1 Model Validation

1.1 Airport Related Activities Emissions

1.1.1 Aircraft Emissions

The approach for determining aircraft emissions for the actual year for this Study is summarized in **Table 1.1**.

Table 1.1 Approach for determination of the aircraft emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Aircraft	EDMS ICAO Air Quality Manual	• Actual 2011 hourly LTO and aircraft fleet mix derived from available chocks-on and chocks-off data provided by AAHK. • Engine and aircraft types from airliners and AAHK by questionnaires. Should these information be not available, the following order of assumptions has been adopted to identify the engine types: i) Information collected from airlines official websites; or ii) ICAO default engine model from Table B-Attachment B to Appendix 1, ICAO Air Quality Manual; or iii) Information collected from official website of aircraft manufacturer; or iv) Engine selected from EDMS default settings; or v) Engine with highest NO_x emission within the available types in EDMS. • Taxiing time estimated from chock-on and chock off data provided by AAHK. • The ICAO default value on climb-out mode is the elapsed time or aircraft ascendant from 1000 ft above ground level to 3000 ft and the approach mode is the elapsed time or aircraft descendant from 3000 ft to the ground level. The climb-out and approach time periods are adjusted to the local hourly mixing height derived from 2011 King's Park mixing height data by PCRAMMET in determining the emission. Nevertheless, for the sake of modelling, the sources distribution was extended to 10,000ft above ground to cater for the maximum altitude of the mixing height. • Take-off times were based on site observation and Year 2011 radar data provided by CAD, which is the best available information. • Emission indices are based on EDMS.

1.1.2 Business Aviation Centre (Business helicopters only)

Apart from business jet emissions associated with the HKBAC (as discussed in above sections), business helicopters operated by HKBAC are a source of pollutant emissions, which has been determined separately. Information on annual LTO, TIMs, engine type used for actual year 2011 was obtained from HKBAC through questionnaires and site visit. According to the information provided by HKBAC, there were on average 2 flights going to Macau and 2 flights going to Kowloon per month in Year 2011. It is therefore assumed to be 4 flights per month in this assessment. **Table 1.2** summarizes the approach in determining the emissions from operation of business helicopters.

Table 1.2 Approach for determination of the business helicopter emissions inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Business helicopter	Guidance on the Determination of Helicopter Emissions published by Swiss Federal Office of Civil Aviation (FOCA)	• Assumed 2 flights to Macau and 2 flights to Kowloon per month. • Emission indices and TIMs based on the "Guidance on the Determination of Helicopter Emissions" published by Swiss Federal Office of Civil Aviation (FOCA). • The default value on climb-out mode is the elapsed time or aircraft ascendant from 1000 ft above ground level to 3000 ft and the approach mode is the elapsed time or aircraft descendant from 3000 ft to the ground level. The climb-out and approach time periods were adjusted to the local hourly mixing height derived from 2011 King's Park mixing height data by PCRAMMET in determining the emission. Nevertheless, for the sake of modelling, the sources distribution was extended to 10,000ft above ground to cater for the maximum altitude of the mixing height. • Takeoff time based on FOCA.

1.1.3 Airside Vehicles Emissions (including those at the Business Aviation Centre)

Airside vehicles consist of two types: Ground Services Equipment (GSE) Vehicles and Non-GSE Vehicles

GSE Vehicles

GSE comprises a diverse range of vehicles and equipment that serve the aircraft after landing and before takeoff. Major services include aircraft towing, cargo loading and unloading, baggage loading and unloading, passenger loading and unloading, potable water storage, lavatory waste tank drainage, aircraft refuelling and food and beverage catering.

The GSE emissions per LTO cycle are the product of the EDMS emission indices, operating time, and the number of GSE for a particular aircraft type. Questionnaires have been sent to the operators to collect available information on

load factor, fuel consumption, age, operating time and engine power of their GSE for the determination of associated air emissions. However, the response rates with respect to some of the requested parameters (e.g. load factor, operating time, engine power) were low. Hence, the default emission factor in the EDMS would be adopted. Site surveys have thus been conducted to establish GSE operation characteristics, such as the operating time and type of GSE to be used, with respect to the categorised aircraft types for the actual year 2011. Information from survey data was adopted to determine the GSE emissions.

According to AAHK's policy, all idling engines on the airside have been banned since 1 June 2008, except for certain vehicles and equipment that are exempt due to safety and operational considerations. This policy has been taken into account in determining the emission loading.

The approach for determining GSE emissions for the actual year for this Study is summarized in **Table 1.3**.

Table 1.3 Summary for determination of the GSE emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
GSE	EDMS	• The operational characteristics of GSE assigned for different category of aircraft type and their operation time were based on on-site survey • Load factor from operator. EDMS default value was adopted subject to the availability of data. • Diesel fuel is adopted as advised by the operators. • Emission indices from EDMS based on USEPA NONROAD model.

Non-GSE Vehicles

Non-GSE vehicles comprise saloon vehicles, vans, light buses, light goods vehicles, crew buses, passenger buses, etc. The non-GSE emissions are the product of the emission indices generated from EMFAC-HK and the distance travelled by each non-GSE vehicle. Questionnaires have been sent to the operators to collect information on the number of vehicles, the fuel type and its consumption (including diesel, LPG and petrol), age, mileage, operating time and engine types of their non-GSE for the determination of associated air emissions. AAHK has also provided available information and data for their fleet. For those operators who cannot provide the mileage information, the distance travelled was based on the operating time and the travelling speed. For those operators who cannot provide any information on their non-GSE fleet, the missing information was filled by making reference to other operators.

The approach for determination of the non-GSE emission for this Study is summarized in **Table 1.4**.

Table 1.4 Summary for determination of the non-GSE emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Non-GSE	EMFAC-HK	• The number of GSE, mileage, operation time, • Fuel type and fuel consumption • Engine standard based on information provided by the operator • Emission indices from EMFAC-HK

1.1.4 Auxiliary Power Unit

Auxiliary power units (APUs) are the on-board generators. They are gas turbine engines, generally one per aircraft, used primarily during aircraft ground operation to provide electricity, compressed air, and/or shaft power for main engine start, air conditioning, electric power and other aircraft systems. APUs can also provide backup electric power during in-flight operation. The APU emissions generated per LTO cycle are estimated from the product of the emission indices, operating time, and the number of APUs for a particular aircraft type. The types of and emissions from APU for existing aircraft were determined through questionnaires sent to airlines. Should these information be not available, the APU was selected from EDMS default settings. The approach for determination of the APU for this Study is summarized in **Table 1.5.**

Table 1.5 Summary for determination of the APU emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
APU	EDMS	• APU model from airlines. EDMS default APU was assumed if information from the operators /survey data was not available. • APU operating time from ramp operator, site survey and aircraft pilot. • Emission indices from EDMS.

1.1.5 Government Flying Service (GFS)

Aviation activities generated by GFS are separated from commercial aircraft LTO. Information on annual LTO and engine types, take off time, idling time, taxiing time and hovering time for helicopters used for Year 2011 has been provided from GFS and verified by site survey. There are two types of aircraft (Jetstream 41 and ZLIN Z242L) and two types of helicopters (Eurocopter EC 155 and Eurocopter Super Puma) operated by GFS. The EDMS v5.1.4.1 only has the ICAO's emission index for Jetstream 41. The emission indices for ZLIN Z242L, Eurocopter EC 155 and Eurocopter Super Puma have therefore been estimated by mading reference to the "FOCA Aircraft Piston Engine Emissions Summary Report" and "Guidance on the Determination of Helicopter Emissions" published by Swiss Federal Office of Civil Aviation (FOCA).

The approach for determination of the GFS emission for the actual year for this Study is summarized in **Table 1.6.**

Table 1.6 Summary of approach for determination of the GFS emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
GFS - Jetstream 41	EDMS	• Annual LTO and engine types from GFS. • The EDMS default value on climb-out mode is the elapsed time or aircraft ascendant from 1000 ft above ground level to 3000 ft and the approach mode is the elapsed time or aircraft descendant from 3000 ft to the ground level. The climb-out and approach time periods are adjusted to the local hourly mixing height derived from 2011 King's Park mixing height data by PCRAMMET in determining the emission. Nevertheless, for the sake of modelling, the sources distribution was extended to 10,000ft above ground to cater for the maximum altitude of the mixing height. • Taxiing time and takeoff time based on site survey in GFS • Emission index from EDMS.
GFS - ZLIN Z242L	Aircraft Piston Engine Emissions Summary Report published by Swiss Federal Office of Civil Aviation (FOCA)	• Annual LTO and engine types from GFS. • No data in EDMS. Reference has been made to "Aircraft Piston Engine Emissions Summary Report". • The EDMS default value on climb-out mode is the elapsed time or aircraft ascendant from 1000 ft above ground level to 3000 ft and the approach mode is the elapsed time or aircraft descendant from 3000 ft to the ground level. The climb-out and approach time periods are adjusted to the local hourly mixing height derived from 2011 King's Park mixing height data by PCRAMMET in determining the emission. Nevertheless, for the sake of modelling, the sources distribution was extended to 10,000ft above ground to cater for the maximum altitude of the mixing height. • Taxiing time, hovering time, idling time and takeoff time based on the site survey in GFS. • Emission indices based on "Guidance on the Determination of Helicopter Emissions".
GFS - Eurocopter EC 155 and Eurocopter Super Puma	Guidance on the Determination of Helicopter Emissions published by Swiss Federal Office of Civil Aviation (FOCA)	• Annual helicopter LTO, engine types, idling and hovering time from GFS. • No data in EDMS. Reference has been made to "Guidance on the Determination of Helicopter Emissions". • Taxiing time, hovering time, idling time and takeoff time based on the site survey in GFS. • The EDMS default value on climb-out mode is the elapsed time or aircraft ascendant from 1000 ft above ground level to 3000 ft and the approach mode is the elapsed time or aircraft descendant from 3000 ft to

Emission Sources	Determination Approach	Data required and assumptions
		the ground level. The climb-out and approach time periods are adjusted to the local hourly mixing height derived from 2011 King's Park mixing height data by PCRAMMET in determining the emission. Nevertheless, for the sake of modelling, the sources distribution was extended to 10,000ft above ground to cater for the maximum altitude of the mixing height. • Emission indices based on "Guidance on the Determination of Helicopter Emissions".

1.1.6 Aviation Fuel Farm

Breathing, displacement and air saturation are the primary states for pollutant emissions from fuel tank. The emission was calculated by EDMS based on the tank size, fuel storage height, tank roof design etc. Information on fuel type, tank dimension, annual fuel used, average and maximum height of fuel in the storage tank were obtained from the tank farm operators (i.e., Aviation Fuel Supply Company and AFSC Operations Ltd.) through questionnaire. Emission indices of aviation fuel are derived from USEPA AP-42 (5th edition), Chapter 7.1. It is noted that the emissions from aviation fuel farm would vary with the meteorological conditions, such as ambient temperature and relative humidity. These factors have also been taken into account in the emission load simulation.

The approach for determination of emissions from the aviation fuel farm is summarized in **Table 1.7**.

Table 1.7 Summary for determination of the aviation fuel farm emission inventory

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Aviation Fuel Tank Farm	USEPA AP42	• Tank size and dimension, fuel type, annual fuel consumption, average and maximum height of fuel in the storage tank from operators • Emission factors based on AP-42 (5th edition), Chapter 7.1

1.1.7 Fire Training Activities

Fire training is periodically performed inside HKIA by the Fire Services Department (FSD). Pollutant emissions are calculated from the product of the relevant emission indices and the quantity of fuel burnt in fire training. Information on fuel types and amount of fuel burnt for future activities and plan has been obtained from FSD through questionnaire. **Table 1.8** summarizes the approach for determination of the emission from fire training activities.

Table 1.8 Summary of approach for determination of the emission for fire training activities

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Fire training activities	EDMS	• Amount of fuel burnt, fuel type, record of fire training from FSD. • Average duration of fuel burnt is 47min per training as advised by FSD. • Emission indices from EDMS

1.1.8 Engine Runup Facility (ERUF)

Engine testing is performed inside HKIA by Hong Kong Aircraft Engineering Company Limited (HAECO). The activities emissions depends on the types and number of engines to be tested, power setting of the tested engines, duration of testing, as well as the emission indices. Information on the type of engines, power setting, test durations, number of engines tested for actual year 2011 has been obtained from HAECO via AAHK through questionnaires. In year 2011, the total LTO is around 335,000.

The emission indices for the aircraft under test have been based on the engine types forecasted by IATA. It should be noted that some of the old engine models adopted in Year 2011 would be phased out. According to the engine testing record in Year 2011, it is found that 70% of the total engine tests were conducted by Cathay Pacific Airways and Hong Kong Dragon Airlines. **Table 1.9** summarizes the approach for determination of emissions from the ERUF.

Table 1.9 Summary of approach for determination of the emission for ERUF

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Engine runup testing	EDMS	• Type and number of engine to be tested, power setting of the test engine, duration of testing from HAECO. • Emission indices from EDMS.

1.1.9 Aircraft Maintenance Centre

Paint spraying inside the aircraft maintenance centre generated VOC. The amount of VOC emissions has been calculated by using EDMS based on the paint usage rate. A dedicated extraction and ventilation system was installed in the hanger paint bay to remove the paint particles. The removal efficiency of the scrubber is around 98% according to the information from HAECO. According to the recent discussion with HAECO, paint spraying activities is not directly related to the LTO growth and also paint spraying activities are not regular in the aircraft maintenance centre. The paint spraying activities undertaken in Year 2011 has been provided by HAECO, which is corresponding to the total ATM of about 335,000. **Table 1.10** summarizes the approach for determination of the emission from paint spraying at aircraft maintenance centre.

Table 1.10 Summary of approach for determination of the emission from aircraft maintenance centre

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Aircraft maintenance centre	EDMS	• Paint usage rate from operator. • Emission indices from EDMS. • Scrubber removal efficiency (i.e 98%) from operator.

1.1.10 Catering

The use of the diesel furnace is the major source of air pollutants from catering facilities. There are three catering operators inside HKIA, including Cathay Pacific Catering Services (H.K.) Ltd., Gate Gourmet Hong Kong Ltd and LSG Lufthansa Service Hong Kong Ltd. Questionnaires have been sent to the three catering operators for the fuel use and chimney information (e.g., the type of diesel furnace used, fuel sulphur content, annual fuel consumption for future years, stack height, stack diameter, exit temperature and exit velocity of the stack). Based on their responses, only Cathay Pacific Catering Services (HK) Ltd. adopted diesel as the fuel.

The emission indices of NO_x and PM_{10} are based on standards listed in the Air Pollution Control (Fuel Restriction) (Amendment) Regulation 2008. The emission factor of SO_2 was determined according to the fuel sulphur content provided by the operator, which complies with the Air Pollution Control (Fuel Restriction) (Amendment) Regulation 2008. The emission factors for CO, and HC were derived from USEPA AP-42 (5th edition), Chapter 1.3-1.4. **Table 1.11** summarizes the approach for determination of air emissions from catering.

Table 1.11 Summary of assumptions for determination of the emission for catering

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Catering	EDMS	• Type of diesel furnace used, annual fuel consumption, and monthly and hourly activities profile from operator • The emission indices of NO_x and PM_{10} were derived from the EDMS. The emission factor of SO_2 was determined according to the fuel sulphur content provided by the operator. It should be noted that the emission factors of NO_x and PM_{10} in EDMS are the same as the restricted liquid fuel standard listed in the Air Pollution Control (Fuel Restriction) (Amendment) Regulation 2008.

1.1.11 Carparks / Truck Parks

There are currently seven major carparks and four major truck parks in HKIA. Five carparks (CP1 – CP4 and skyplaza) are being operated by AAHK, and the

remaining two passenger car parks are being operated by Airport Freight Forwarding Centre Co Ltd (AFFC) and Tradeport Hong Kong Ltd. The operators for the four truck parks are AFFC, Asia Airfreight Terminal Co Ltd (AAT), Hong Kong Air Cargo Terminals (HACTL) and Tradeport Hong Kong Ltd respectively.

Vehicle movements inside carparks / truck parks would generate exhaust air emission. Since all vehicles are expected to switch off their engine after parking, idling emission inside carparks / truck parks is considered negligible. The amounts of emission exhausts from vehicle movements inside the carparks/ truck parks depend on the number of vehicle, vehicle mix, distance travelled, etc and are modelled by EMFAC-HK v2.6. Questionnaires have been sent to the car park / truck park operators to collate the operation details in actual year 2011.

Since the EMFAC-HK cannot be used for calculation of SO_2 emissions, an alternative method is therefore adopted. The SO_2 emission factor is derived based on the assumption that 98% of the sulphur in the fuel is emitted as SO_2. This is in line with the assumption used in the USEPA PART5 program (refer to USEPA PART5 Model Draft User Guide – 1995) for calculating emissions from motor vehicles. Using this assumption, the emission factor is calculated from the following equation:

$$EfSO_2 \text{ [g/km]} = 1.96 \times (Sf/100) \times (Df \times 1000) \times (Ef/100)$$

Where

1.96	=	Factor to account for fraction emitted (98% of sulphur content in fuel) and weight ratio of SO_2 to S (2.0)
Sf	=	Fuel sulphur content (weight percentage)
Df	=	Density of fuel (0.73 kg/L for gasoline; 0.845 kg/L for diesel fuel)
Ef	=	Vehicle fuel efficiency (in L/100 km)

The vehicle fuel efficiencies for different types of vehicle can be extracted from the Electrical and Mechanical Service Department (EMSD) Primary Indicator Values, and they are listed in **Table 1.12**. References shall be made to the EMSD's websites.

Table 1.12 Fuel efficiencies for different vehicles types

Subgroup ID	Vehicle Type	Fuel Type	Engine Size (cc)	Gross Vehicle Weight (tonnes)	Fuel Efficiency (L/100km)
Principal Group 1 – Private Car and Motorcycle					
V1	Motorcycle	Petrol	--	--	4.2
V2	Private Car	Diesel	--	--	11.8
V3	Private Car	Petrol	<=1000	--	8.1
V4	Private Car	Petrol	1001-1500	--	9
V5	Private Car	Petrol	1501-2500	--	11.5
V6	Private Car	Petrol	2501-3500	--	14
V7	Private Car	Petrol	3501-4500	--	16.3
V8	Private Car	Petrol	>4500	--	17.3
Principal Group 2 – Bus and Light Bus					
V11	Private Bus (Double Deck)	Diesel	--	--	47
V12	Private Bus (Single Deck)	Diesel	--	--	23.9
V13	Non-franchised Public Bus (Double Deck)	Diesel	--	--	59.3
V14	Non-franchised Public Bus (Single Deck)	Diesel	--	--	24.9
V15	Private Light Bus	Diesel	--	--	16
V16	Public Light Bus	Diesel	--	--	15.4
V17	Private Light Bus	LPG	--	--	29.7
V18	Public Light Bus	LPG	--	--	20.5
Principal Group 3 – Taxi					
V21	Taxi LPG (Urban)	LPG	--	--	14.3
V22	Taxi LPG (Lantau Island)	LPG	--	--	14.5
V23	Taxi LPG (NT)	LPG	--	--	12.6
Principal Group 4 – Vehicle – Light Goods Vehicle (LGV)					
V31	Light Goods Vehicle	Petrol	--	<=1.9	11.4
V32	Light Goods Vehicle	Petrol	--	>1.9	12.2
V33	Light Goods Vehicle	Diesel	--	<=2.5	11
V34	Light Goods Vehicle	Diesel	--	2.51-4	11.3
V35	Light Goods	Diesel	--	4.01-5.5	15.6

Subgroup ID	Vehicle Type	Fuel Type	Engine Size (cc)	Gross Vehicle Weight (tonnes)	Fuel Efficiency (L/100km)
	Vehicle				
Principal Group 5 – Vehicle – Medium Goods Vehicle (MGV)					
V36	Medium Goods Vehicle, Tractors	Diesel	--	5.51-24	47.9
V37	Medium Goods Vehicle, Non-tractors	Diesel	--	5.51-10	19.3
V38	Medium Goods Vehicle, Non-tractors	Diesel	--	10.01-15	25.8
V39	Medium Goods Vehicle, Non-tractors	Diesel	--	15.01-20	28.5
V40	Medium Goods Vehicle, Non-tractors	Diesel	--	20.01-24	41.5
Principal Group 6 – Vehicle – Heavy Goods Vehicle (HGV)					
V41	Heavy Goods Vehicle	Diesel	--	24.01-38	46.2

Note:

Referenced from EMSD Website: http://ecib.emsd.gov.hk/en/indicator_trp.htm

Table 1.13 summarizes the approach for determination of the emission from carparks / truck parks.

Table 1.13 Summary of Approach for Determination of the Emission from Car Parks / Truck Parks

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Carpark / Truck park	EMFAC-HK USEPA PART5 program for SO_2 emission	• Annual number of trip, fleet mix, monthly and daily profile, distance travelled from operator • In case information on the daily profile is not available, it would be assumed the same as the road networks connected to the carpark as advised by Traffic Engineer. • The exhaust technology fractions available in EPD's website were adopted. • Default vehicle populations in EMFAC-HK were adopted. • SO_2 emission estimation was based on EMSD Primary Indicator Values and in accordance with USEPA PART5 program.

1.1.12 Roads on Airport Island

Vehicular tailpipe emissions from all roads in Airport Island were calculated by the EMFAC-HK. The traffic flow data, fleet mix, speed etc for Year 2011 were simulated by a traffic model, which has been validated against the observed data at various key road links and junctions. EMFAC-HK model was separately run for different road categories of similar nature and driving pattern as shown in **Table 1.14**.

Table 1.14 Road categories for Airport Island assumed in EMFAC-HK

Group	Roads	Justification
Group 1	Roads of design speed of 80km/h and without cold start (Expressway)	• Design speed of 80kph • No cold start trips
Group 2	Roads of design speed of 50km/h and without cold start (District Distributor/ Primary Distributor)	• Design speed of 50kph • No cold start trips
Group 3	Roads of design speed of 50km/h and with cold start (Local Distributor)	• Design speed of 50kph • With cold start trips

The latest implementation programme of vehicle emission standards, vehicle population, vehicle population forecast function, exhaust technology fractions and the calculations of SO_2 emission are described in above section. **Table 1.15** summarizes the approach for determination of the vehicular emissions on the Airport Island.

Table 1.15 Summary of approach for determination of the vehicular emission on airport island

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Vehicular emission	EMFAC-HK USEPA PART5 program for SO_2 emission	• Traffic flow data, fleet mix, speed etc were simulated by traffic model. • The exhaust technology fractions available in EPD's website were adopted. • Default vehicle populations fin EMFAC-HK were adopted. • SO_2 emission estimation was based on EMSD Primary Indicator Values and in accordance with USEPA PART5 program.

1.1.13 Ferry at Sky Pier

There are two marine emission sources in airport, including Skypier and the Chu Kong Shipping Enterprises (Group) Co Ltd (CKS). The SkyPier provides speedy ferry services for transit passengers in HKIA. It connects to eight ports in the PRD and Macau. CKS provides river shipping for air cargoes between Hong Kong and the Pearl River Delta. Questionnaires have been sent to the operators to

gather information on the ferry types and weight, on-board marine engine types and engine loading, daily and annual trips, etc. CKS has provided written responses on the existing activities. For the ferry activities in skypier, their latest schedules were collected and site survey has been conducted in Skypier to determine the ferry idling, manoeuvring and cruising time. The engine emission factors were determined based on "Study on Marine Vessels Emission Inventory, HKUST".

Table 1.16 summarizes the approach for determination of the marine emission at SkyPier.

Table 1.16 Summary of approach for determination of the marine emission at SkyPier

Emission Sources	Determination Approach	Data required and assumptions
Actual Year		
Ferry at Sky Pier	EMEP / EEA, Approved EIAs, or EPD's Study on Marine Vessels Emission Inventory (2012)	• Ferry type and weight, engine power, engine loading factor, fuel consumption rate from operator or their website. • Sulphur content of the fuel from operator. If no information, nominal sulphur limit of 0.5% based on "Controlling Emissions from Vessels" Legislative council panel on environmental affairs discussion paper on 21 Dec 2011 was assumed. • Manoeuvring time, cruising time and hotelling time from "Study on Marine Vessels Emission Inventory, HKUST". • Marine traffic profile based on the published operation timetable.

1.1.14 Aircraft Brake and Tire Wear

Aircraft brake and tire emissions are reported on a per LTO basis. Much like vehicles, aircraft tire and break emissions estimates contain large uncertainties and vary depending on the type of aircraft and the landing conditions. According to London Luton Airport – Air Quality Assessment Methodology 2012, estimation of PM emissions arising from brake and tire wear were based on the methodology developed by Project for the Sustainable Development of Heathrow (PSDH). For brake wear, an emission factor of 2.51 x 10^{-7} kg PM_{10} per kg MTOW was assumed. For tire wear, the following relationship was used:

PM_{10} (kg) per landing = 2.23 x 10^{-6} x (MTOW kg) – 0.0874 kg

where MTOW is the maximum take off weight.

In this study, the methodology developed by Luton Airport was adopted to determine the brake and tire wear emission. According to ACRP Report 9 - Summarizing and Interpreting Aircraft Gaseous and Particulate Emissions Data. Nearly all tire wear emissions are larger than $PM_{2.5}$. For brakes, a study conducted by Sanders et al. (2003) observed that between 50% and 90% of brake emissions become airborne particles (mass mean diameter is 6 µm and the number-weighted mean is between 1 µm to 2 µm). Hence, no $PM_{2.5}$ emission was assumed for tire wear emission. For brake emission, $PM_{2.5}$ would contribute 100% of PM_{10} emission for conservative assessment purpose.

1.2 Proximity Infrastructure Emissions

The proximity infrastructure emission sources accounted for in the air quality assessment include the concurrent infrastructural projects/sources (existing projects/sources) in the proximity of the sensitive receivers/uses within the study area (i.e. 5km from the boundary of the Project site). **Table 1.17** below lists the proximity infrastructure emission sources in Lantau and Tuen Mun areas. The specific emission sources (except CLPP) have been modelled by a near-field dispersion model.

Table 1.17 List of proximity infrastructure emissions in Lantau and Tuen Mun areas

Source		Description
Lantau Area		
NLH and other roads in Tung Chung	Existing source	Vehicular emissions from road network
Tuen Mun Area		
Other roads in Tuen Mun	Existing source	Vehicular emissions from road network
Shiu Wing Steel Mill	Existing source	Chimney emissions
GIC	Existing source	Chimney emissions
CPPP	Existing source	Chimney emissions
EcoPark	Existing source	Chimney emissions
Butterfly Beach Laundry	Existing source	Chimney emissions
Flare at PPVL	Existing source	Chimney emissions
PAFF	Existing source	Chimney emissions
River Trade Terminal	Existing sources	Emissions from marine vessels and land-based equipment

1.2.1 Proximity Infrastructure Emissions in Lantau

1.2.1.1 Vehicular Emissions from Existing Roads

Vehicular tailpipe emissions from all roads in Lantau are calculated by the EMFAC-HK. The traffic flow data, fleet mix, speed etc for Year 2011 are simulated by a traffic model, which has been validated against the observed data at various key road links and junctions. EMFAC-HK model was separately run for different road categories of similar nature and driving pattern as shown in **Table 1.18**. The extent of roads included in the proximity infrastructure emissions for Lantau area is shown in **Figure 2.8**.

Table 1.18 Road categories for Lantau assumed in EMFAC-HK

Group	Roads
Group 1	Roads with design speed of 110km/h and without cold start (Expressway)
Group 2	Roads with design speed of 80km/h and without cold start (Expressway)
Group 3	Roads with design speed of 50km/h and without cold start (District Distributor/ Primary Distributor)
Group 4	Roads with design speed of 50km/h and with cold start (Local Distributor)

The latest implementation programme for vehicle emission standards, vehicle population, vehicle population forecast function, exhaust technology fractions and the calculations of SO_2 emission are described as **Section 3.2.12**. **Table 1.19** summarizes the approach for determination of the vehicular emission in Lantau.

Table 1.19 Summary of approach for determination of the vehicular emission on Lantau

Emission Sources	Determination Approach	Data required and assumptions
Vehicular emission	EMFAC-HK USEPA PART5 program for SO_2 emission	• Traffic flow data, fleet mix, speed etc are simulated by traffic model. • Latest implementation programme for vehicle emission standards (i.e. as of 16 November 2012) has been adopted. • The exhaust technology fractions available in EPD's website were adopted. • Default vehicle populations forecast in EMFAC-HK v2.6 was adopted. • SO_2 emission estimation was based on EMSD Primary Indicator Values and in accordance with USEPA PART5 program.

1.3 Emission Inventory

The emission inventory for the Year 2011 is summarized in the Table below:

Table 1.20 Emission Inventory at Hong Kong International Airport for Year 2011

Source	Annual Emission (kg)					
	CO	VOC	NO_x	SO_2	PM_{10}	$PM_{2.5}$
Aircraft LTO (included business jets)	3,206,819	542,536	5,684,412	474,513	32,251	32,251
Airsides (GSE + non-GSE) (including all on-road, tunnel and at stand emission)	242,994	49,781	728,884	1,822	59,300	57,245
APU (includes BAC)	369,452	37,496	365,159	49,110	65,172	65,172
GFS	9,670	5,819	2,555	516	100	100
Aviation Fuel Tank	0	84,122	0	0	0	0
Fire Training	16,660	507	126	25	3,784	3,784
ERUF	1,399	2,191	120,349	5,373	477	477
Aircraft Maintenance Centre	0	5372	0	0	0	0

Source	Annual Emission (kg)					
	CO	**VOC**	**NO_x**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**
Catering	2,653	319	7,955	54	510	354
Carpark /Truck Park	15,845	9,311	21,196	14	2,039	1,876
Vehicular Emission (Airport Island)	361,844	39,607	309,615	1,036	11,300	10,390
Marine emission at airport (Skypier + CKSA)	6,620	1,887	60,555	12,359	1,846	1,649
Vehicular Emission (Lantau)	887,929	74,480	856,981	3,727	24,476	22,504
Vehicular Emission (Tuen Mun)	254,309	64,156	208,230	689	16,669	15,327
BAC Helicopter	48	42	6	2	0.23	0.23
Brake and Tire Wear	0	0	0	0	77,260	9,261

2 Methodology on Operational Air Quality Impact Assessment

2.1 General Approach

The following modelling techniques were adopted to model the operational air quality impacts at representative ASRs:

ASR	Airport Related Activities	Proximity Infrastructures (Tung Chung)	Ambient
Lantau area	AERMOD	CALINE4 / AERMOD	HKA AQMS Data

Modelling details are summarised in the following sections.

2.2 Air Quality Impact from Hong Kong Airport

AERMOD model (Version 12345) , the model being accepted by USEPA for the air quality assessment, was adopted as the air quality impact model for major airport related activities, except for roads on Airport Island which were modelled by the CALINE4 model. The AERMOD model basically allows three types of sources: Point, Area and Volume. Hence, the emission sources inside the HKIA were modelled as one of the three source categories according to their emission characteristics.

The LTO cycle, which consists of 4 modes was modelled according to their source emission characteristics as summarized in **Table 2.1** below.

Table 2.1 Emission characteristics of different Time-in-Modes

Time in Modes	Emission characteristics and modelling
	Actual Scenario
Take-off	Hourly emission load for the worst scenarios was distributed as area sources according to site observation statistics and radar data.
Climb out	Hourly emission load for the worst scenarios was spatially distributed as area sources according to take off angle with support by Radar data (starting from around 300m above ground to mixing height).
Approach	Hourly emission load for the worst scenarios was spatially distributed as area sources according to approach angle (from mixing height to wheel touch down), and supported by radar data.
Taxiing	Hourly emission load for the worst scenarios was spatially distributed as area sources according to chock-on and chock off data provided by AAHK.

Note:

[1] The height of the aircraft sources was determined from the physical dimension, together with the plume rise based on FAA-AEE -04-01 “Final Report on The Use of LIDAR to Characterize the Aircraft Plume Width”.

For other source types including GSE, APU, car parks, engine testing, fuel tanks, fire training, catering and helicopter are summarized in **Table 2.2** below.

Table 2.2 Emission characteristics of other emission sources

Sources	Emission characteristics and Modelling
GSE & APU	GSE and APU emission have been distributed to the aircraft stand location and possible airside roads (if there is stand movement) as area sources.
Non-GSE	Distribute to the possible airside roads as area sources.
Vehicle Parking	Emission from single storey open space car park has been distributed into an area source. Emission from multi storey car park with roof has been distributed on all 4 sides of the car park façade surfaces.
Engine Testing	Engine run up testing emission has been modelled as area source at the designated location.
Fuel Tank	Each fuel tank has been modelled as an individual point source.
Fire Training	The fire pit has been modelled as point source.
Catering	Chimney emission generated from catering has been modelled as point source.
GFS Helicopter	Typical helicopter emission load has been spatially distributed along the helicopter flight paths in Hong Kong provided by GFS as area sources.
Marine Vessels	Marine emission generated has been modelled as point sources based on the navigation routes identified site survey and in Marine Traffic Impact Assessment Report prepared under the Engineering Feasibility and Environmental Assessment study for Airport Master Plan 2030.
Roads on Airport Island	Vehicular emission has been modelled as line source according to the land side road layout

Note:

[1] The height of the aircraft sources (e.g APU, GFS helicopter, Engine Testing) was determined from the physical dimension, together with the plume rise based on FAA-AEE -04-01 "Final Report on The Use of LIDAR to Characterize the Aircraft Plume Width".

Tables 2.3 – 2.12 summarize the assumptions and input parameters for different modelling sources.

Table 2.3 Parameters adopted in AERMOD for aircraft

Field	Assumptions and Input Parameters
Sources Type	Area
Plume Spread Width	73.16 m [1]
Vertical Plume Spread	4.1 m [2]
Emission Variation	AERMOD Hourly Emission files
Height of Source	14.93 m [3] above the flight Path

Note:

[1] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume Width", the standard derivation (SD) for horizontal plume width is 10.5m for each engine regardless of aircraft type. Plume spread width for aircraft is therefore determined by summation of the distance between two outermost engines of B747-400 (41.66 m) and 3 x SD, corresponding to 99% confidence level.

[2] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume width", SD for vertical plume spread is 4.1 m regardless of aircraft type.

[3] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume Width", the plume rise is 12 m regardless of aircraft type. The engine height is 2.93m. Summation of plume rise and engine height (14.93m) is the height of source.

Table 2.4 Parameters adopted in AERMOD for GSE equipment

Field	Assumption and Input Parameters
Sources Type	Area
Emission Area	Individual Stand and Taxiway areas
Vertical Plume Spread	3m (EDMS Technical Manual)
Emission Variation	AERMOD Hourly Emission files
Height of Source	0.5m above ground

Table 2.5 Parameters adopted in AERMOD for APU

Field	Assumption and Input Parameters
Sources Type	Area
Emission Area	Individual Stand and Taxiway Areas
Vertical Plume Spread	3m (EDMS Technical Manual)
Emission Variation	AERMOD Hourly Emission files
Height of Source	17m above ground [1]

Note:

[1] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume width", plume rise is 12m regardless of aircraft type. The APU height above ground is 5m

Table 2.6 Parameters adopted in AERMOD for open space car parks

Field	Assumption and Input Parameters
Sources Type	Area
Emission Area	Actual car park area
Vertical Plume Spread	3m (EDMS Technical Manual)
Emission Variation	Hourly, Daily and Monthly Profiles
Height of Source	0.5m above ground

Table 2.7 Parameters adopted in AERMOD for multi-storey car parks

Field	Assumption and Input Parameters
Sources Type	Volume
Plume Spread Width	5.81 - 11.16 m [1]
Vertical Plume Spread	6.25 – 12 m [2]
Model length	12.5 - 24 m [3]
Emission Variation	Hourly, Daily and Monthly Profiles where available
Height of Source	The middle storey of the car park building

Note:

[1] According to AERMOD's User's Guide Table 3-1, plume spread width is determined by center-to-center distance between 2 adjoining volume sources divided by 2.15.

[2] According to AERMOD's User's Guide Table 3-1, vertical plume spread is determined from building height divided by 2.15.

[3] Model length is equal to the building height of the car park.

Table 2.8 Parameters adopted in AERMOD for underground car parks

Field	Assumption and Input Parameters
Sources Type	Point
Temperature	303 K [1]
Gas velocity	5 m/s [1]
Diameter	5.8 m [1]
Emission Variation	Hourly, Daily and Monthly Profiles where available
Height of Source	5 m above around [1]

Note:

[1] Exit temperature, gas velocity, ventilation building diameter and height are based on information from approved EIAs for "Hong Kong - Zhuhai - Macao Bridge Hong Kong Boundary Crossing Facilities"

Table 2.9 Parameters adopted in AERMOD for catering

Field	Assumption and Input Parameters
Sources Type	Point
Temperature	373 K [1]
Gas velocity	6 m/s[[1]
Diameter	0.65m
Emission Variation	Flat Hourly, Daily and Monthly Profiles
Height of Source	15.9m above ground

Note:

[1] Since gas velocity, temperature and diameter are not available from the operator, these parameters are based on the "Guidelines on Estimating Height Restriction and Position of Fresh Air Intake Using Gaussian Plume Models" by EPD.

Table 2.10 Parameters adopted in AERMOD for fire training

Field	Assumption and Input Parameters
Sources Type	Point
Temperature	116 K above ambient [1]
Gas velocity	11.2 m/s [1]
Diameter	25 m [2]
Emission Variation	Hourly, Daily and Monthly Profiles
Height of Source	19.2 m above ground [3]

Note:

[1] Gas velocity and temperature are determined by equations derived from fire dynamics. Fire size in kW is calculated according to CIBSE TM19: 1995. Details on the parameters adopted are given in Appendix 5.3.15-1.

[2] Based on size of the fire training simulator: http://www.hkfsd.gov.hk/home/eng/airport/.

[3] Based on height of the fire training simulator and B747-400 and various external and internal fire scenarios in FSD website: http://www.hkfsd.gov.hk/home/eng/airport/.

Table 2.11 Parameters adopted in AERMOD for engine run-up testing

Field	Assumption and Input Parameters
Sources Type	Area
Emission Area	100m x 440m [1]
Vertical Plume Spread	4.1m [2]
Emission Variation	Hourly Emission [3]
Height of Source	14.93m above ground[4]

Note:

[1] Width = 100m is based on the size of the engine run up test facility. Length = 440m is on the weighted average of the distance extracted from jet engine exhaust velocity contour for the 8 most tested aircraft types, which weights more than 90% of the total aircrafts tested.

[2] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume width" , SD for vertical plume spread is 4.1m regardless of aircraft type.

[3] Hourly emission rates are calculated for each hour based on engine run up test records provided by AAHKand HAECO for Year 2011.

[4] According to FAA-AEE -04-01" Final Report on The Use of LIDAR to Characterize the Aircraft Plume width", plume rise is 12m regardless of aircraft type with assumed engine height at 2.93m above ground based on B747-400.

Table 2.12 Parameters adopted in AERMOD for marine vessel

Field	Assumption and Input Parameters
Sources Type	Point
Temperature	588 – 773 K [1]
Gas Velocity	8 m/s [2]
Diameter	0.2 – 0.7 m [3]
Emission Variation	Daily Profile
Height of Source	6.2 – 11 m [4]

Note:

[1] According to information from approved EIAs for "Expansion of Heliport Facilities at Macau Ferry Terminal" and "Organic Waste Treatment Facilities, Phase I", exit temperature for passenger ferries and barges are 773K and 588K respectively.

[2] According to information from approved EIAs for "Organic Waste Treatment Facilities, Phase I", gas velocity is 8m/s.

[3] According to information from approved EIAs for "Expansion of Heliport Facilities at Macau Ferry Terminal" and "Organic Waste Treatment Facilities, Phase I", chimney diameter for passenger ferries and barges are 0.7m and 0.2m respectively.

[4] According to information from approved EIAs for "Expansion of Heliport Facilities at Macau Ferry Terminal" and "Organic Waste Treatment Facilities, Phase I", exit temperature for passenger ferries and barges are 6.2m and 11m respectively.

2.3 Impact from Proximity Infrastructure

2.3.1 Vehicular Emissions from Existing Roads

CALINE4 model was used to predict air pollutants impacts at ASRs near open roadways by taking into account the composite emission factors generated from EmFAC-HK model. Any other specific modelling approach, such as the use of AERMOD to stimulate portal emissions as described below, would also be proposed for agreement with EPD. Roadways are divided into a series of

segments from which incremental concentrations are computed and then summed to form a total concentration estimate at the ASRs and simulated grid points.

The spatial distribution of the road works has been modelled as line sources. Owing to the constraint of the CALINE4 model in modelling elevated roads higher than 10m, the road heights of elevated road sections in excess of 10m high above local ground or water surface are set to 10m in the model as the worst-case assumption. For barriers along roads (e.g. the existing noise barriers along the NLH near existing Tung Chung area), the line source has been modelled at the tip of the barrier and the mixing width was limited to the actual road width. The road type of the concerned sections is set to the "fill" option.

2.4 Ambient Air Quality Impact

Real air quality monitoring data in Year 2011 at EPD monitoring station (i.e. Tung Chung Station) and at AAHK monitoring stations (i.e. Lung Kwu Chau Station) were adopted for actual year (i.e. Year. 2011) modelling. Subject to the wind direction, the upwind station was selected as the background concentration. Since there is insufficient air quality monitoring data available for Tuen Mun area for model verification, actual year 2011 modelling was not conducted.

2.5 Cumulative Impact

Modelling results from AERMOD and CALINE4 was combined hour by hour and cumulative concentrations for each pollutant were computed. The 1-hour pollution concentrations, 8-hour pollution concentrations, 24-hour average and the annual average at each ASR at 10 levels (1.5m, 5m, 10m, 20m, 30m, 40m, 50m, 60m, 70m and 80m above ground) were determined through different averaging. The conversion of nitrogen dioxide is discussed in the following sub-sections. The approach in analyzing the potential effect on ambient ozone concentration during the operation of the Project is also discussed below.

2.5.1 Nitrogen Dioxide

Ozone Limiting Method (OLM) has been adopted to determine the NO_2 levels at the ASR. OLM has been applied to major sources (including airport operation emissions as a whole, and proximity infrastructural development) for NO_2 calculation. Basically, the NO_x concentrations at the receivers from respective grouped sources are calculated from the AERMOD and CALINE4 models. The hourly ozone concentrations at the receivers are determined from PATH. The hourly NO_x concentrations are then converted to NO_2 according to method proposed by the USEPA draft paper on "Use of the OLM for estimating NO_2 concentration". The conversion formulas are listed below:

Aircraft related emission sources and other airport sources—GSE, APU, catering, engine run-up testing, marine vessel (grouped)

$$[NO_2]_{pred} = R_i \times [NO_X]_{pred} + MIN\ \{(1-R_i) \times [NO_X]_{pred}\ ,\ or\ (46/48) \times [O_3]_{bkgd}\}$$

where

Mode	R_i - Initial NO_2 / NO_x ratio from exhaust
Take off[1]	5.3 % (1 – 8%)
Climb Out	5.3% (2 – 8.5%)
Approach	15% (10 – 20%)
Taxi-in and Taxi-out	37.5% (25 – 50%)
Other Airport Sources	10%

Note [1]: According to Heathrow study, the NO_2 / NO_x for take off mode is 4.5%. In our assessment, take off and climb out modes are in the same group for OLM processing. Hence, 5.3%is adopted for conservative assessment purpose

Source: Revised Emissions Methodology for Heathrow - Base year 2002, 2007

Industrial emission sources:

$$[NO_2]_{pred} = 0.1 \times [NO_X]_{pred} + MIN\ \{0.9 \times [NO_X]_{pred}\ ,\ or\ (46/48) \times [O_3]_{bkgd}\}$$

Vehicular emission sources (grouped)

$$[NO_2]_{pred} = 0.075 \times [NO_X]_{pred} + MIN\ \{0.925 \times [NO_X]_{pred}\ ,\ or\ (46/48) \times [O_3]_{bkgd}\}$$

where

$[NO_2]_{pred}$ is the predicted NO_2 concentration

$[NO_X]_{pred}$ is the predicted NO_X concentration

MIN means the minimum of the two values within the brackets

$[O_3]_{bkgd}$ is the representative O_3 background concentration (The ozone concentration has been determined from PATH model with airport emission incorporated)

(46/48)is the molecular weight of NO_2 divided by the molecular weight of O_3

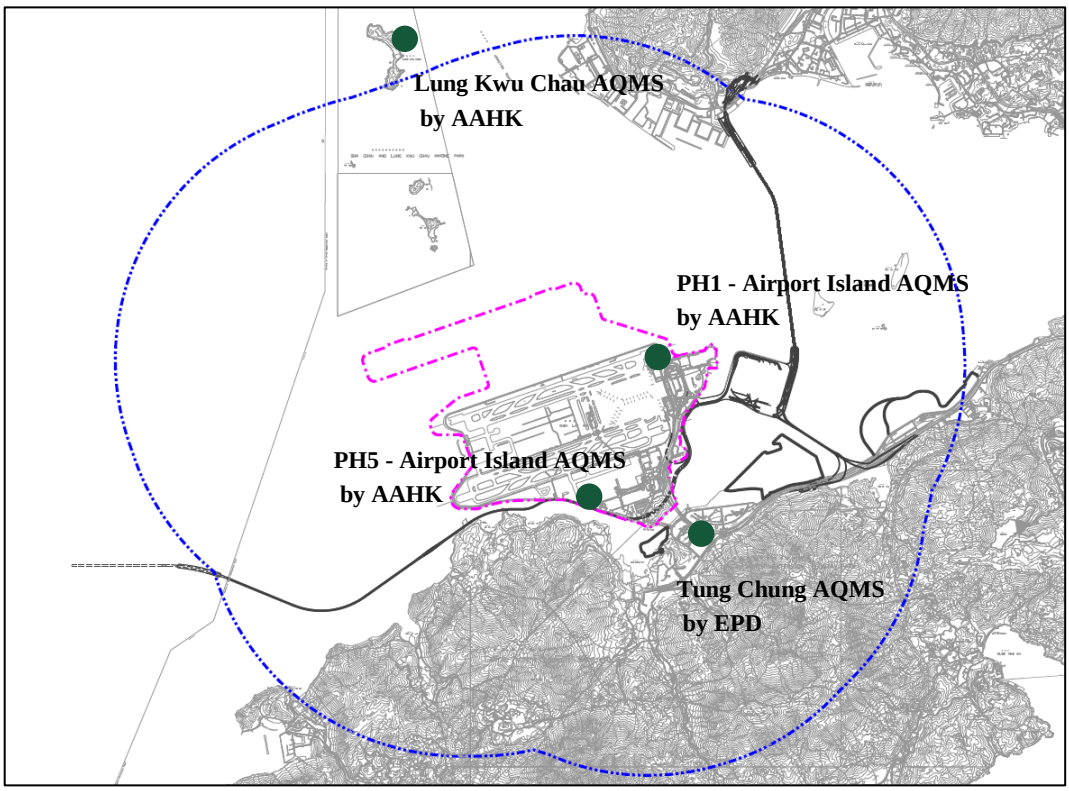
2.6 Model Verification

The objective of model verification is to verify if the calculated emission inventory as well as the modelling assumptions / techniques from the near field model would tally with the actual monitoring data.

Emissions generated from the airport operation activities and proximity infrastructures during Year 2011 were modelled by AERMOD and CALINE4 respectively, as detailed in above sections. The ambient concentrations were established from air quality monitoring stations. The north / northern wind direction episode was studied. Under this episode, the AAHK Lung Kwu Chau (LKC) AQMS was selected as the background station and the monitoring data at this station was used as ambient concentrations, whilst that the Seawater Pumping Stations 5 (PH5) was be used as the impact stations for comparison.

Modelling results has been verified against the actual air quality monitoring data at actual year (i.e. Year 2011). Cumulative frequency distribution of concentration plots of the 1-hour pollutant concentrations from the modelling results and various monitoring data at AQMSs were computed subject to the specific wind directions. Percentile plots were also used to compare the model output of variables. The following figure illustrates the air quality monitoring stations in the vicinity.

Figure 2.1 Air quality monitoring stations in the vicinity of Hong Kong International Airport



Figures 2.2 - Figure 2.5 show the percentile plot comparing the NO_2, RSP, SO_2 and CO from modelling results and monitoring data at PH5 AQMS under northerly and north-westerly winds.

Figure 2.2 Percentile plot of actual and modelled NO_2 concentration at PH5 AQMS

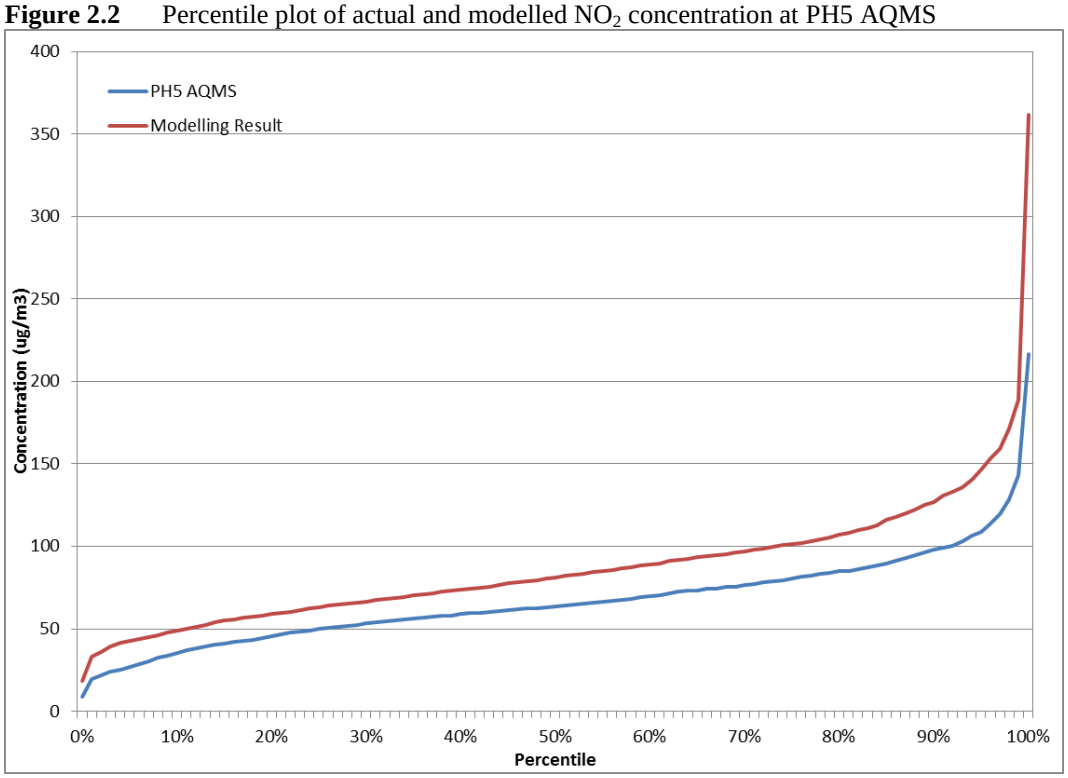


Figure 2.3 Percentile plot of actual and modelled RSP concentration at PH5 AQMS

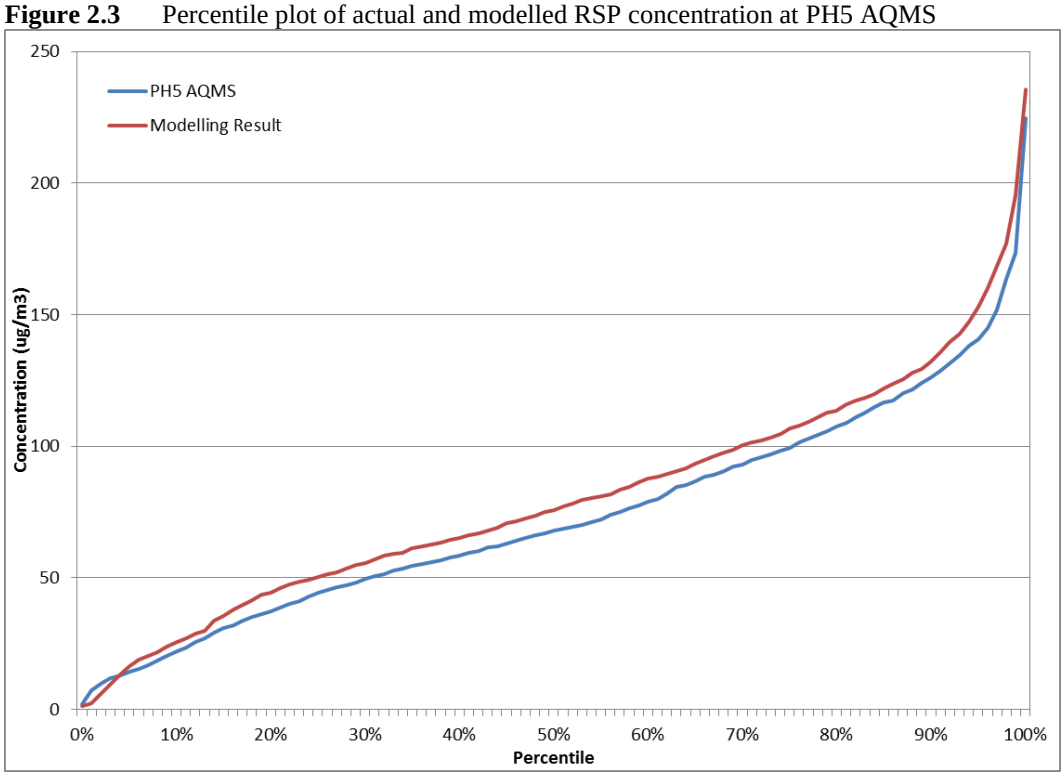


Figure 2.4 Percentile plot of actual and modelled SO_2 concentration at PH5 AQMS

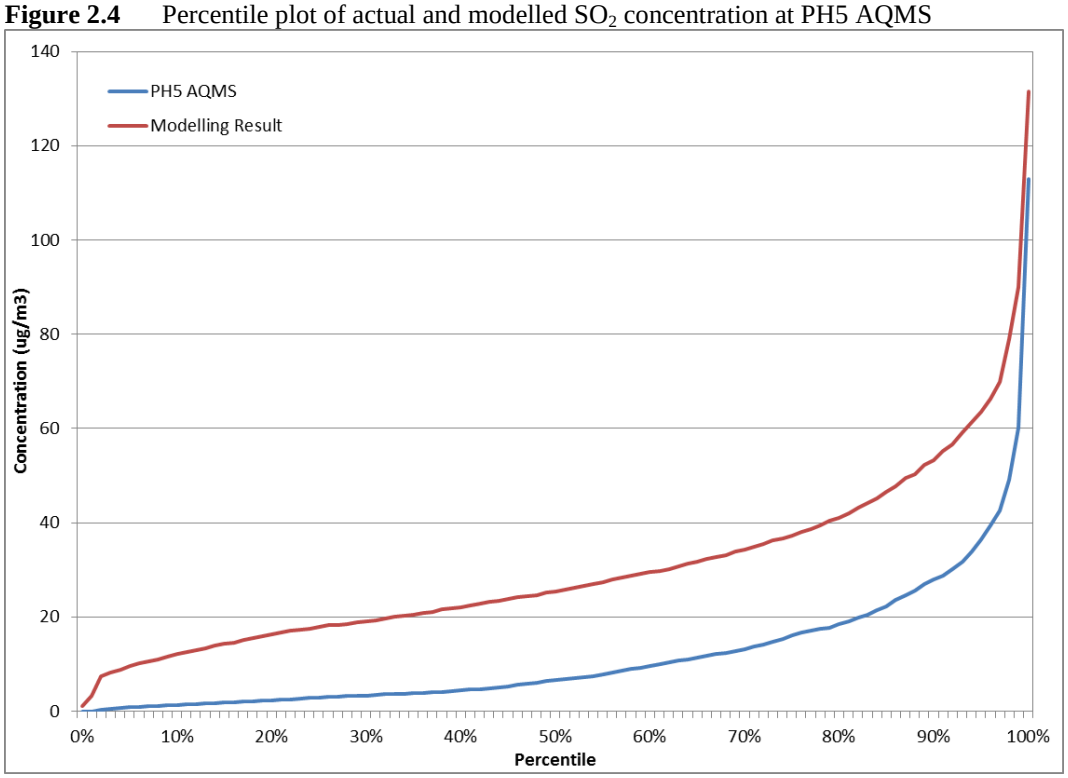
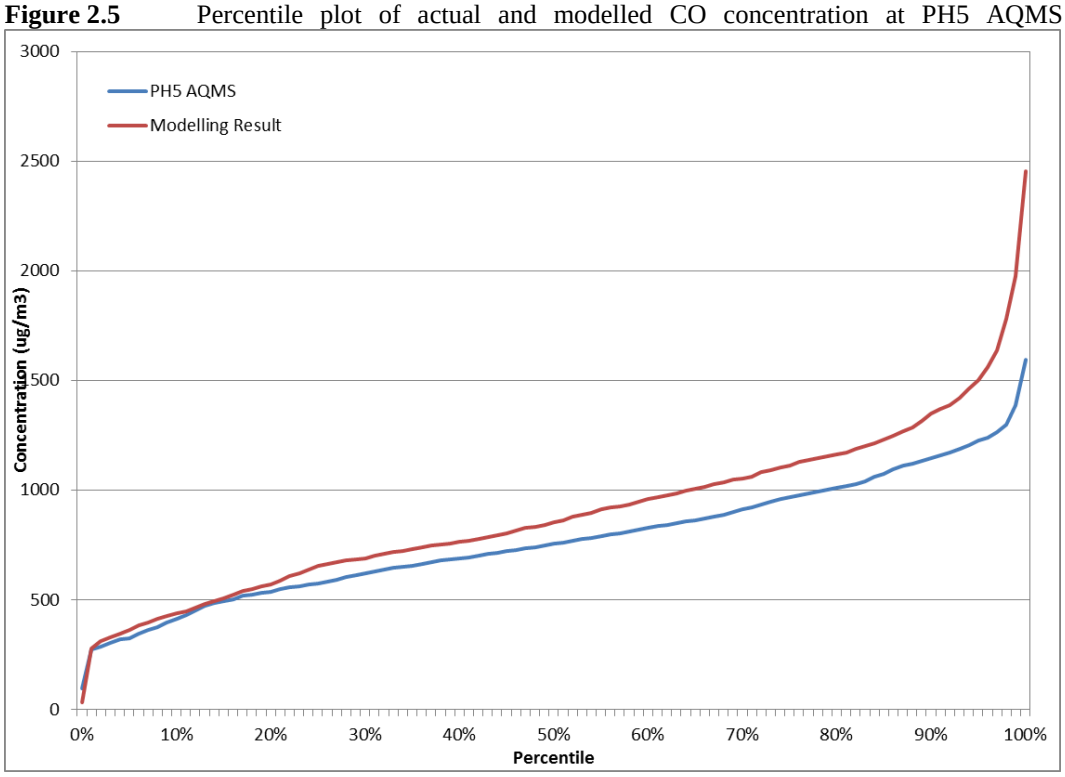


Figure 2.5 Percentile plot of actual and modelled CO concentration at PH5 AQMS



3 Conclusion

As shown in the above plots, modelling results are higher than the monitoring data collected at PH5 AQMS. Thus the current model parameters and assumptions tend to provide conservative assessment results and are acceptable for modeling the future scenario.