Appendix 3.2 – EMFAC-HK Model Assumptions

Appendix 3.2 EMFAC-HK Model Assumptions

Estimation of Vehicular Emission for the Study Area with EMFAC-HK model

EMFAC-HK v4.2 model was adopted to estimate the vehicular emission rates of NO_X, NO_2 and RSP. The input parameters and model assumptions made in EMFAC-HK model are summarized as follows.

Model Year

EMFAC-HK considers 45 years of model years for the estimation of vehicular emission. The model years start from 45 years preceding the year of interest to the year of interest as the final model year. The following table summarizes the starting and final model years of the assessment years implemented in EMFAC-HK.

Table 1 Starting and Final Model Years in EMFAC-HK

Scenario Year	Starting Model Year	Final Model Year
2025	1981	2025
2031	1987	2031
2035	1991	2035
2040	1996	2040

Vehicle Technology fraction

Exhaust technology fraction and evaporative technology fraction in the model are based on the default value.

The “2016 Licensed Vehicle by Age and Technology Group Fractions” provided in EPD’s website, was adopted in this assessment. Since the provided exhaust technology fractions are only up to Year 2016 at the time of the assessment, those after Year 2016 are projected in accordance with EPD’s *Guideline on Modelling Vehicle Emissions* – Appendix 3 “Implementation Schedule of Vehicle Emission Standards in Hong Kong (updated as at May 2020)” and Appendix 4 “EMFAC-HK Technology Group Indexes (Released in January 2020)”.

Vehicle Population

As recommended in the EPD’s *Guideline on Modelling Vehicle Emissions*, default vehicle populations forecast in EMFAC-HK was used.

Vehicle Accrual

The default accrual rates in EMFAC-HK are estimated from the local mileage data adjusted to reflect the total VKT for each vehicle class. The default value was used.

Vehicle Kilometre Travel (VKT)

The “vehicle fleet” refers to all motor vehicles operating on roads within this assessment area. The modelled fleet was broken down into 16 vehicle classes based on the information in the Transport Monthly Digest and vehicle population provided by EPD.

Vehicle-kilometre-travelled (VKT) represents the total distance travelled on a weekday. The VKT is calculated by multiplying the number of vehicles, which based on the highest predicted hourly traffic flow, and the length of road travelled in the assessment area. The diurnal variation of VKT in the assessment area was provided by the traffic consultant.

Appendix 3.2 EMFAC-HK Model Assumptions

Trips

Start emissions of vehicles in the assessment were simulated by two approaches, namely broad-brush approach and precise approach, which would be detailed later in this appendix. Given that no buses would be parked on street and start emission factors of franchised single-deck buses (FBSD) and franchised double-deck buses (FBDD) are more significant than other vehicle classes, broad-brush approach was applied for all vehicle class except FBSD and FBDD, while the start emission of FBSD and FBDD were localized at the bus terminuses using precise approach.

Although no heavy goods vehicles (HGV) parking site was identified within the study area, start emissions of HGV were included on local and rural roads (broad-brush approach) in the assessment to avoid any possible underestimation of air quality impact. For other vehicle classes such as private cars, it was noted that the start emission factors are minimal when compared to FBSD, FBDD and HGV. A sensitivity test for the starting emission of private cars was conducted to compare the impacts predicted from different modelling approaches (precise and broad-brush approaches). A planned carpark within WKCD with mechanical ventilation and with ASRs located in close proximity to the ventilation exhausts has been selected and the modelling approaches are illustrated in **Annex A**. The findings showed that the air quality impact induced by the start emission was insignificant, with the max. hourly NOx concentration of around 0.7 µg/m^3 among the identified ASRs. In addition, the NOx concentrations using broad-brush approach were slightly higher than that using precise approach, with the max. differences of around 0.7 µg/m^3 (1st highest hourly), 0.2 µg/m^3 (19th highest hourly) and 0.01µg/m^3 (annual average). Therefore, broad-brush approach was considered reasonable and adopted for all vehicles other than FBSD and FBDD.

Other than bus terminuses, public light bus (PLB) and coach (NFB) terminuses were identified within the study area. To avoid any underestimation of air quality impact at the exit of terminuses, precise approach has also been adopted, on top of the broad-brush approach, to further simulate the start emissions of PLB and NFB induced by the minibus and coach terminuses.

Diurnal variation of daily trips was used to estimate the start emissions of petrol, LPG vehicles and diesel vehicles fitted with selective catalytic reduction (SCR) devices. Zero trip was assumed for roads with post speed greater than 50 km/hr as no cold start would be anticipated on these roads.

Broad-brush Approach

Start emissions of vehicles were distributed on local and rural roads with the number of trips for each vehicle class on local and rural roads with post speed of 50 km/hr was assumed directly proportional to VKT and estimated by the following formula.

$$\begin{aligned} &Trip\ for\ local\ and\ rural\ roads\ within\ the\ study\ area \\ &\quad = VKT\ for\ local\ and\ rural\ roads\ within\ the\ study\ area \\ &\quad \times \frac{Trip\ for\ local\ and\ rural\ roads\ within\ Hong\ Kong}{VKT\ for\ local\ and\ rural\ roads\ within\ Hong\ Kong} \end{aligned}$$

Trip within Hong Kong and VKT within Hong Kong were obtained from the default values from EMFAC-HK. The proportion of local and rural roads within Hong Kong was obtained from the Annual Traffic Census prepared by Transport Department and is presented in **Annex B**. VKT within the study area was calculated by multiplying the number of vehicles by the distance travelled within the study area. The trips per VKT is presented in **Annex C**.

The highest NO_x (and the corresponding NO and NO_2) and RSP start emission factor for each vehicle class among different soak time were adopted as a conservative approach.

Precise Approach

Bus (FBSD & FBDD), PLB and NFB terminuses were identified within the study area. For these terminuses, the number of trips and soak time for FBSD, FBDD, PLB and NFB were obtained by on-site survey and published schedules from the operators. Calculations of emissions associated with these terminuses have made reference to the *Calculation of Start Emissions in Air Quality Impact Assessment* (**Appendix 3.6**) published by EPD.

Travelling Speed

Based on the available speed information provided by traffic consultant, emission factors of each vehicle class were adopted according to the travelling speed of each road link at each hour. All the vehicle classes on the same road link were assumed to have the same travelling speed, except medium goods vehicles, heavy goods vehicles, buses and public light buses, which have speed limit.

In accordance with the Road Traffic Ordinance, for any road with design speed limit of 70 kph or above, the speed limit for medium goods vehicles, heavy goods vehicles and buses would be limited to not more than 70 kph. Thus, for medium goods vehicles, heavy goods vehicles and buses, the flow speed or 70 kph, whichever is lower, have been adopted. For the public light buses, the speed limit should be limited to speed limit of the carriageway or 80 kph, whichever is lower, were adopted.

Temperature and Humidity Profile

The lowest temperature (12^{o}C) and relative humidity data (32%) (>90% valid data) provided by Hong Kong Observatory (HKO) at Hong Kong Observatory weather station for Year 2019 were adopted for the model input.

Estimation of Composite Vehicular Emission Factor

Referring to the EPD's *Guideline on Modelling Vehicle Emissions*, "Emfac mode" was used for calculating emission factors in terms of grams of pollutants emitted per vehicle activity. It was applied for this Project, since it provides the emission factors according to the actual hourly travelling speeds of vehicles of each road.

Assuming that NO_X is comprised of NO and NO_2 only, the hourly emission of NO was calculated as the difference in emissions between NO_x and NO_2 extracted from EMFAC-HK for each vehicle type. The NO, NO_2 and RSP running exhaust and start emission factors of 16 vehicle classes are presented in **Appendix 3.3**.

Given that there would be no cold starts on roads with post speed greater than 50 km/hr, only running exhaust was considered for these road sections, while both running exhaust and starting emissions were considered for local road with post speed of 50km/hr. The 24-hour traffic flows and composite emission factors for each road adopted in the subsequent air dispersion modelling are presented in **Appendix 3.4**.

Appendix 3.2 EMFAC-HK Model Assumptions

Vehicular Emission Burden by EMFAC-HK (for Determination of Assessment Year)

Vehicular emission burdens (NOx and RSP) for the Years of 2025, 2031, 2035 and 2040 were calculated based on the traffic forecast and composite emission factors. The results are summarized as below:

Table 2 Vehicular Emission Burden of Open Road Source

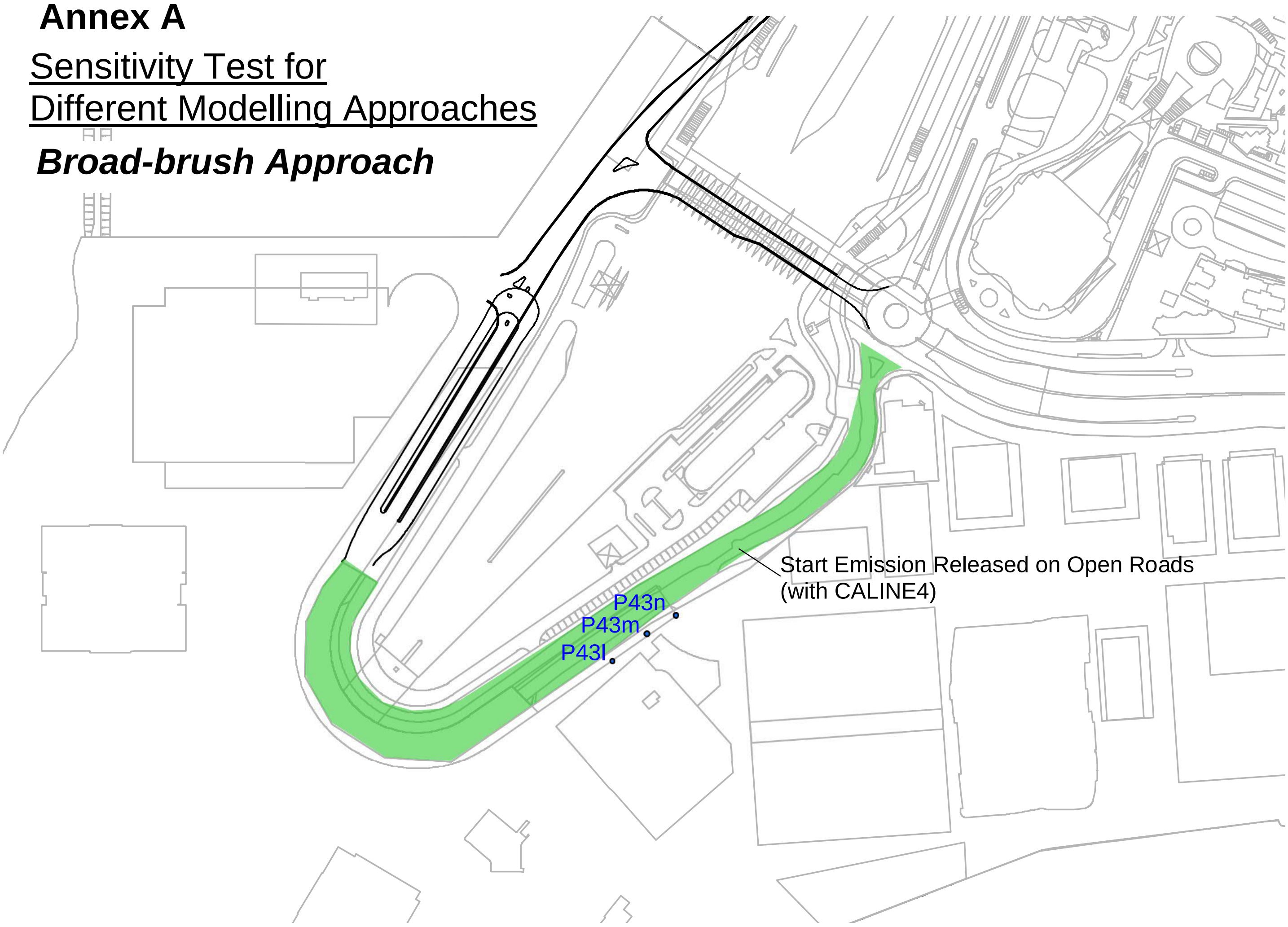
Year	NOx (g/day)	RSP (g/day)
2025	**119976**	**3245**
2031	85255	2505
2035	63785	1500
2040	65566	1410

According to the results, Year 2025 was selected as the worst affected year for the air quality assessment.

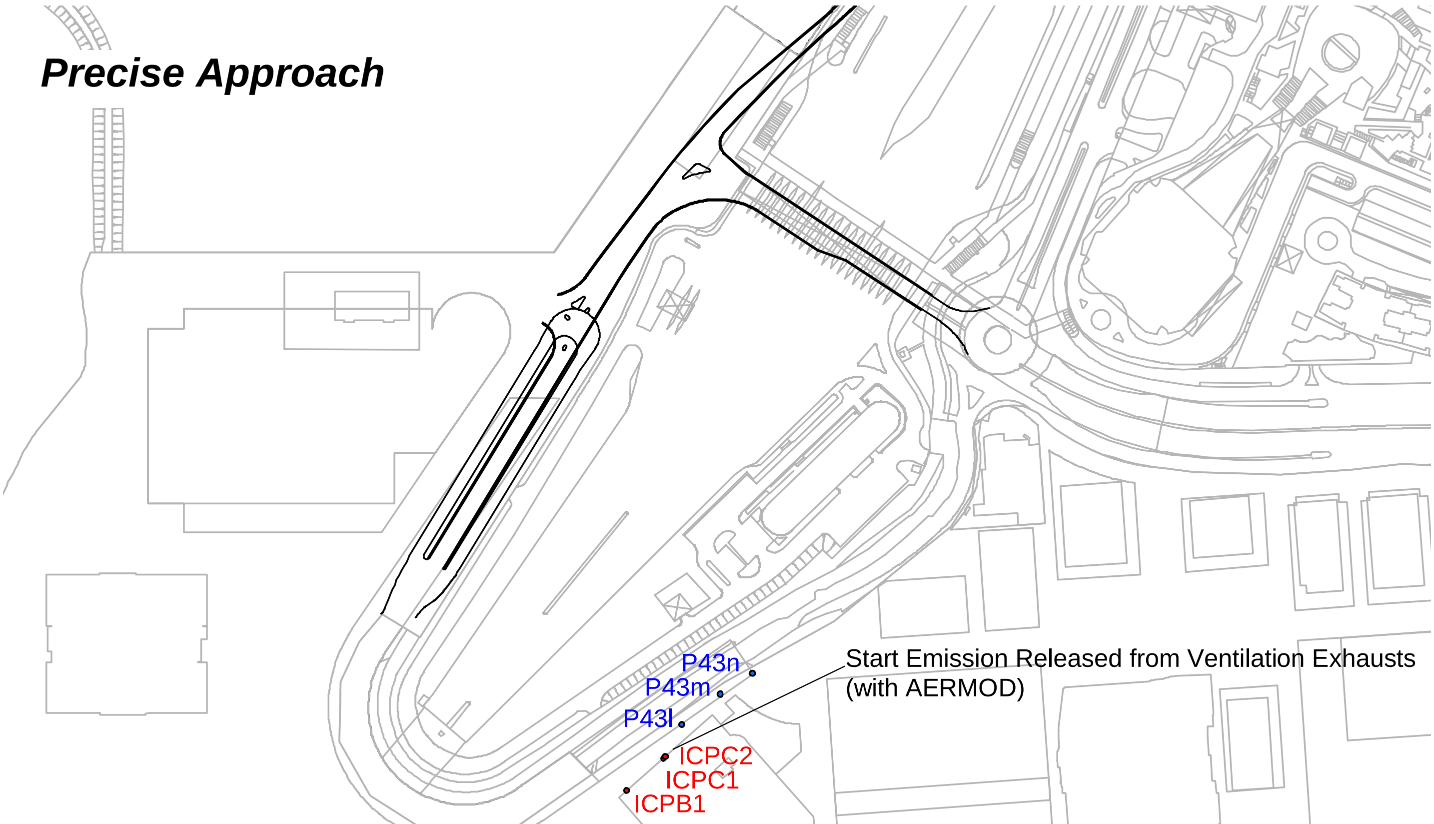
Annex A

Sensitivity Test for Different Modelling Approaches

Broad-brush Approach



Precise Approach



Source	Type	Release Height	Exit Temperature	Exit Velocity	Diameter	Max. Hourly Emission Rate	
						NO	NO2
ID		(mAG)	(K)	(m/s)	(m)	(g/s)	
ICPB1	POINTHOR	1.0	0	1.9	4.05	1.613E-03	8.490E-05
ICPC1	POINTHOR	4.3	0	2.2	2.14	5.244E-04	2.759E-05
ICPC2	POINTHOR	4.3	0	2.1	1.59	2.756E-04	1.450E-05

Number of cold start was referenced to the approved WKCD's *Traffic Impact Assessment for Minor Relaxation on GFA and Building Height Restrictions*.
Locations and design parameters of ventilation exhausts of the carpark were identified according to the planned layouts provided by WKCDA.

Annex B

Proportion of Local and Rural Roads within Hong Kong

Region	Average Daily Vehicle-Kilometre in Year 2018		
	Major Roads	Minor Roads	Total
HK Island	4933249	1067857	6001106
Kowloon	7464204	1065993	8530197
New Territories	20915781	2804469	23720250
Total	**33313234**	**4938319**	**38251553**
Percentage	**87%**	**13%**	**100%**

Annex C

Year 2025	No. of Trips within HK			VKT within HK			VKT for Local and Rural Roads within HK			Trips per VKT
	Petrol	Diesel	LPG	Petrol	Diesel	LPG	Petrol	Diesel	LPG	
01 - Private Cars (PC)	976174	10727	0	18890002	194723	0	2436810	25119	0	0.40086
02 - Taxi	44	0	73149	4731	0	7947692	610	0	1025252	0.07135
03 - Light Goods Vehicles<=2.5t	74	2227	0	1129	37881	0	146	4887	0	0.45725
04 - Lt Goods Vehicles 2.5-3.5t	5682	208165	0	92700	3634372	0	11958	468834	0	0.44478
05 - Light Goods Vehicles>3.5t	0	84317	0	0	1959376	0	0	252760	0	0.33359
06 - Medium & Heavy Goods Vehicl	0	49154	0	0	1047974	0	0	135189	0	0.36360
07 - Medium & Heavy Goods Vehicl	0	129007	0	0	2754482	0	0	355328	0	0.36306
08 - Public Light Buses	0	11240	6148	0	776442	424731	0	100161	54790	0.11222
09 - Private Light Bus <=3.5t	701	999	0	18647	31860	0	2405	4110	0	0.26094
10 - Private Light Bus >3.5t	11	8320	1951	221	237524	39917	29	30641	5149	0.28706
11 - Non-franchised Bus<=6.4t	0	10945	0	0	321369	0	0	41457	0	0.26401
12 - Non-franchised Bus 6.4-15t	0	7593	0	0	224095	0	0	28908	0	0.26265
13 - Non-franchised Bus >15t	0	13613	0	0	400492	0	0	51663	0	0.26350
14 - Franchised Bus (SD)	0	3340	0	0	77969	0	0	10058	0	0.33208
15 - Franchised Bus (DD)	0	59633	0	0	1247754	0	0	160960	0	0.37049
16 - Motorcycles (MC)	379283	0	0	1043271	0	0	134582	0	0	2.81823
17 - <Placeholder (P1)>	0	0	0	0	0	0	0	0	0	0.00000
18 - <Placeholder (P2)>	0	0	0	0	0	0	0	0	0	0.00000
19 - <Placeholder (P3)>	0	0	0	0	0	0	0	0	0	0.00000
20 - <Placeholder (P4)>	0	0	0	0	0	0	0	0	0	0.00000
21 - <Placeholder (P5)>	0	0	0	0	0	0	0	0	0	0.00000

Year 2031	No. of Trips within HK			VKT within HK			VKT for Local and Rural Roads within HK			Trips per VKT
	Petrol	Diesel	LPG	Petrol	Diesel	LPG	Petrol	Diesel	LPG	
01 - Private Cars (PC)	1088553	10727	0	20836588	207390	0	2687920	26753	0	0.40494
02 - Taxi	29	0	73164	3132	0	7949292	404	0	1025459	0.07135
03 - Light Goods Vehicles<=2.5t	54	2317	0	880	40559	0	113	5232	0	0.44352
04 - Lt Goods Vehicles 2.5-3.5t	4732	215611	0	79712	3817386	0	10283	492443	0	0.43830
05 - Light Goods Vehicles>3.5t	0	86878	0	0	2072341	0	0	267332	0	0.32498
06 - Medium & Heavy Goods Vehicl	0	50648	0	0	1084974	0	0	139962	0	0.36187
07 - Medium & Heavy Goods Vehicl	0	132926	0	0	2848582	0	0	367467	0	0.36174
08 - Public Light Buses	0	14559	2829	0	1005726	195447	0	129739	25213	0.11222
09 - Private Light Bus <=3.5t	586	1114	0	16360	35008	0	2110	4516	0	0.25657
10 - Private Light Bus >3.5t	5	9438	839	82	266222	14979	11	34343	1932	0.28336
11 - Non-franchised Bus<=6.4t	0	10945	0	0	321416	0	0	41463	0	0.26398
12 - Non-franchised Bus 6.4-15t	0	7593	0	0	223852	0	0	28877	0	0.26294
13 - Non-franchised Bus >15t	0	13613	0	0	400430	0	0	51655	0	0.26354
14 - Franchised Bus (SD)	0	3340	0	0	77969	0	0	10058	0	0.33208
15 - Franchised Bus (DD)	0	59633	0	0	1254229	0	0	161796	0	0.36857
16 - Motorcycles (MC)	422947	0	0	1153655	0	0	148821	0	0	2.84197
17 - <Placeholder (P1)>	0	0	0	0	0	0	0	0	0	0.00000
18 - <Placeholder (P2)>	0	0	0	0	0	0	0	0	0	0.00000
19 - <Placeholder (P3)>	0	0	0	0	0	0	0	0	0	0.00000
20 - <Placeholder (P4)>	0	0	0	0	0	0	0	0	0	0.00000
21 - <Placeholder (P5)>	0	0	0	0	0	0	0	0	0	0.00000

Year 2035	No. of Trips within HK			VKT within HK			VKT for Local and Rural Roads within HK			Trips per VKT
	Petrol	Diesel	LPG	Petrol	Diesel	LPG	Petrol	Diesel	LPG	
01 - Private Cars (PC)	1132752	10727	0	21561556	203559	0	2781441	26259	0	0.40727
02 - Taxi	26	0	73167	2827	0	7949594	365	0	1025498	0.07135
03 - Light Goods Vehicles<=2.5t	46	2372	0	752	39603	0	97	5109	0	0.46461
04 - Lt Goods Vehicles 2.5-3.5t	4418	220365	0	74564	3847039	0	9619	496268	0	0.44433
05 - Light Goods Vehicles>3.5t	0	88629	0	0	2141481	0	0	276251	0	0.32083
06 - Medium & Heavy Goods Vehicl	0	51668	0	0	1104789	0	0	142518	0	0.36254
07 - Medium & Heavy Goods Vehicl	0	135605	0	0	2901876	0	0	374342	0	0.36225
08 - Public Light Buses	0	16396	992	0	1132640	68533	0	146111	8841	0.11222
09 - Private Light Bus <=3.5t	565	1135	0	16155	36000	0	2084	4644	0	0.25269
10 - Private Light Bus >3.5t	3	9802	477	43	268252	7959	6	34605	1027	0.28852
11 - Non-franchised Bus<=6.4t	0	10945	0	0	319488	0	0	41214	0	0.26557
12 - Non-franchised Bus 6.4-15t	0	7593	0	0	223855	0	0	28877	0	0.26293
13 - Non-franchised Bus >15t	0	13613	0	0	399973	0	0	51597	0	0.26384
14 - Franchised Bus (SD)	0	3340	0	0	77969	0	0	10058	0	0.33208
15 - Franchised Bus (DD)	0	59633	0	0	1313118	0	0	169392	0	0.35204
16 - Motorcycles (MC)	440120	0	0	1191688	0	0	153728	0	0	2.86298
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18 - <Placeholder (P2)>	0	0	0	0	0	0	0	0	0	0.00000
19 - <Placeholder (P3)>	0	0	0	0	0	0	0	0	0	0.00000
20 - <Placeholder (P4)>	0	0	0	0	0	0	0	0	0	0.00000
21 - <Placeholder (P5)>	0	0	0	0	0	0	0	0	0	0.00000

Year 2040	No. of Trips within HK			VKT within HK			VKT for Local and Rural Roads within HK			Trips per VKT
	Petrol	Diesel	LPG	Petrol	Diesel	LPG	Petrol	Diesel	LPG	
01 - Private Cars (PC)	1190534	10727	0	22746278	201082	0	2934270	25940	0	0.40580
02 - Taxi	25	0	73167	2757	0	7949662	356	0	1025506	0.07135
03 - Light Goods Vehicles<=2.5t	48	2432	0	795	41661	0	103	5374	0	0.45277
04 - Lt Goods Vehicles 2.5-3.5t	4468	225991	0	75759	3952401	0	9773	509860	0	0.44350
05 - Light Goods Vehicles>3.5t	0	90867	0	0	2118751	0	0	273319	0	0.33246
06 - Medium & Heavy Goods Vehicl	0	52973	0	0	1130353	0	0	145816	0	0.36329
07 - Medium & Heavy Goods Vehicl	0	139029	0	0	2970846	0	0	383239	0	0.36277
08 - Public Light Buses	0	17254	134	0	1191900	9272	0	153755	1196	0.11222
09 - Private Light Bus <=3.5t	544	1156	0	15631	36042	0	2016	4649	0	0.25505
10 - Private Light Bus >3.5t	1	10038	242	21	280823	3803	3	36226	491	0.28001
11 - Non-franchised Bus<=6.4t	0	10945	0	0	321791	0	0	41511	0	0.26367
12 - Non-franchised Bus 6.4-15t	0	7593	0	0	223998	0	0	28896	0	0.26276
13 - Non-franchised Bus >15t	0	13613	0	0	400583	0	0	51675	0	0.26344
14 - Franchised Bus (SD)	0	3340	0	0	77969	0	0	10058	0	0.33208
15 - Franchised Bus (DD)	0	59633	0	0	1279963	0	0	165115	0	0.36116
16 - Motorcycles (MC)	462571	0	0	1254237	0	0	161797	0	0	2.85896
17 - <Placeholder (P1)>	0	0	0	0	0	0	0	0	0	0.00000
18 - <Placeholder (P2)>	0	0	0	0	0	0	0	0	0	0.00000
19 - <Placeholder (P3)>	0	0	0	0	0	0	0	0	0	0.00000
20 - <Placeholder (P4)>	0	0	0	0	0	0	0	0	0	0.00000
21 - <Placeholder (P5)>	0	0	0	0	0	0	0	0	0	0.00000

Revised Austin Road Flyover Scenario

Original Austin Road Flyover Scenario