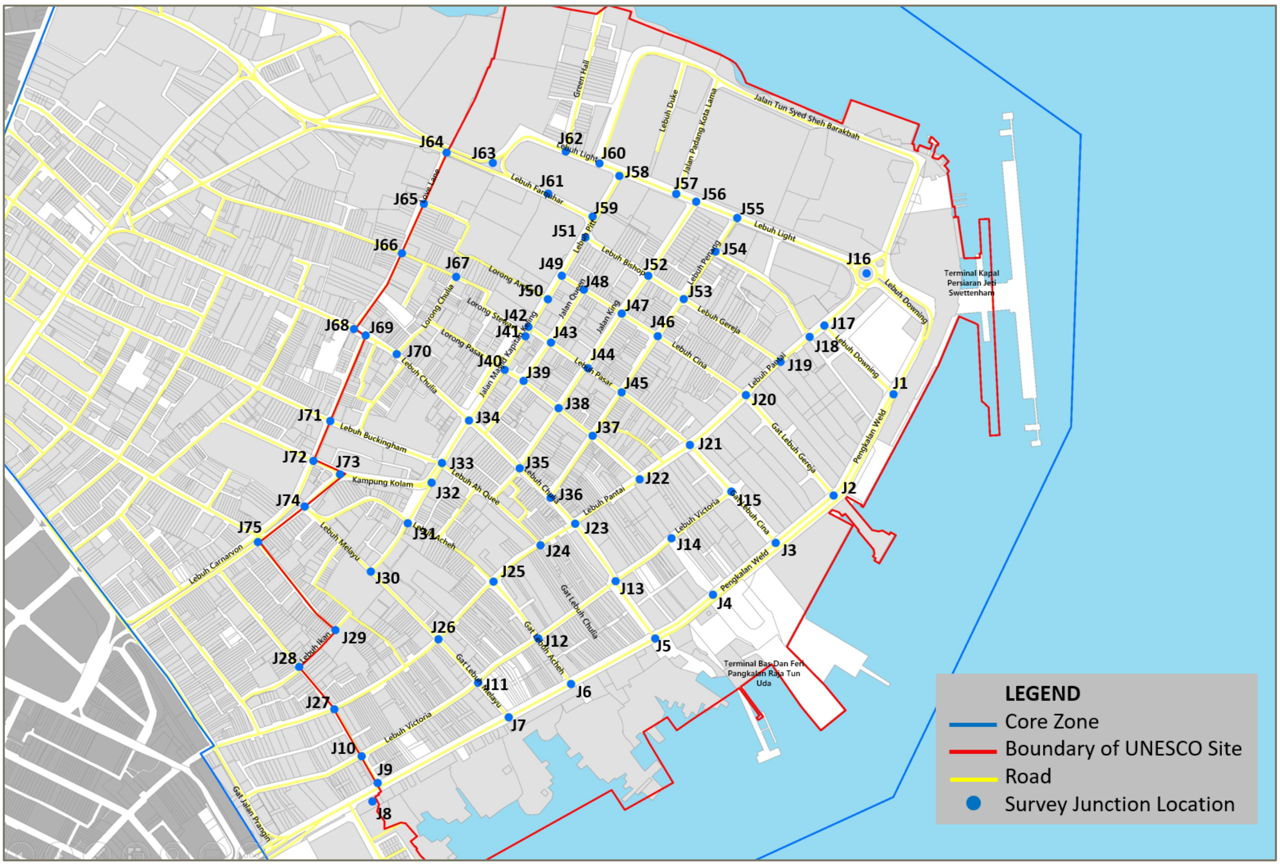

Figure 2-14 Existing Pedestrian / Cyclist Crossings Surveyed in Study Area

Pedestrian / cyclists counts results were 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 2-4 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 3.13 to 3.17)
Weekday PM	16:30 to 19:30	17:00 to 18:00 (flows shown in Figure 3.18 to 3.22)

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.

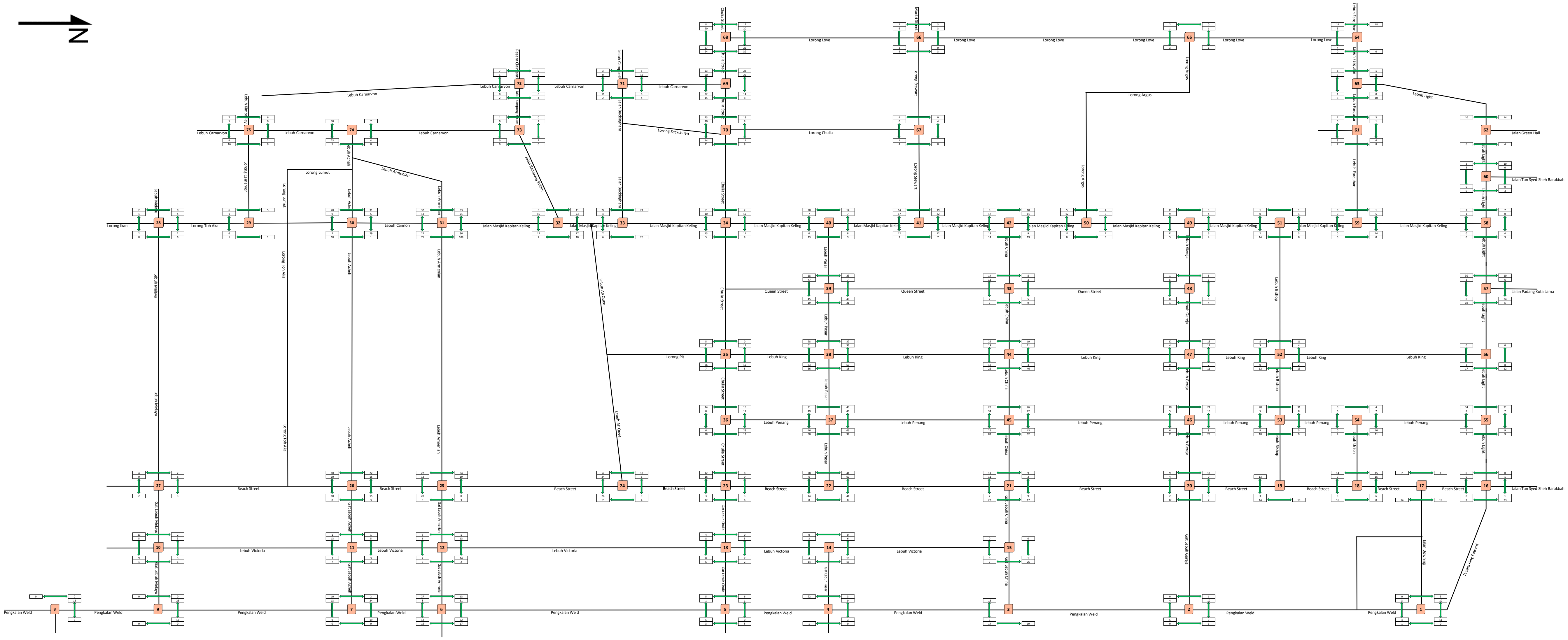

Figure 2-15 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Full

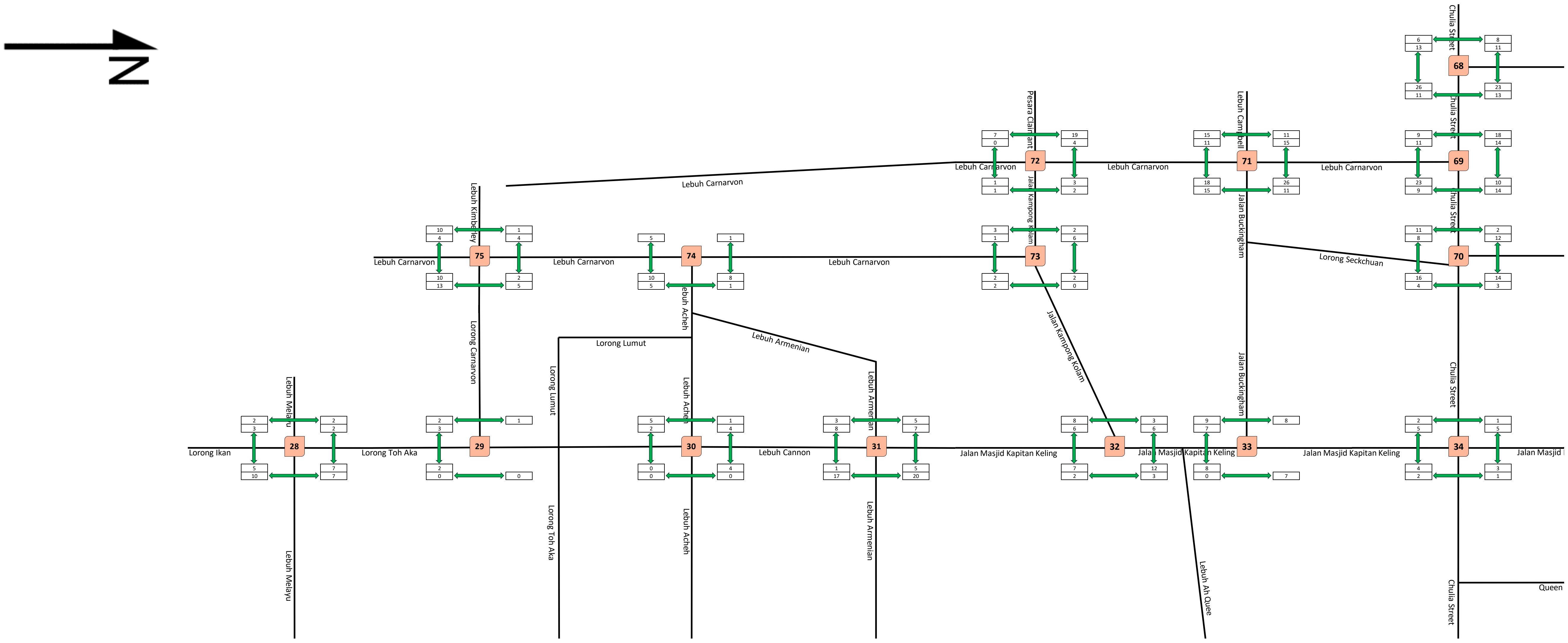

Figure 2-16 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northwest Section

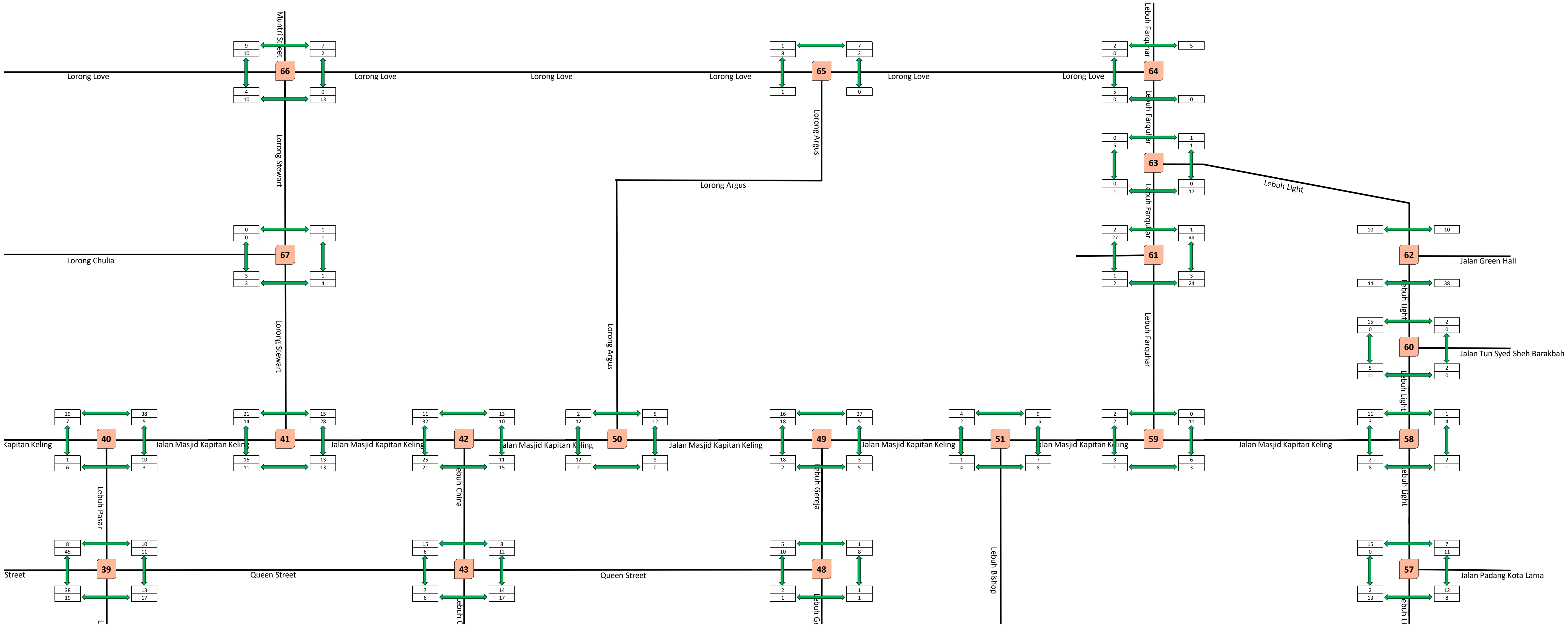

Figure 2-17 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Northeast Section

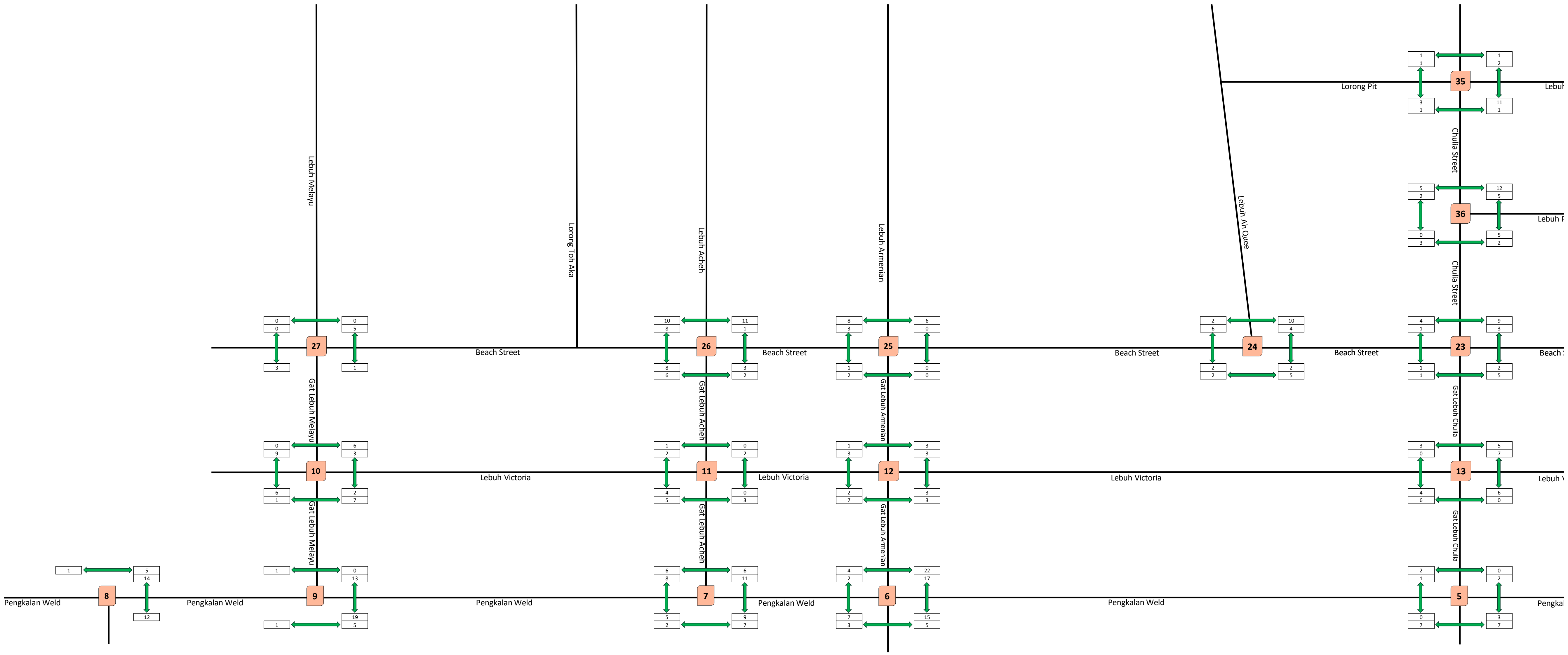

Figure 2-18 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southwest Section

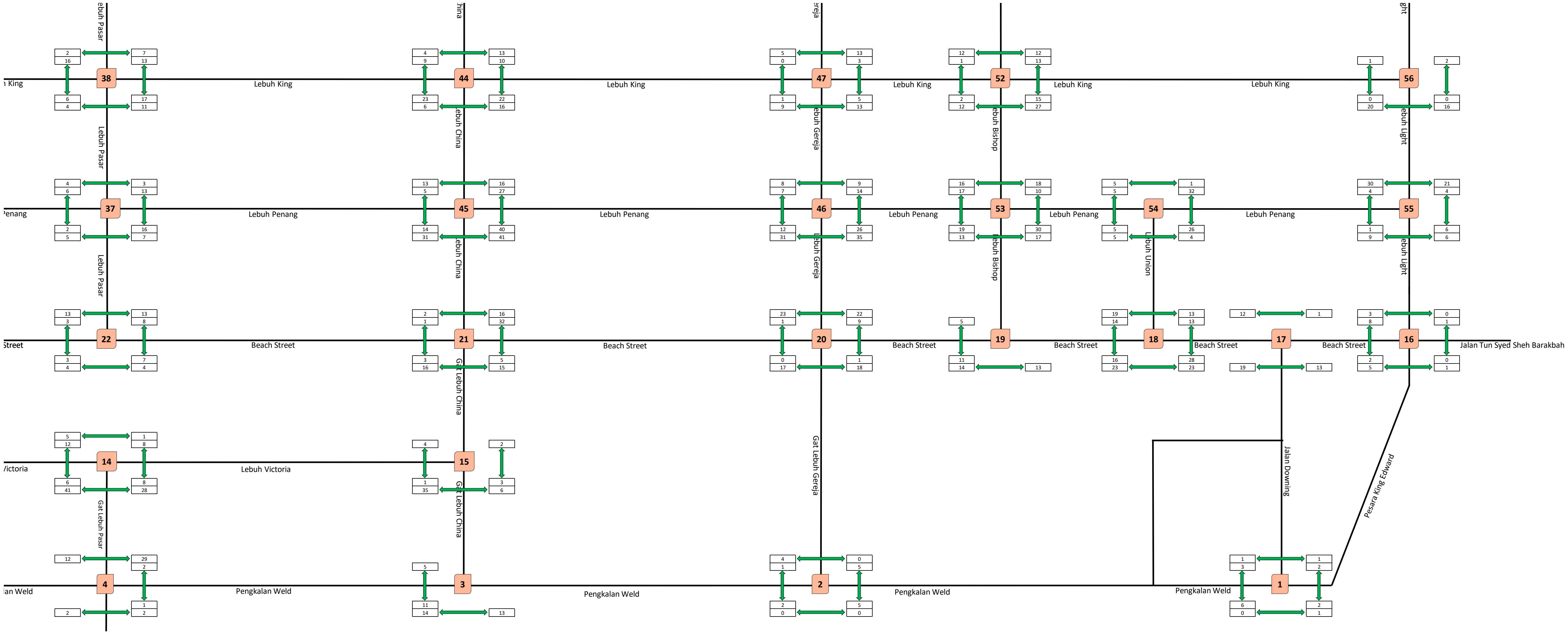

Figure 2-19 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) AM Peak – Southeast Section

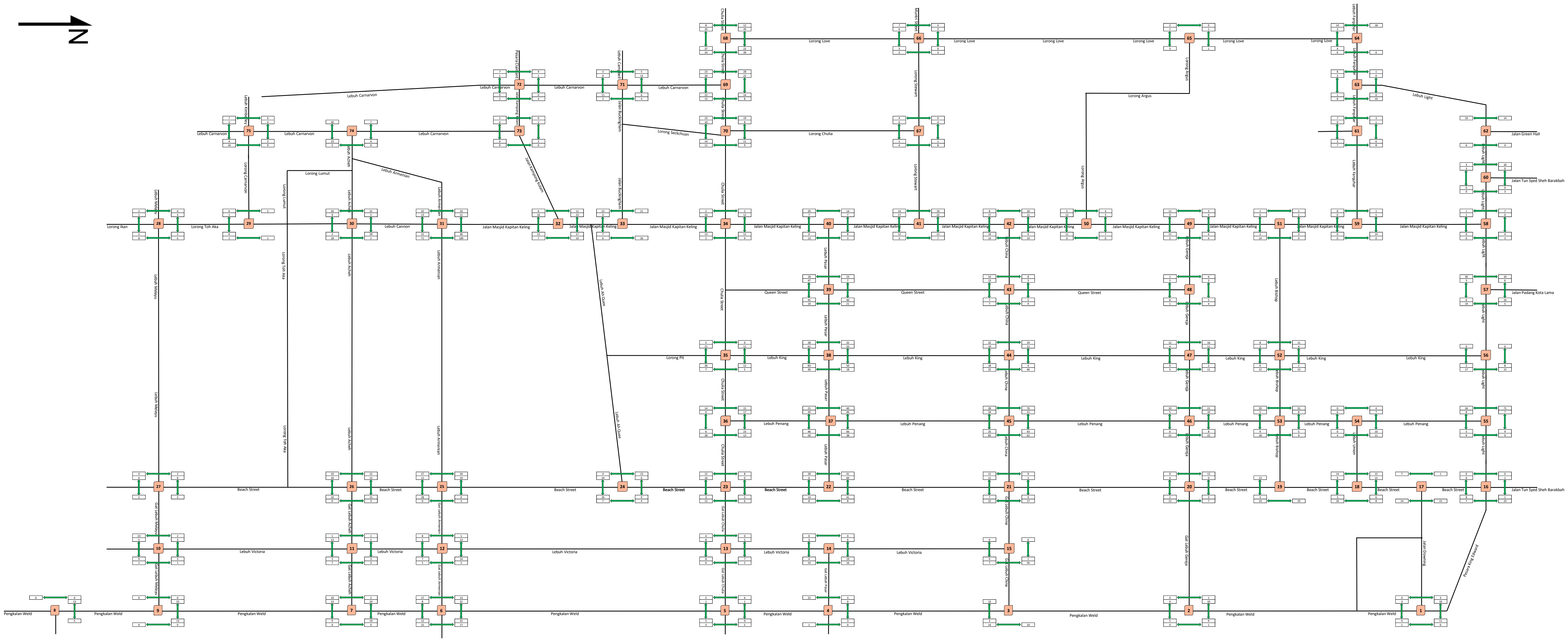

Figure 2-20 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Full

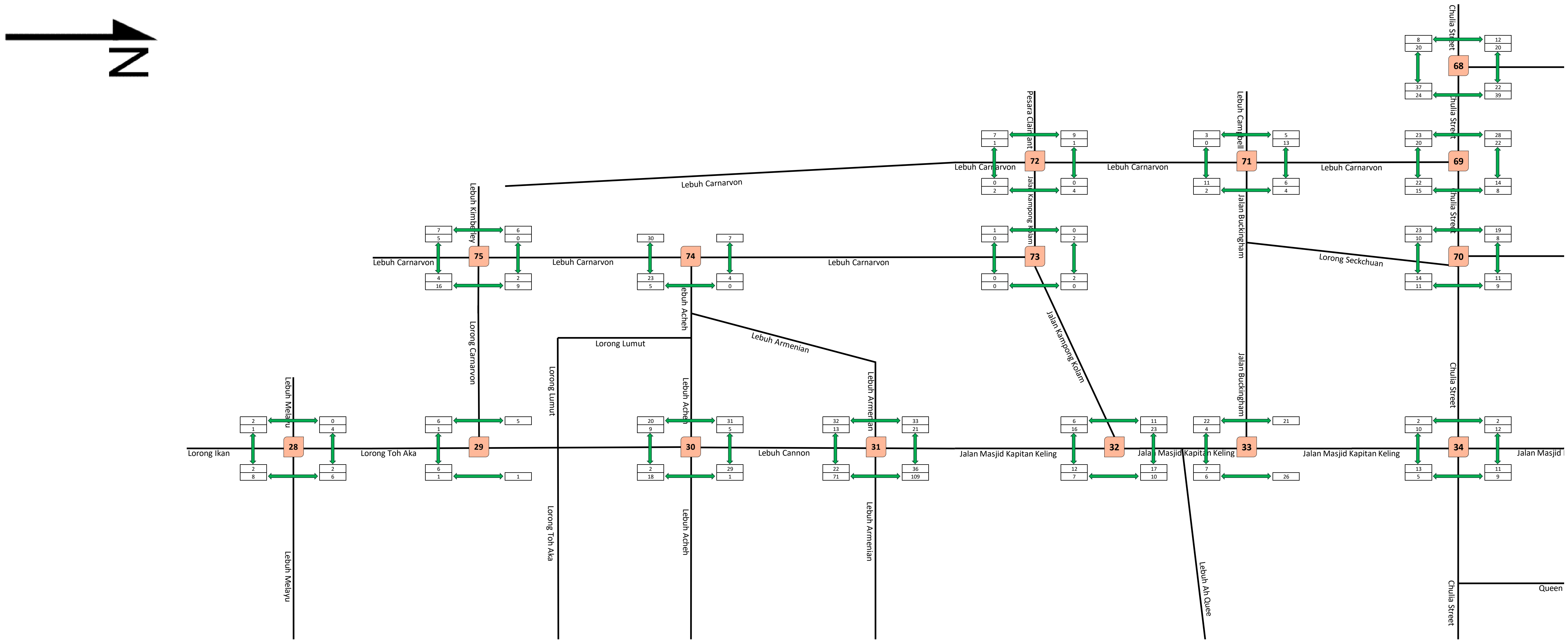

Figure 2-21 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northwest Section

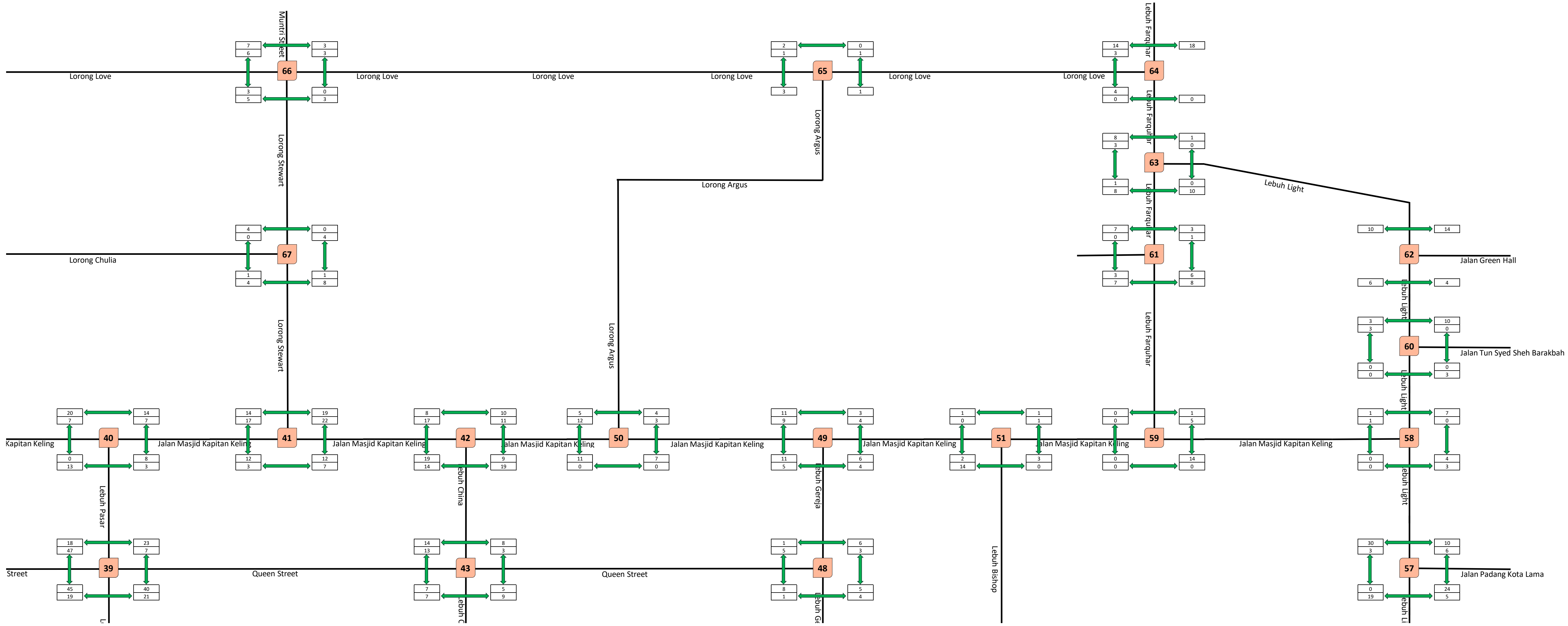

Figure 2-22 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Northeast Section

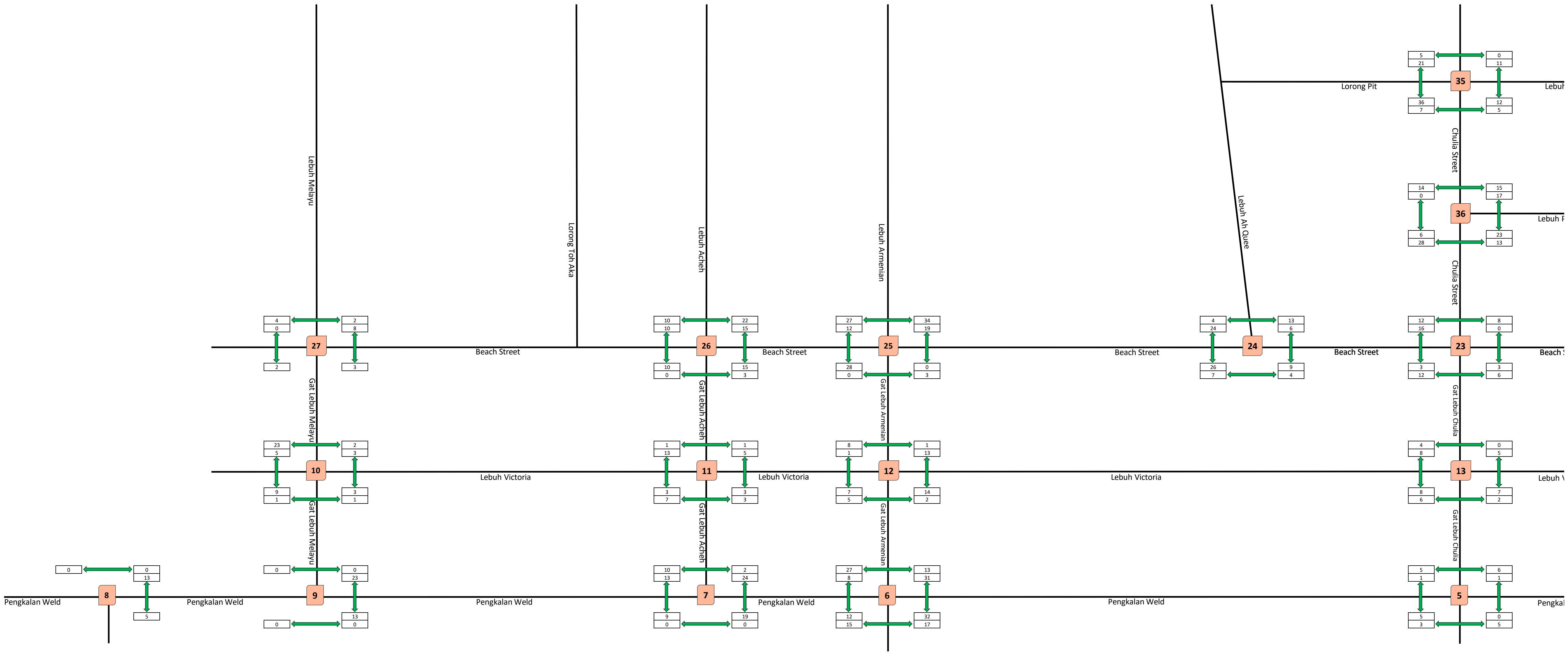

Figure 2-23 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southwest Section

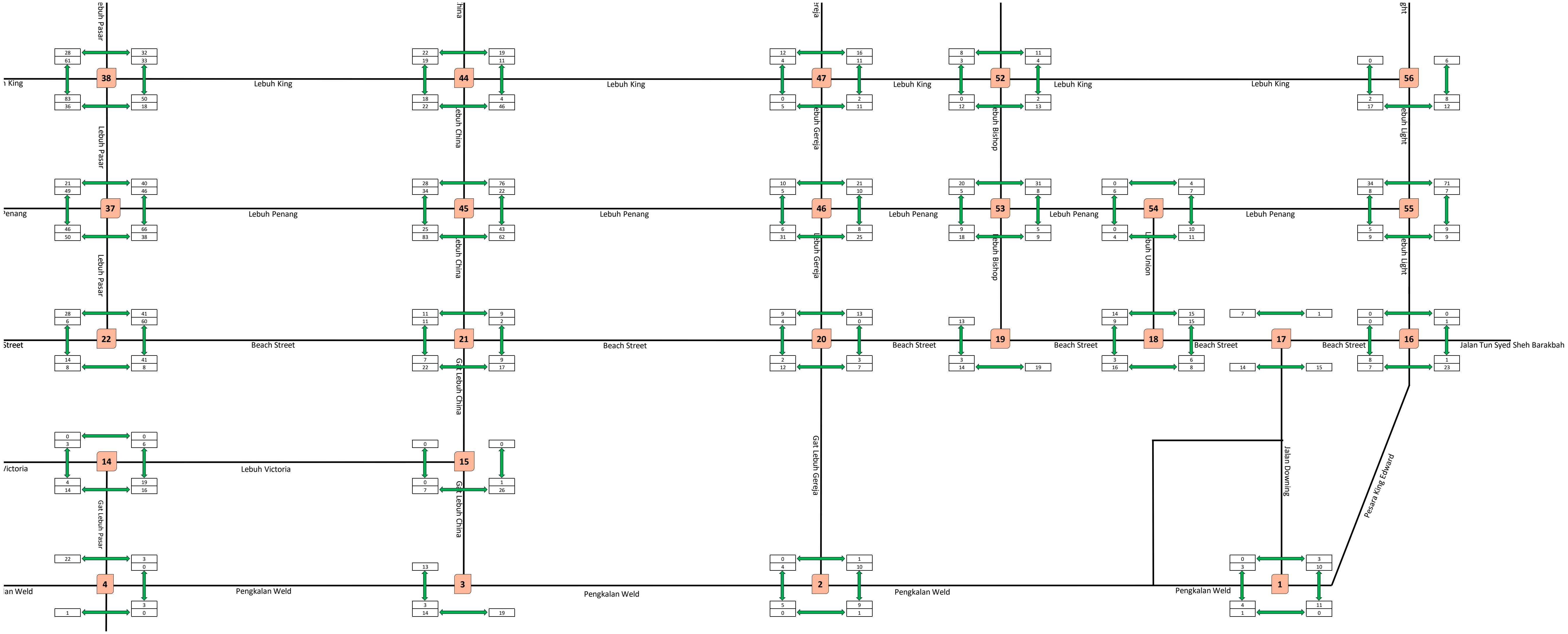

Figure 2-24 2021 Existing Pedestrian / Cyclist Flows (Pax/Hr) PM Peak – Southeast Section

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.

Table 2-5 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 2-6 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 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.

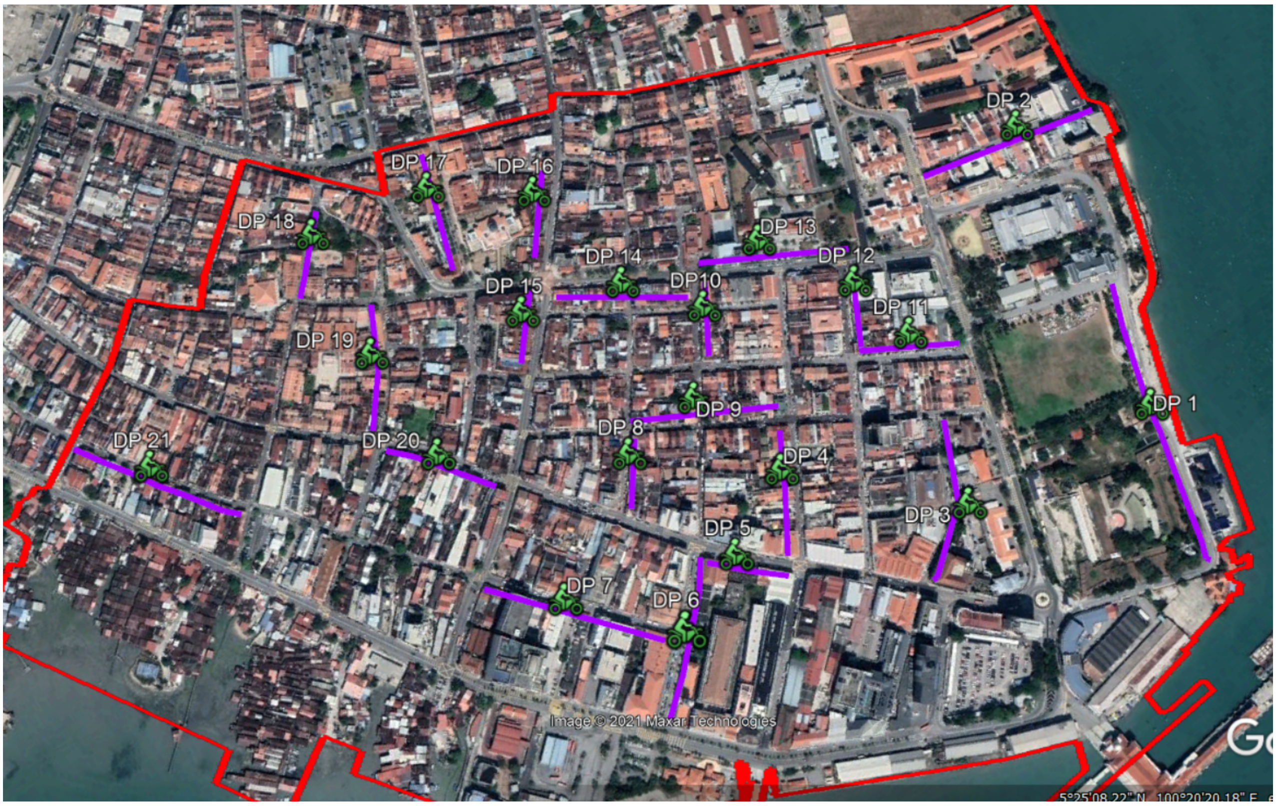

Figure 2-26 Parking Dwell Time Survey Locations

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

Table 2-7 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.

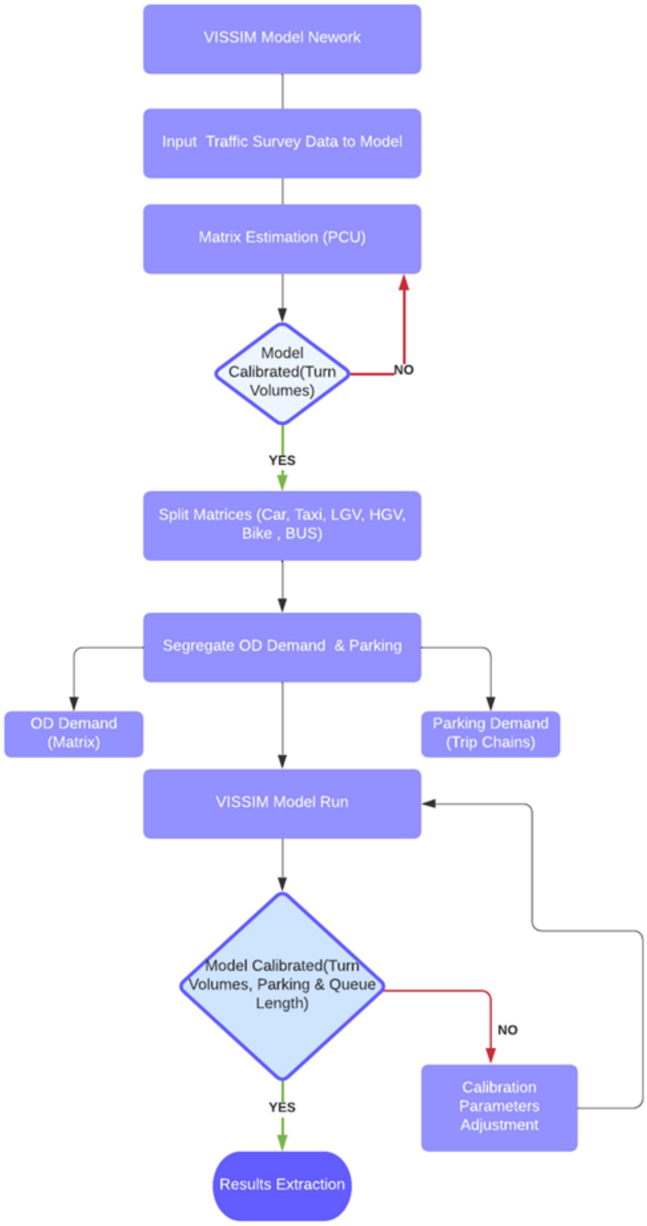

Figure 2-27 Study Methodology

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 2-8 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
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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
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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 2-9 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
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
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

2.7.2 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 model calibration section at 4.1.1.

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 AM Peak Traffic Compositions

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
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
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
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 2-11 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
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
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
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%

2.7.4 Segregate Parking Demand

Trip chain will used to model parking in Vissim model from the final matrix used for calibration. 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 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 2-12 and Figure 2-28 below.

Table 2-12 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 2-28 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.

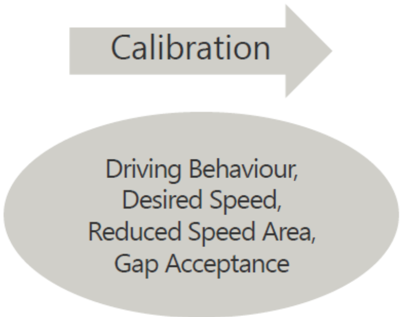
Queues are formed as a results of all the factor impacting vehicles in the network. It could be due to traffic volume, network capacity, signal configuration, vehicle speed, or driving behavior.

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)		
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 2-29 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.

3. MODEL VERIFICATION

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 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.

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.

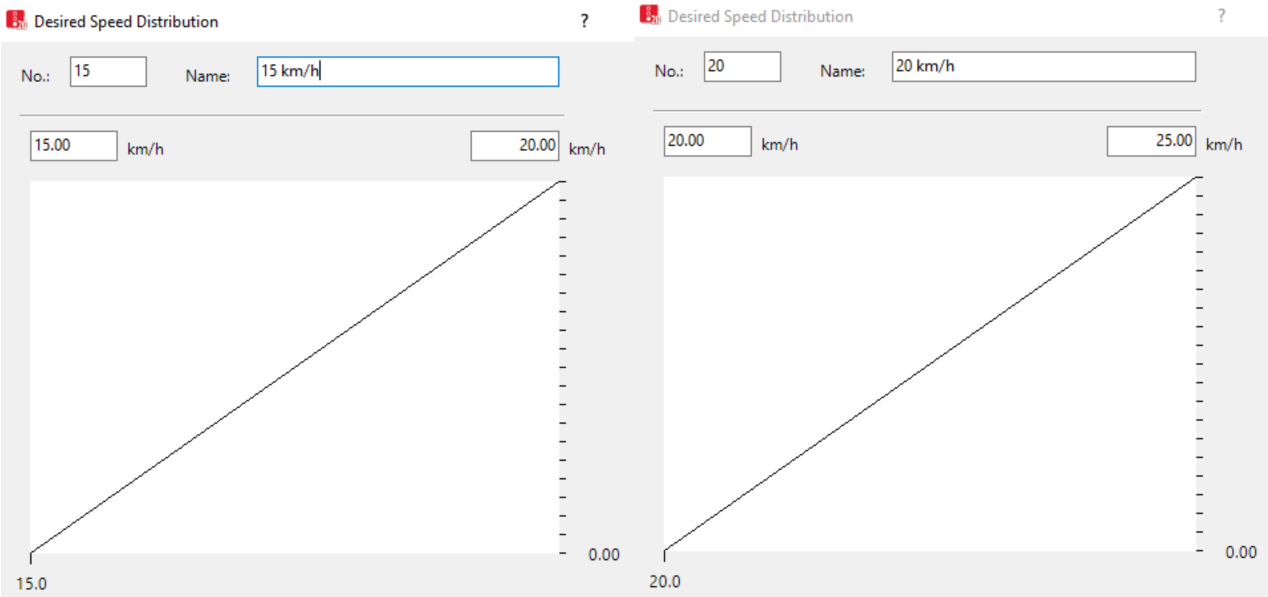


Figure 3-1 Speed Distribution at Turn Movements

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.

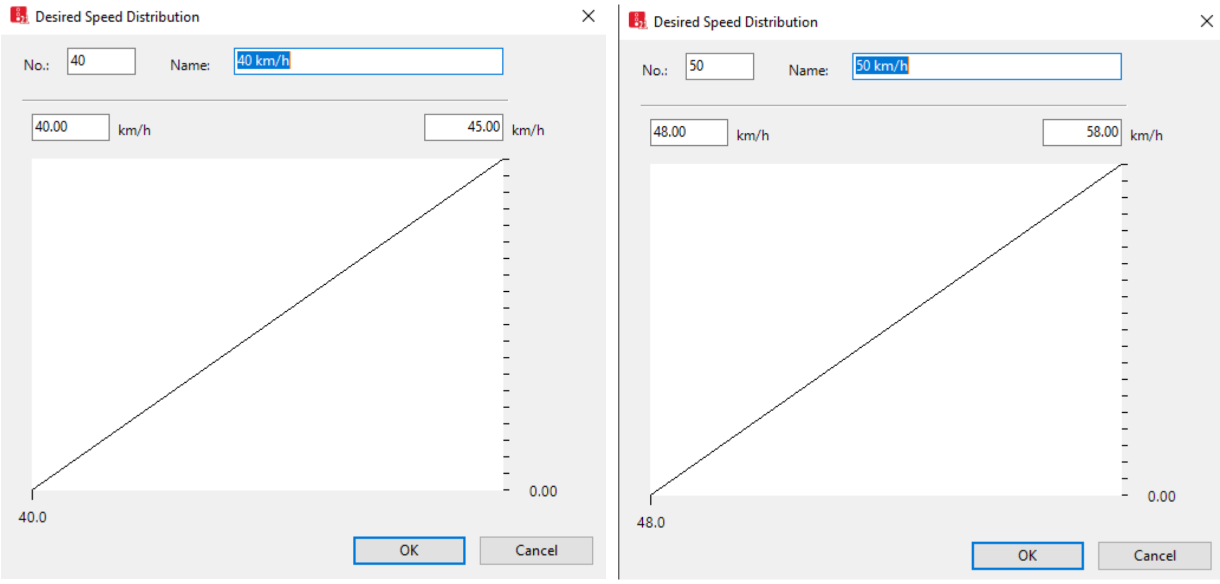


Figure 3-2 Speed Distribution for All Vehicle Types

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 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 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.

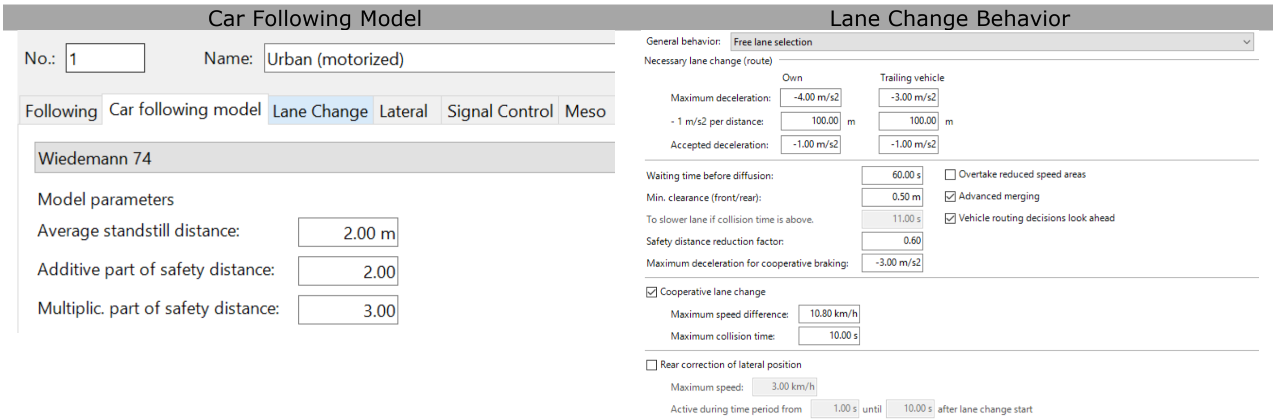


Figure 3-3 Default Car Following and Lane Change Behavior

4. MODEL CALIBRATION

4.1 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:

(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.

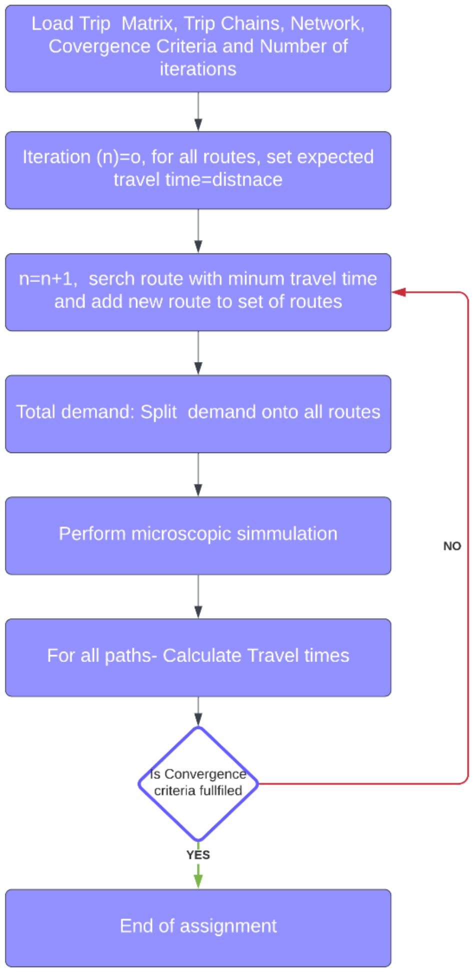


Figure 4-1 Dynamic Assignment Process

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 4-1 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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
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
	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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
	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
	J26-W-Through	357	340	0.9	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
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
	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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
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
	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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
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
	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
	J71-W-Right	91	106	1.5	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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.

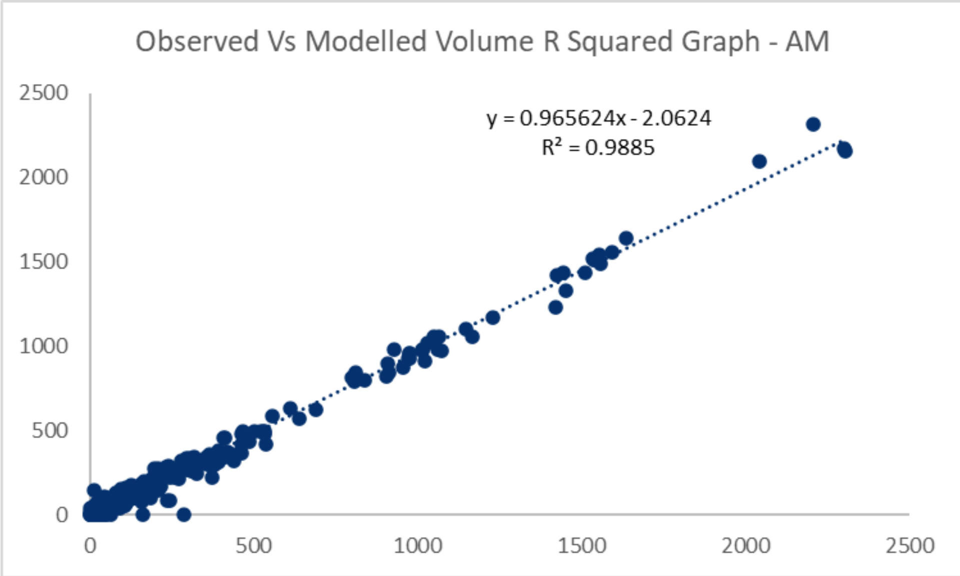


Figure 4-2 AM Peak R-Squared Graph after Turn Volume Calibration

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 4-2 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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
	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
J13	J13-S-Through	305	293	0.7	YES
	J13-N-Through	155	152	0.2	YES

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
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

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
	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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
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
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
	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

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
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
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

Junction	Approach	Observed	Modelled	GEH	GEH<5
	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
	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
	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%					

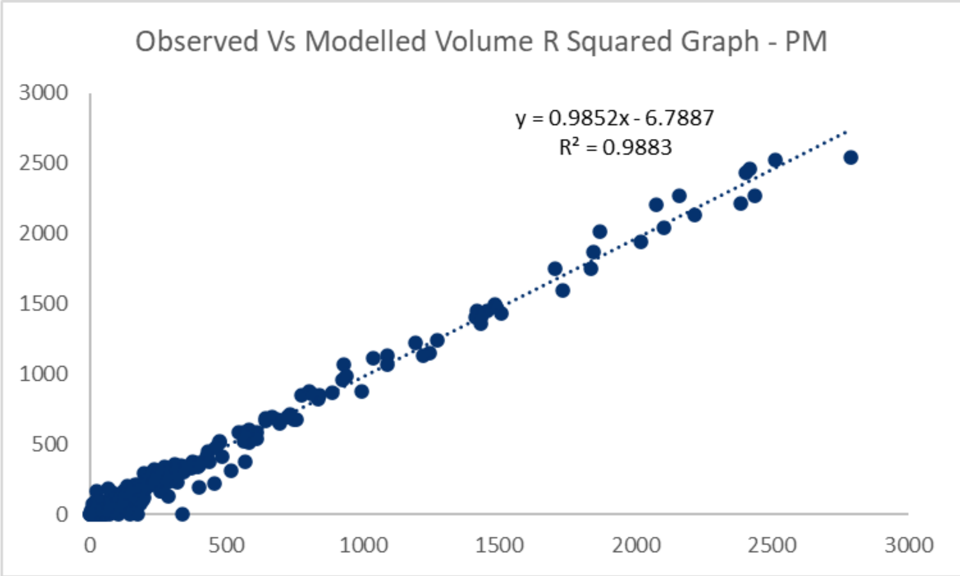


Figure 4-3 R-Squared Graph for PM after Turn Volume Calibration

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 4-3 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
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 4-4 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
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

4.2 Queue Length Comparison

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

Table 4-5 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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
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
	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
	J15-N-Through	0	0		J51-W-Right	74	0
	J15-S-Through	11	0		J51-E-Left	0	0

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	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
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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	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 4-6 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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	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
	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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
	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
	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

Junction	Movement	Queue (m)		Junction	Movement	Queue (m)	
		Modelled	Observed			Modelled	Observed
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
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. MODEL ASSESSMENT

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	26-35	16-25
D	36-55	26-35
E	56-80	36-50
F	>80	>50

Figure 5-1 LOS Criteria

5.2 Assessment Result

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

Table 5-1 Delay Results Base AM Peak

Junction	Movement	Volume	Delay	LOS	Junction	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
	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
	J13-S-Through	300	0	A		J50-W-Through	496	0	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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**
	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
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**

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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 5-2 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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
	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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	Total	**569**	**1**	**A**		J49-E-Through	365	0	A
	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**
13	J13-S-Left	0	0	A		J50-W-Left	0	0	A
	J13-S-Through	293	4	A	50	J50-W-Through	585	0	A
	J13-S-Right	44	3	A		J50-E-Right	6	1	A
	Total	**942**	**3**	**A**		**Total**	**591**	**2**	**A**
	J14-W-Through	209	1	A		J51-W-Through	697	1	A
14	J14-W-Right	0	0	A		J51-W-Right	142	2	A
	J14-S-Right	29	2	A	51	J51-E-Left	84	0	A
	Total	**238**	**1**	**A**		J51-E-Through	366	0	A
	J15-W-Left	150	2	A		**Total**	**1289**	**1**	**A**
	J15-W-Right	74	2	A		J52-W-Through	105	0	A
15	J15-N-Through	11	0	A		J52-W-Right	82	1	A
	J15-S-Through	194	0	A	52	J52-N-Left	187	1	A
	Total	**428**	**1**	**A**		J52-N-Through	274	1	A
	J16-W	1495	3	A		**Total**	**648**	**1**	**A**
16	J16-N	1433	12	B		J53-E-Left	161	2	A
	J16-E	263	1	A		J53-E-Through	308	2	A
	Total	**3191**	**6**	**A**	53	J53-N-Through	182	0	A
	J17-W-Through	669	0	A		J53-N-Right	173	0	A
17	J17-S-Left	273	0	A		**Total**	**824**	**1**	**A**
	J17-S-Right	819	1	A		J54-E-Through	133	0	A
	Total	**1760**	**0**	**A**	54	J54-S-Left	337	1	A
	J18-W-Left	186	1	A		**Total**	**470**	**1**	**A**
	J18-W-Through	680	1	A		J55-N-Through	1448	2	A
18	J18-E-Through	209	1	A		J55-N-Right	99	14	B
	J18-E-Right	63	4	A	55	J55-S-Left	35	1	A
	Total	**1138**	**1**	**A**		J55-S-Through	1072	1	A
	J19-W-Through	315	11	B		**Total**	**2654**	**2**	**A**
19	J19-N-Left	341	4	A		J56-W-Left	187	10	B
	J19-E-Through	261	10	B		J56-W-Right	105	12	B
	Total	**918**	**8**	**A**	56	J56-N-Through	1446	2	A
	J20-W-Left	203	2	A		J56-S-Through	1067	6	A
20	J20-W-Through	217	0	A		**Total**	**2805**	**4**	**A**
	J20-W-Right	0	0	A	57	J57-N-Left	57	6	A

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
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**

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
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
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
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

Junction	Movement	Volume	Delay	LOS	Junction	Movement	Volume	Delay	LOS
	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
	J35-N-Left	71	1	A		**Total**	**2346**	**2**	**A**
	J35-N-Through	375	3	A					
	J35-N-Right	71	8	A					
35	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.

6. NEXT STEPS

6.1 Next Model Stages

With the Stage 2 micro-simulation model calibrated, the scenario testing will commence as the next step of the project. The Stage 2 scenario testing report will contain information on the process and result from scenario testing.

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

ASEAN AUSTRALIA SMART CITIES TRUST FUND
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ADB