Appendix 3.8A **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Eastbound)**

One-way Enclosure - Normal Condition

Tunnel Parameter

Length L	=	2200	m	
Cross-sectional area A_T = H x W =				67.1 m^2
Perimeter P	=	32.7	m	

Emission Data

		Traffic Breakdown (%)														
Tunnel Traffic (Link no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Non-franchised Bus<=6.4t	Non-franchised Bus 6.4-15t	Non-franchised Bus >15t	Private Light Bus <=3.5t	Private Light Bus >3.5t	Light Goods Vehicles<=2.5t	Lt Goods Vehicles 2.5-3.5t	Light Goods Vehicles>3.5t	Heavy Goods Vehicles<=15t	Heavy Goods Vehicles >15t	Single Deck Franchised Bus	Double Deck Franchised Bus	Public Light Bus
198	2463	4.70%	52.54%	14.00%	1.24%	0.89%	0.90%	0.51%	0.43%	0.29%	11.10%	6.59%	1.71%	4.85%	0.00%	0.08%	0.17%
NOx Emission Factor (g/mile)		0.449	0.021	0.496	1.263	2.511	3.984	0.102	0.921	1.577	1.083	1.651	2.155	4.043	4.316	4.989	1.429

Total NO_2 emission rate = total NO_X emission factor x traffic flow x tunnel length x NO_2 conversion factor
where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5% of NO_X and 5% of NO_2/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.406	g/km/veh	
Total NO_2 emission factor (g/s)	=	7.63E-02	g/sec	(assuming that no operation of ventilation building)

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m
Motorcycles	1.7	1.5	4.6
Petrol PC &LGV	1.7	1.5	4.6
Taxi	1.7	1.5	4.6
Non-franchised Bus <6.4t	2.5	3.5	12
Non-franchised Bus 6.4-15t	2.5	3.5	12
Non-franchised Bus >15t	2.5	3.5	12
Private Light Bus <3.5t	2	3	6.5
Private Light Bus >3.5t	2	3	6.5
PC&LGV <2.5t	2.1	1.6	5.2
LGV 2.5-3.5t	2.1	1.6	5.2
LGV >3.5t	2.1	1.6	5.2
HGV<15t	2.5	4.6	16
HGV>15t	2.5	4.6	16
Single Deck Franchised Buses	2.5	3.5	12
Double Deck Franchised Buses	2.5	4.6	12
Public Light Bus	2	3	6.5

* No dimensions for motorcycles and non-franchised bus are provided.
* For the purpose of this study, the dimensions of motorcycles and taxi are assumed to be the same as private car and the dimension of non-franchised bus are assumed to be the same as single deck franchised bus.

Nominal cross-sectional area A_C = (1.7*1.5*0.047)+(1.7*1.5*0.525)+(1.7*1.5*0.14)+(2.5*3.5*0.012)+(2.5*3.5*0.009)+(2.5*3.5*0.009)+(2*3*0.005)+(2*3*0.004)+(2.1*1.6*0.003)+(2.1*1.6*0.111)+(2.1*1.6*0.066)
+(2.5*4.6*0.017)+(2.5*4.6*0.048)+(2.5*3.5*0)+(2.5*4.6*0.001)+(2*3*0.002)
= 3.5163 m^2

Appendix 3.8A — Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Eastbound)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

$$F_C = \frac{1}{2}\rho\ (V_C - V_T)^2\ C_d\ A_C\ N$$

Resisting Force by tunnel:

$$F_T = \frac{1}{2}\rho\ V_T^{\ 2}\ (K_{in} + K_{out} + \frac{f\,L}{D})\ A_T$$

External Wind at the Entrance and Exit Portals:

$$F_W = \frac{1}{2}\rho\ C_W (V_W \cos\theta)^2\ A_T$$

where	ρ	=	Air density	=	1.2	kg/m^3
	V_C	=	Velocity of vehicle, m/s			
	V_T	=	Velocity of air flow in tunnel, m/s			
	C_d	=	Vehicle drag coefficient	=	0.645	
	A_C	=	Vehicle frontal area	=	3.51626309	m^2
	N	=	No. of vehicles in tunnel			
	K_{in}	=	Inlet loss coefficient	=	0.5	
	K_{out}	=	Outlet loss coefficient	=	1.0	
	f	=	Tunnel friction factor	=	0.0155	
	L	=	Length of tunnel	=	2200	m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P$ =	8.20795107	m, P is the Perimeter of tunnel
	A_T	=	Cross-sectional area of tunnel	=	67.1	m^2
	C_W	=	External wind coefficient	=	0.3	
	$V_{W(ref)}$	=	Velocity of wind at SE Station	=	3.19	m/s (Average of 2011 Southeast Kowloon Weather Station data)
	θ	=	Angle of the wind velocity component parallel to the roadway			

For the worst scenario, only external wind at the exit portal is considered and the wind is parallel to the roadway.

Force balance :

$$F_C - F_T - F_W = 0 \qquad (1)$$

Solving the equation,

$$a\ V_T^{\ 2} + b\ V_T + c = 0$$

where

$$a = C_d A_c N - (K_{in} + K_{out} + \frac{fL}{D}) A_T$$

$$b = -2\ C_d\ A_c\ N\ V_c$$

$$c = C_d A_c N V_c^{\ 2} - C_w V_w^{\ 2} A_T$$

For normal traffic condition

traffic flow Q	=	0.684166667	veh/s		
Vehicle speed V_C	=	80	km/h		
	=	22.22222222	m/s		
Number of vehicles in tunnel N	=	QL/V_C			
	=	67.7325			
Solving for V_T by equation (1)					
a	=	-225.80			
b	=	-6827.40			
c	=	75655.21			
tunnel air flow velocity V_T	=	8.622330065	m/sec	or	-38.858726 m/sec (rejected)

Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area)

NO_2 = 132 ug/m^3

Appendix 3.8A **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Eastbound)**

One-way Enclosure - Worst Condition

Tunnel Parameter

Length L = 2200 m

Cross-sectional area A_T = H x W = 67.1 m^2

Perimeter P = 32.7 m

Emission Data

Traffic Breakdown (%)

Tunnel Traffic (Link no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Non-franchised Bus<=6.4t	Non-franchised Bus 6.4-15t	Non-franchised Bus >15t	Private Light Bus <=3.5t	Private Light Bus >3.5t	Light Goods Vehicles<=2.5t	Lt Goods Vehicles 2.5-3.5t	Light Goods Vehicles>3.5t	Heavy Goods Vehicles<=15t	Heavy Goods Vehicles >15t	Single Deck Franchised Bus	Double Deck Franchised Bus	Public Light Bus
198	2463	4.7%	52.5%	14.0%	1.2%	0.9%	0.9%	0.5%	0.4%	0.3%	11.1%	6.6%	1.7%	4.8%	0.0%	0.1%	0.2%
NOx Emission Factor (g/mile)		0.69	0.04	0.86	3.39	6.82	10.85	0.16	1.71	2.20	1.55	4.17	5.32	9.77	11.29	12.69	1.64

Total NO_2 emission rate = total NO_X emission factor x traffic flow x tunnel length x NO_2 conversion factor
where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5% of NO_X and 5% of NO_2/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh) = 0.877 g/km/veh

Total NO_2 emission factor (g/s) = 1.65E-01 g/sec

Assuming fully operation of ventilation building removes 60% air pollutant,

Total NO_2 emission factor (g/s) = 6.60E-02 g/sec

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m
Motorcycles	1.7	1.5	4.6
Petrol PC &LGV	1.7	1.5	4.6
Taxi	1.7	1.5	4.6
Non-franchised Bus <6.4t	2.5	3.5	12
Non-franchised Bus 6.4-15t	2.5	3.5	12
Non-franchised Bus >15t	2.5	3.5	12
Private Light Bus <3.5t	2	3	6.5
Private Light Bus >3.5t	2	3	6.5
PC&LGV <2.5t	2.1	1.6	5.2
LGV 2.5-3.5t	2.1	1.6	5.2
LGV >3.5t	2.1	1.6	5.2
HGV<15t	2.5	4.6	16
HGV>15t	2.5	4.6	16
Single Deck Franchised Buses	2.5	3.5	12
Double Deck Franchised Buses	2.5	4.6	12
Public Light Bus	2	3	6.5

* No dimensions for motorcycles and non-franchised bus are provided.
* For the purpose of this study, the dimensions of motorcycles and taxi are assumed to be the same as private car and the dimension of non-franchised bus are assumed to be the same as single deck franchised bus.

Nominal cross-sectional area A_C = (1.7*1.5*0.042)+(1.7*1.5*0.496)+(1.7*1.5*0.175)+(2.5*3.5*0.002)+(2.5*3.5*0.031)+(2.5*3.5*0.001)+(2*3*0.003)+(2*3*0.005)+(2.1*1.6*0)+(2.1*1.6*0.108)+(2.1*1.6*0.035)
+(2.5*4.6*0.093)+(2.5*4.6*0.008)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

= 3.5163 m^2

Appendix 3.8A **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Eastbound)**

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

$$F_C = \frac{1}{2}\rho\ (V_C - V_T)^2\ C_d\ A_C\ N$$

Resisting Force by tunnel:

$$F_T = \frac{1}{2}\rho\ V_T^{\ 2}\ (K_{in} + K_{out} + \frac{f\,L}{D})\ A_T$$

External Wind at the Entrance and Exit Portals:

$$F_W = \frac{1}{2}\rho\ C_W (V_W \cos\theta)^2\ A_T$$

where	ρ	=	Air density	=	1.2	kg/m^3
	V_C	=	Velocity of vehicle, m/s			
	V_T	=	Velocity of air flow in tunnel, m/s			
	C_d	=	Vehicle drag coefficient	=	0.645	
	A_C	=	Vehicle frontal area	=	3.51626309	m^2
	N	=	No. of vehicles in tunnel			
	K_{in}	=	Inlet loss coefficient	=	0.5	
	K_{out}	=	Outlet loss coefficient	=	1.0	
	f	=	Tunnel friction factor	=	0.0155	
	L	=	Length of tunnel	=	2200	m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P$ =	8.20795107	m, P is the Perimeter of tunnel
	A_T	=	Cross-sectional area of tunnel	=	67.1	m^2
	C_W	=	External wind coefficient	=	0.3	
	$V_{W(ref)}$	=	Velocity of wind at SE Station	=	3.19	m/s (Average of 2011 Southeast Kowloon Weather Station data)
	θ	=	Angle of the wind velocity component parallel to the roadway			

For the worst scenario, only external wind at the exit portal is considered and the wind is parallel to the roadway.

Force balance : $F_C - F_T - F_W = 0$ (1)

Solving the equation, $a\ V_T^{\ 2} + b\ V_T + c = 0$

where

$$a = C_d A_c N - (K_{in} + K_{out} + \frac{fL}{D}) A_T$$

$$b = -2\ C_d\ A_c\ N\ V_c$$

$$c = C_d A_c N V_c^2 - C_w V_w^{\ 2} A_T$$

For congested traffic condition

Vehicle speed Vc	=	10	km/h
	=	2.777777778	m/s
average length of vehicle	=	(4.6*0.05)+(4.6*0.53)+(4.6*0.14)+(12*0.01)+(12*0.01)+(12*0.01)+(6.5*0.01)+(6.5*0)+(5.2*0)+(5.2*0.11)+(5.2*0.07)+(16*0.02)+(16*0.05)+(12*0)+(12*0)+(6.5*0)	
	=	5.707118641	m
distance between vehicle	=	1	m
head to head length	=	6.707118641	m
Number of vehicles per lane	=	328.009704	
Number of lanes	=	1	
Number of vehicles in tunnel N	=	328.009704	

Solving for V_T by equation (1)

a	=	364.51
b	=	-4132.90
c	=	5535.30

tunnel air flow velocity V_T	=	1.551672704	m/sec	or	9.7867233	m/sec (rejected)

Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area)

NO_2	=	634	ug/m^3

Appendix 3.8A Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Eastbound)

Overall Concentrations (TKO-LT Tunnel (Eastbound))

Four assessment points (ASRs InA1-InA4) at the boundary of the enclosure are chosen. (Locations refer to drawings attached in Appendix 3.9)
Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated.
The highest concentration among the eight assessment points is assumed to be the background concentration inside the proposed enclosure section.

Elevation	NO_2 Concentrations (ug/m^3) at Various Levels
	(mAG)	NO_2
InEA1	0.0	234
InEA1	4.8	237
InEA1	9.5	234
InEA2	0.0	217
InEA2	4.8	219
InEA2	9.5	222
InEA3	0.0	246
InEA3	4.8	241
InEA3	9.5	240
InEA4	0.0	241
InEA4	4.8	240
InEA4	9.5	240

Therefore, the NO_2 background concentration inside the enclosure is 246 ug/m^3

Total Maximum NO_2 concentration inside deckover on Road P2 (Normal Speed) = **132 + 246**
= **378** **ug/m^3**

Total Maximum NO_2 concentration inside deckover on Road P2 (Worse Case) = **634 + 246**
= **880** **ug/m^3**

Note: The mechanical ventilation system for TKO-LT Tunnel is designed following “The Practice Note on Control of Air Pollution in Vehicle Tunnels” issued by EPD. The calculations are presented for reference only.

Appendix 3.8B **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Westbound)**

One-way Enclosure - Normal Condition

Tunnel Parameter

Length L = 2200 m

Cross-sectional area A_T = H x W = 67.1 m^2

Perimeter P = 32.7 m

Emission Data

		Traffic Breakdown (%)															
Tunnel Traffic (Link no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Non-franchised Bus<=6.4t	Non-franchised Bus 6.4-15t	Non-franchised Bus >15t	Private Light Bus <=3.5t	Private Light Bus >3.5t	Light Goods Vehicles<=2.5t	Lt Goods Vehicles 2.5-3.5t	Light Goods Vehicles>3.5t	Heavy Goods Vehicles<=15t	Heavy Goods Vehicles >15t	Single Deck Franchised Bus	Double Deck Franchised Bus	Public Light Bus
198	1200	3.3%	36.9%	9.8%	0.9%	0.6%	0.6%	0.4%	0.3%	0.6%	21.3%	12.7%	3.3%	9.3%	0.0%	0.0%	0.0%
NOx Emission Factor (g/mile)		0.449	0.021	0.496	1.263	2.511	3.984	0.102	0.921	1.577	1.083	1.651	2.155	4.043	4.316	4.989	1.429

Total NO_2 emission rate = total NO_X emission factor x traffic flow x tunnel length x NO_2 conversion factor
where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5% of NO_X and 5% of NO_2/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh) = 0.636 g/km/veh

Total NO_2 emission factor (g/s) = 5.83E-02 g/sec (assuming that no operation of ventilation building)

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m
Motorcycles	1.7	1.5	4.6
Petrol PC &LGV	1.7	1.5	4.6
Taxi	1.7	1.5	4.6
Non-franchised Bus <6.4t	2.5	3.5	12
Non-franchised Bus 6.4-15t	2.5	3.5	12
Non-franchised Bus >15t	2.5	3.5	12
Private Light Bus <3.5t	2	3	6.5
Private Light Bus >3.5t	2	3	6.5
PC&LGV <2.5t	2.1	1.6	5.2
LGV 2.5-3.5t	2.1	1.6	5.2
LGV >3.5t	2.1	1.6	5.2
HGV<15t	2.5	4.6	16
HGV>15t	2.5	4.6	16
Single Deck Franchised Buses	2.5	3.5	12
Double Deck Franchised Buses	2.5	4.6	12
Public Light Bus	2	3	6.5

* No dimensions for motorcycles and non-franchised bus are provided.
* For the purpose of this study, the dimensions of motorcycles and taxi are assumed to be the same as private car and the dimension of non-franchised bus are assumed to be the same as single deck franchised bus.

Nominal cross-sectional area A_C = (1.7*1.5*0.033)+(1.7*1.5*0.369)+(1.7*1.5*0.098)+(2.5*3.5*0.009)+(2.5*3.5*0.006)+(2.5*3.5*0.006)+(2*3*0.004)+(2*3*0.003)+(2.1*1.6*0.006)+(2.1*1.6*0.213)+(2.1*1.6*0.127)
+(2.5*4.6*0.033)+(2.5*4.6*0.093)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

= 4.1128 m^2

Appendix 3.8B — Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Westbound)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

$$F_C = \frac{1}{2}\rho\ (V_C - V_T)^2\ C_d\ A_C\ N$$

Resisting Force by tunnel:

$$F_T = \frac{1}{2}\rho\ V_T^{\ 2}\ (K_{in} + K_{out} + \frac{f\,L}{D})\ A_T$$

External Wind at the Entrance and Exit Portals:

$$F_W = \frac{1}{2}\rho\ C_W (V_W \cos\theta)^2\ A_T$$

where	ρ	=	Air density	=	1.2	kg/m^3
	V_C	=	Velocity of vehicle, m/s			
	V_T	=	Velocity of air flow in tunnel, m/s			
	C_d	=	Vehicle drag coefficient	=	0.645	
	A_C	=	Vehicle frontal area	=	4.11278653	m^2
	N	=	No. of vehicles in tunnel			
	K_{in}	=	Inlet loss coefficient	=	0.5	
	K_{out}	=	Outlet loss coefficient	=	1.0	
	f	=	Tunnel friction factor	=	0.0155	
	L	=	Length of tunnel	=	2200	m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P$ =	8.20795107	m, P is the Perimeter of tunnel
	A_T	=	Cross-sectional area of tunnel	=	67.1	m^2
	C_W	=	External wind coefficient	=	0.3	
	$V_{W(ref)}$	=	Velocity of wind at SE Station	=	3.19	m/s (Average of 2011 Southeast Kowloon Weather Station data)
	θ	=	Angle of the wind velocity component parallel to the roadway			

For the worst scenario, only external wind at the exit portal is considered and the wind is parallel to the roadway.

Force balance :

$$F_C - F_T - F_W = 0 \qquad (1)$$

Solving the equation,

$$a\ V_T^{\ 2} + b\ V_T + c = 0$$

where

$$a = C_d A_c N - (K_{in} + K_{out} + \frac{fL}{D}) A_T$$

$$b = -2\ C_d\ A_c\ N\ V_c$$

$$c = C_d A_c N V_c^{\ 2} - C_w V_w^{\ 2} A_T$$

For normal traffic condition

traffic flow Q	=	0.333333333	veh/s		
Vehicle speed V_C	=	80	km/h		
	=	22.22222222	m/s		
Number of vehicles in tunnel N	=	QL/V_C			
	=	33			

Solving for V_T by equation (1)

a	=	-291.88
b	=	-3890.70
c	=	43025.11

tunnel air flow velocity V_T = 7.185314718 m/sec or -20.515239 m/sec (rejected)

Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area)

NO_2 = 121 ug/m^3

Appendix 3.8B **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Westbound)**

One-way Enclosure - Worst Condition

Tunnel Parameter

Length L = 2200 m
Cross-sectional area A_T = H x W = 67.1 m^2
Perimeter P = 32.7 m

Emission Data

Traffic Breakdown (%)

Tunnel Traffic (Link no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Non-franchised Bus<=6.4t	Non-franchised Bus 6.4-15t	Non-franchised Bus >15t	Private Light Bus <=3.5t	Private Light Bus >3.5t	Light Goods Vehicles<=2.5t	Lt Goods Vehicles 2.5-3.5t	Light Goods Vehicles>3.5t	Heavy Goods Vehicles<=15t	Heavy Goods Vehicles >15t	Single Deck Franchised Bus	Double Deck Franchised Bus	Public Light Bus
198	1200	3.3%	36.9%	9.8%	0.9%	0.6%	0.6%	0.4%	0.3%	0.6%	21.3%	12.7%	3.3%	9.3%	0.0%	0.0%	0.0%
NOx Emission Factor (g/mile)		0.69	0.04	0.86	3.39	6.82	10.85	0.16	1.71	2.20	1.55	4.17	5.32	9.77	11.29	12.69	1.64

Total NO_2 emission rate = total NO_X emission factor x traffic flow x tunnel length x NO_2 conversion factor
where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5% of NO_X and 5% of NO_2/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh) = 1.381 g/km/veh
Total NO_2 emission factor (g/s) = 1.27E-01 g/sec

Assuming fully operation of ventilation building removes 60% air pollutant,
Total NO_2 emission factor (g/s) = 5.06E-02 g/sec

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m
Motorcycles	1.7	1.5	4.6
Petrol PC &LGV	1.7	1.5	4.6
Taxi	1.7	1.5	4.6
Non-franchised Bus <6.4t	2.5	3.5	12
Non-franchised Bus 6.4-15t	2.5	3.5	12
Non-franchised Bus >15t	2.5	3.5	12
Private Light Bus <3.5t	2	3	6.5
Private Light Bus >3.5t	2	3	6.5
PC&LGV <2.5t	2.1	1.6	5.2
LGV 2.5-3.5t	2.1	1.6	5.2
LGV >3.5t	2.1	1.6	5.2
HGV<15t	2.5	4.6	16
HGV>15t	2.5	4.6	16
Single Deck Franchised Buses	2.5	3.5	12
Double Deck Franchised Buses	2.5	4.6	12
Public Light Bus	2	3	6.5

* No dimensions for motorcycles and non-franchised bus are provided.
* For the purpose of this study, the dimensions of motorcycles and taxi are assumed to be the same as private car and the dimension of non-franchised bus are assumed to be the same as single deck franchised bus.

Nominal cross-sectional area A_C = (1.7*1.5*0.042)+(1.7*1.5*0.496)+(1.7*1.5*0.175)+(2.5*3.5*0.002)+(2.5*3.5*0.031)+(2.5*3.5*0.001)+(2*3*0.003)+(2*3*0.005)+(2.1*1.6*0)+(2.1*1.6*0.108)+(2.1*1.6*0.035)
+(2.5*4.6*0.093)+(2.5*4.6*0.008)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)
= 4.1128 m^2

Appendix 3.8B **Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Westbound)**

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles: $$F_C = \frac{1}{2}\rho\ (V_C - V_T)^2\ C_d\ A_C\ N$$

Resisting Force by tunnel: $$F_T = \frac{1}{2}\rho\ V_T^{\ 2}\ (K_{in} + K_{out} + \frac{f\,L}{D})\ A_T$$

External Wind at the Entrance and Exit Portals: $$F_W = \frac{1}{2}\rho\ C_W (V_W \cos\theta)^2\ A_T$$

where	ρ	=	Air density	=	1.2	kg/m^3
	V_C	=	Velocity of vehicle, m/s			
	V_T	=	Velocity of air flow in tunnel, m/s			
	C_d	=	Vehicle drag coefficient	=	0.645	
	A_C	=	Vehicle frontal area	=	4.11278653	m^2
	N	=	No. of vehicles in tunnel			
	K_{in}	=	Inlet loss coefficient	=	0.5	
	K_{out}	=	Outlet loss coefficient	=	1.0	
	f	=	Tunnel friction factor	=	0.0155	
	L	=	Length of tunnel	=	2200	m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P$ =	8.20795107	m, P is the Perimeter of tunnel
	A_T	=	Cross-sectional area of tunnel	=	67.1	m^2
	C_W	=	External wind coefficient	=	0.3	
	$V_{W(ref)}$	=	Velocity of wind at SE Station	=	3.19	m/s (Average of 2011 Southeast Kowloon Weather Station data)
	θ	=	Angle of the wind velocity component parallel to the roadway			

For the worst scenario, only external wind at the exit portal is considered and the wind is parallel to the roadway.

Force balance : $$F_C - F_T - F_W = 0 \qquad (1)$$

Solving the equation, $$a\ V_T^{\ 2} + b\ V_T + c = 0$$

where

$$a = C_d A_c N - (K_{in} + K_{out} + \frac{fL}{D}) A_T$$

$$b = -2\ C_d\ A_c\ N\ V_c$$

$$c = C_d A_c N V_c^2 - C_w V_w^{\ 2} A_T$$

For congested traffic condition

Vehicle speed Vc	=	10 km/h
	=	2.777777778 m/s
average length of vehicle	=	(4.6*0.03)+(4.6*0.37)+(4.6*0.1)+(12*0.01)+(12*0.01)+(12*0.01)+(6.5*0)+(6.5*0)+(5.2*0.01)+(5.2*0.21)+(5.2*0.13)+(16*0.03)+(16*0.09)+(12*0)+(12*0)+(6.5*0)
	=	6.414402671 m
distance between vehicle	=	1 m
head to head length	=	7.414402671 m
Number of vehicles per lane	=	296.7197895
Number of lanes	=	1
Number of vehicles in tunnel N	=	296.7197895

Solving for V_T by equation (1)

a	=	407.71
b	=	-4372.90
c	=	5868.63

tunnel air flow velocity V_T = 1.5726284 m/sec or 9.15302407 m/sec (rejected)

Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area)

NO_2 = 480 ug/m^3

Appendix 3.8B Calculation of In-Tunnel Air Quality for TKO-LT Tunnel (Westbound)

Overall Concentrations (TKO-LT Tunnel (Westbound))

Four assessment points (ASRs InA1-InA4) at the boundary of the enclosure are chosen. (Locations refer to drawings attached in Appendix 3.9)
Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated.
The highest concentration among the eight assessment points is assumed to be the background concentration inside the proposed enclosure section.

Elevation	**NO_2 Concentrations (ug/m^3) at Various Levels**	
	(mAG)	NO_2
InWE1	0.0	242
InWE1	4.8	242
InWE1	9.5	242
InWE2	0.0	243
InWE2	4.8	243
InWE2	9.5	244
InWE3	0.0	216
InWE3	4.8	219
InWE3	9.5	226
InWE4	0.0	216
InWE4	4.8	217
InWE4	9.5	218

Therefore, the NO_2 background concentration inside the enclosure is 244 ug/m^3

Total Maximum NO_2 concentration inside deckover on Road P2 (Normal Speed) = **121 + 244**
= **365** **ug/m^3**

Total Maximum NO_2 concentration inside deckover on Road P2 (Worse Case) = **480 + 244**
= **724** **ug/m^3**

Note: The mechanical ventilation system for TKO-LT Tunnel is designed following “The Practice Note on Control of Air Pollution in Vehicle Tunnels” issued by EPD. The calculations are presented for reference only.