



Calculation of In-Tunnel Air Quality for Proposed Deckover on Road P2

Normal Condition

(Deckover TKO-P2)

Tunnel Parameter		
Tunnel length (m), L	=	200
Tunnel height (m), H	=	7
Tunnel width (m), W	=	22
Tunnel size (m2), At	=	H * W
		154
Equivalent diameter (m), dt	=	(4*At/π)^0.5
		14.00282313
Effective length of the tunnel (m), Le	=	L + 2*3*dt
		284.0169388

Emission Data

Traffic Breakdown (%)

						Non-	Non-	Non-			Light Goods	Lt Goods		Heavy Good	S	Single Deck	Double Deck	
						franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2.	Vehicles 2.5-	Light Goods	Vehicles<=1	5 Heavy Goods	Franchised	Franchised	Public Light
Tunnel traffic (Link no.)	Traffic flow (veh/hr))	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	5t	3.5t	Vehicles>3.5t	t	Vehicles >15t	Bus	Bus	Bus
113	1078		4.3%	60.0%	20.9%	0.9%	0.7%	0.7%	0.3%	0.3%	0.1%	4.6%	2.7%	1.1%	3.1%	0.0%	0.1%	0.1%
114	1025		4.2%	59.1%	20.6%	1.0%	0.7%	0.7%	0.4%	0.3%	0.1%	5.0%	3.0%	1.2%	3.4%	0.0%	0.1%	0.2%
Total	2104	no. vehicle	46	647	226	10	7	7	4	3	1	50	29	12	33	0	1	2
			43	606	211	10	7	7	4	3	1	52	31	12	35	0	1	2
NOx Emission Factor (g/m	nile)	80km/hr	0.45	0.02	0.50	1.27	2.53	4.01	0.10	0.93	1.56	1.08	1.67	2.17	4.07	4.35	5.03	1.44
		50km/hr	0.75	0.05	0.60	1.62	3.25	5.17	0.20	1.95	2.02	1.02	2.02	2.57	4.73	5.28	5.96	2.00
Weighted NOX E.F. (g/km NO ₂ emission factor per un	,		=	0.3201 12.5% * Weight	NO _X E.F. *	Traffic flow												

2.34E-05

=

Vehicle Data

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

W	н	L
1.7	1.5	4.6
1.7	1.5	4.6
1.7	1.5	4.6
2.5	3.5	12
2.5	3.5	12
2.5	3.5	12
2	3	6.5
2	3	6.5
2.1	1.6	5.2
2.1	1.6	5.2
2.1	1.6	5.2
2.5	4.6	16
2.5	4.6	16
2.5	3.5	12
2.5	4.6	12
2	3	6.5
	1.7 1.7 2.5 2.5 2.5 2.5 2 2 2 2 2 2 2 2 2 2 1 2.1 2.1 2.1 2.5 2.5 2.5 2.5 2.5 2.5	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

* No dimensions for motor cycles and non-franchised buses are provided.

* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car

and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Nominal cross-sectional area (m²) = [(1.7*1.5*89.45)+(1.7*1.5*1252.36)+(1.7*1.5*437.05)+(2.5*3.5*14.63)+(2.5*3.5*14.63)+(2*3*7.35)+(2*3*6.09)+(2.1*1.6*2.65)+(2.1*1.6*101.19)+(2.1*1.6*60.06)+(2.5*4.6*23.92)+(2.5*4.6*67.82)+(2.5*3.5*0.09)+(2.5*4.6*2.42)+(2*3*3.14)]/2104= 3.19

Calculation of In-Tunnel Air Quality for Proposed Deckover on Road P2

Normal Condition

(Deckover TKO-P2)

Number of lanes per direction, nl Equivalent cross-sectional area for each direc Equivalent diameter of vehicle (m), dv	= tion (m2), Av =	2 (4*Αν/π)^0.5	=	6.376635271
	=	2.849384328		
Traffic density (traffic flow /s), N	=	0.584308647		
Weighted Average vehicle speed (m/s), v	=			
	=	18.16055715		
Head to head distance on a lane (m), I	=	2*nl*v/N		
	=	124.3216731		
Diffusion Parameters				
Reynolds number, Re	=	(v*dv)/σ	where $\sigma = 15$.6*10^-6
	=	3317077.367		
According to Figure 16 (Ohashi and Koso)				
Since I / dt	=	8.878329176		
D / (N * dt^2 * Re^0.13)	=	0.4		
Longitudinal				
diffusion coefficient (m ² /s) , D	=	0.4 * (N * dt^2 * Re^0.13)		
	=	322.7243532		
Maximum Concentration of NO ₂				
Cmax (µg/m³)	=	w * Le^2 / (8 * D * At)		
(without background)	=	5		

Calculation of In-Tunnel Air Quality for Proposed Deckover on Road P2

Worse Condition

(Deckover TKO-P2)

Tunnel Parameter		
Tunnel length (m), L	=	200
Tunnel height (m), H	=	7
Tunnel width (m), W	=	22
Tunnel size (m2), At	=	H * W
		154
Equivalent diameter (m), dt	=	(4*At/π)^0.5
		14.00282313
Effective length of the tunnel (m), Le	=	L + 2*3*dt
		284.0169388

Emission Data

Traffic Breakdown (%)

				wii (70)														
												Lt Goods						
						Non-franchised	Non-franchised	Non-franchised	Private Light	Private Light	Light Goods	Vehicles 2.5-	Light Goods	Heavy Goods	Heavy Goods	Single Deck	Double Deck	
Tunnel traffic (Link no.)	Traffic flow (veh/hr	.)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	Vehicles<=2.5t	3.5t	Vehicles>3.5t	Vehicles<=15t	Vehicles >15t	Franchised Bus	Franchised Bus	Public Light Bus
113	1078		4.3%	60.0%	20.9%	0.9%	0.7%	0.7%	0.3%	0.3%	0.1%	4.6%	2.7%	1.1%	3.1%	0.0%	0.1%	0.1%
114	1025		4.2%	59.1%	20.6%	1.0%	0.7%	0.7%	0.4%	0.3%	0.1%	5.0%	3.0%	1.2%	3.4%	0.0%	0.1%	0.2%
Total	2104	no. vehicle	46	647	226	10	7	7	4	3	1	50	29	12	33	0	1	2
			43	606	211	10	7	7	4	3	1	52	31	12	35	0	1	2
NOx Emission Factor (g/mi	ile)	80km/hr	0.70	0.04	0.87	3.41	6.87	10.93	0.17	1.72	2.22	1.56	4.20	5.36	9.84	11.37	12.78	1.66
		50km/hr	0.94	0.06	0.87	3.41	6.87	10.93	0.25	2.65	2.87	1.58	4.20	5.36	9.84	11.37	12.78	2.29
Weighted NO ₂ E E $(g/km/s)$	veh)		_	0 6240														

vveignted NO _X E.F. (g/km/ven)	=	0.6240
NO ₂ emission factor per unit length (g/m/s), w	=	12.5% * Weight NO _X E.F. * Traffic flow
	=	4.56E-05

Vehicle Data

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

	W	н	L
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 motor cycles and non-franchised buses are provided.

* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car

and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Nominal cross-sectional area (m²)

=

 $[(1.7^{*}1.5^{*}89.45) + (1.7^{*}1.5^{*}1252.36) + (1.7^{*}1.5^{*}437.05) + (2.5^{*}3.5^{*}20.41) + (2.5^{*}3.5^{*}14.63) + (2.5^{*}3.5^{*}14.88) + (2^{*}3^{*}7.35) + (2^{*}3^{*}6.09) + (2.1^{*}1.6^{*}2.65) + (2.1^{*}1.6^{*}101.19) + (2.1^{*}1.6^{*}60.06) + (2.5^{*}4.6^{*}23.92) + (2.5^{*}4.6^{*}67.82) + (2.5^{*}3.5^{*}0.09) + (2.5^{*}4.6^{*}2.42) + (2^{*}3^{*}3.14)]/2104$

^{3.19}

Calculation of In-Tunnel Air Quality for Proposed Deckover on Road P2

Worse Condition	(Deckover TKO-P2)
Number of lanes per direction, nl = Equivalent cross-sectional area for each direction (m ²), Av Equivalent diameter of vehicle (m), dv = =	2 = 6.376635271 (4*Av/π)^0.5 2.849384328
Equivalent length of each vehicle (m) = Distance between vehicle (m) = Head to head distance on a lane (m), I = Traffic density (traffic flow /s), N = Average vehicle speed (m/s), v =	(4.6*89.45)+(4.6*1252.36)+(4.6*437.05)+(12*20.41)+(12*14.63)+(12*14.88)+(6.5*7.35)+(6.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*2.654)+(5.2*101.19)+(5.5*6.09)+(5.2*101.19)+(
Diffusion ParametersReynolds number, Re=According to Figure 16 (Ohashi and Koso)Since I / dt D / (N * dt^2 * Re^0.13)=Longitudinal=diffusion coefficient (m²/s) , D==	(v*dv)/ σ where $\sigma = 15.6*10^{-6}$ 169249.0397 0.45300381 0.13 0.13 * (N * dt^2 * Re^0.13) 71.24022453
Maximum Concentration of NO2Cmax (μ g/m ³)(without background)	w * Le^2 / (8 * D * At) 42

+(5.2*60.06)+(16*23.92)+(16*67.82)+(12*0.09)+(12*2.42)+(6.5*3.14)

Appendix 3.9ACalculation of In-Tunnel Air Quality
for Proposed Deckover on Road P2

Overall Concentrations (Deckover TKO-P2)

Four assessment points (ASRs InA1-InA4) at the boundary of the enclosure are chosen.

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 Concer	ntrations (ug/m ³) at Various Levels	;
	(mAG)	NO ₂	
InA1	0.0	212	
InA1	3.8	210	
InA1	7.5	209	
InA2	0.0	209	
InA2	3.8	209	
InA2	7.5	209	
InA3	0.0	209	
InA3	3.2	209	
InA3	6.3	209	
InA4	0.0	210	
InA4	3.2	209	
InA4	6.3	209	

Therefore, the NO_2 background concentration inside the enclosure is					
Total Maximum NO ₂ concentration inside deckover on					
Road P2 (Normal Speed)	=	5 + 212			
	=	217	ug/m³		
Total Maximum NO ₂ concentration inside deckover on					
Road P2 (Worse Case)	=	42 + 212			
	=	254	ug/m³		

212 ug/m³

Appendix 3.9B Calculation of In-Tunnel Air Quality for Portal C (Lam Tin)

y Enclosure - Nor arameter	mal Condition	(Porta	al C)
Length L	= 200	m	
Height H	= 8	m	
Width W	= 7	m	
Cross-sectional are		56 m ²	
Perimeter P	=	30 m	

Emission Data

Traffic Breakdown (%)	
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		Hame Dieakuowii	(70)														
													Heavy	Heavy		Double	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	Deck	
Traffic (Link					franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised	Franchised	Public Light
no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	Bus	Bus
190	355	3.6%	50.6%	17.7%	1.1%	0.8%	0.8%	0.4%	0.3%	0.3%	9.8%	5.8%	2.3%	6.6%	0.0%	0.0%	0.0%
NOx Emission	Factor (g/mile)	0.75	0.05	0.60	1.62	3.25	5.17	0.20	1.95	2.02	1.02	2.02	2.57	4.73	5.28	5.96	2.00

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_X and 5% of NO₂/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.523 g/km/veh
Total NO ₂ emission factor (g/s)	=	1.29E-03 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 $A_{C} = (1.7^{*}1.5^{*}0.036) + (1.7^{*}1.5^{*}0.506) + (1.7^{*}1.5^{*}0.177) + (2.5^{*}3.5^{*}0.008) + (2.5^{*}3.5^{*}0.008) + (2.5^{*}3.5^{*}0.004) + (2^{*}3^{*}0.003) + (2.1^{*}1.6^{*}0.003) + (2.1^{*}1.6^{*}0.098) + (2.1^{*}1.6^{*}0.09$ +(2.5*4.6*0.023)+(2.5*4.6*0.066)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

= 3.6643 m²

Calculation of In-Tunnel Air Quality for Portal C (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

$$F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$$
$$F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$$

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	=	3.6643006 m ²
	Ν	=	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	=	200 m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.466666667 m, P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56 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	he roadway	y

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,

where

equation,

$$a V_T^2 + b V_T + c = 0$$

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

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

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

For normal traffic condition

traffic flow Q Vehicle speed V _C		0.098545418 50	veh/s km/h		
Number of vehicles in tunnel N	=	13.88888889 QL/V _c			
	=	1.419054024			
Solving for V_T by equation (1)					
а	=	-103.90			
b	=	-93.16			
c	=	476.01			
tunnel air flow velocity \boldsymbol{V}_{T}	=	1.738573494	m/sec	or	-2.6352752 m/sec (rejected)
Inside tunnel concentration NO ₂	= =		nel air flow x tu ug/m ³	nnel cross	-sectional area)

Appendix 3.9B Calculation of In-Tunnel Air Quality for Portal C (Lam Tin)

One-way Enclosure - Wo Tunnel Parameter	orst Condition	(Portal C)
Length L	= 200	m
Height H	= 8	m
Width W	= 7	m
Cross-sectional a	rea A _T = H x W =	56 m ²
Perimeter P	=	30 m

Emission Data

Traffic Breakdown (%)

			(,,,)										Heavy	Heavy	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck
Traffic (Link			Private		franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised
no.)	Traffic flow (veh/hr)	Motorcycles	Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus
190	355	3.6%	50.6%	17.7%	1.1%	0.8%	0.8%	0.4%	0.3%	0.3%	9.8%	5.8%	2.3%	6.6%	0.0%
NOx Emission	Factor (g/mile)	0.94	0.06	0.87	3.41	6.87	10.93	0.25	2.65	2.87	1.58	4.20	5.36	9.84	11.37

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO₂ emission taken as 7.5%

of NO_{χ} and 5% of NO₂/NO_{χ} for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.983 g/km/veh
Total NO ₂ emission factor (g/s)	=	2.42E-03 g/sec

Vehicle Data

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

Motorcycles Petrol PC &LGV Taxi Non-franchised Bus <6.4t Non-franchised Bus <6.4t Non-franchised Bus >15t Private Light Bus <3.5t Private Light Bus <3.5t PC&LGV <2.5t LGV 2.5-3.5t LGV >3.5t HGV<15t HGV>15t Single Deck Franchised Buses Double Deck Franchised Buses	W /m 1.7 1.7 2.5 2.5 2.5 2.5 2.1 2.1 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5	H /m 1.5 1.5 3.5 3.5 3.5 3 1.6 1.6 4.6 4.6 3.5 4.6	L/m 4.6 4.6 12 12 12 6.5 6.5 5.2 5.2 5.2 16 16 12 12
Single Deck Franchised Buses Double Deck Franchised Buses Public Light Bus	2.5 2.5 2	3.5 4.6 3	12 12 6.5
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 $A_C = (1.7*1.5*0.042) + (1.7*1.5*0.496) + (1.7*1.5*0.175) + (2.5*3.5*0.002) + (2.5*3.5*0.031) + (2.5*3.5*0.003) + (2*3*0.003) + (2*3*0.005) + (2.1*1.6*0) + (2.1*1.6*0.108) + (2.1*$

+(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)

 $= 3.6643 \text{ m}^2$

Double ck Deck d Franchised Public Light Bus Bus 0.0% 0.0% 12.78 2.29

Calculation of In-Tunnel Air Quality for Portal C (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

 $F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$ $F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$

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 k	g/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	=	3.6643006 n	n ²
	Ν	=	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	=	200 n	n
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.46666667 n	n, P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56 n	n ²
	C_W	=	External wind coefficient	=	0.3	
١	V _{W(ref)}	=	Velocity of wind at SE Station	=	3.19 ⁿ	n/s (Average of 2011 Southeast Kowloon Weather Station data)
	θ	=	Angle of the wind velocity component parallel	to the roa	dway	

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

= 2.77777778 m/s average length of vehicle = $(4.6^{\circ}0.04)+(4.6^{\circ}0.51)+(4.6^{\circ}0.18)+(12^{\circ}0.01)+(12^{\circ}0.01)+(6.5^{\circ}0)+(5.2^{\circ}0.1)+(5.2^{\circ}0.06)+(16^{\circ}0.02)+(16^{\circ}0.07)+(12^{\circ}0)+(6.5^{\circ}0)$ = $5.919486811 $ m distance between vehicle = $1 $ m head to head length = $6.919486811 $ m Number of vehicles per lane = 28.90387762 Number of vehicles in tunnel N = 28.90387762
= 5.919486811 m distance between vehicle = 1 m head to head length = 6.919486811 m Number of vehicles per lane = 28.90387762 Number of lanes = 1
= 5.919486811 m distance between vehicle = 1 m head to head length = 6.919486811 m Number of vehicles per lane = 28.90387762 Number of lanes = 1
head to head length=6.919486811 mNumber of vehicles per lane=28.90387762Number of lanes=1
Number of vehicles per lane = 28.90387762 Number of lanes = 1
Number of vehicles per lane = 28.90387762 Number of lanes = 1
Number of lanes = 1
Number of vehicles in tubber $N = 28.90387767$
Solving for V_T by equation (1)
a = -38.94
b = -379.52
c = 356.15
tunnel air flow velocity $V_T = 0.862167436$ m/sec or -10.609329 m/sec
(rejected)
Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area)
$NO_2 = 50 \text{ ug/m}^3$
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Appendix 3.9B Calculation of In-Tunnel Air Quality for Portal C (Lam Tin)

Overall Concentrations (Portal C)

Four assessment points (ASRs InC1-InC4) at the boundary of the enclosure are chosen. Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated. The highest concentration among the four 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								
InC1	0.0	226								
InC1	4.0	226								
InC1	8.0	225								
InC2	0.0	226								
InC2	4.0	226								
InC2	8.0	225								
InC3	0.0	226								
InC3	4.0	226								
InC3	8.0	225								
InC4	0.0	226								
InC4	4.0	226								
InC4	8.0	225								

226 ug/m³

Therefore, the NO₂ background concentration inside the enclosure is

Total Maximum NO₂ concentration inside tunnel at

Portal C (Normal Speed)	=	13 + 226 239	ug/m ³
Total Maximum NO ₂ concentration inside tunnel at			
Portal C (Worst Case)	=	50 + 226	
	=	276	ug/m ³

Appendix 3.9C Calculation of In-Tunnel Air Quality for Portal D (Lam Tin)

vay Enclosure - No Parameter	(Porta	al D)	
Length L	= 100	m	
Height H	= 8	m	
Width W	= 9	m	
Cross-sectional a		72 m ²	
Perimeter P	=	34 m	

Emission Data

Traffic Breakdown (%)	
-----------------------	--

		Hame Dieakuown	(70)														
													Heavy	Heavy		Double	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	Deck	
Traffic (Link					franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised	Franchised	Public Light
no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	Bus	Bus
191	1725	4.4%	61.4%	21.4%	1.3%	1.0%	1.0%	0.5%	0.4%	0.1%	3.4%	2.0%	0.8%	2.3%	0.0%	0.0%	0.0%
NOx Emission	Factor (g/mile)	0.75	0.05	0.60	1.62	3.25	5.17	0.20	1.95	2.02	1.02	2.02	2.57	4.73	5.28	5.96	2.00

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_X and 5% of NO₂/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.317 g/km/veh
Total NO ₂ emission factor (g/s)	=	1.90E-03 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 $A_C = (1.7*1.5*0.044) + (1.7*1.5*0.614) + (1.7*1.5*0.214) + (2.5*3.5*0.013) + (2.5*3.5*0.01) + (2.5*3.5*0.01) + (2*3*0.005) + (2*3*0.004) + (2.1*1.6*0.001) + (2.1*1.6*0.034) + (2.$ +(2.5*4.6*0.008)+(2.5*4.6*0.023)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

Calculation of In-Tunnel Air Quality for Portal D (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

$$F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$$
$$F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$$

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	g/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	=	3.10710049 m	2
	Ν	=	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	=	100 m	1
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	8.47058824 m	n, P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	72 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)
	0	_	Angle of the wind velocity component parallel to	the readur		

(1)

 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 :
$$F_C - F_T - F_W = 0$$

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	=	0.479249508	veh/s		
Vehicle speed V_{C}	=	50	km/h		
	=	13.88888889	m/s		
Number of vehicles in tunnel N	=	QL/V _C			
	=	3.450596456			
Solving for V_T by equation (1)					
а	=	-114.26			
-		-192.09			
C	=	1114.16			
tunnel air flow velocity $V_{\rm T}$	=	2.393249773	m/sec	or	-4.074427 m/sec (rejected)
Inside tunnel concentration NO ₂	= =		nel air flow x t ug/m ³	tunnel cros	ss-sectional area)

Appendix 3.9C Calculation of In-Tunnel Air Quality for Portal D (Lam Tin)

One-way Enclosure - We Tunnel Parameter	(Portal D)	
Length L	= 100	m
Height H	= 8	m
Width W	= 9	m
Cross-sectional a	72 m ²	
Perimeter P	=	34 m

Emission Data

Traffic Breakdown (%)

			(,,,)										Heavy	Heavy	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck
Traffic (Link			Private		franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised
no.)	Traffic flow (veh/hr)	Motorcycles	Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus
191	1725	4.4%	61.4%	21.4%	1.3%	1.0%	1.0%	0.5%	0.4%	0.1%	3.4%	2.0%	0.8%	2.3%	0.0%
NOx Emission	Factor (g/mile)	0.94	0.06	0.87	3.41	6.87	10.93	0.25	2.65	2.87	1.58	4.20	5.36	9.84	11.37

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_{χ} and 5% of NO₂/NO_{χ} for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.564 g/km/veh
Total NO ₂ emission factor (g/s)	=	3.38E-03 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 $A_C = (1.7*1.5*0.042) + (1.7*1.5*0.496) + (1.7*1.5*0.175) + (2.5*3.5*0.002) + (2.5*3.5*0.031) + (2.5*3.5*0.003) + (2*3*0.003) + (2*3*0.005) + (2.1*1.6*0) + (2.1*1.6*0.108) + (2.1*$

 $+(2.5^{*}4.6^{*}0.093)+(2.5^{*}4.6^{*}0.008)+(2.5^{*}3.5^{*}0)+(2.5^{*}4.6^{*}0)+(2^{*}3^{*}0)$

 $= 3.1071 \text{ m}^2$

Double ck Deck d Franchised Public Light Bus Bus 0.0% 0.0% 12.78 2.29

Calculation of In-Tunnel Air Quality for Portal D (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

 $F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$ $F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$

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	=	3.1071	10049 m ²	
	Ν	=	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	=		100 m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	8.4705	58824 m, P	e is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=		72 m ²	
	C_W	=	External wind coefficient	=		0.3	
١	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 paral	lel to the roa	adway		

(1)

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

Force balance : $F_C - F_T - F_W = 0$

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

= 2.7777778 m/s average length of vehicle = (4.6*0.04)+(4.6*0.61)+(4.6*0.21)+(12*0.01)+(12*0.01)+(6.5*0)+(5.2*0.03)+(5.2*0.02)+(16*0.01)+(16*0.02)+(12*0)+(6.5*0) = 5.247437833 m distance between vehicle = 1 m head to head length = 6.247437833 m Number of vehicles per lane = 16.00656184 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³ P:\600981311.1.01\Deliverables\EIA\EIA Report\Final\Sec 3 Air\Appendices\Appendix 3-9C (LT).xis	Vehicle speed Vc :	= 10 km/h
$= 5.247437833 \text{ m}$ $= 5.247437833 \text{ m}$ $head to head length = 6.247437833 \text{ m}$ $Number of vehicles per lane = 16.00656184$ $Number of vehicles in tunnel N = 16.00656184$ Solving for V _T by equation (1) $a = -89.10$ $b = -178.21$ $c = 27.71$ $tunnel air flow velocity V_T = 0.145003724 \text{ m/sec} \text{ or } -2.145232 \text{ m/sec}$ $(rejected)$ Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) $NO_2 = 323 \text{ ug/m}^3$:	= 2.777777778 m/s
distance between vehicle = 1 m head to head length = 6.247437833 m Number of vehicles per lane = 16.00656184 Number of lanes = 1 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	average length of vehicle	$= (4.6^{\circ}0.04) + (4.6^{\circ}0.61) + (4.6^{\circ}0.21) + (12^{\circ}0.01) + (12^{\circ}0.01) + (6.5^{\circ}0) + (6.5^{\circ}0) + (5.2^{\circ}0.03) + (5.2^{\circ}0.02) + (16^{\circ}0.01) + (16^{\circ}0.02) + (12^{\circ}0) + (6.5^{\circ}0) + (6.5^{\circ}0) + (5.2^{\circ}0.03) + (5.2^{\circ}0.02) + (16^{\circ}0.02) + (12^{\circ}0.02) + (12^{\circ$
head to head length = 6.247437833 m Number of vehicles per lane = 16.00656184 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = $0.145003724 \text{ m/sec}$ or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m^3		= 5.247437833 m
Number of vehicles per lane = 16.00656184 Number of lanes = 1 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO_2 = 323 ug/m ³	distance between vehicle	= 1 m
Number of vehicles per lane = 16.00656184 Number of lanes = 1 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO_2 = 323 ug/m ³	head to head length	= 6.247437833 m
Number of lanes = 1 Number of vehicles in tunnel N = 16.00656184 Solving for V _T by equation (1) a = -89.10 b = -178.21 c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	5	
Solving for V _T by equation (1) a = -89.10 $b = -178.21$ $c = 27.71$ tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	•	
a = -89.10 $b = -178.21$ $c = 27.71$ tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	Number of vehicles in tunnel N	= 16.00656184
a = -89.10 $b = -178.21$ $c = 27.71$ tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³		
$b = -178.21$ $c = 27.71$ tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) $NO_2 = 323 \text{ ug/m}^3$	Solving for V_T by equation (1)	
c = 27.71 tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	а	= -89.10
tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) NO ₂ = mission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	þ	= -178.21
tunnel air flow velocity V _T = 0.145003724 m/sec or -2.145232 m/sec (rejected) NO ₂ = emission rate / (tunnel air flow x tunnel cross-sectional area) NO ₂ = 323 ug/m ³	C	= 27.71
(rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO_2 = 323 ug/m ³		
(rejected) Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO_2 = 323 ug/m ³	tunnel air flow velocity V_{τ}	- 0.145003724 m/sec or -2.145232 m/sec
Inside tunnel concentration = emission rate / (tunnel air flow x tunnel cross-sectional area) NO_2 = 323 ug/m ³		
$NO_2 = 323 \text{ ug/m}^3$		(rejected)
$NO_2 = 323 \text{ ug/m}^3$	Inside tunnel concentration	= emission rate / (tunnel air flow x tunnel cross-sectional area)
P:\60098131\1.01\Deliverables\EIA\EIA Report\Final\Sec 3 Air\Appendices\Appendix 3-9C (LT).xls	NO2	- 525 -5
P:\60098131\1.01\Deliverables\EIA\EIA Report\Final\Sec 3 Air\Appendices\Appendix 3-9C (LT).xls		
	P:\60098131\1.01\Deliverables\EIA	\EIA Report\Final\Sec 3 Air\Appendices\Appendix 3-9C (LT).xls

Appendix 3.9C Calculation of In-Tunnel Air Quality for Portal D (Lam Tin)

Overall Concentrations (Portal D)

Four assessment points (ASRs InD1-InD4) at the boundary of the enclosure are chosen. Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated. The highest concentration among the four 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					
InD1	0.0	249					
InD1	4.0	252					
InD1	8.0	259					
InD2	0.0	247					
InD2	4.0	246					
InD2	8.0	245					
InD3	0.0	250					
InD3	4.0	249					
InD3	8.0	248					
InD4	0.0	249					
InD4	4.0	249					
InD4	8.0	248					

259 ug/m³

Therefore, the NO₂ background concentration inside the enclosure is

Total Maximum NO₂ concentration inside tunnel at

Portal D (Normal Speed)	= 11 + 259 = 270 ug/m ³	
Total Maximum NO ₂ concentration inside tunnel at		
Portal D (Worst Case)	= 323 + 259	
	= 582 ug/m ³	

Appendix 3.9D Calculation of In-Tunnel Air Quality for Portal E (Lam Tin)

One-wa Tunnel Pa	y Enclosure - Nor arameter	(Porta	al E)	
	Length L	= 160	m	
	Height H	= 8	m	
	Width W	= 7	m	
	Cross-sectional are		56 m ²	
	Perimeter P	=	30 m	

Emission Data

Traffic Breakdown (%)	
-----------------------	--

		Traffic Dreakuowii	(70)														
													Heavy	Heavy		Double	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	Deck	
Traffic (Link					franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised	Franchised	Public Light
no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	Bus	Bus
192	1082	4.0%	55.5%	19.4%	1.2%	0.9%	0.9%	0.4%	0.4%	0.2%	6.9%	4.1%	1.6%	4.6%	0.0%	0.0%	0.0%
NOx Emission	Factor (g/mile)	0.75	0.05	0.60	1.62	3.25	5.17	0.20	1.95	2.02	1.02	2.02	2.57	4.73	5.28	5.96	2.00

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_X and 5% of NO₂/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.428 g/km/veh
Total NO ₂ emission factor (g/s)	=	2.57E-03 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 $A_{C} = (1.7*1.5*0.04) + (1.7*1.5*0.555) + (1.7*1.5*0.194) + (2.5*3.5*0.012) + (2.5*3.5*0.009) + (2.5*3.5*0.009) + (2*3*0.004) + (2*3*0.004) + (2.1*1.6*0.002) + (2.1*1.6*0.069) + (2.1*1.6*0.041) + (2.1*1.6*0.02) + (2.1*1.6*0.042) + ($ +(2.5*4.6*0.016)+(2.5*4.6*0.046)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

= 3.4083 m²

Calculation of In-Tunnel Air Quality for Portal E (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

$$F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$$
$$F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$$

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	=	3.40825581 m ²	
	Ν	=	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	=	160 m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.46666667 m, P is the Perin	neter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56 m ²	
	C_{W}	=	External wind coefficient	=	0.3	
,	V _{W(ref)}	=	Velocity of wind at SE Station	=	3.19 m/s (Average of	f 2011 Southeast Kowloon Weather Station data)
	0	_	Angle of the wind velocity component parallel to	the readure	,	

(1)

 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 :
$$F_C - F_T - F_W = 0$$

 $a V_T^2 + b V_T + c = 0$

Solving the equation,

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		0.300465461			
Vehicle speed V _c	=	50	km/h		
	=	13.88888889	m/s		
Number of vehicles in tunnel N	=	QL/V _c			
	=	3.461362116			
Solving for V_T by equation (1)					
а	=	-94.99			
b	=	-211.37			
С	=	1296.87			
tunnel air flow velocity V_T	=	2.746235907	m/sec	or	-4.9713633 m/sec
					(rejected)
Inside tunnel concentration	=			innel cros	s-sectional area)
NO ₂	=	17	ug/m³		

Appendix 3.9D Calculation of In-Tunnel Air Quality for Portal E (Lam Tin)

One-way Enclosu Tunnel Parameter	(Portal E)			
Length L	= 160	m		
Height H	= 8	m		
Width W	= 7	m		
Cross-se	Cross-sectional area $A_T = H \times W =$			
Perimete	r P =	30 m		

Emission Data

Traffic Breakdown (%)

			(,,,)										Heavy	Heavy	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck
Traffic (Link			Private		franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised
no.)	Traffic flow (veh/hr)	Motorcycles	Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus
192	1082	4.0%	55.5%	19.4%	1.2%	0.9%	0.9%	0.4%	0.4%	0.2%	6.9%	4.1%	1.6%	4.6%	0.0%
NOx Emission	Factor (g/mile)	0.94	0.06	0.87	3.41	6.87	10.93	0.25	2.65	2.87	1.58	4.20	5.36	9.84	11.37

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_{χ} and 5% of NO₂/NO_{χ} for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.790 g/km/veh
Total NO ₂ emission factor (g/s)	=	4.75E-03 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 $A_C = (1.7*1.5*0.042) + (1.7*1.5*0.496) + (1.7*1.5*0.175) + (2.5*3.5*0.002) + (2.5*3.5*0.031) + (2.5*3.5*0.003) + (2*3*0.003) + (2*3*0.005) + (2.1*1.6*0) + (2.1*1.6*0.108) + (2.1*$

+(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)

 $= 3.4083 \text{ m}^2$

Double ck Deck d Franchised Public Light Bus Bus 0.0% 0.0% 12.78 2.29

Calculation of In-Tunnel Air Quality for Portal E (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

 $F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$ $F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$

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	2 kg/m ³	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	5	
	A_{C}	=	Vehicle frontal area	=	3.40825581	m ²	
	Ν	=	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	=	160) m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.46666667	′ m, P	is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56	s m²	
	C_{W}	=	External wind coefficient	=	0.3	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 paralle	I to the roa	adway		

(1)

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

Force balance : $F_C - F_T - F_W = 0$

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 =	
	= 2.77777778 m/s
average length of vehicle	= (4.6*0.04) + (4.6*0.56) + (4.6*0.19) + (12*0.01) + (12*0.01) + (6.5*0) + (6.5*0) + (5.2*0) + (5.2*0.07) + (5.2*0.04) + (16*0.02) + (16*0.05) + (12*0) + (12*0) + (6.5*0) + (6.5*0) + (5.2*0) + (
	= 5.610666627 m
distance between vehicle	= 1 m
head to head length	= 6.610666627 m
Number of vehicles per lane	= 24.20330793
Number of lanes	= 1
Number of vehicles in tunnel N	= 24.20330793
Solving for V_T by equation (1)	
а	= -49.39
b	= -295.59
С	= 239.59
tunnel air flow velocity V_{τ}	= 0.723147978 m/sec or -6.7076277 m/sec
	= 0.723147978 m/sec or -6.7076277 m/sec (rejected)
Incide tunnel concentration	aminging rate (/ tupped air flow y tupped proce exertional grad)
	= emission rate / (tunnel air flow x tunnel cross-sectional area)
NO ₂	= 117 ug/m ³
	ELA Depart/Fine//Sec 2 Air/Appendices/Appendix 2 0D /LT) v/s
P:\00098131\1.01\Deliverables\EIA	EIA Report\Final\Sec 3 Air\Appendices\Appendix 3-9D (LT).xls

Appendix 3.9D Calculation of In-Tunnel Air Quality for Portal E (Lam Tin)

Overall Concentrations (Portal E)

Four assessment points (ASRs InE1-InE4) at the boundary of the enclosure are chosen.

Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated. The highest concentration among the four 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							
InE1	0.0	242							
InE1	4.0	242							
InE1	8.0	241							
InE2	0.0	244							
InE2	4.0	243							
InE2	8.0	241							
InE3	0.0	248							
InE3	4.0	247							
InE3	8.0	246							
InE4	0.0	247							
InE4	4.0	247							
InE4	8.0	246							

Therefore, the NO₂ background concentration inside the enclosure is

Total Maximum NO₂ concentration inside tunnel at

Portal E (Normal Speed)	=
	=
Total Maximum NO ₂ concentration inside tunnel at	

Portal E (Worst Case)

17 + 248

ug/m³

248 ug/m³

= 117 + 248

265

= 366 ug/m³

Appendix 3.9E Calculation of In-Tunnel Air Quality for Portal H (Lam Tin)

One-way Enclosure - No Tunnel Parameter	(Porta	al H)	
Length L	= 200	m	
Height H	= 8	m	
Width W	= 9	m	
Cross-sectional a	rea A _T = H x W =		72 m ²
Perimeter P	=	34 m	

Emission Data

Traffic Breakdown (%)	
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		Hame Dieakuuwii	(70)														
													Heavy	Heavy		Double	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	Deck	
Traffic (Link					franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised	Franchised	Public Light
no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	Bus	Bus
225	1624	5.3%	59.3%	15.8%	1.4%	1.0%	1.0%	0.6%	0.5%	0.2%	6.8%	4.0%	1.1%	3.0%	0.0%	0.0%	0.0%
NOx Emission	Factor (g/mile)	0.64	0.04	0.59	1.65	3.31	5.26	0.17	1.62	1.78	1.01	2.04	2.58	4.74	5.20	5.87	1.95

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_X and 5% of NO₂/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.369 g/km/veh
Total NO ₂ emission factor (g/s)	=	4.16E-03 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 $A_C = (1.7*1.5*0.053) + (1.7*1.5*0.593) + (1.7*1.5*0.158) + (2.5*3.5*0.014) + (2.5*3.5*0.01) + (2.5*3.5*0.01) + (2*3*0.006) + (2*3*0.005) + (2.1*1.6*0.002) + (2.1*1.6*0.068) + (2.$ +(2.5*4.6*0.011)+(2.5*4.6*0.03)+(2.5*3.5*0)+(2.5*4.6*0)+(2*3*0)

m²

Calculation of In-Tunnel Air Quality for Portal H (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

$$F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$$
$$F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$$

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	n ³
	V _C	=	Velocity of vehicle, m/s			
	V_{T}	=	Velocity of air flow in tunnel, m/s			
	\mathbf{C}_{d}	=	Vehicle drag coefficient	=	0.645	
	A_{C}	=	Vehicle frontal area	=	3.24895583 m ²	
	Ν	=	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	=	200 m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	8.47058824 m, P	P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	72 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)
	0	_	Angle of the wind velocity component parallel to	the readure		

(1)

 θ = Angle of the wind velocity component parallel to the roadway

 $a V_T^2 + b V_T + c = 0$

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

Force balance :
$$F_C - F_T - F_W = 0$$

Solving the equation,

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	=	0.451026541	veh/s		
Vehicle speed V_{C}	=	50	km/h		
	=	13.88888889	m/s		
Number of vehicles in tunnel N	=	QL/V _C			
	=	6.494782197			
Solving for V_T by equation (1)					
а	=	-120.74			
-		-378.06			
C	=	2405.64			
tunnel air flow velocity $V_{\rm T}$	=	3.164643228	m/sec	or	-6.2958775 m/sec (rejected)
Inside tunnel concentration NO ₂	= =		nel air flow x tu ug/m ³	unnel cro	ss-sectional area)

Appendix 3.9E Calculation of In-Tunnel Air Quality for Portal H (Lam Tin)

One-way Enclosure - Wo Tunnel Parameter	(Portal H)				
Length L	= 200	m			
Height H	= 8	m			
Width W	= 9	m			
Cross-sectional a	Cross-sectional area A _T = H x W =				
Perimeter P	=	34 m			

Emission Data

Traffic Breakdown (%)

													Heavy	Heavy		
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	
Traffic (Link			Private		franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised F	-
no.)	Traffic flow (veh/hr)	Motorcycles	Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	
225	1624	5.3%	59.3%	15.8%	1.4%	1.0%	1.0%	0.6%	0.5%	0.2%	6.8%	4.0%	1.1%	3.0%	0.0%	
NOx Emission	Factor (g/mile)	0.82	0.05	0.86	3.39	6.82	10.85	0.22	2.29	2.62	1.56	4.17	5.32	9.77	11.29	

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_{χ} and 5% of NO₂/NO_{χ} for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.669 g/km/veh
Total NO ₂ emission factor (g/s)	=	7.54E-03 g/sec

Vehicle Data

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

Motorcycles Petrol PC &LGV Taxi Non-franchised Bus <6.4t Non-franchised Bus <6.4t Non-franchised Bus >15t Private Light Bus <3.5t Private Light Bus <3.5t PC&LGV <2.5t LGV 2.5-3.5t LGV >3.5t HGV<15t HGV>15t Single Deck Franchised Buses Double Deck Franchised Buses	W /m 1.7 1.7 2.5 2.5 2.5 2.5 2.1 2.1 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5	H /m 1.5 1.5 3.5 3.5 3.5 3 1.6 1.6 4.6 4.6 3.5 4.6	L/m 4.6 4.6 12 12 12 6.5 6.5 5.2 5.2 5.2 16 16 12 12
Single Deck Franchised Buses Double Deck Franchised Buses Public Light Bus	2.5 2.5 2	3.5 4.6 3	12 12 6.5
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 $A_C = (1.7*1.5*0.042) + (1.7*1.5*0.496) + (1.7*1.5*0.175) + (2.5*3.5*0.002) + (2.5*3.5*0.031) + (2.5*3.5*0.003) + (2*3*0.003) + (2*3*0.005) + (2.1*1.6*0) + (2.1*1.6*0.108) + (2.1*$

+(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)

 $= 3.2490 m^2$

Double k Deck d Franchised Public Light Bus Bus 0.0% 0.0% 12.69 2.24

Calculation of In-Tunnel Air Quality for Portal H (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

 $F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$ $F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$

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	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	5
	A_{C}	=	Vehicle frontal area	=	3.24895583	3 m ²
	Ν	=	No. of vehicles in tunnel			
	K _{in}	=	Inlet loss coefficient	=	0.5	5
	K _{out}	=	Outlet loss coefficient	=	1.0	0
	f	=	Tunnel friction factor	=	0.0155	5
	L	=	Length of tunnel	=	200	0 m
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	8.47058824	4 m, P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	72	2 m ²
	C_{W}	=	External wind coefficient	=	0.3	3
v	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 parall	el to the roa	adway	

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
	2.77777778 m/s (4.6*0.05)+(4.6*0.59)+(4.6*0.16)+(12*0.01)+(12*0.01)+(12*0.01)+(6.5*0.01)+(6.5*0)+(5.2*0)+(5.2*0.07)+(5.2*0.04)+(16*0.01)+(16*0.03)+(12*0)+(12*0)+(6.5*0) 5.399116974 m
distance between vehicle =	1 m
head to head length =	6.399116974 m
Number of vehicles per lane =	31.25431225
Number of lanes =	1
Number of vehicles in tunnel N =	31.25431225
Solving for V_T by equation (1)	
a =	-68.85
b =	-363.87
с =	285.57
tunnel air flow velocity V_T =	0.693738192 m/sec or -5.978319 m/sec (rejected)
Inside tunnel concentration =	emission rate / (tunnel air flow x tunnel cross-sectional area)
NO ₂ =	151 ug/m ³
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Appendix 3.9E Calculation of In-Tunnel Air Quality for Portal H (Lam Tin)

Overall Concentrations (Portal H)

Four assessment points (ASRs InH1-InH4) at the boundary of the enclosure are chosen. Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated. The highest concentration among the four 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					
InH1	0.0	225					
InH1	4.0	225					
InH1	8.0	225					
InH2	0.0	225					
InH2	4.0	225					
InH2	8.0	225					
InH3	0.0	225					
InH3	4.0	225					
InH3	8.0	225					
InH4	0.0	226					
InH4	4.0	225					
InH4	8.0	225					

Therefore, the NO₂ background concentration inside the enclosure is

Total Maximum NO ₂ concentration inside tunnel at	

Portal H (Normal Speed)	= =	18 + 226 244 ug/m ³
Total Maximum NO ₂ concentration inside tunnel at Portal H (Worst Case)	=	151 + 226

= 377 ug/m³

226 ug/m³

Appendix 3.9F Calculation of In-Tunnel Air Quality for Portal I (Lam Tin)

One-way Tunnel Pa	y Enclosure - Norr arameter	(Porta	al I)	
	Length L	= 200	m	
	Height H	= 8	m	
	Width W	= 7	m	
	Cross-sectional are		56 m ²	
	Perimeter P	=	30 m	

Emission Data

Traffic Breakdown (%)
---------------------	----

		Traffic Dieakuowii	(70)														
													Heavy	Heavy		Double	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck	Deck	
Traffic (Link					franchised	franchised	franchised	Private Light	Private Ligh	t Vehicles<=2	Vehicles 2.5	- Vehicles>3.	Vehicles<=1	Vehicles	Franchised	Franchised	Public Light
no.)	Traffic flow (veh/hr)	Motorcycles	Private Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus	Bus	Bus
226	728	4.1%	58.1%	20.3%	1.3%	0.9%	0.9%	0.5%	0.4%	0.1%	5.4%	3.2%	1.3%	3.6%	0.0%	0.0%	0.0%
NOx Emission	Factor (g/mile)	0.75	0.05	0.60	1.62	3.25	5.17	0.20	1.95	2.02	1.02	2.02	2.57	4.73	5.28	5.96	2.00

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO_2 emission taken as 7.5%

of NO_X and 5% of NO₂/NO_X for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.380 g/km/veh
Total NO ₂ emission factor (g/s)	=	1.92E-03 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 $A_C = (1.7*1.5*0.041) + (1.7*1.5*0.581) + (1.7*1.5*0.203) + (2.5*3.5*0.013) + (2.5*3.5*0.009) + (2.5*3.5*0.009) + (2*3*0.005) + (2*3*0.004) + (2.1*1.6*0.001) + (2.1*1.6*0.054) + (2.1*1.6*0.032) + (2.5*3.5*0.009) + ($ $+(2.5^{*}4.6^{*}0.013)+(2.5^{*}4.6^{*}0.036)+(2.5^{*}3.5^{*}0)+(2.5^{*}4.6^{*}0)+(2^{*}3^{*}0)$

$$= 3.2771$$
 m²

Calculation of In-Tunnel Air Quality for Portal I (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

$$F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$$
$$F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$$

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/	′m³
	V _c	=	Velocity of vehicle, m/s			
	V _T	=	Velocity of air flow in tunnel, m/s			
	\mathbf{C}_{d}	=	Vehicle drag coefficient	=	0.645	
	A_{C}	=	Vehicle frontal area	=	3.27708228 m ²	
	Ν	=	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	=	200 m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.46666667 m,	P is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56 m ²	
	C_{W}	=	External wind coefficient	=	0.3	
,	V _{W(ref)}	=	Velocity of wind at SE Station	=	3.19 m/s	s (Average of 2011 Southeast Kowloon Weather Station data)
	0	_	Angle of the wind velocity component parallel t	o the readure		

(1)

 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 :
$$F_C - F_T - F_W = 0$$

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	=	0.202154327	veh/s		
Vehicle speed V_{C}	=	50	km/h		
	=	13.88888889	m/s		
Number of vehicles in tunnel N	=	QL/V _C			
	=	2.911022306			
Solving for V_T by equation (1)					
а	=	-101.10			
b	=	-170.92			
C	=	1015.98			
tunnel air flow velocity $V_{\rm T}$	=	2.435549403	m/sec	or	-4.1261934 m/sec (rejected)
Inside tunnel concentration NO ₂	= =		nel air flow x tu ug/m ³	innel cros	s-sectional area)

Appendix 3.9F Calculation of In-Tunnel Air Quality for Portal I (Lam Tin)

One-way Enclosure - N Tunnel Parameter	Norst Condition	(Portal I)
Length L	= 200	m
Height H	= 8	m
Width W	= 7	m
Cross-sectiona	56 m ²	
Perimeter P	=	30 m

Emission Data

Traffic Breakdown (%)

			(,,,)										Heavy	Heavy	
Tunnel					Non-	Non-	Non-			Light Goods	Lt Goods	Light Goods	Goods	Goods	Single Deck
Traffic (Link			Private		franchised	franchised	franchised	Private Light	Private Light	Vehicles<=2	Vehicles 2.5-	Vehicles>3.	Vehicles<=1	Vehicles	Franchised
no.)	Traffic flow (veh/hr)	Motorcycles	Cars	Taxi	Bus<=6.4t	Bus 6.4-15t	Bus >15t	Bus <=3.5t	Bus >3.5t	.5t	3.5t	5t	5t	>15t	Bus
226	728	4.1%	58.1%	20.3%	1.3%	0.9%	0.9%	0.5%	0.4%	0.1%	5.4%	3.2%	1.3%	3.6%	0.0%
NOx Emission	Factor (g/mile)	0.94	0.06	0.87	3.41	6.87	10.93	0.25	2.65	2.87	1.58	4.20	5.36	9.84	11.37

Total NO₂ emission rate = total NO_X emission factor x traffic flow x tunnel length x NO₂ conversion factor

where conversion factor = 12.5% (including tailpipe NO₂ emission taken as 7.5%

of NO_{χ} and 5% of NO₂/NO_{χ} for tunnel air)

Weighted NOX E.F. (g/km/veh)	=	0.692 g/km/veh
Total NO ₂ emission factor (g/s)	=	3.50E-03 g/sec

Vehicle Data

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

Motorcycles Petrol PC &LGV Taxi Non-franchised Bus <6.4t Non-franchised Bus <6.4t Non-franchised Bus >15t Private Light Bus <3.5t Private Light Bus <3.5t PC&LGV <2.5t LGV 2.5-3.5t LGV >3.5t HGV<15t HGV>15t Single Deck Franchised Buses Double Deck Franchised Buses	W /m 1.7 1.7 2.5 2.5 2.5 2.5 2.1 2.1 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5	H /m 1.5 1.5 3.5 3.5 3.5 3 1.6 1.6 4.6 4.6 3.5 4.6	L/m 4.6 4.6 12 12 12 6.5 6.5 5.2 5.2 5.2 16 16 12 12
Single Deck Franchised Buses Double Deck Franchised Buses Public Light Bus	2.5 2.5 2	3.5 4.6 3	12 12 6.5
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 $A_C = (1.7*1.5*0.042) + (1.7*1.5*0.496) + (1.7*1.5*0.175) + (2.5*3.5*0.002) + (2.5*3.5*0.031) + (2.5*3.5*0.003) + (2*3*0.003) + (2*3*0.005) + (2.1*1.6*0) + (2.1*1.6*0.108) + (2.1*$

 $+(2.5^{*}4.6^{*}0.093)+(2.5^{*}4.6^{*}0.008)+(2.5^{*}3.5^{*}0)+(2.5^{*}4.6^{*}0)+(2^{*}3^{*}0)$

 $= 3.2771 m^2$

Double k Deck d Franchised Public Light Bus Bus 0.0% 0.0% 12.78 2.29

Calculation of In-Tunnel Air Quality for Portal I (Lam Tin)

Tunnel Airflow

For Uni-directional Traffic,

Push Force by vehicles:

Resisting Force by tunnel:

 $F_{c} = \frac{1}{2} \rho (V_{c} - V_{T})^{2} C_{d} A_{c} N$ $F_{T} = \frac{1}{2} \rho V_{T}^{2} (K_{in} + K_{out} + \frac{fL}{D}) A_{T}$

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	1	
	A_{C}	=	Vehicle frontal area	=	3.27708228	m²	
	Ν	=	No. of vehicles in tunnel				
	K_{in}	=	Inlet loss coefficient	=	0.5		
	K _{out}	=	Outlet loss coefficient	=	1.0	I.	
	f	=	Tunnel friction factor	=	0.0155	1	
	L	=	Length of tunnel	=	200	m	
	D	=	Hydraulic diameter of tunnel =	$4A_T/P =$	7.46666667	m, P	is the Perimeter of tunnel
	A_{T}	=	Cross-sectional area of tunnel	=	56	; m ²	
	C_W	=	External wind coefficient	=	0.3	,	
١	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 paralle	el to the roa	adway		

(1)

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

Force balance : $F_C - F_T - F_W = 0$

 $a V_T^2 + b V_T + c = 0$

Solving the equation,

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
=	= 2.77777778 m/s
average length of vehicle	$= (4.6^{*}0.04) + (4.6^{*}0.58) + (4.6^{*}0.2) + (12^{*}0.01) + (12^{*}0.01) + (12^{*}0.01) + (6.5^{*}0) + (5.2^{*}0) + (5.2^{*}0.05) + (5.2^{*}0.03) + (16^{*}0.01) + (16^{*}0.04) + (12^{*}0) + (6.5^{*}0) + (5.2^{*}0) + (5.2^{*}0.05) + (5.2^{*}0.03) + (16^{*}0.04) + (12^{*}$
	= 5.4524559 m
distance between vehicle	= 1 m
head to head length	= 6.4524559 m
Number of vehicles per lane	= 30.99594993
Number of lanes	= 1
Number of vehicles in tunnel N	= 30.99594993
Solving for V_T by equation (1)	
а	= -41.73
b	= -363.98
С	= 334.57
tunnel air flow velocity V_T	= 0.838571527 m/sec or -9.5601838 m/sec
	(rejected)
Inside tunnel concentration	= emission rate / (tunnel air flow x tunnel cross-sectional area)
	= 74 ug/m ³
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Appendix 3.9F Calculation of In-Tunnel Air Quality for Portal I (Lam Tin)

Overall Concentrations (Portal I)

Four assessment points (ASRs InI1-InI4) at the boundary of the enclosure are chosen.

Using CALINE4 and ISCST3 model, the air pollutants concentrations at the 4 assessment points at different levels are calculated. The highest concentration among the four 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		
Inl1	0.0	226		
Inl1	4.0	225		
Inl1	8.0	225		
Inl2	0.0	230		
Inl2	4.0	225		
Inl2	8.0	225		
Inl3	0.0	238		
Inl3	4.0	233		
Inl3	8.0	233		
Inl4	0.0	241		
Inl4	4.0	239		
Inl4	8.0	235		

241 ug/m³

Therefore, the NO₂ background concentration inside the enclosure is

Total Maximum NO₂ concentration inside tunnel at

		44.044		
Portal I (Normal Speed)	=	14 + 241		
	=	255	ug/m³	
Total Maximum NO ₂ concentration inside tunnel at				
Portal I (Worst Case)	=	74 + 241		
	=	315	ug/m³	