Calculation of Composite Emission Factor of Full Enclosure F1

In normal traffic condition, the traffic speed is 70 km/h. The emission factor of NOx, generated by the EMFAC-HK model, is provided as follows:

Emission Factor (g/mile-veh)	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.1259	0.4210	0.2852	0.1730	2.4413	4.9336	6.1162	3.2759
Traffic Breakdown+	40%	8%	8%	0%	8%	11%	12%	0%

Emission Factor (g/mile-veh)	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	1.1503	0.2272	0.0000	0.2517	1.7962	4.2219	4.4873	2.7767
Traffic Breakdown+	4%	4%	0%	0%	3%	2%	1%	0%

Note+ : Please note that F1 is situated in road section "I". Please refer reference 7 for the detail information of the traffic breakdown

Total NOx Emission Factor in normal traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]
1.13 g/km-veh

In congested traffic condition, the traffic speed is 10 km/h. The emission factor of NOx, as generated by the EMFAC-HK model, is provided as follows:

Emission Factor (g/mile-veh)	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.2106	0.6520	0.4417	0.2246	3.7812	7.6412	9.4729	6.2813
Traffic Breakdown+	40%	8%	8%	0%	8%	11%	12%	0%

Emission Factor (g/mile-veh)	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.8549	0.3881	0.0000	0.3631	2.7820	6.5389	6.9509	5.3235
Traffic Breakdown+	4%	4%	0%	0%	3%	2%	1%	0%

Note+ : Please note that F1 is situated in road section "I". Please refer reference 7 for the detail information of the traffic breakdown

Total NOx Emission Factor in congested traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]
1.73 g/km-veh

Calculation of NO_2 Concentration inside Full Enclosure F1 along Tsuen Wan Road (Normal Traffic)

Full Enclosure Parameter

Number of Lanes:	3		Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L		=	110.4	m
Full Enclosure Height, H		=	7.6	m
Full Enclosure Width, W		=	13.9	m
Full Enclosure Cross Section Area		=	105.6	m^2
Perimeter, P		=	43.0	m

Emission Data

Traffic Flow = 2,650 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.1259	0.4210	0.2852	0.1730	2.4413	4.9336	6.1162	3.2759
% of vehicle	40%	8%	8%	0%	8%	11%	12%	0%

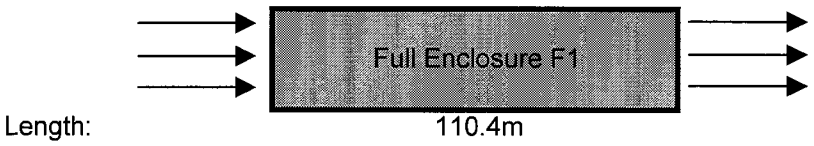
Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	1.1503	0.2272	0.0000	0.2517	1.7962	4.2219	4.4873	2.7767
% of vehicle	4%	4%	0%	0%	3%	2%	1%	0%

Total NOx Emission Factor in normal traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]

Total NO_X Emission Factor = 1.13 g/km/veh

Total NO_2 Emission Rate = Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)

= 1.15E-02 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	40%	2.6
LGV3	5.2	2.1	1.6	8%	3.4
LGV4	5.2	2.1	1.6	8%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	8%	3.4
HGV7	16.0	2.5	4.6	11%	11.5
HGV8	16.0	2.5	4.6	12%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	4%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	3%	8.8
NFB7	12.0	2.5	3.5	2%	8.8
NFB8	12.0	2.5	3.5	1%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 5.2 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6524	
A_c	=	Vehicle Frontal Area	=	5.2	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	110.4	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.8	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	105.6	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^{\,2} + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^{\,2} - C_W V_W^{\,2} A_T$$

For Normal Traffic Condition

Traffic Flow, Q	=	0.74 veh/s		
Vehicle Speed, V_C	=	70 km/h		
	=	19.44 m/s		
Number of Vehicles in Full Enclosure, N	=	QL/V_C		
	=	4.18		

Solving for V_T by Equation 1

a	=	-162.77		
b	=	-548.02		
c	=	4,875.14		
Air Velocity in Full Enclosure V_T	=	4.04 m/s or	-7.41 m/s	(rejected)

NO_2 Concentration inside Full Enclosure by Vehicular Emission = Emission Rate / (V_T x A_t)

= 26.9 $\mu g/m^3$

Six assessment points (T1-T6) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO_2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO_2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road in F1				
ASR		0m	3.8m	7.6m
T1	F1 Inlet	239.8	229.8	220.2
T2	F1 Inlet	257.1	245.6	235.3
T3	F1 Inlet	286.2	278.7	254.8
T4	F1 Outlet	267.1	255.7	243.3
T5	F1 Outlet	309.7	294.4	283.2
T6	F1 Outlet	360.5	337.7	376.8

The highest background concentration is 376.8 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition
= 26.9 + 376.8

= **404 $\mu g/m^3$**

Calculation of NO_2 Concentration inside Full Enclosure F1 along Tsuen Wan Road (Congested Traffic)

Full Enclosure Parameter

Number of Lanes:	3		Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L		=	110.4 m	
Full Enclosure Height, H		=	7.6 m	
Full Enclosure Width, W		=	13.9 m	
Full Enclosure Cross Section Area		=	105.6 m^2	
Perimeter, P		=	43.0 m	

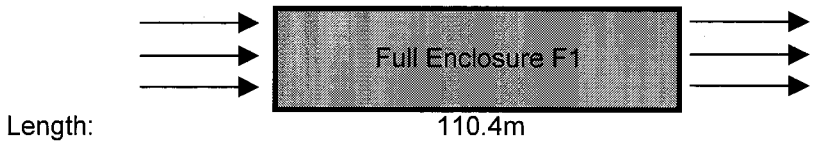
Emission Data

Traffic Flow = 2,650 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.2106	0.6520	0.4417	0.2246	3.7812	7.6412	9.4729	6.2813
% of vehicle	40%	8%	8%	0%	8%	11%	12%	0%

Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.8549	0.3881	0.0000	0.3631	2.7820	6.5389	6.9509	5.3235
% of vehicle	4%	4%	0%	0%	3%	2%	1%	0%

Total NOx Emission Factor in normal traffic condition	=	Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]
Total NO_X Emission Factor	=	1.73 g/km/veh
Total NO_2 Emission Rate	=	Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)
	=	1.76E-02 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	40%	2.6
LGV3	5.2	2.1	1.6	8%	3.4
LGV4	5.2	2.1	1.6	8%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	8%	3.4
HGV7	16.0	2.5	4.6	11%	11.5
HGV8	16.0	2.5	4.6	12%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	4%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	3%	8.8
NFB7	12.0	2.5	3.5	2%	8.8
NFB8	12.0	2.5	3.5	1%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 5.2 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6524	
A_c	=	Vehicle Frontal Area	=	5.2	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	110.4	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.8	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	105.6	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^2 + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^2 - C_W V_W^2 A_T$$

For Congested Traffic Condition

Vehicle Speed V_C	=	10	km/h		
	=	2.78	m/s		
Average Length of Vehicle	=	7.8	m		
Distance Between Vehicle	=	1.0	m		
Head to Head Length	=	8.8	m		
Number of Vehicles per Lane	=	12.5			
Number of Lanes	=	3			
Number of Vehicles in Full Enclosure N	=	37.6			
Solving for V_T by Equation 1					
a	=	-50.02			
b	=	-704.68			
c	=	525.89			
Air Velocity in Full Enclosure V_T	=	0.71	m/s or	-14.80 m/s	(rejected)
NO_2 Concentration inside Full Enclosure by Vehicular Emission	=	Emission Rate / (V_T x A_t)			
	=	234.5	$\mu g/m^3$		

Six assessment points (T1-T6) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO_2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO_2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road in F1				
ASR		0m	3.8m	7.6m
T1	F1 Inlet	239.8	229.8	220.2
T2	F1 Inlet	257.1	245.6	235.3
T3	F1 Inlet	286.2	278.7	254.8
T4	F1 Outlet	267.1	255.7	243.3
T5	F1 Outlet	309.7	294.4	283.2
T6	F1 Outlet	360.5	337.7	376.8

The highest background concentration is 376.8 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition

= 234.5 + 376.8

= **611 $\mu g/m^3$**

Calculation of Composite Emission Factor of Full Enclosure F2 and F3

In normal traffic condition, the traffic speed is 70 km/h. The emission factor of NOx, as generated by the EMFAC-HK model, is provided as follows:

Emission Factor (g/mile-veh)	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.1259	0.4210	0.2852	0.1730	2.4413	4.9336	6.1162	3.2759
Traffic Breakdown+	26%	13%	13%	0%	13%	9%	11%	0%

Emission Factor (g/mile-veh)	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	1.1503	0.2272	0.0000	0.2517	1.7962	4.2219	4.4873	2.7767
Traffic Breakdown+	4%	9%	0%	0%	1%	1%	0%	0%

Note+ : Please note that F2 and F3 is situated in road section "AB". Please refer reference 7 for the detail information of the traffic breakdown

Total NOx Emission Factor in normal traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]
1.06 g/km-veh

In congested traffic condition, the traffic speed is 10 km/h. The emission factor of NOx, as generated by the EMFAC-HK model, is provided as follows:

Emission Factor (g/mile-veh)	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.2106	0.6520	0.4417	0.2246	3.7812	7.6412	9.4729	6.2813
Traffic Breakdown+	26%	13%	13%	0%	13%	9%	11%	0%

Emission Factor (g/mile-veh)	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.8549	0.3881	0.0000	0.3631	2.7820	6.5389	6.9509	5.3235
Traffic Breakdown+	4%	9%	0%	0%	1%	1%	0%	0%

Note+ : Please note that F2 and F3 is situated in road section "AB". Please refer reference 7 for the detail information of the traffic breakdown

Total NOx Emission Factor in congested traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]
1.62 g/km-veh

Calculation of NO_2 Concentration inside Full Enclosure F2 along Tsuen Wan Road (Normal Traffic)

Full Enclosure Parameter

Number of Lanes:	3		Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L		=	93.0 m	
Full Enclosure Height, H		=	7.6 m	
Full Enclosure Width, W		=	13.0 m	
Full Enclosure Cross Section Area		=	98.8 m^2	
Perimeter, P		=	41.2 m	

Emission Data

Traffic Flow = 1,550 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.1259	0.4210	0.2852	0.1730	2.4413	4.9336	6.1162	3.2759
% of vehicle	26%	13%	13%	0%	13%	9%	11%	0%

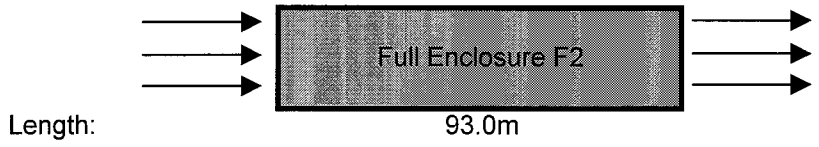
Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	1.1503	0.2272	0.0000	0.2517	1.7962	4.2219	4.4873	2.7767
% of vehicle	4%	9%	0%	0%	1%	1%	0%	0%

Total NOx Emission Factor in normal traffic condition = = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]

Total NO_X Emission Factor = 1.06 g/km/veh

Total NO_2 Emission Rate = Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)

= 5.30E-03 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	26%	2.6
LGV3	5.2	2.1	1.6	13%	3.4
LGV4	5.2	2.1	1.6	13%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	13%	3.4
HGV7	16.0	2.5	4.6	9%	11.5
HGV8	16.0	2.5	4.6	11%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	9%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	1%	8.8
NFB7	12.0	2.5	3.5	1%	8.8
NFB8	12.0	2.5	3.5	0%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 4.8 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6398	
A_c	=	Vehicle Frontal Area	=	4.8	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	93.0	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.6	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	98.8	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^2 + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^2 - C_W V_W^2 A_T$$

For Normal Traffic Condition

Traffic Flow, Q	=	0.43	veh/s		
Vehicle Speed, V_C	=	70	km/h		
	=	19.44	m/s		
Number of Vehicles in Full Enclosure, N	=	QL/V_C			
	=	2.06			

Solving for V_T by Equation 1

a	=	-156.68			
b	=	-247.67			
c	=	1,984.40			

Air Velocity in Full Enclosure V_T	=	2.86	m/s or	-4.44 m/s	(rejected)

NO_2 Concentration inside Full Enclosure by Vehicular Emission	=	Emission Rate / (V_T x A_t)	
	=	18.8	$\mu g/m^3$

Six assessment points (T7-T12) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO_2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO_2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road in F2				
ASR		0m	3.8m	7.6m
T7	F3 Outlet	287.7	273.7	240.5
T8	F3 Outlet	309.8	300.7	239.8
T9	F3 Outlet	266.4	254.8	223.1
T10	F3 Inlet	264.2	244.3	227.4
T11	F3 Inlet	271.3	247.9	226.7
T12	F3 Inlet	265.0	243.8	224.6

The highest background concentration is 309.8 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition

= 18.8 + 309.8

= **329 $\mu g/m^3$**

Calculation of NO_2 Concentration inside Full Enclosure F2 along Tsuen Wan Road (Congested Traffic)

Full Enclosure Parameter

Number of Lanes:	3	Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L	=	93.0 m	
Full Enclosure Height, H	=	7.6 m	
Full Enclosure Width, W	=	13.0 m	
Full Enclosure Cross Section Area	=	98.8 m^2	
Perimeter, P	=	41.2 m	

Emission Data

Traffic Flow = 1,550 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.2106	0.6520	0.4417	0.2246	3.7812	7.6412	9.4729	6.2813
% of vehicle	26%	13%	13%	0%	13%	9%	11%	0%

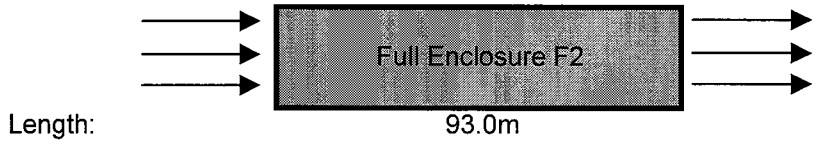
Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.8549	0.3881	0.0000	0.3631	2.7820	6.5389	6.9509	5.3235
% of vehicle	4%	9%	0%	0%	1%	1%	0%	0%

Total NOx Emission Factor in normal traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]

Total NO_X Emission Factor = 1.62 g/km/veh

Total NO_2 Emission Rate = Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)

= 8.12E-03 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	26%	2.6
LGV3	5.2	2.1	1.6	13%	3.4
LGV4	5.2	2.1	1.6	13%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	13%	3.4
HGV7	16.0	2.5	4.6	9%	11.5
HGV8	16.0	2.5	4.6	11%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	9%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	1%	8.8
NFB7	12.0	2.5	3.5	1%	8.8
NFB8	12.0	2.5	3.5	0%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 4.8 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6398	
A_c	=	Vehicle Frontal Area	=	4.8	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	93.0	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.6	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	98.8	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^{\,2} + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^{\,2} - C_W V_W^{\,2} A_T$$

For Congested Traffic Condition

Vehicle Speed V_C	=	10	km/h		
	=	2.78	m/s		
Average Length of Vehicle	=	7.3	m		
Distance Between Vehicle	=	1.0	m		
Head to Head Length	=	8.3	m		
Number of Vehicles per Lane	=	11.2			
Number of Lanes	=	3			
Number of Vehicles in Full Enclosure N	=	33.5			

Solving for V_T by Equation 1

a	=	-59.46			
b	=	-575.47			
c	=	375.75			

Air Velocity in Full Enclosure V_T	=	0.61	m/s or	-10.29	m/s	(rejected)

NO_2 Concentration inside Full Enclosure by Vehicular Emission	=	Emission Rate / (V_T x A_t)	
	=	133.9	$\mu g/m^3$

Six assessment points (T7-T12) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO_2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO_2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road in F2				
ASR		0m	3.8m	7.6m
T7	F3 Outlet	287.7	273.7	240.5
T8	F3 Outlet	309.8	300.7	239.8
T9	F3 Outlet	266.4	254.8	223.1
T10	F3 Inlet	264.2	244.3	227.4
T11	F3 Inlet	271.3	247.9	226.7
T12	F3 Inlet	265.0	243.8	224.6

The highest background concentration is 309.8 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition

= 133.9 + 309.8

= **444 $\mu g/m^3$**

Calculation of NO_2 Concentration inside Full Enclosure F3 along Tsuen Wan Road (Normal Traffic)

Full Enclosure Parameter

Number of Lanes:	3	Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L	=	58.0 m	
Full Enclosure Height, H	=	7.6 m	
Full Enclosure Width, W	=	12.0 m	
Full Enclosure Cross Section Area	=	91.2 m^2	
Perimeter, P	=	39.2 m	

Emission Data

Traffic Flow = 1,550 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.1259	0.4210	0.2852	0.1730	2.4413	4.9336	6.1162	3.2759
% of vehicle	26%	13%	13%	0%	13%	9%	11%	0%

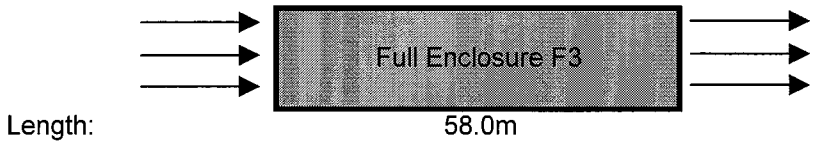
Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	1.1503	0.2272	0.0000	0.2517	1.7962	4.2219	4.4873	2.7767
% of vehicle	4%	9%	0%	0%	1%	1%	0%	0%

Total NOx Emission Factor in normal traffic condition = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]

Total NO_X Emission Factor = 1.06 g/km/veh

Total NO_2 Emission Rate = Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)

= 3.31E-03 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	26%	2.6
LGV3	5.2	2.1	1.6	13%	3.4
LGV4	5.2	2.1	1.6	13%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	13%	3.4
HGV7	16.0	2.5	4.6	9%	11.5
HGV8	16.0	2.5	4.6	11%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	9%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	1%	8.8
NFB7	12.0	2.5	3.5	1%	8.8
NFB8	12.0	2.5	3.5	0%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 4.8 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6398	
A_c	=	Vehicle Frontal Area	=	4.8	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	58.0	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.3	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	91.2	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^{\,2} + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^{\,2} - C_W V_W^{\,2} A_T$$

For Normal Traffic Condition

Traffic Flow, Q	=	0.43	veh/s		
Vehicle Speed, V_C	=	70	km/h		
	=	19.44	m/s		
Number of Vehicles in Full Enclosure, N	=	QL/V_C			
	=	1.28			

Solving for V_T by Equation 1

a	=	-141.64			
b	=	-154.46			
c	=	1,110.78			

Air Velocity in Full Enclosure V_T	=	2.31	m/s or	-3.40 m/s	(rejected)

NO_2 Concentration inside Full Enclosure
by Vehicular Emission = Emission Rate / (V_T x A_t)

= 15.7 $\mu g/m^3$

Six assessment points (T13-T18) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road				
ASR		0m	3.8m	7.6m
T13	F4 Outlet	242.1	231.7	222.3
T14	F4 Outlet	233.3	228.3	222.5
T15	F4 Outlet	230.4	227.0	222.6
T16	F4 Inlet	258.7	247.4	234.7
T17	F4 Inlet	294.3	289.3	285.7
T18	F4 Inlet	291.9	288.4	286.2

The highest background concentration is 294.3 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition
= 15.7 + 294.3

= **310 $\mu g/m^3$**

Calculation of NO_2 Concentration inside Full Enclosure F3 along Tsuen Wan Road (Congested Traffic)

Full Enclosure Parameter

Number of Lanes:	3		Direction of Flow:	Uni-directional Way Traffic
Full Enclosure Length, L		=	58.0 m	
Full Enclosure Height, H		=	7.6 m	
Full Enclosure Width, W		=	12.0 m	
Full Enclosure Cross Section Area		=	91.2 m^2	
Perimeter, P		=	39.2 m	

Emission Data

Traffic Flow = 1,550 veh/hr

Traffic Breakdown	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.2106	0.6520	0.4417	0.2246	3.7812	7.6412	9.4729	6.2813
% of vehicle	26%	13%	13%	0%	13%	9%	11%	0%

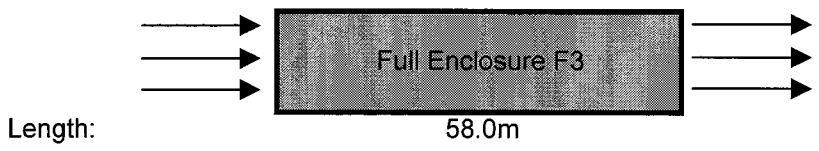
Traffic Breakdown	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
Emission Factor NOx along Trunk Road (g/mile-veh)	0.8549	0.3881	0.0000	0.3631	2.7820	6.5389	6.9509	5.3235
% of vehicle	4%	9%	0%	0%	1%	1%	0%	0%

Total NOx Emission Factor in normal traffic condition = = Σ[(AM Emission Factor NOx along Trunk Road)(Traffic Breakdown%)]

Total NO_X Emission Factor = 1.62 g/km/veh

Total NO_2 Emission Rate = Total NO_X Emission Factor x Traffic Flow x Full Enclosure Length x NO_2 Conversion Factor (12.5%)

= 5.07E-03 g/sec



Vehicle Dimension (Ref 6)

	L/m	W/m	H/m	% of vehicle	Cross Section Area of Vehicle/m^2
PC-p	4.6	1.7	1.5	26%	2.6
LGV3	5.2	2.1	1.6	13%	3.4
LGV4	5.2	2.1	1.6	13%	3.4
PLB	6.5	2.0	3.0	0%	6.0
LGV6	5.2	2.1	1.6	13%	3.4
HGV7	16.0	2.5	4.6	9%	11.5
HGV8	16.0	2.5	4.6	11%	11.5
FBDD	12.0	2.5	4.6	0%	11.5
MC	4.6	1.7	1.5	4%	2.6
taxi	4.6	1.7	1.5	9%	2.6
PV4	6.5	2.0	3.0	0%	6.0
PV5	6.5	2.0	3.0	0%	6.0
NFB6	12.0	2.5	3.5	1%	8.8
NFB7	12.0	2.5	3.5	1%	8.8
NFB8	12.0	2.5	3.5	0%	8.8
FBSD	12.0	2.5	3.5	0%	8.8

Nominal Cross-Section Area, A_c

= Σ[(Width of Veh.)(Height of Veh.)(% of Veh.)]

= 4.8 m^2

Full Enclosure Airflow

For Uni-directional Traffic,

Push Force by Vehicles:

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

Resisting Force by Full Enclosure:

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

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 Full Enclosure, m/s			
C_d	=	Vehicle Drag Coefficient *	=	0.6398	
A_c	=	Vehicle Frontal Area	=	4.8	m^2
N		Number of Vehicles in Full Enclosure			
K_{in}	=	Inlet Loss Coefficient	=	0.5	(Ref 2)
K_{out}	=	Outlet Loss Coefficient	=	1.0	(Ref 2)
f	=	Full Enclosure Friction Factor	=	0.0155	
L	=	Length of Full Enclosure	=	58.0	m
D	=	Hydraulic Diameter of Full Enclosure = 4At/P	=	9.3	m
A_t	=	Cross-Sectional Area of Full Enclosure	=	91.2	m^2
C_W	=	External Wind Coefficient	=	0.3	(Ref 4 and 5)
V_W	=	Wind Velocity	=	3.78	m/s (Ref 3)

θ = Angle of the Wind Velocity Component Parallel to Roadway

* Please refer to **Table A4-Q.2**

For the worst scenario, only external wind in parallel to the roadway at the exit portal is considered. Hence, $\theta = 0$

Force Balance: $$F_c - F_T - F_W = 0 \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Solving the equation,

$$aV_T^{\,2} + bV_T + c = 0$$

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

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

$$c = C_d A_c N V_c^{\,2} - C_W V_W^{\,2} A_T$$

For Congested Traffic Condition

Vehicle Speed V_C	=	10	km/h
	=	2.78	m/s
Average Length of Vehicle	=	7.3	m
Distance Between Vehicle	=	1.0	m
Head to Head Length	=	8.3	m
Number of Vehicles per Lane	=	7.0	
Number of Lanes	=	3	
Number of Vehicles in Full Enclosure N	=	20.9	

Solving for V_T by Equation 1

a	=	-81.01
b	=	-358.89
c	=	107.53

Air Velocity in Full Enclosure V_T	=	0.28	m/s or	-4.71 m/s	(rejected)

NO_2 Concentration inside Full Enclosure by Vehicular Emission	=	Emission Rate / (V_T x A_t)
	=	197.2 $\mu g/m^3$

Six assessment points (T13-T18) at the boundary of the full enclosure are chosen (see Figure A4-M.1). Using CALINE4 model, the NO_2 concentrations at the six assessment points at different levels are calculated. Also, the the portal emission from the full noise enclosures has been incorporated into the result. Sample input and output file are attached electronically. The highest concentration among the six assessment points is assumed to be the background NO_2 concentration inside the full enclosure.

NO_2 concentrations ($\mu g/m^3$) at various levels above Tsuen Wan Road				
ASR		0m	3.8m	7.6m
T13	F4 Outlet	242.1	231.7	222.3
T14	F4 Outlet	233.3	228.3	222.5
T15	F4 Outlet	230.4	227.0	222.6
T16	F4 Inlet	258.7	247.4	234.7
T17	F4 Inlet	294.3	289.3	285.7
T18	F4 Inlet	291.9	288.4	286.2

The highest background concentration is 294.3 $\mu g/m^3$

Overall Maximum NO_2 concentration inside the full enclosure under normal traffic condition

= 197.2 + 294.3

= **491 $\mu g/m^3$**

The overall vehicle drag coefficients depend on the vehicle mix. of traffic flow and they are calculated by weighted average of vehicle mix. percentage and their corresponding vehicle drag coefficient.

For F1, it is situated on the Kowloon bound viaduct fronting Clague Garden, which is situated at road section "I" *. **Table A4-Q.1** lists the percentage of vehicle mix. along the road section and the drag coefficient of the types of vehicles:

Table A4-Q.1

Type of Vehicle	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
% of Vehicle mix. **	40%	8%	8%	0%	8%	11%	12%	0%
C_d ***	0.50	0.60	0.60	0.60	0.60	0.96	0.96	0.96

Type of Vehicle	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
% of Vehicle mix. **	4%	4%	0%	0%	3%	2%	1%	0%
C_d ***	0.40	0.50	0.60	0.60	0.96	0.96	0.96	0.96

* see Reference 7 for the the exact location and the vehicle mix. of road section "I"

** Please see Section 2.1 of Reference 8 for the detail vehicle mixing breakdown.

*** see Reference 1

Hence the weighted drag coefficient = 0.6524

Similarly for F2 and F3, these enclosures are situated on Tuen Mun bound viaduct, which is situated at road section "AB" *. **Table A4-Q.2** lists the percentage of vehicle mix. along the road section and the drag coefficient of the types of vehicles:

Table A4-Q.2

Type of Vehicle	PC-p	LGV3	LGV4	PLB	LGV6	HGV7	HGV8	FBDD
% of Vehicle mix. **	26%	13%	13%	0%	13%	9%	11%	0%
C_d ***	0.50	0.60	0.60	0.60	0.60	0.96	0.96	0.96

Type of Vehicle	MC	taxi	PV4	PV5	NFB6	NFB7	NFB8	FBSD
% of Vehicle mix. **	4%	9%	0%	0%	1%	1%	0%	0%
C_d ***	0.40	0.50	0.60	0.60	0.96	0.96	0.96	0.96

* see Reference 7 for the the exact location and the vehicle mix. of road section "AB"

** Please see Section 2.1 of Reference 8 for the detail vehicle mixing breakdown.

*** see Reference 1

Hence the weighted drag coefficient = 0.6398

Reference

[1] Frank M. White, *Fluid Mechanics,* Fifth Edition, McGraw Hill, 2003 (figure 7.17, p.487; Table 7.3, p. 485)
[2] Munson, Yong, Okiishi, *Fundamental of Fluid Mechanics,* Third Edition, John Wiley & Sons Inc, 1998 (figure 8.22b, p. 498; Figure 8.26, p. 500)
[3] Hong Kong Observatory, *Summary of Meteorological Observations in Hong Hong*, Hong Kong Observatory, Hong Kong, 2006
[4] Babtie Asia, Agreement No. CE 4/99 (DS) Lei Yue Mun Road Underpass, Modification at Junction with Yau Tong Road and Associated Improvement Works – Feasibility Study –*Final Environmental Impact Assessment Report (EIA-056/2001),* 2001
[5] Maunsell Aecom, Hong Kong Convention and Exhibition Centre, Atrium Link Extension, *Environmental Impact Assessment Report (EIA-120/2006),* 2006
[6] Transport Department, *Transport Planning and Design Manual*, Transport Department, Hong Kong, 2004
[7] Scott Wilson Ltd, Agreement No. CEE69/2001(HY), Tsuen Wan Road Upgrading - Investigation, Final TIA Review Report (January 2007), 2007