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Study on
Marine Vessels Emission Inventory

Final Report

submitted to

The Environmental Protection Department
The HKSAR Government

by

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Star Cruises

GLOSSARY

AB	auxiliary boiler
AE	auxiliary engine
AIS	Automatic Identification System
ATA	vessel arrival time
ATD	vessel departure time
BACT	best available control technology
BAU	business-as-usual
BSFC	brake specific fuel consumption
CAAP	San Pedro Bay Ports Clean Air Action Plan
CAMx	Comprehensive Air Quality Model with extensions
CARB	California Air Resources Board
CO	carbon monoxide
CO_2	carbon dioxide
DPM	diesel particulate matter
DWT	deadweight tonnage
EC	European Community
ECA	emission control area
EEDI	Energy Efficiency Design Index
EF	emission factor
ENT	time when a vessel enters into Hong Kong waters
EPAT	Environmental Protection Administration Taiwan
EPD	Environmental Protection Department (Hong Kong)
EU	European Union
EXR	time when a vessel departs from Hong Kong waters
FCCV	fully cellular container vessel
FWC	Fair Winds Charter
g/kWh	gram per kilowatt hour
GDP	gross domestic product
GHKFA	Guangdong Hong Kong Feeder Association
GRT	gross registered tonnage
GT	gas turbine
h	hour
HC	hydrocarbon
HFO	heavy fuel oil
HKGCC	Hong Kong General Chambers of Commerce
HKLSA	Hong Kong Liner Shipping Association
HKPA	Hong Kong Pilots Association
HKSAR	Hong Kong Special Administration Region
HKSOA	Hong Kong Shipowners Association
hp	horse power
HSD	high speed diesel engine
HTML	HyperText Markup Language
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ISO	International Organization for Standardization
KCCT	Kwai Chung Container Terminals
KTCT	Kai Tak Cruise Terminal

kW	kilowatt
kWh	kilowatt-hour
LF	load factor
LNG	liquefied natural gas
LOA	length overall
LPG	liquefied petroleum gas
LRF	Lloyd's Register-Fairplay
LRS	Lloyd's Register of Ships
LV	local vessel
MARPOL VI	Annex VI to the International Convention for the Prevention of Marine Pollution from Ships
MD	Marine Department (Hong Kong)
MDO	marine diesel oil
ME	main engine
MGO	marine gas oil
MM5	Fifth-generation National Centre for Atmospheric Research/ Pennsylvania State University Mesoscale Model
MPA	Maritime and Port Authority of Singapore
MS	Microsoft
MSD	medium speed diesel engine
n.a.	not applicable
n/a	not available
nm	nautical mile
NO_X	nitrogen oxides
NRT	net registered tonnage
OBO	ore/bulk/oil
OGV	ocean-going vessel
PAN	pre-arrival notification
PAS	publicly available specification
PATH	Pollutants in the Atmosphere and their Transport over Hongkong model
PAX	passenger carrying capacity
PCWA	public cargo working area
PDF	Portable Document Format
PHKST	Port of Hong Kong Statistical Tables
PM_{10}	respirable suspended particulates
$PM_{2.5}$	fine particulate matter
PoLA	Port of Los Angeles
PoLB	Port of Long Beach
ppb	parts per billion
ppm	parts per million
PRD	Pearl River Delta
RPM	revolution per minute
RTT	river trade terminal
RTV	river trade vessel
RV	river vessel
SCC	Special Conditions of Contract
SCR	selective catalytic reduction
SECA	sulphur emission control area
SEEMP	Ship Energy Efficiency Management Plan
SLA	south of Lamma Island

SO_2	sulphur dioxide
SSD	slow speed diesel engine
ST	steam turbine
TEU	twenty-foot equivalent unit
THB	Transport and Housing Bureau (Hong Kong)
TIM	time-in-mode
UK	United Kingdom
ULSA	ultra low sulphur diesel
UN	United Nations
US	United States
USEPA	Environmental Protection Agency of the United States
VAN	vessel arrival number
VAR	Vessel Activity Report
VDN	vessel departure number
VLCC	very large crude carrier
VOC	volatile organic compound
VSR	vessel speed reduction
VTC	Vessel Traffic Centre
VTMS	vessel traffic management system
WHA	western harbour area
WRF	Weather Research and Forecasting modeling system
XML	eXtensible Markup Language

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EXECUTIVE SUMMARY

Introduction

The Environmental Protection Department (EPD) of the Hong Kong Special Administration Region (HKSAR) Government commissioned the Institute for the Environment of the Hong Kong University of Science and Technology (the Consultant) in August 2008 to carry out a study on marine vessels emission inventory (the Study). The main objectives of the Study are to (a) compile an emission inventory for ocean-going vessels (OGVs) and river vessels (RVs) consisting of pollutants including sulphur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compound (VOC), carbon monoxide (CO), respirable suspended particulates (PM_{10}) and fine particulate matter ($PM_{2.5}$) for 2007, which is the base year, within Hong Kong waters; (b) to backcast an emission inventory for OGVs and RVs for the historical years of 1990 to 2006; and (c) to project an emission inventory for OGVs and RVs for 2008 to 2020. Emissions produced by vessels transiting Hong Kong to neighbouring Pearl River Delta (PRD) ports were not included in the HKSAR marine emission inventory according to international practice.

Emissions Estimation Approach

In this Study, marine vessels emission was estimated by the activity-based approach. Air pollutant emission from a ship during a particular voyage is the function of (a) the installed power of on-board equipments, (b) operation time-in-mode, (c) fractional load of equipment in a specific mode, and (d) fractional load emission factor of equipments in units of works (gram per kilowatt-hour), as shown in this equation:

$$\textbf{\textit{Total Emission}}_{(pollutant)} = \sum \textbf{\textit{Emission}}_{(pollutant,\ activity\ mode,\ equipment)}$$

$$\textbf{\textit{Emission}}_{(pollutant,\ activity\ mode,\ equipment)} = P \times FL \times T \times EF$$

where P is the installed power of equipment;
FL is fractional load of equipment in a specific mode;
T is operation time-in-mode; and
EF is fractional load emission factor of equipment.

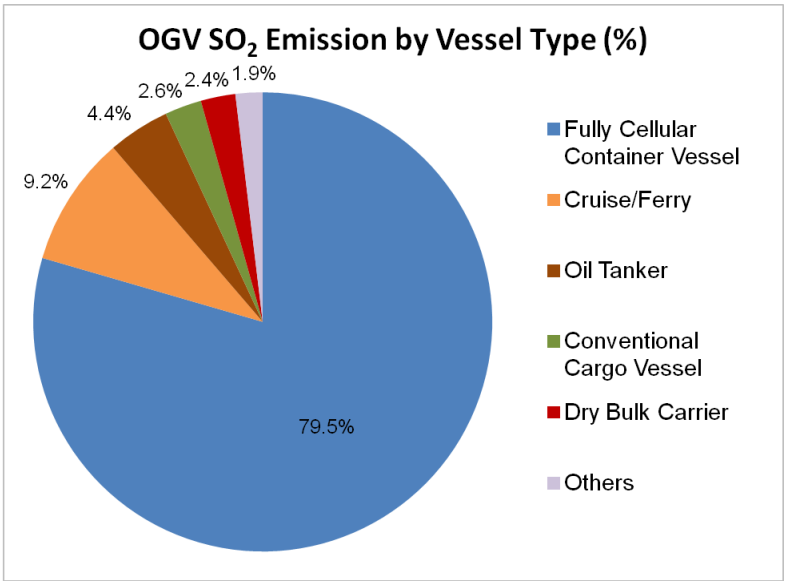
Data Collection

In general, information required for this Study included (a) vessel call information, (b) vessel characteristics data, (c) vessel activity and movement information, (d) engine activity and fuel use information, and (e) emission factors. Details of information were collected down to vessel class and tonnage or passenger capacity sub-class as far as possible and practical.

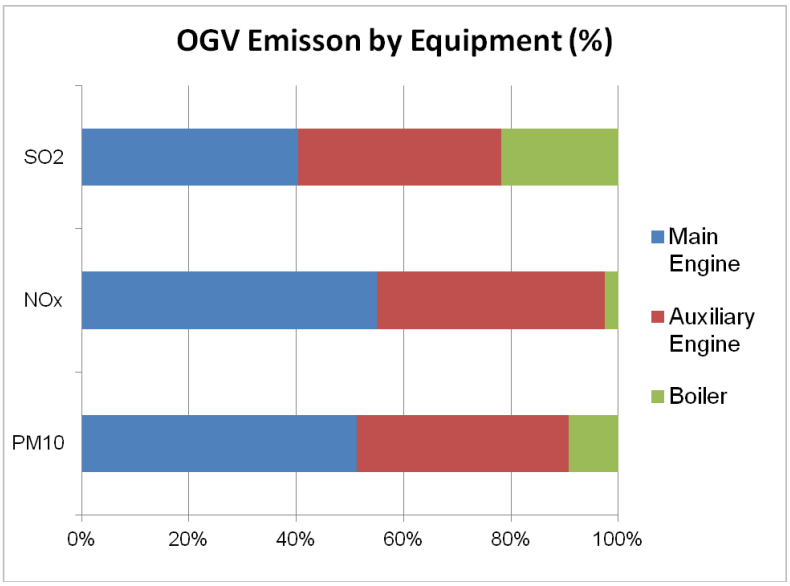
Marine Department (MD) was the main source of information with respect to vessel call numbers and vessel activity. Published statistical reports and archived data, including vessel track data were gathered from MD. Lloyd's Register of Ships (LRS), by far the largest database of commercial vessels, was a major source of important vessel data such as engine power rating and vessel tonnage. A marine vessel survey, as well as personal interviews with members of the marine sector, was carried out to collect representative local data such as engine activity and fuel quality. References were also made to major overseas studies regarding methodology and input parameters.

Ocean-going Vessel Emissions 2007

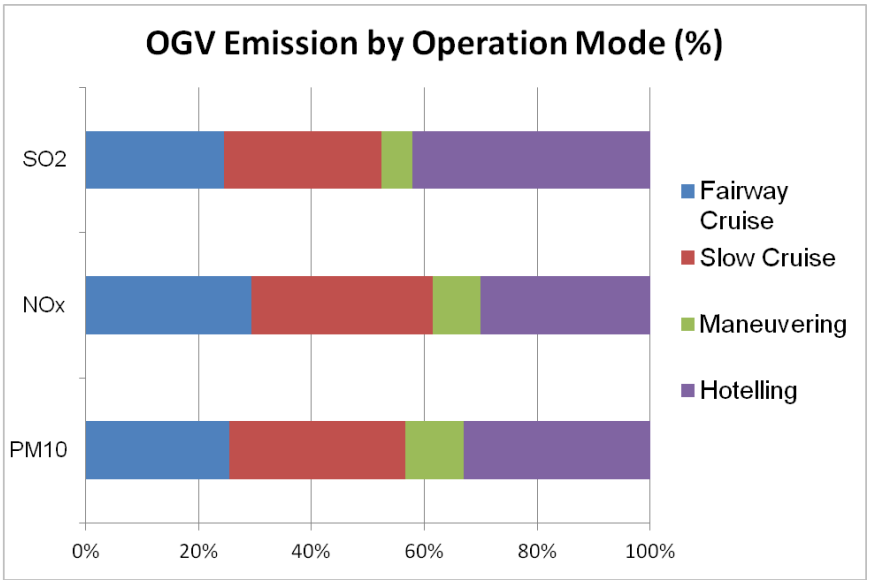
It was estimated that 12,438 tonnes of SO_2, 14,462 tonnes of NO_X, 1,447 tonnes of PM_{10}, 1,309 tonnes of $PM_{2.5}$, 635 tonnes of VOC and 1,421 tonnes of CO were emitted from the 37,152 OGVs that visited the port of Hong Kong in 2007, within Hong Kong waters. The top emitter amongst OGVs was fully cellular container vessel (FCCV), accounted for about 79% to 82% of the emissions. In total, the top five emitters (including FCCV, cruise/ferry, oil tanker, conventional cargo vessel, and dry bulk carrier) contributed approximately 98% of emissions from OGVs.



In terms of equipment, main engine (ME) and auxiliary engine (AE) were equally important sources of OGV emissions. Study findings show that ME emitted 40% of SO_2, 55% of NO_X, and 51% of PM_{10}, while 38% of SO_2, 43% of NO_X, and 40% of PM_{10} were emitted from AE. Emission from boiler was relatively smaller in percentage, but still significant. For example, 2,705 tonnes of SO_2 (22%) and 135 tonnes of PM_{10} (9%) were emitted from boilers installed onboard of OGVs.

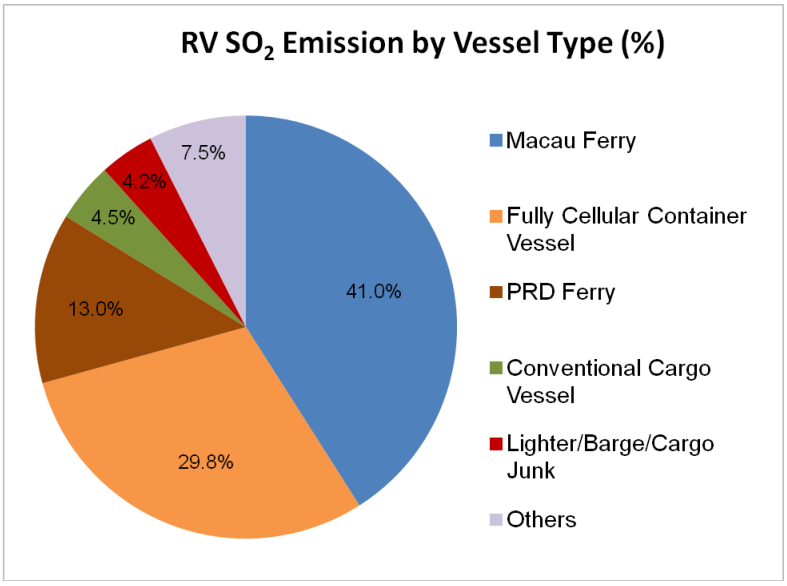


It was also found that most air pollutants were emitted during hotelling, followed by slow cruise (vessel speed 8 to 12 knots) and fairway cruise (over 12 knots). For examples, about 42% of SO_2, 30% of NO_X and 33% of PM_{10} were emitted during hotelling. The corresponding shares for slow cruise were 28%, 32%, and 31%. Least emissions were produced during maneuvering.



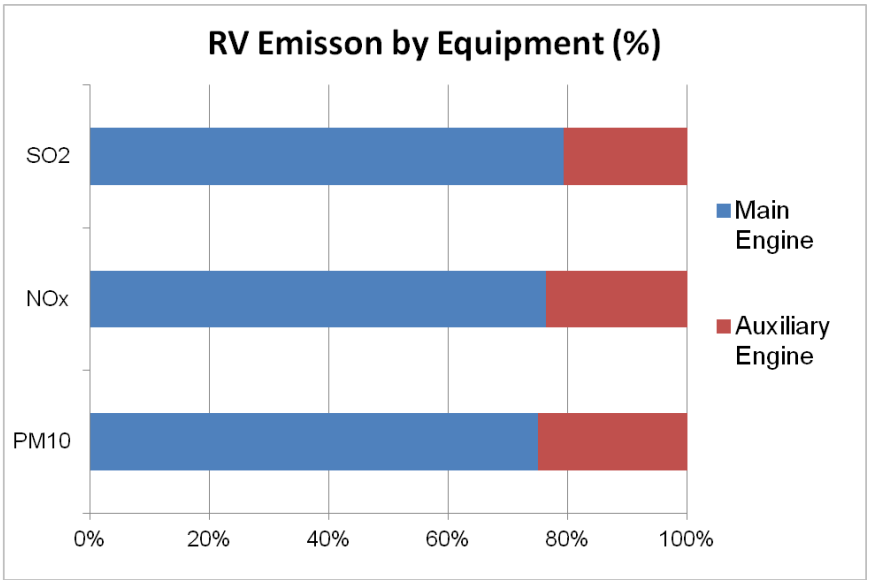
River Vessel Emissions 2007

In total, 1,848 tonnes of SO_2, 7,779 tonnes of NO_X, 287 tonnes of PM_{10}, 275 tonnes of $PM_{2.5}$, 230 tonnes of VOC and 882 tonnes of CO were emitted from the 190,860 RVs that visited Hong Kong during 2007, within Hong Kong waters. Major emitters amongst the RVs were Macau Ferry, FCCV, PRD Ferry, conventional cargo vessel, and lighter/barge/cargo junk. Macau Ferry accounted for about 41%, 29%, and 34% of SO_2, NO_X, and PM_{10} emissions, respectively.

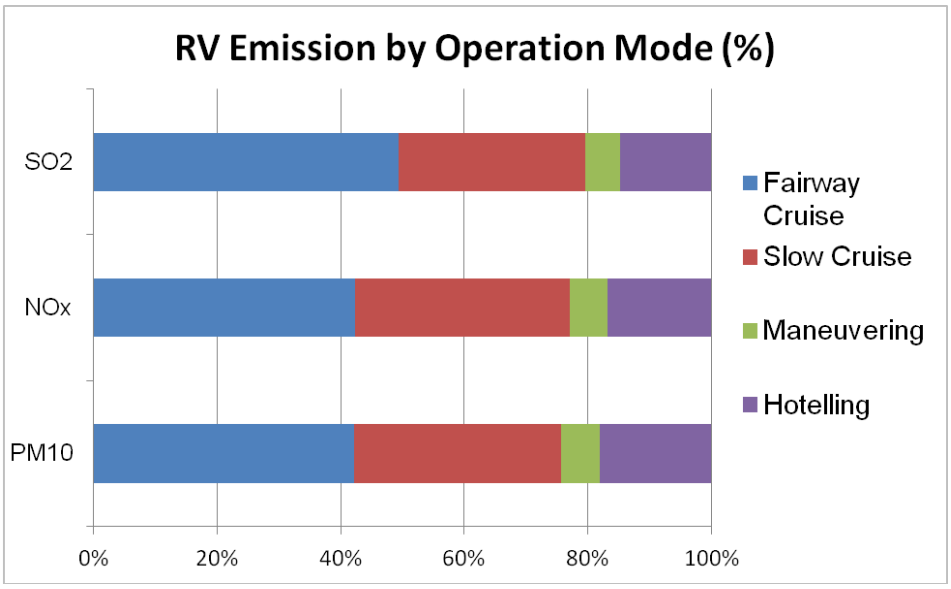


In terms of emissions by equipment, Study results show that ME was the major source of emission, accounting for three quarters of SO_2, NO_X, PM_{10} and VOC emissions, as well as

two-thirds of CO emissions. The remainder was emissions from AE, as it was assumed that no boiler was installed on board of RVs and hence there was no boiler emission.



In terms of emissions by mode, results show that most pollutants were emitted during fairway cruise mode. Only Macau and PRD Ferries would operate in fairway cruise mode inside Hong Kong waters, and they contributed roughly 50% of SO_2 and 42% of PM_{10} emissions. Emission from slow cruise mode was also significant, producing 28% to 43% of the pollutants considered in this Study. In total, RVs emitted about 70% to 80% of their total emissions while underway (that is, fairway cruise and slow cruise modes combined).



Total Marine Vessel Emissions 2007

In order to show a complete picture of marine vessels emission within Hong Kong waters in base year 2007, emission estimates for local vessels (LVs), developed by EPD's in-house study, were added to the findings of this Study. In total, 15,719 tonnes of SO_2, 32,744 tonnes of NO_X, 2,139 tonnes of PM_{10}, 3,489 tonnes of VOC and 10,535 tonnes of CO were emitted from all marine vessel sources, including OGVs, RVs, and LVs**.** In terms of percentage share,

OGVs accounted for 79% of SO_2, 44% of NO_X, 68% of PM_{10}, 18% of VOC, and 13% of CO emissions. LVs were significant in the contribution of VOC (75%) and CO (78%).

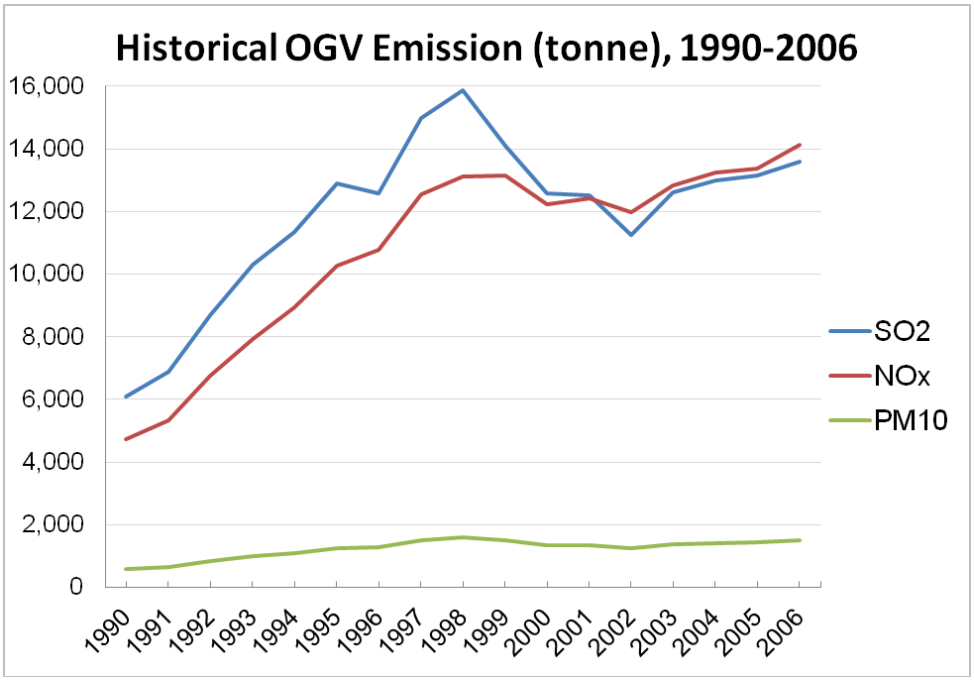
Uncertainty of OGV and RV Emissions Inventory 2007

A quantitative analysis of uncertainty of OGV and RV emissions inventory in 2007 was conducted. Bootstrap simulation to quantify uncertainty in input parameters and Monte Carlo simulation to propagate uncertainties were performed. Uncertainty ranges of OGV emissions are -23% to 26% for SO_2, -26% to 29% for NO_X, -23% to 26% for PM_{10}, -36% to 40% for VOC, and -22% to 25% for CO. On the other hand, uncertainty ranges of RV emissions are -21% to 24% for SO_2, -31% to 34% for NO_X, -37% to 42% for PM_{10}, -34% to 38% for VOC, and -25% to 29% for CO.

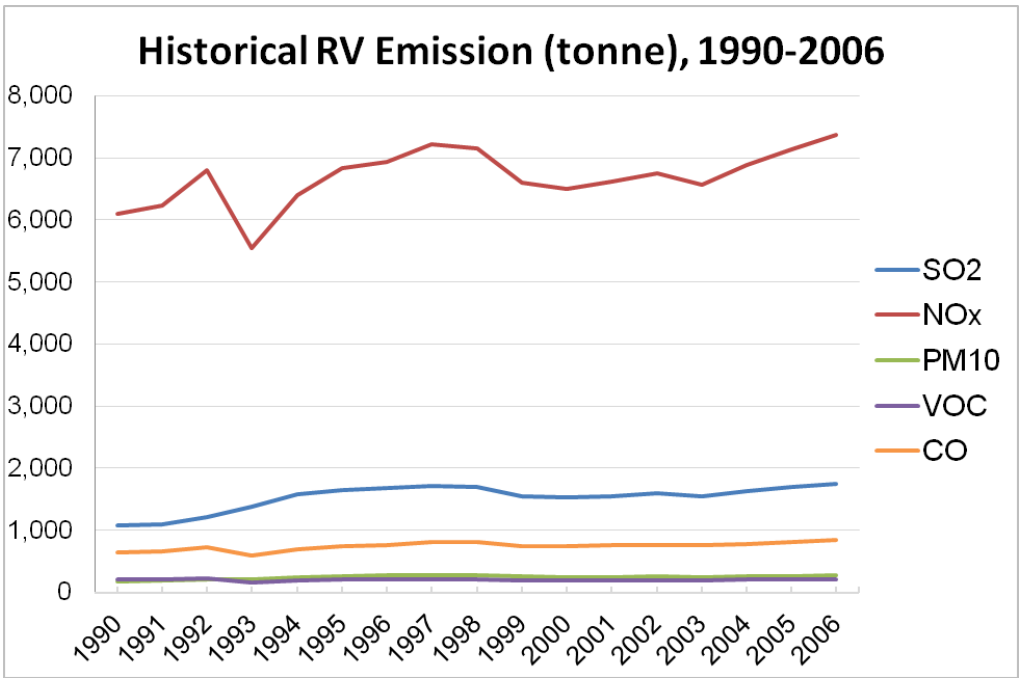
Historical Emission Inventory 1990-2006

Past emissions between 1990 and 2006 were estimated for both OGVs and RVs, based on the 2007 inventory. Several parameters over the backcasting period were considered, including historical trend in vessel arrival number, average time-in-port, vessel size and power rating. Change in average fuel sulphur content and onboard emission reduction technology, and their impact on the selection of emission factors were also considered.

It was found that between 1990 and 2006, OGV emissions of SO_2 had grown by a factor of 2.2, NO_X by 3, and PM by 2.6. FCCV was the key contributor to the significant increase of emissions in quantity. Emissions of SO_2, NO_X and PM_{10} from FCCV were 3.4 times, 4.2 times and 3.5 times of the respective 1990 levels. On the other hand, cruise ship had recorded the highest percentage growth during the same period. Emissions from cruise ship were 4 times, 5.6 times and 4.8 times of the respective 1990 percentage shares.



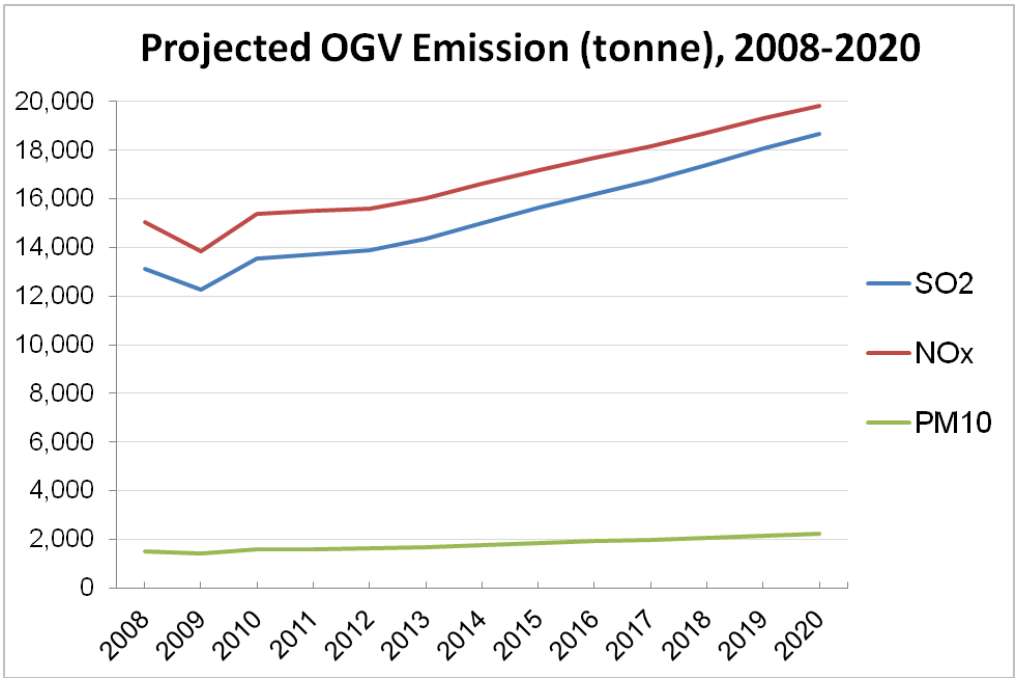
For RVs, it was calculated that emissions of SO_2, NO_X, PM_{10}, VOC and CO had increased by 62%, 21%, 49%, 4% and 29% respectively, from 1990 to 2006.

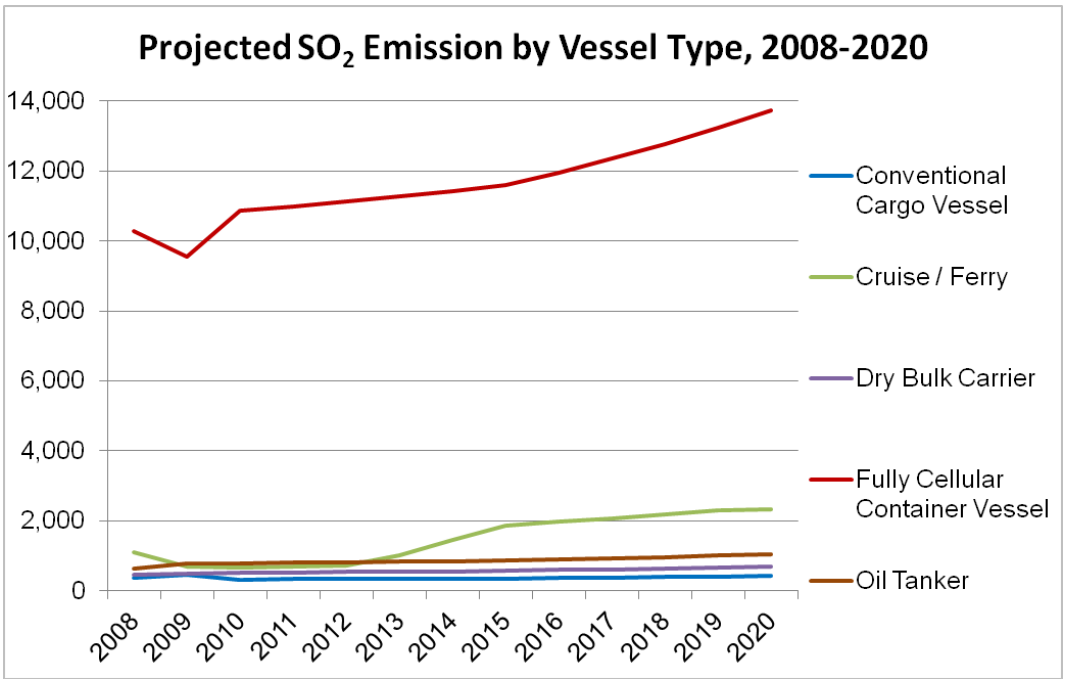


Projected Emission Inventory 2008-2020

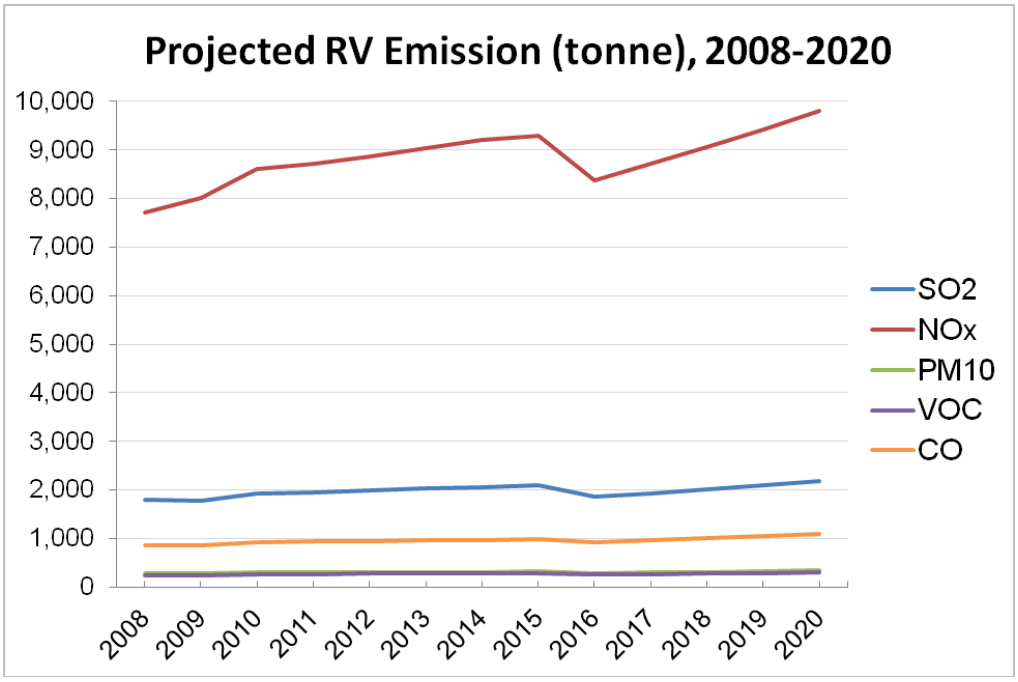
OGV and RV emissions from 2008 to 2020 were projected on a business-as-usual (BAU) basis, based on the 2007 inventory. Future trends in vessel arrival number, average time-in-port, average fuel sulphur content and emission factor were considered.

It was estimated that after a drop in emissions in 2008 and 2009 due to the global financial crisis, OGV emissions will grow by 12% to 17% from 2010 to 2015, and by 29% to 41% from 2010 to 2020. FCCV was predicted to remain the top emitter, but the percentage share of cruise ship was projected to grow strongly during the forecast period.



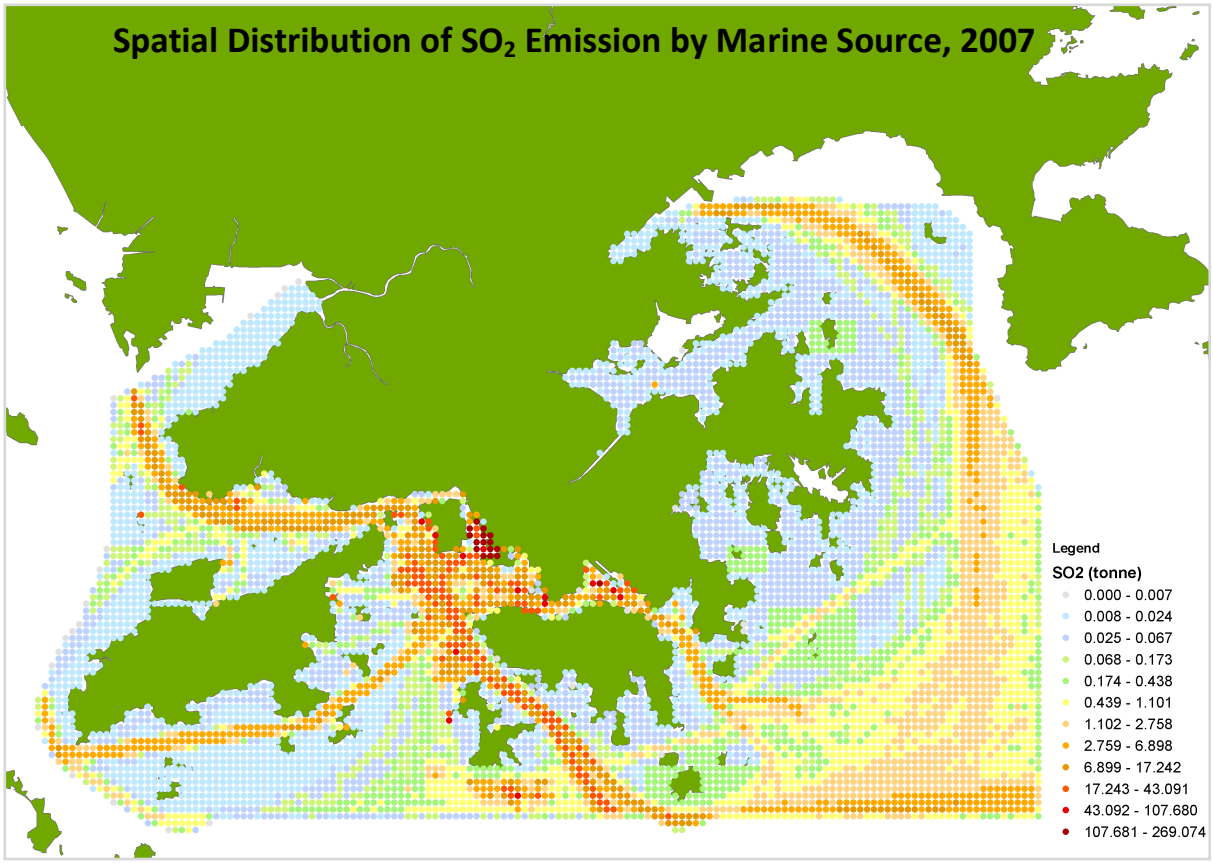


For RVs, it was predicted that emissions will increase by 5% to 9% from 2010 to 2015, and by 12% to 18% from 2010 to 2020.

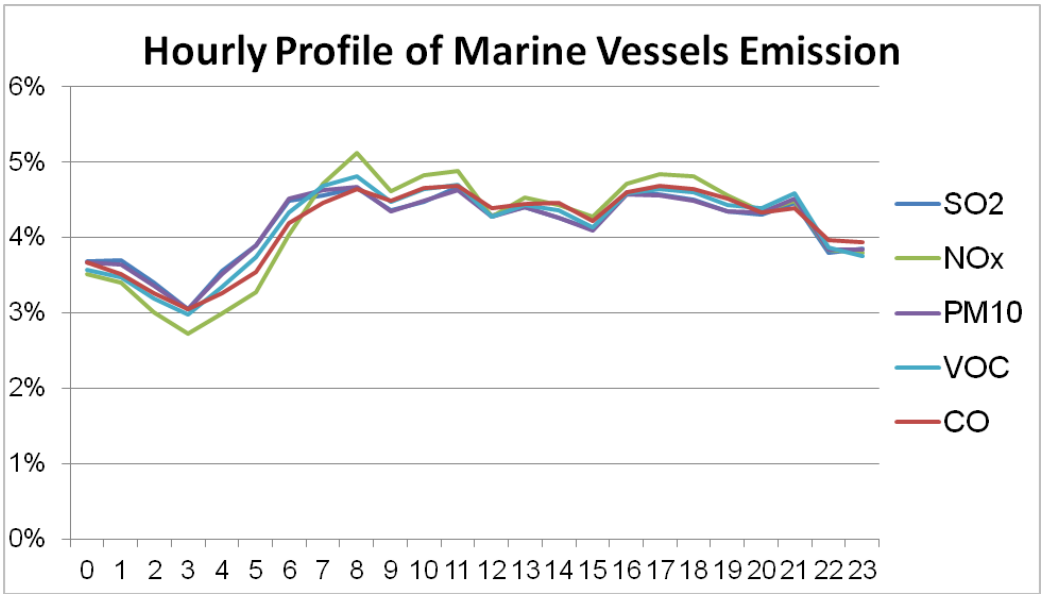


Spatial and Temporal Profiles of 2007 Emissions

In the Study, vessel track data of MD were used to determine the spatial distribution of OGV, RV and LV emissions in 2007. Emission maps by pollutant were produced to identify emission hot spots. It becomes apparent that Kwai Chung Container Terminals (KCCT), among other major cargo and passenger terminals, was an important emission hot spot. Emissions produced along major fairways, such as the East Lamma Channel and Ma Wan Fairway were also significant.



Hourly, weekly and monthly profiles of OGV, RV and LV emission were also developed, based on vessel track data and other surrogate information such as vessel arrival numbers. In general, a day/night pattern can be identified from the hourly profiles. However, the variation of emission within a 24-hour period was much greater for passenger vessels than cargo-carrying vessels. For the monthly profiles, a slight dip in emission during Chinese New Year period (usually January or February) was common for cargo ships.



Air Dispersion Model

An air dispersion model run was performed for SO_2 over a two-week period in July 2007, to demonstrate the impact of marine sources on ambient air quality in areas adjacent to KCCT. By comparing simulation results to observed readings from selected air quality monitoring stations, it is shown that during the days with southerly and southwesterly wind and negligible regional influence, marine sources contributed significantly to the ambient air in Kwai Chung and Tsuen Wan.

Policy Analysis

A quick analysis of a number of marine vessels emission reduction measures for OGV was carried out, including fuel switching, vessel speed reduction, shore power and emission control area (ECA). Measures for harbour craft were also studied. Applicability of these policy options in the context of Hong Kong was briefly assessed based on five criteria, namely, technical feasibility, institutional support, emission reduction benefits, financial costs and operational viability. It was concluded that for OGV, fuel switching is most ready to be considered in the short term, while ECA is an important long-term goal due to its emission reduction potential. For harbour craft, the use of low sulphur fuel is the most appealing option at the moment.

Conclusion and Recommendation

In this Study, a better understanding of marine fuel use, engine power rating, engine activity, boiler emission, and time-in-mode apportionment through extensive data collection, engagement with the marine sector and detailed analyses have vastly improved the quality of the marine vessels emission inventory. New spatial and temporal dimensions were also added to the inventory, providing valuable information to policy makers in devising effective emission reduction measures to tackle ship emissions.

Nevertheless, some data gaps still remain, such as OGV AE power ratings, RV power information, RV operational characteristics, as well as multiple berthing locations information of some OGV and RV types. In order to reduce uncertainties, more effort is required in the future to collect more information.

Given the proximity of the Shenzhen ports of Yantian, Shekou and others, and the impact of their marine activities on Hong Kong's air quality (and vice versa), it will be a useful next step to compile an emission inventory for the PRD area, as well as to conduct health impact studies related to marine sources. It will serve the need to understand the impact of marine sources in a regional context, to prepare for region-wide control strategies in the short and medium term, and to pave the ground work for the ultimate goal of establishing an ECA in PRD waters.

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PART I INTRODUCTION

1. INTRODUCTION

1.1. Background

1.1.1. This Final Report is prepared by the Institute for the Environment of the Hong Kong University of Science and Technology (hereinafter called the Consultant) for the provision of service for "Tender Ref. AS08-068: Study on Marine Vessels Emission Inventory" (the Study) for the Environmental Protection Department (EPD) of the Hong Kong Special Administrative Region (HKSAR) Government.

1.1.2. The Study was commissioned by EPD in August 2008. The objective of this Final Report is to document the works carried out by the Consultant, according to the scope as originally described in the Special Conditions of Contract (SCC) and subsequently revised with EPD's approval:

- To collect local data on ocean-going vessels (OGVs) and river vessels (RVs) entering and leaving Hong Kong waters by conducting surveys to and collecting information from relevant trade associations, trade practitioners such as pilots and the pilotage advisory committee, trade operators such as shipping companies and government departments;
- To produce an emission inventory for ocean-going vessels and river vessels consisting of pollutants including sulphur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compound (VOC), carbon monoxide (CO), respirable suspended particulates (PM_{10}) and fine particulate matter ($PM_{2.5}$) for the years 1990 to 2007 within Hong Kong waters; and
- To project the emission inventory from 2008 to 2020 under different control scenarios and making reference to latest port development study reports, cruise development plans and vessel forecast data.

1.1.3. In essence, the Study is comprised of six tasks as follows:

- Task 1: Data collection and survey;
- Task 2: Compilation of historical emission inventory from 1990 to 2007;
- Task 3: Compilation of projected emission inventory from 2008 to 2020;
- Task 4: Preparation of temporal/spatial distribution of 2007 emission inventories;
- Task 5: Marine vessel air pollutant dispersion model; and
- Task 6: Policy analysis for marine emissions control.

1.1.4. Although the study scope is limited to OGVs and RVs, in order to present a complete picture of marine vessels emission, this Final Report also incorporates emission estimates of EPD's in-house study of local vessels (LVs). The latter involves various surveys to local vessel trades and data collection from government departments and follows the same methodology used by overseas studies.

1.1.5. For the vessels transiting Hong Kong to Shenzhen ports or other Guangdong ports without calling Hong Kong, even though their emissions fall within the boundary of Hong Kong waters, they are to be reported under the ports of call in line with international practice, thus will not be discussed in this Final Report. Similarly, emissions of vessels calling and transiting outside the Hong Kong waters are not discussed, though pollutants travel without boundary and they may also affect local air quality.

1.1.6. Prior to preparation of this Final Report, the Consultant had submitted three interim reports to EPD and a report on OGVs and RVs emission inventory for year 2007 to Marine Department (MD) for comments. The draft of this Final Report was also submitted to EPD for comments before being finalized.

1.2. Overview of the Port of Hong Kong

1.2.1. Hong Kong is one of the leading ports in the world, in terms of vessel arrivals, cargo throughput and passenger throughput. According to MD's *Port of Hong Kong Statistical Tables (PHKST)*, an annual publication of port and maritime statistics, 32,645 OGVs and 179,168 RVs entered Hong Kong in 2010. These vessels altogether represented a combined total of about 511 million net registered tonnes. About 268 million tonnes of cargoes were handled, and total passenger throughput from Macau and mainland ports was about 26.5 million.

1.2.2. In 2010, Hong Kong was the third busiest container ports in the world after Shanghai and Singapore, with a throughput of about 23.7 million containers in twenty-foot equivalent unit (TEU). About 400 container liner services were provided each week to over 480 destinations in other parts of the world.

1.2.3. The Kwai Chung and Tsing Yi Container Terminals (KCCT) are the most important cargo handling facilities in Hong Kong. Located in the north-western part of the harbour, KCCT comprised of nine container terminals and 24 berths, offering about 7,694 meters of deep water frontage, with a combined annual handling capacity of over 19 million TEUs. In addition, containers are also handled mid-stream in Hong Kong, with barges and container feeders working alongside anchored container vessels in the harbour area. Other handling facilities for boxed and general cargoes include public cargo working areas[1] (PCWAs), river trade terminal[2] (RTT), and other private wharves and terminals.[3] Bulk cargo handling facilities are provided, for examples, at the power stations in Castle Peak and on Lamma Island, as well as the Green Island cement plant in Tuen Mun.

1.2.4. Ocean Terminal in Tsim Sha Tsui is the major berthing point for ocean cruise ships in Hong Kong, with China Merchants Wharf in Kennedy Town also serving as an alternative for larger cruise ships in recent years. Some Hong Kong-based cruise ships, on the other hand, berthed at China Hong Kong Terminal next to Ocean

[1] There are eight PCWAs managed by MD: Western District, Chai Wan, Cha Kwo Lang, Kwun Tong, New Yau Ma Tei, Stonecutters Island, Rambler Channel, and Tuen Mun. They provide a total of 6,672 metres of sea frontage, and on average handled about 8 million tonnes of cargo each year.

[2] Situated to the west of Tuen Mun, RTT is a privately owned terminal for handling river trade cargoes in Hong Kong. There are 49 berths, providing about 3,000 metres of quay length.

[3] For examples, China Merchants Wharf in Kennedy Town, various oil terminals on Tsing Yi Island, and Hong Kong & China Gas Company's terminal in Tolo Harbour.

Terminal, or moored to Government buoys inside Victoria Harbour. On the other hand, the Hong Kong Macau Ferry Terminal in Sheung Wan, the China Ferry Terminal in Tsim Sha Tsui, the Tuen Mun Ferry Terminal in Tuen Mun, and the SkyPier at the Hong Kong International Airport in Chek Lap Kok provide ferry services to Macau and to other ports in the Pearl River Delta (PRD) area. River passenger throughput increased by 11% from 2004 to 2009. In contrast, patronage on local ferries decreased by 10% during the same period.

1.2.5. In 2010, there were about 14,500 licensed local vessels in operation within or in vicinity of Hong Kong waters, berthing at various terminals discussed above, typhoon shelters, or marinas. This is significant in terms of both vessel number and activity compared with overseas ports. For example, there were only 264 harbour crafts (excluding pleasure vessels) in operation in the Port of Los Angeles (PoLA) in 2010.

1.2.6. Figure 1-1 below shows the boundary of Hong Kong waters, major berthing and anchorage locations, and principal fairways.

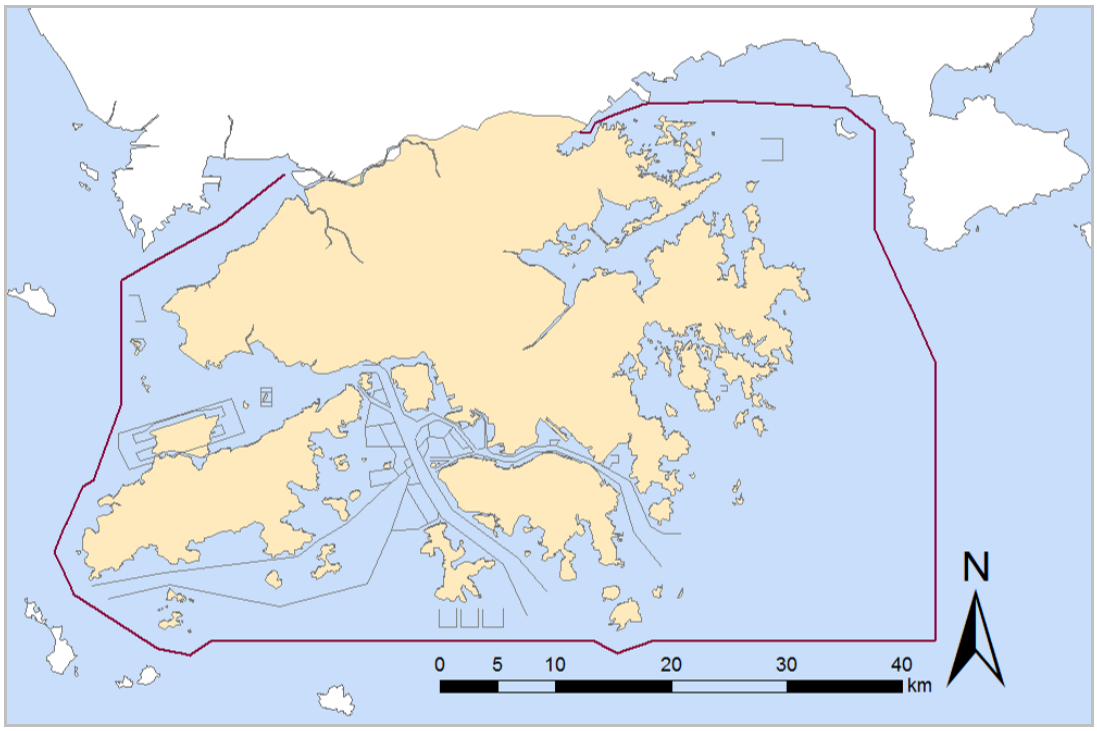

Figure 1-1 Waters of Hong Kong Special Administrative Region

1.3. Marine Vessels Inventory Methodology Review

1.3.1. In the last decade, as land-based emission sources in North America and Europe were progressively regulated and reduced, marine vessels emission have become increasingly significant and attracted overdue attention. A growing number of studies were conducted to estimate ship emissions in different parts of the world. New methodologies were developed and tested, and many port authorities are in the process of refining and improving their emission inventory with less uncertainty.

Fuel-based Approach

1.3.2. In the past, marine vessels emission was estimated based on fuel consumption. Emission factors were derived in gram per unit of fuel used. The basic equation is:

$$\textbf{Emission} = \textbf{Fuel Consumption} \times \textbf{Emission Factor}$$

1.3.3. This is a simple method, but fuel consumption data is always difficult to obtain from the marine sector due to the sensitive nature of the information. When precise ship traffic and movements information are not known, whereas total fuel consumption estimates are available, fuel-based method is often the preferred approach.

Activity-based Approach

1.3.4. In 2000, the Environmental Protection Agency of the United States (USEPA) issued a new set of guidelines on compiling marine vessels emission inventories (USEPA, 2000). Emission factors were derived in units of works (gram per kilowatt-hour), dependent on fractional load of the equipment during different vessel activity modes. The equations for emissions calculation of a specific air pollutant during a single voyage are as follows:

$$\textbf{Total Emission}_{(pollutant)} = \sum \textbf{Emission}_{(pollutant,\ activity\ mode,\ equipment)}$$

$$\textbf{Emission}_{(pollutant,\ activity\ mode,\ equipment)} = P \times FL \times T \times EF$$

where P is the installed power of equipment;
FL is fractional load of equipment in a specific mode;
T is operation time-in-mode; and
EF is fractional load emission factor of equipment.

1.3.5. In this Study, the activity-based approach of marine vessels emission estimation was adopted unless otherwise stated. This is considered more accurate[4], when detailed information of vessels and their operations are readily available.

1.3.6. Whilst overseas marine vessels emission may include criteria and toxic air pollutants and greenhouse gas emission, toxic and greenhouse gas emissions fall outside the scope of this Study. Nevertheless, toxic and greenhouse gas emissions could be estimated with the same methodology once their emission factors are known.

1.4. Scope of Study

Geographical Boundary

1.4.1. The key objective of the Study, as explained in paragraph 1.1.2, is to compile an emission inventory for OGVs and RVs that called at Hong Kong. Specifically, the geographical extent covered in this Final Report is defined by the boundary of Hong Kong waters, as illustrated in Figure 1-1. The coordinates of the boundary are listed below in Table 1-1 for easy reference.

[4] Entec UK Limited 2002; Corbett and Koehler, 2003.

Table 1-1 Study Boundary Coordinates

Point	Latitude	Longitude
1	22°32'37.21"N	114°13'34.85"E
2	22°32'45.42"N	114°13'32.40"E
3	22°32'52.26"N	114°13'36.91"E
4	22°32'52.83"N	114°13'36.86"E
5	22°33'23.49"N	114°12'24.25"E
6	22°30'36.23"N	113°59'42.20"E
7	22°28'20.49"N	113°56'52.10"E
8	22°25'43.70"N	113°52'8.80"E
9	22°19'60.00"N	113°52'8.80"E
10	22°16'23.20"N	113°50'50.60"E
11	22°16'3.80"N	113°50'20.40"E
12	22°14'21.40"N	113°49'35.00"E
13	22°13'1.60"N	113°49'1.60"E
14	22°11'1.90"N	113°49'56.60"E
15	22° 8'33.10"N	113°53'47.60"E
16	22° 8'12.20"N	113°55'20.60"E
17	22° 8'54.50"N	113°56'22.40"E
18	22° 8'54.50"N	114°14'9.60"E
19	22° 8'18.80"N	114°15'18.60"E
20	22° 8'54.50"N	114°17'2.40"E
21	22° 8'54.50"N	114°30'8.80"E
22	22°21'54.50"N	114°30'8.80"E
23	22°28'7.40"N	114°27'17.60"E
24	22°32'41.90"N	114°27'18.50"E
25	22°33'43.20"N	114°26'2.30"E
26	22°34'6.00"N	114°19'58.70"E
27	22°34'0.00"N	114°18'32.70"E
28	22°33'55.80"N	114°16'33.70"E
29	22°33'20.60"N	114°14'55.20"E
30	22°33'2.60"N	114°14'13.40"E
31	22°32'37.20"N	114°14'1.10"E

Source: http://www.hydro.gov.hk/useful/hkboundary.htm

Vessel Coverage

1.4.2. This Study covers emissions estimated from OGVs and RVs that berthed in Hong Kong, but not LVs or transit vessels (see paragraph 1.1.5 for explanations). By definition, OGVs are vessels that sail between Hong Kong and ports that are beyond the river trade limits as defined by MD. RVs are defined in accordance with the Shipping and Port Control Ordinance, Cap.313, Laws of Hong Kong, as those travelling between Hong Kong and ports that lie within the river trade limits.

1.4.3. River trade limits are defined as the waters in the vicinity of Hong Kong, broadly including the Pearl River, Mirs Bay and Macau, and other inland waters in Guangdong and Guangxi which are accessible from waters in the vicinity of Hong Kong. The precise definition of river trade limits, as shown in Figure 1-2, refer to waters that fall within the following boundaries:

- To the East, meridian 114°30' East;
- To the South, parallel 22°09' North; and
- To the West, meridian 113°31' East.

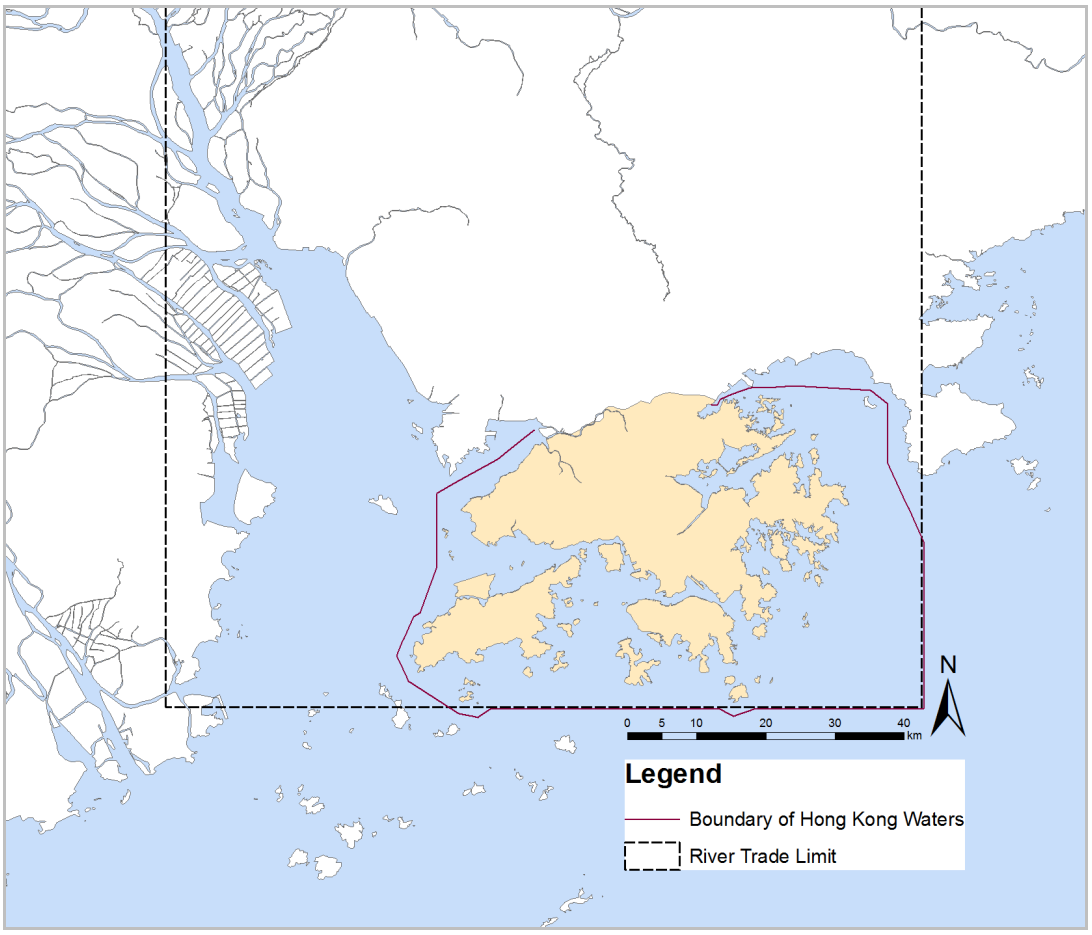

Figure 1-2 Boundary of Hong Kong Waters and River Trade Limits

1.4.4. It is important to note that some river vessels and locally licensed vessels are granted the right to operate both within and beyond the river trade limits. Whenever they operate beyond that limit, the voyage will be classified as an ocean-going journey. In that respect, many coastal voyages have been re-classified by MD as ocean-going calls according to this definition, even if the vessels involved were river vessels or local crafts, rather than the larger, sea-going vessels.[5]

[5] Caution should be taken to compare our emissions with overseas which used to refer OGVs as exclusively large vessels, say typically over 5,000 deadweight tonne (DWT) and several hundred feet long.

Study Base Year

1.4.5. The base year of the Study is 2007. With the base year inventory, emissions from 1990 to 2006 and from 2008 to 2020 were then backcasted and projected respectively.

1.4.6. A full calendar year of 2007 include all vessels that entered Hong Kong during the period starting from midnight of 1st January 2007 until just before midnight of 1st January of 2008. By this definition, vessels that entered Hong Kong in 2006 and lapsed into 2007 were excluded from the 2007 emission inventory. By the same token, vessels that entered Hong Kong in 2007 were included, even if the vessels stayed beyond 2007 and actually left Hong Kong in 2008.

1.4.7. One merit of this approach is that in an inventory year, all vessel calls are complete calls. Analysis of emission by vessel call is therefore more effective. In addition, the number of calls included in an inventory would tally with published vessel arrival numbers.

1.4.8. A minor disadvantage of this approach is that strictly speaking, some of the emissions included in an inventory year were actually produced by marine activities that took place in the following year. Likewise, emissions produced in an inventory year were taken away and re-assigned to the previous year if the vessels entered Hong Kong before the start of the inventory year. Nevertheless, it is reasonable to assume that their emissions cancel out each other and the error so introduced is negligible.

Pollutants and Emission Sources

1.4.9. Emissions of six criteria air pollutants were estimated for the inventory, including SO_2, NO_X, PM_{10}, $PM_{2.5}$, VOC, and CO.

1.4.10. In line with overseas emission inventories, three main sources of emission from OGVs were considered in this Study, namely main engine (ME), auxiliary engine (AE), and auxiliary boiler (AB). In other words, onboard incinerators or other minor sources were excluded.

1.4.11. Majority of OGVs use a single diesel engine as ME for propulsion. Diesel main engines are subdivided according to their engine speed (revolution per minute or RPM) at the crankshaft into high, medium and slow speeds; and split into 2-stroke or 4-stroke types. Apart from motor diesel, there are small percentages of diesel-electric and steam or gas turbine engines. See paragraphs 3.2.4 to 3.2.6 below for details.

1.4.12. AE provides electricity for lighting, cabin air conditioning, and refrigeration. In some vessels, they may be used to power hydraulic pumps, water pumps, air compressors, and other equipment such as bow thruster.

1.4.13. AB provides hot water or drive steam pumps. They are used to heat up residual fuel or cargo (e.g. in oil tanker) to reduce its viscosity.

1.4.14. Two main sources of emission from RVs are ME for propulsion and AE for onboard electricity. Majority of ME uses diesel engine with few gas turbine. As all RVs are

assumed to use distillate that do not require heating, there is no AB onboard.

1.5. Structure of the Report

1.5.1. This Final Report is organized into nine parts and seventeen chapters.

1.5.2. Parts I and II set the scene for the readers. After this introductory Part I, which provides background, context and scope of the Study, the process of data collection and summary of findings will be consolidated in Part II (Chapter 2).

1.5.3. Parts III to VI represent the core of this Final Report, with prime focus on marine vessels emission inventory. In Part III, compilation of inventory for 2007 (base year) will be explained (Chapters 3 to 5), and uncertainty of the inventory will also be discussed (Chapter 6). Part IV (Chapters 7 to 9) then switches focus to the historical inventory of 1990 to 2006. It is followed by Part V on emission projection for 2008 to 2020, based on a business-as-usual (BAU) or uncontrolled case (Chapters 10 to 12). In Part VI, the spatial and temporal dimension of marine vessels emission will be charted and explained (Chapters 13 and 14).

1.5.4. The focus of this Study is the emission inventory, on which effective policy and control measures can be formulated in reducing marine emissions, thus improving air quality and protecting public health. In this regard, Parts VII and VIII briefly go beyond the inventory to touch upon air dispersion modeling for ambient air quality using SO_2 as a surrogate (Chapter 15), and emission control policy assessed by comparing several strategies (Chapter 16).

1.5.5. Finally in Part IX (Chapter 17), contributions of the current Study will be highlighted, and recommendations for further improvement will also be made.

PART II DATA COLLECTION AND SURVEY

2. DATA REQUIREMENTS AND COLLECTION

2.1. Objectives of Data Collection

2.1.1. The main objective of the data collection exercise was to gather relevant information of marine vessels and vessels activities for compiling a marine vessels emission inventory for Hong Kong.

2.1.2. In addition, representative and local data were collected to reflect the local profiles of marine activities in Hong Kong, and to fill the data gaps in previous emission inventories, in order to reduce uncertainties of marine emission estimates.

2.2. Data Requirements

2.2.1. Generally speaking, information required for this Study included (a) vessel call information, (b) vessel characteristics data, (c) vessel activity and movement information, (d) engine activity and fuel use information, and (e) emission factors. Details of information were collected down to vessel class and tonnage or passenger carrying capacity (PAX) sub-class as far as possible and practical.

2.2.2. For vessel classification, MD classifies both OGVs and RVs according to the known specific function of the vessel. This classification system has been used for publication like *PHKST*, and it was basically adopted in this Study, as follows:

- Chemical Carrier/Tanker;
- Conventional Cargo Vessel;
- Cruise/Ferry;
- Dry Bulk Carrier;
- Fishing/Fish Processing Vessel;
- Fully Cellular Container Vessel (FCCV);
- Gas Carrier/Tanker;
- Lighter/Barge/Cargo Junk;
- Oil Tanker;
- Pleasure Vessel;
- Roll On/Roll Off;
- Semi-container Vessel;
- Tug; and

- Others[6]

2.2.3. As vessel characteristics and operation may vary between small and large vessels, efforts were made to collect cargo vessel information down to the deadweight tonnage (DWT) sub-class level to offer greater details. For example, given the importance of FCCV among all the OGVs, eight DWT sub-classes were defined as follows:

- Under 10,000;
- 10,000 – 19,999;
- 20,000 – 29,999;
- 30,000 – 39,999;
- 40,000 – 49,999;
- 50,000 – 74,999;
- 75,000 – 99,999; and
- 100,000 and above

2.2.4. This is consistent with the seven DWT sub-classes used by MD for FCCV, except that the 50,000 to 99,999 DWT sub-class was split further into two in this Study (50,000 to 74,999 and 75,000 to 99,999) to account for their growing importance in recent years.

2.2.5. On the other hand, ocean-going Cruise/Ferry were classified as regular and non-regular callers according to their home ports and business nature, with the former mainly related to gambling-oriented short cruises and the latter to longer sightseeing voyage. They were further split into five PAX sub-classes.

2.2.6. All the remaining OGV types were split into five DWT sub-classes, except Fishing/Fish Processing Vessel, Lighter/Barge/Cargo Junk, Pleasure Vessel and Tug, which were considered as small vessels.

2.2.7. For RVs, all cargo carrying vessels or river trade vessels (RTVs) were classified into three gross registered tonnage (GRT) sub-classes, namely (a) less than 500, (b) 500 to 999, and (c) 1,000 and above, which is consistent with EPD's past practice and historical data. For passenger RVs, they were grouped under Macau Ferry and PRD Ferry, and then by engine type, destination or berthing terminal where appropriate.

Vessel Call Information

2.2.8. The historical number of call each year by vessel type over the entire study period from 1990 to 2010 was collected for the Study, to determine the frequency of vessel entry into Hong Kong and the magnitude of vessel activities within Hong Kong waters, both of which are important factors determining the level of ship emissions.

[6] Others include car carrier, OBO (ore/bulk/oil) carrier, other cargo vessel, other fluid carrier, and other vessel.

2.2.9. Vessel call data for year 2007 was collected in greater details for better emission estimation of the base year, including:

- Vessel name;
- Vessel identification number of Hong Kong's MD;
- Vessel type;
- GRT;
- Net registered tonnage (NRT);
- DWT;
- Arrival time;
- Departure time;
- Last port of call; and
- Next port of call.

Vessel Characteristics

2.2.10. For each identified vessel, the following information was collected as far as possible to facilitate emission estimation (some of the fields are only applicable to OGVs):

- Vessel registration information (e.g. vessel name, ex-names, International Maritime Organization (IMO) number, call sign, and flag);
- Construction information (e.g. keel laid date, launch date, and delivery date);
- Vessel class information (e.g. main vessel type, and vessel sub-type);
- Vessel size information (e.g. length overall (LOA), GRT, NRT, and DWT);
- ME information (e.g. number of engine, model, make, builder, engine speed, engine type, total engine power, maximum RPM of propulsion unit(s), engine stroke, cylinder bore, cylinder stroke, vessel service speed, and vessel maximum speed);
- AE information (e.g. number of engine, model, make, builder, and total engine power);
- AB information (e.g. number of boiler, and boiler fuel rate); and
- Other information for specific vessel types (e.g. maximum total number of containers in TEU, and maximum number of reefer containers)

Vessel Activity and Movement

2.2.11. Vessel activity is important to determine time-in-mode of vessel operation. In

general, vessel activity consists of movements (including arrival, departure and shifts) and non-movements (hotelling). Arrivals are inbound trips (or calls) from open sea to a terminal or an anchorage. Departures are outbound trips (or calls) from a terminal or an anchorage to open sea. Shifts are movements from one terminal/anchorage to another, as some vessels often make multiple stops whilst in Hong Kong waters. Usually all shifts within a trip or call are grouped together to be reported as one, with total time as time-in-port, that is, time between first berthing and last berthing. A vessel is hotelling when it is stationary. Due to insufficient information related to berthing locations and berthing time, shifting and the additional emissions associated with it were not considered in the Study. With respect to vessel activity and movement, the following information were collected for analysis:

- Vessel arrival time (ATA) and departure time (ATD) (defined by MD as the times when a vessel arrived at the first and departed from the last berthing locations respectively);
- Time when a vessel enters into Hong Kong waters (ENT);
- Time when a vessel departs from Hong Kong waters (EXR);
- Vessel time-in-mode;
- Berthing locations including terminal/anchorage;
- Vessel service schedule; and
- Vessel speed.

Engine Activity and Fuel Use Information

2.2.12. Engine activity and fuel use information are important determinants of emission factors. In this Study, information listed below were gathered for different vessel types and vessel operation modes:

- Fuel type and fuel sulphur content;
- Fuel switching (if applicable);
- Fuel consumption (if available);
- ME and AE load factors; and
- AB energy information.

Emission Factors

2.2.13. As locally derived emission factors for marine vessels are not available, emission factors derived for and adopted in the latest marine emission studies or marine vessels emission inventories elsewhere in the world were examined, adapted and applied in this Study.

2.3. Data Sources

2.3.1. Figure 2-1 below summarizes data requirements, main data sources and emission estimation methodology of this Study. It identifies the main sources of information as follows:

- MD;
- Lloyd's Register of Ships (LRS);
- Marine vessel surveys;
- Personal interviews; and
- Other data sources

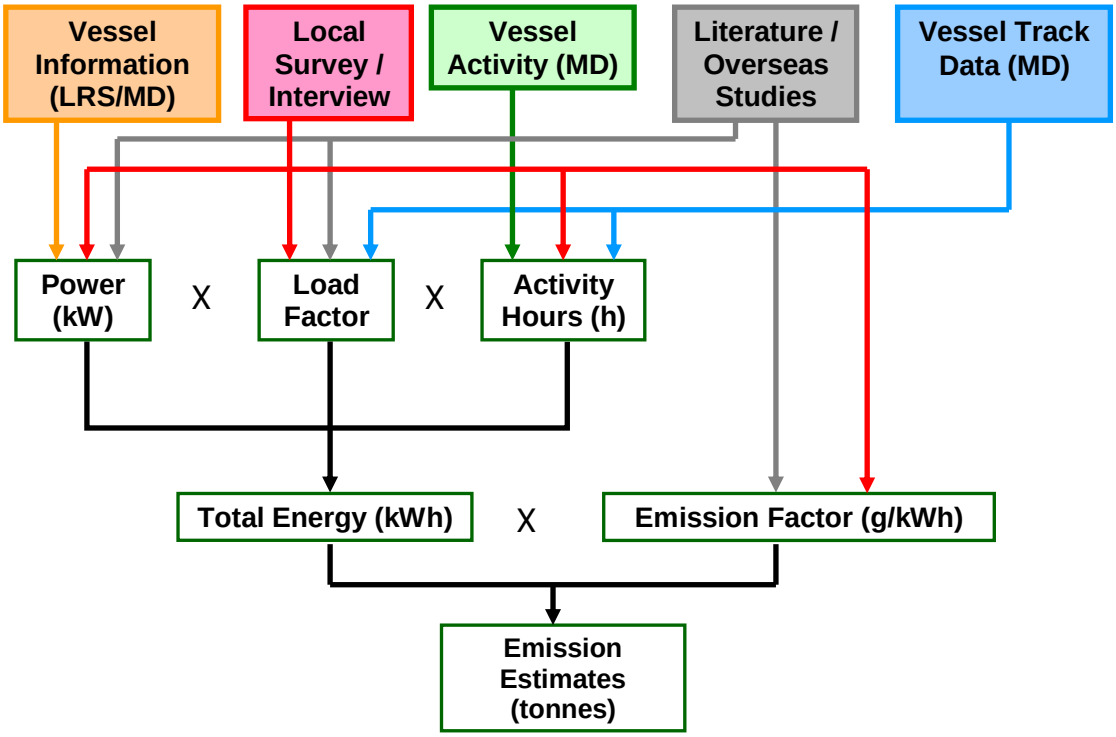

Figure 2-1 Data Requirements and Emissions Estimation

Marine Department

2.3.2. MD of the HKSAR Government was the main source of vessel call information in this Study.

2.3.3. OGVs and RTVs are required to submit Pre-Arrival Notification (PAN) to MD before entering Hong Kong waters. Vessel arrival and departure statistics are regularly published in MD's statistical reports such as *PHKST*.

2.3.4. Besides, under MD's Vessel Traffic Management System (VTMS), participating vessels (including all OGVs, RTVs of over 1,000 GRT, and RTVs carrying dangerous goods) are required to report their movements to MD. MD's Vessel Traffic Centre (VTC) publishes a series of eight current reports as follows:

- Due To Enter Hong Kong Report;
- Intend To Depart Hong Kong Report;
- Enter Hong Kong Water Report;
- Depart Hong Kong Water Report;
- Vessel In Port Report;
- Vessel Activity Report (VAR);
- Buoy Utilization Report; and
- Transit Vessel Report.

2.3.5. All reports are updated daily at 6:00 am and are accessible on MD's website (http://www.mardep.gov.hk/en/pub_services/arridepa.html). They contain useful information in determining the number of vessel arrivals and departures, as well as characterizing typical vessel movements and activities in the port of Hong Kong.

2.3.6. In addition, MD's VTC employs twelve shore-based radars to provide surveillance coverage of the Hong Kong navigable waters. The information of all tracked vessel movements are relayed via microwave link to VTC for central processing and displayed on electronic monitors as traffic images. The system is capable of automatically receiving and displaying vessel information such as vessel name, vessel type, call sign, GRT, overall length, navigating speed, and coordinating location, transmitted by the Automatic Identification System (AIS) installed on the vessels. These vessel track data has been a useful resource for analysing vessel movement characteristics, such as vessel routes, berthing locations, vessel speed and time-in-mode information, as well as understanding the spatial and temporal distribution of marine emissions.

2.3.7. MD was also the key source of RTV information, which was a major data gap in past inventories. Marine Offices of MD's Licensing and Port Formalities Section collect and keep a record of RTV's trading certificate as one of the port formality requirements. These certificates are kept in hard copies for one year before disposal. Since most RTVs are regular visitors to Hong Kong, the trading certificates submitted to MD every time they enter Hong Kong waters is an important source of information for RTV particulars, such as vessel tonnage and engine power. However, not all the trading certificates submitted include main and auxiliary engine power ratings, as such information is not mandatorily required.

Lloyd's Register of Ships (LRS)[7]

2.3.8. LRS has been widely used as the main resource for acquiring vessel characteristics information. LRS is compiled of an array of detailed information of vessels with GRT of 100 and above, and it is the largest (but not complete) database of commercial vessels in the world, containing detailed information of over 160,000 vessels in their latest version. Vessels classified by Lloyd's Register are included in the database with high accuracy and completeness. Vessels classified by other classification societies may not be included in the database, or included with incomplete data.

2.3.9. To estimate emissions, information of all identified vessels was retrieved from the database by using one or a combination of identifiers, such as vessel name, IMO number and call sign. Majority of the vessel information required in this Study as listed in paragraph 2.2.10 were provided by LRS, except AE and AB information.

Marine Vessel Surveys

2.3.10. Engines and boiler activity information were also required to estimate emissions. However, there is no mandatory requirement for vessels to provide such information to any government agencies in Hong Kong, nor are they complete in LRS. While marine vessel surveys were conducted in the past by other major ports, such as the Vessel Boarding Programme in Port of Los Angeles (PoLA) and Port of Long Beach (PoLB), they could at best serve as a general reference as local vessel activity profiles here in Hong Kong could be quite different from those of the California ports.

2.3.11. In this respect, marine vessel surveys were planned and conducted in 2009 for (a) OGVs; (b) RTVs; and (c) passenger ferries sailing between Hong Kong and Macau.[8] The main objective of the Survey was to collect information of vessel movements, and engine and boiler operations within Hong Kong waters so as to better estimate marine vessel emissions.

2.3.12. With the support of MD and other trade associations of the maritime sector, the surveys were carried out on a voluntary basis.

Personal Interviews

2.3.13. To supplement information collected from the sources listed above, a series of personal interviews were conducted during the course of the Study with various trade associations, operators, shipping agents, fuel suppliers, and other members of the maritime trade.

[7] Lloyd's Register of Ships (LRS) is one of many maritime information products provided by Lloyd's Register – Fairplay (LRF), and it is offered in different formats, such as web-based format, DVD/CD-based package with Microsoft Windows user interfaces, and printed version. PC Register of Ships, which is a DVD/CD-based package, was subscribed for this Study. LRF's database is comprised of several component parts, including the AIS Movement Database, Ships Database, Companies Database, Ports Database, and News Archive Database. Major data sources include Flag authorities, classification societies, owner and manager advice, government and maritime authorities, ship builders, and other associated companies. In June 2009, IHS Inc. acquired LRF to become IHS Fairplay.

[8] A survey form was designed for passenger ferries operating between Hong Kong and PRD ports, but no operator was willing to participate in the survey.

2.3.14. This was a worthwhile exercise for a number of reasons: (a) information gathered in these exercises helped fill data gaps, notably typical, local operation characteristics of vessels plying in Hong Kong waters; (b) interviews with experienced members of trade were an important means to understand and assess operational behaviour of different types of vessels; (c) information collected was also used to validate secondary data collected from other sources; and (d) the local trade was an alternative resource for historical data and past operational practice, like fuel use and vessel speed.

Other Data Sources

2.3.15. EPD has been compiling air pollutant emission inventory for Hong Kong since 1990, and has therefore gathered a wealth of information related to vessel arrivals and operation. They were an important complementary source of information.

2.3.16. Apart from local sources, the Study has also drawn upon experience and relevant information from overseas marine emission studies and emission inventories. In particular, two recent documents on marine vessels methodology and emissions studies were used: (a) *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories – Final Report* by ICF International for USEPA issued on April 2009 (*ICF 2009 Report*); and (b) *Port of Los Angeles Inventory of Air Emissions – 2008* by Starcrest Consulting Group published on December 2009 (*PoLA 2009 Report*). Both reports incorporated latest emission factors used by the European Community (EC)[9]. Other reports used in the Study were listed in the Reference section of this Final Report.

2.4. Ocean-going Vessels

2.4.1. In this section, data collection information specific to OGVs are elaborated further.

Vessel Arrival Number

2.4.2. Vessel arrival number (VAN) of OGVs by vessel type was provided by MD's *PHKST*, accessible from MD's website including issues published since 1999. VAN of years from 1990 to 1998 was obtained from MD through EPD's past data requests.

2.4.3. *PHKST* also provided the number of vessels berthed at KCCT each year by DWT sub-class. As the vast majority of vessels berthing at KCCT were FCCV, the number of FCCV that berthed at locations outside KCCT by DWT sub-class, such as mid-stream locations, was derived[10], assuming that all vessels at KCCT are FCCV. The only exception is year 2007 when vessel activity reports were analyzed to provide such data.

2.4.4. To supplement the published information listed above, vessel call information for 2007 was also requested from MD for cross-checking. Information essential to

[9] Entec UK Limited (2002) *Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community*, prepared for the European Commission, July 2002.

[10] This is based on the assumption that all vessels berthed at Kwai Chung Container Terminals were container vessels. In reality, large vessels such as cruise ships may pull alongside container terminals, but the number of such incidence each year was negligible.

emission estimation, such as vessel name, arrival time and departure time for each call were provided in this data set.

Vessel Activity Reports (VAR)

2.4.5. VAR is produced, updated and uploaded everyday to MD's website (http://www.mardep.gov.hk/en/pub_services/arridepa.html) in both HTML and XML formats. It keeps a daily record of OGV activities within Hong Kong waters, including information such as arrival and departure time, as well as berthing location(s) and berthing time. Past VARs will be kept for seven days before removal from the website. See also paragraph 2.3.4 for more information about MD's web-based reports.

2.4.6. In this Study, daily VARs of 2007 were analysed. Based on a series of activity records of a particular vessel during a particular call, which usually spanned over a couple of days, the movement pattern of that vessel was visualized based on the time and location information provided in the VARs.

2.4.7. With these time and location information, total call duration spent by a particular vessel within Hong Kong waters was derived by deducting ENT time (time when a vessel enters Hong Kong waters) from EXR time (time when a vessel leaves Hong Kong waters). Berthing duration was derived by deducting berthing start time from berthing end time. The difference between total call duration and berthing duration was the combined time of slow cruise and maneuvering.

2.4.8. The accuracy of these estimations, however, depends on the completeness and accuracy of the information provided in the VARs. This is, however, a limitation of VARs. For example, it was found that the VARs of 2007 yielded a total of 32,069 calls (of ocean-going vessels), which was 5,081 calls short of the number of OGV calls published by MD's *PHKST* (37,150). The difference between the two numbers is significant (13.7%). In other words, some of the OGV calls were not included in the VARs.

2.4.9. Besides, only 28,073 calls recorded in the VAR (out of 32,069) were complete calls. For the incomplete calls, either ENT time or EXR time was missing, or berthing time information was incomplete. In some cases, there was no berthing location information.

2.4.10. Given the limitations listed above, all the incomplete calls were discarded, and VAR was used as a reference for vessel activities with a couple of conditions: (a) an upper bound value of 8 hours was set for both the inbound and outbound slow cruise time, in order not to misinterpret incomplete calls with missing berthing locations as complete calls. The value was determined based on consultation with trade about the reasonable inbound sailing time to the first berthing location and outbound sailing time from the last berthing location; and (b) the calls that met such criteria, or the 'good calls', were used only if a match could be found amongst other vessel call data provided by MD. The number of 'good calls' from VAR that were used for 2007 emission estimation is listed in Table 2-1 below by vessel class:

Table 2-1 Number of VAR Good Calls used in 2007 Emission Estimation

Vessel Type	Total Calls	Good Calls
A. Chemical Carrier/Tanker	452	283 (62.6%)
B. Conventional Cargo Vessel	4,664	2,375 (50.9%)
C. Cruise/Ferry	3,562	n.a.
D. Dry Bulk Carrier	1,362	699 (51.3%)
E. Fishing/Fish Processing Vessel	509	256 (50.3%)
F. Fully Cellular Container Vessel	23,563	7,850 (33.3%)
Below 10,000	*7,505*	*616 (8.2%)*
10,000 – 19,999	*4,190*	*1,501 (35.8%)*
20,000 – 29,999	*3,217*	*1,389 (43.2%)*
30,000 – 39,999	*2,120*	*929 (43.8%)*
40,000 – 49,999	*1,485*	*889 (59.9%)*
50,000 – 74,999	*3,309*	*1,659 (50.1%)*
75,000 – 99,999	*888*	*475 (53.5%)*
≥ 100,000	*849*	*392 (46.2%)*
G. Gas Carrier/Tanker	342	129 (37.7%)
H. Lighter/Barge/Cargo Junk	152	0
I. Oil Tanker	1,400	683 (48.8%)
J. Pleasure Vessel	127	0
K. Roll On/Roll Off	461	293 (63.6%)
L. Semi-container Vessel	190	33 (17.4%)
M. Tug	249	32 (12.9%)
N. Others	119	49 (41.2%)
Total	**37,152**	**12,682 (34.1%)**

n.a. = Not applicable. Emissions of cruise ship were estimated by individual vessels, not by single calls, as majority were regular callers, providing regular services with similar routings. 'Good calls' were therefore not used to derive different time-in-mode for cruise ships.
Figures in bracket are percentage share.

Vessel Track Data

2.4.11. Digital vessel track data has been captured by VTC of MD for marine traffic control. It is a snapshot of tracks in 3-second intervals that fall within the area covered by the radar system. Vessels that carried ship-borne AIS transponder are captured and these are called AIS tracks or simply vessel tracks herewith. (see paragraph 2.3.6 for more information)

2.4.12. The vessel track data contains a number of data fields that are useful for the analyses of vessel movement and activity, such as vessel name, vessel type identifier, vessel position, vessel speed, and data update time. With these information, vessel track data was used in the Study to determine typical vessel routes, call duration, time-in-mode characterization of a single call, speed profile of the vessel, and main engine load factor by the Propeller Law. It is an important and new source of information for marine vessels emission estimation in Hong Kong, as it provides a

spatial dimension to the inventory. Besides, information generated from the vessel track data was used to verify data collected from other sources.

2.4.13. In the Study, two weeks' of vessel track data in 30-second intervals[11], from 27th August to 9th September 2007, was analyzed. This was a randomly selected period in the base year, subject to data availability from MD.

2.4.14. Vessel tracks were plotted on different maps by vessel type to show movement and berthing patterns (see Figure 2-2 for an example). Vessel track and speed profile of individual vessels were also plotted for detailed analyses of time-in-mode and vessel speed (Figures 2-3 and 2-4).

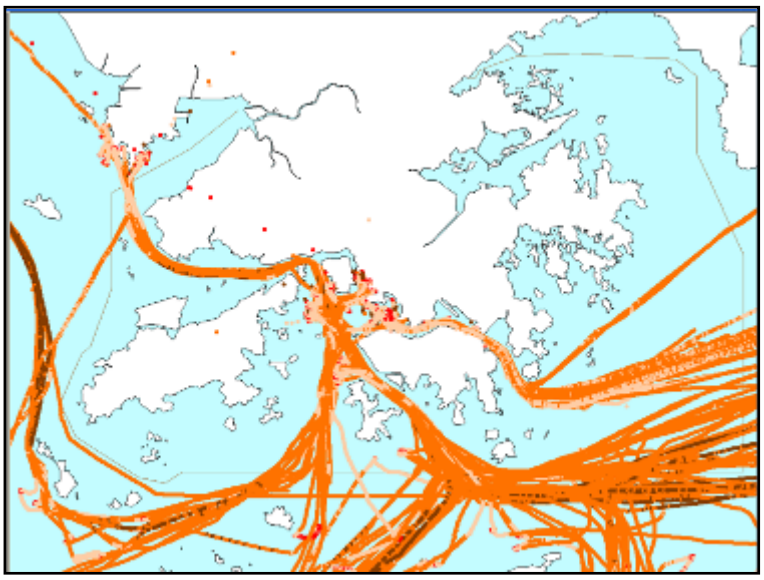

Figure 2-2 Sampled Container Vessel Tracks over the Two-week Period

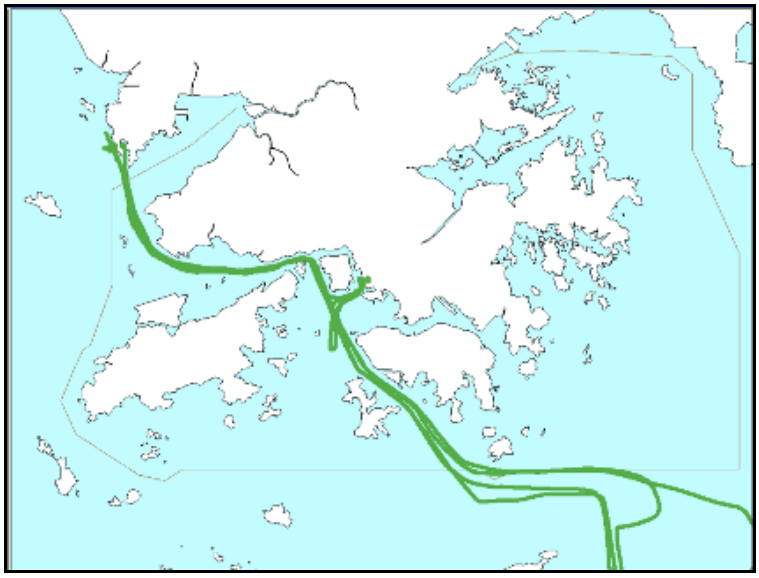

Figure 2-3 Vessel Track of a Sampled Container Ship

[11] As explained in paragraph 2.4.11, vessels are tracked at 3-second intervals. In this Study, data at 30-second intervals were requested to vastly reduce the number of data points, and in turn largely reduce data retrieval time for MD, and data processing time for the Consultant.

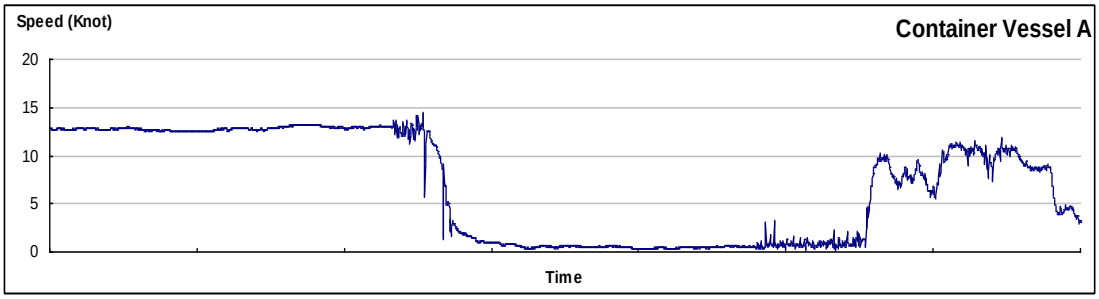

Figure 2-4 Speed Profile of a Sampled Container Ship

2.4.15. Table 2-2 below summarizes the number of calls processed in the vessel track data analysis. Most of the vessel types are well represented, except for fishing/fish processing vessel, lighter/barge/cargo junk, and pleasure vessel. Altogether 1,619 calls were identified, and 751 calls were processed (or 46%).

Table 2-2 Processed OGV Track Data (Number of Call) by Vessel Type

Vessel Type	Total Calls	Processed Calls
A. Chemical Carrier/Tanker	35	25 (71.4%)
B. Conventional Cargo Vessel	147	69 (46.9%)
C. Cruise/Ferry	140	60 (42.9%)
Regular callers	138	58 (42.0%)
Non-regular callers	2	2 (100%)
D. Dry Bulk Carrier	65	46 (70.8%)
E. Fishing/Fish Processing Vessel	3	0 (0%)
F. Fully Cellular Container Vessel	1091	470 (43.1%)
Below 10,000	89	29 (32.6%)
10,000 – 19,999	183	64 (35.0%)
20,000 – 29,999	154	55 (35.7%)
30,000 – 39,999	135	81 (60.0%)
40,000 – 49,999	107	52 (48.6%)
50,000 – 99,999	324	120 (37.0%)
≥100,000	99	69 (69.7%)
G. Gas Carrier/Tanker	14	6 (42.9%)
H. Lighter/Barge/Cargo Junk	0	n.a.
I. Oil Tanker	92	63 (68.5%)
J. Pleasure Vessel	0	n.a.
K. Roll On/Roll Off	14	4 (28.6%)
L. Semi-container Vessel	4	2 (50.0%)
M. Tug	8	4 (50.0%)
N. Others	6	2 (33.3%)
Total	**1,619**	**751 (46.4%)**

n.a. not applicable
Figures in bracket are percentage share.

Lloyd's Register of Ships (LRS)

2.4.16. LRS was used in this Study as the most comprehensive database of marine vessel particulars for filling data gaps, as well as for data verification. For more information about this data source, please refer to paragraphs 2.3.8 to 2.3.9.

2.4.17. Among all the data required in the Study, as listed in paragraph 2.2.10, engine information was the key area where LRS played a significant role, especially for OGVs.

2.4.18. ME and AE power are major factors determining the quantity of emission. In past marine emission inventories, ME power was estimated from vessel tonnage due to a lack of engine power information. In this Study, ME information of individual vessel was drawn directly from LRS, thus reducing the uncertainty factor of this parameter. Data fields related to ME were listed as follows:

- number of engine;
- model and make;
- builder;
- engine speed and type;
- total engine power;
- RPM of propulsion unit(s);
- engine stroke;
- cylinder bore and stroke; and
- vessel service speed and vessel maximum speed.

2.4.19. AE and AB information were also drawn from LRS, but they were very incomplete. As an alternative, AE to ME power ratios developed under the Oceangoing Ship Survey conducted by the California Air Resources Board (CARB) in 2005 were used to derive AE power from ME power provided by LRS in general. As for the estimation of emission from on-board boilers, AB power information is not necessary. Instead, AB energy defaults used by PoLA were used to derive a set of AB energy defaults applicable to vessels visiting Hong Kong. See paragraphs 3.2.19 and 3.2.20 for more information.

2.4.20. Engine speed information (slow, medium or high), based on maximum RPM of the engine, was extracted from LRS for each vessel for the selection of emission factors. For vessels with no engine speed information, the number of strokes was considered to determine engine speed.

2.4.21. Similarly, engine type information was carefully considered as different emission factors were used for diesel engine, steam turbine engine and gas turbine engine. For diesel-electric engine, combined ME power was used for both propulsion and as AE power, with a ratio of 1:0.278 between the two based on *ICF 2009 Report*.

2.4.22. Apart from engine information, construction information such as vessel keel date was also considered in this Study to determine the reduction of air pollutant emissions as a result of implementation of advanced technology and IMO regulations requirement. For example, vessels constructed on or after 1st January 2000 and before 1st January 2011 are required to satisfy Tier 1 standard of IMO Regulation 13 on NO_X emission with each of their marine diesel engine with a power output of over 130 kW. For more discussion on emission reduction technologies of vessels and their impact on emission estimation, see paragraphs 3.2.39 to 3.2.43 of this Final Report.

2.4.23. In 2007, there were 37,152 OGV arrivals in Hong Kong, involving 4,738 unique vessels.[12] Among those vessels, 4,347 or 92% were matched with LRS.

Marine Vessel Survey

2.4.24. With the support of MD, its Port Operations Committee, and Local Vessels Advisory Committee, as well as trade associations such as Hong Kong Shipowners Association (HKSOA), Hong Kong Liner Shipping Association (HKLSA), the Shipping and Transport Committee of the Hong Kong General Chambers of Commerce (HKGCC), and Hong Kong Pilots Association (HKPA), a marine vessel survey was carried out between 1st February and 30th April 2009 for OGVs. Ship masters or chief engineers were asked to complete and return a survey form (see Appendix A) on a voluntary basis.

2.4.25. Survey forms were prepared in both English and Chinese versions, and in both hard and soft copies (in MS Word and in PDF formats). The forms were distributed to vessels calling at or transiting Hong Kong through a number of channels:

- HKPA distributed survey forms to vessels that patronized pilotage service during the study period. Pilotage is compulsory in Hong Kong for all vessels over 3,000 GRT (both OGVs and RVs);
- HKLSA, HKSOA and the Shipping and Transport Committee of HKGCC either distributed survey forms to their members or asked their members to download and submit an electronic survey form through the internet; and
- A simple web page (http://ienv.ust.hk/marine) was designed with downloadable survey forms in both English and Chinese version for easy access.

2.4.26. In order to improve the response rate of dry bulk carriers, chemical/gas carriers and oil tankers, the survey period for the aforementioned vessel types was extended to the end of 2009. Additional arrangements were made with companies which regularly receive OGVs at their loading and unloading facilities. Survey forms were sent to these companies and their agents in electronic format.

2.4.27. At the end of the survey period, altogether 277 survey forms were returned – 197 from OGVs calling Hong Kong, 76 from OGVs transitting Hong Kong, and 4 from RVs (Table 2-3). In this section, discussion will focus on the 273 returns from OGVs.

[12] The 4,738 unique vessels contributed a total of 36,324 identified calls. There were 828 unidentified calls. See Table 3-1 for more information.

Table 2-3 Summary Table on Survey Returns

Vessel Type	Number	Percentage
Ocean-going vessel calling	197	71.1%
Ocean-going vessel transit	76	27.4%
River vessel calling	4	1.4%
Total	**277**	**100%**

2.4.28. Frequent caller – Over the survey period, a number of OGVs had called or made transit through Hong Kong waters more than once, and had contributed more than one survey form in the Study. Frequent caller is herewith defined as vessels visiting Hong Kong six times or more. It is a fair reflection that many vessels visiting Hong Kong are frequent callers. From the survey returns, 134 unique OGVs (out of 240) were frequent callers during 2008 based on the definition above.

2.4.29. Vessel Type Distribution – Among all OGVs, the majority was fully cellular container vessel (88.6%), followed by oil tanker (3.7%), and chemical carrier (2.6%). There was no sample for fishing vessel, lighter/barge/cargo junk, pleasure vessel, roll on/roll off, tug boat, and others (Table 2-4).

Table 2-4 Survey Returns (All OGVs) by Vessel Type

Vessel Type	Number	Percentage
A. Chemical Carrier/Tanker	7	2.6%
B. Conventional Cargo Vessel	3	1.1%
C. Cruise/Ferry	3	1.1%
D. Dry Bulk Carrier	3	1.1%
E. Fishing/Fish Processing Vessel	0	0%
F. Fully Cellular Container Vessel	242	88.6%
G. Gas Carrier/Tanker	3	1.1%
H. Lighter/Barge/Cargo Junk	0	0%
I. Oil Tanker	10	3.7%
J. Pleasure Vessel	0	0%
K. Roll On/Roll Off	0	0%
L. Semi-container Vessel	2	0.7%
M. Tug	0	0%
N. Others	0	0%
Total	**273**	**100%**

2.4.30. Deadweight Tonnage – Table 2-5 shows that average DWT of all OGV samples was 59,947 tonnes. For individual vessel type, the three dry bulk carriers yielded an average of 104,363 tonnes, followed by 62,407 tonnes of FCCV (242 vessels), and 58,354 tonnes of oil tanker (10 vessels).

Table 2-5 Average DWT of Surveyed OGVs

Vessel Type	Number	Average DWT
A. Chemical Carrier/Tanker	7	32,657
B. Conventional Cargo Vessel	3	7,807
C. Cruise/Ferry	3	4,334
D. Dry Bulk Carrier	3	104,363
E. Fishing/Fish Processing Vessel	0	0
F. Fully Cellular Container Vessel	242	62,407
G. Gas Carrier/Tanker	3	28,564
H. Lighter/Barge/Cargo Junk	0	0
I. Oil Tanker	10	58,354
J. Pleasure Vessel	0	0
K. Roll On/Roll Off	0	0
L. Semi-container Vessel	2	7,835
M. Tug	0	0
N. Others	0	0
Total	**273**	**59,947**

2.4.31. Engine Power – Average ME power of the survey OGVs was 39,434 kW (Table 2-6). Among all vessel types, FCCV has the largest ME power (43,324 kW), to be followed by cruise ship (18,402 kW). On the other hand, cruise ship has the largest installed AE power of 8,042 kW, followed closely by FCCV in second place (7,783 kW). Average AE power of the samples was 7,236 kW (Table 2-7).

Table 2-6 Average Main Engine Power (kW) of Surveyed OGVs

Vessel Type	Number	Average ME Power
A. Chemical Carrier/Tanker	7	6,992
B. Conventional Cargo Vessel	3	2,805
C. Cruise/Ferry	3	18,402
D. Dry Bulk Carrier	3	9,070
E. Fishing/Fish Processing Vessel	0	0
F. Fully Cellular Container Vessel	242	43,324
G. Gas Carrier/Tanker	3	11,327
H. Lighter/Barge/Cargo Junk	0	0
I. Oil Tanker	10	9,730
J. Pleasure Vessel	0	0
K. Roll On/Roll Off	0	0
L. Semi-container Vessel	2	5,000
M. Tug	0	0
N. Others	0	0
Total	**273**	**39,434**

Table 2-7 Average Auxiliary Engine Power (kW) of Surveyed OGVs

Vessel Type	Number	Average AE Power
A. Chemical Carrier/Tanker	7	3,096
B. Conventional Cargo Vessel	3	1,560
C. Cruise/Ferry	3	8,042
D. Dry Bulk Carrier	3	1,500
E. Fishing/Fish Processing Vessel	0	0
F. Fully Cellular Container Vessel	241	7,783
G. Gas Carrier/Tanker	2	950
H. Lighter/Barge/Cargo Junk	0	0
I. Oil Tanker	9	2,155
J. Pleasure Vessel	0	0
K. Roll On/Roll Off	0	0
L. Semi-container Vessel	2	888
M. Tug	0	0
N. Others	0	0
Total	**270**	**7,236**

2.4.32. Fully Cellular Container Vessel – Sample distribution and average DWT of FCCV are summarized in Table 2-8. 70% of all the FCCV samples were large vessels with a DWT of 50,000 or above.

Table 2-8 Sample Distribution and Average DWT of FCCV

DWT Class	Number	Percentage	Average DWT
Below 10,000	5	2.1%	8,596
10,000 – 19,999	14	5.8%	15,749
20,000 – 29,999	12	5.0%	23,050
30,000 – 39,999	24	10.0%	36,270
40,000 – 49,999	16	6.6%	43,115
50,000 – 74,999	113	46.7%	61,829
75,000 – 99,999	25	10.3%	94,551
≥ 100,000	33	13.6%	110,656
Total	**242**	**100%**	**62,507**

2.4.33. Average ME and AE power of the survey FCCVs by DWT class are tabulated in Tables 2-9 and 2-10 below. One FCCV belonging to DWT Class 75,000 to 99,999 did not provide auxiliary engine information in the survey form, and the information could not be found in LRS, hence the total number of FCCV with auxiliary engine data is 241.

Table 2-9 Average Main Engine Power (kW) of Surveyed FCCV

DWT Class	Number	Percentage	Average ME Power
Below 10,000	5	2.1%	6,878
10,000 – 19,999	14	5.8%	9,756
20,000 – 29,999	12	5.0%	15,265
30,000 – 39,999	24	10.0%	25,856
40,000 – 49,999	16	6.6%	32,388
50,000 – 74,999	113	46.7%	46,168
75,000 – 99,999	25	10.3%	67,166
≥ 100,000	33	13.6%	63,498
Total	**242**	**100%**	**43,324**

Table 2-10 Average Auxiliary Engine Power (kW) of Surveyed FCCV

DWT Class	Number	Average AE Power
Below 10,000	5	1,830
10,000 – 19,999	14	3,656
20,000 – 29,999	12	3,451
30,000 – 39,999	24	5,192
40,000 – 49,999	16	4,452
50,000 – 74,999	113	7,406
75,000 – 99,999	24	13,319
≥ 100,000	33	12,774
Total	**241**	**7,783**

2.4.34. Auxiliary Boiler – Information provided by the survey forms on AB capacity was unsatisfactory. Only 223 OGV samples returned with boiler capacity data, ranging from 0.3 to over 100 ton of steam per hour. Another 14 vessels instead filled in boiler thermal output in kW, ranging from 1,040 kW to 13,500 kW. The overall thermal output for all 237 samples ranges from 210 to 70,000 kW[13]. The remaining vessels did not provide any information.

2.4.35. As for the use of AB, provision of hot water and the heating of residual oil were the most frequent answers quoted from the returns.

2.4.36. On-board Fuel Quality – For all the surveyed OGVs, average sulphur contents of primary fuel carried on-board for ME, AE, and AB were 2.95%, 2.78% and 2.8%, respectively (Table 2-11). Primary fuel refers to fuel used at sea or in normal circumstances, and thus its fuel content was considered for emission calculation. Secondary fuel, also covered in the survey, is fuel being used in some areas for compliance of local regulation or special circumstances. Therefore, findings about

[13] Based on products of Aalborg, 700 kWh thermal output is equivalent to 1 tonne steam output. See http://www.aalborg-industries.com/marine_boilers_and_heat_exchangers/.

secondary fuel were not used for emission estimation.

Table 2-11 Average Sulphur Content of Primary Fuel

	Main Engine		Auxiliary Engine		Boiler	
	Sample Size	Average Sulphur %	Sample Size	Average Sulphur %	Sample Size	Average Sulphur %
Overall	273	2.95	273	2.78	273	2.8
HFO	273	2.95	257	2.92	261	2.9
MDO	0		10	0.58	8	0.6
MGO	0		6	0.52	4	0.4

Keys: HFO = Heavy Fuel Oil; MDO = Marine Diesel Oil; MGO = Marine Gas Oil

2.4.37. Fuel Switching – According to the returned survey forms, vessels that switched fuel within Hong Kong waters accounted for a small percentage, ranging from 4% for ME, 5% for AE, and 1% for AB. (Table 2-12)

Table 2-12 Fuel Switching Practice Findings from Survey Returns

	Main Engine		Auxiliary Engine		Boiler	
Sample Size	273		273		273	
Switching within HK waters	**12**	**4%**	**15**	**5%**	**3**	**1%**
HFO to MDO	9	3%	8	3%	2	1%
HFO to MGO	2	1%	6	2%	0	0%
HFO to LNG	1	0%	1	0%	1	0%
No Switching	**261**	**96%**	**258**	**95%**	**270**	**99%**

Keys: HFO = Heavy Fuel Oil; MDO = Marine Diesel Oil; MGO = Marine Gas Oil; LNG = Liquefied Natural Gas

2.4.38. Effective Fuel Sulphur Content – Based on sulphur content of primary fuel and switched fuel, and fuel switching practice information provided by the survey returns, effective fuel sulphur contents for ME, AE and AB were estimated and shown in Table 2-13:

Table 2-13 Effective Fuel Sulphur Contents

	Main Engine		Auxiliary Engine		Boiler	
	Sample Size	Average Sulphur %	Sample Size	Average Sulphur %	Sample Size	Average Sulphur %
Overall	***273***	***2.83***	***273***	***2.64***	***273***	***2.77***
HFO	261	2.94	242	2.90	258	2.90
MDO	9	0.46	18	0.60	10	0.59
MGO	2	0.38	12	0.48	4	0.40
LNG	1	0	1	0	1	0

2.4.39. Adoption of Survey Findings – The marine vessels survey conducted in this Study, being voluntary in nature, did not yield many returns as some mandatory surveys

carried out in the United States (US). Nevertheless, it was still a useful exercise in collecting information about vessels that visited Hong Kong, some of which on a regular basis. This is important as the profile of vessels operating here in Hong Kong could be quite different from those operating in overseas ports, and a better understanding of the former would definitely improve Hong Kong's marine emission inventory. Some of the data collected in the survey, such as engine information and fuel quality, also served to fill past information gaps and to provide a second data source for cross-checking and data validation.

2.4.40. However, as the sample size was rather small, the Consultant has been careful in selecting and adopting local survey findings for the Study. After thorough discussion with EPD, decisions were made with respect to the use of survey findings as explained in the following paragraphs.

2.4.41. For general vessel information that would be used for classification, in particular tonnage information, data entered in the survey forms was fairly consistent with LRS, except for a few typing errors. As information provided by LRS is collected from reliable sources such as classification societies, it was used as the basis of vessels' general information.

2.4.42. Similarly, LRS was preferred over the surveyed ME information because of its reliability. In addition, the sampled ME information from the survey was insufficient. For the same reasons, ME load factors derived from MD's vessel track data were used, as the data covered tracks of about 750 vessel calls.

2.4.43. AE information was a major data gap in the past. To a certain extent, data collected from the survey had shed some lights on AE power, load factors during different operating modes, and load defaults for FCCV. However, due to the small sample size, some of the parameters derived from survey findings were quite different from the same parameters collected by PoLA under their Vessel Boarding Programme, which covered about 600 vessels from 2003 to 2009. As a result, the AE to ME ratio developed by CARB was used in this Study to estimate AE power. AE load factors (for all vessel types except FCCV) and AE load defaults (for FCCV only) were adapted from *PoLA 2009 Report*.

2.4.44. By the same token, AB energy defaults were adapted from *PoLA 2009 Report* for this Study.

2.4.45. As explained in paragraph 2.4.38, a set of effective fuel sulphur content parameters were derived for ME, AE and AB based on survey returns, ranging from 2.83% to 2.64%. (see also Table 2-13) This is very much in line with DNV Petroleum Services' fuel sulphur monitoring programme results. In 2005, average fuel sulphur content for heavy fuel oil (HFO) was 2.7%, and it dropped to 2.59% in 2006. The three year average (2007 to 2009) sulphur content in fuel oils was 2.46%.[14] Fuel sulphur content usually varies regionally, and historically Asia had an average sulphur content higher than the global average.[15]

[14] DNV (2009).
[15] See Endresen, O, et.al (2005).

Interviews with Marine Trade

2.4.46. In addition to the data collected as discussed in the previous sections, information provided by members of the marine trade during personal interviews had contributed significantly to the better understanding of the marine sector as a whole, and in some cases specific operational characteristics of particular vessel types. Key findings of the interviews were used to beef up various sections of this Final Report.

Information Adopted from Overseas Studies

2.4.47. It was explained earlier in paragraph 2.3.16 that where locally produced parameters are not available, overseas examples were studied and considered if appropriate.

2.4.48. In this Study, the following parameters were adopted from the latest overseas studies, with modification if necessary:

- ME and AE emission factors – based on ICF 2009 Report, with modifications adopted by Starcrest Consulting Group (2009) for PoLA;
- AE power ratios – based on CARB (2005);
- AE load factor – derived from Starcrest Consulting Group (2009) for PoLA;
- AE load defaults – based on Starcrest Consulting Group (2009) for PoLA; and
- AB energy defaults – based on Starcrest Consulting Group (2009) for PoLA.

2.5. River Vessels

2.5.1. In this section, data collection information related to RVs are discussed in greater details.

Vessel Arrival Number

2.5.2. VAN of RTVs by vessel type, and river passenger vessels by vessel type and destination was provided by MD's *PHKST*, published annually since 1999. VAN of years from 1990 to 1998 was obtained from MD through EPD's past data requests.

River Vessel Trading Certificate

2.5.3. Vessel characteristics information of RTVs trading between Hong Kong and the Pearl River Delta has been a major data gap for past emission inventories. In this Study, efforts were made to gather RTV information, such as vessel tonnage and engine power, in order to improve emissions estimation.

2.5.4. RTVs entering Hong Kong is required to submit its trading certificate as part of port formalities to Marine Offices of MD's Licensing and Port Formalities Section (see paragraph 2.3.7 for more information). For vessels that submitted a full copy of the trading certificate (as against those submitting only the first page that is required by MD), detailed vessel information such as engine particulars became available for this Study.

2.5.5. Between March and May 2009, RTV information was collected from the RV trading certificates archived in three of the eight marine district offices of MD in Hong Kong, namely Central Marine Office, Yau Ma Tei Marine Office, and Tuen Mun Marine Office. According to MD's advice, these three offices are the most popular ones for agents of RTVs to file their documentation.

2.5.6. For the record, data of 1,261 river vessels were collected. The distribution by vessel type is summarized in Table 2-14.

Table 2-14 River Vessel Records by Vessel Type

Vessel Type	Number of Record
A. Chemical Carrier/Tanker	2
B. Conventional Cargo Vessel	189
C. Cruise/Ferry	1
D. Dry Bulk Carrier	32
E. Fishing/Fish Processing Vessel	4
F. Fully Cellular Container Vessel	880
G. Gas Carrier/Tanker	0
H. Lighter/Barge/Cargo Junk	43
I. Oil Tanker	28
J. Pleasure Vessel	2
K. Roll On/Roll Off	1
L. Semi-container Vessel	27
M. Tug	34
N. Others	18
Total	**1,261**

2.5.7. Among all the records reviewed, 1,217 of them covered ME information. However, only 60 records had AE information.

Vessel Track Data

2.5.8. Vessel track data captured by VTC of MD not only covered OGVs but also some of the RVs that can be tracked by MD's radar system (see paragraph 2.3.6 for more information about the radar data).

2.5.9. From the vessel track data obtained from MD, movement tracks of river vessels and related data points were identified and extracted for further analysis. Altogether 55 container vessel calls, 7 conventional cargo vessel calls, and 5 oil tanker calls were studied (Table 2-15). Unfortunately for other vessel types, either there was no sample track, or the identified tracks were broken or incomplete for any meaningful analysis. Findings of the analysis had formed the basis of time-in-mode information for emission estimation.

Table 2-15 Processed RV Track Data (Number of Call) by Vessel Type

Vessel Type	Total Calls	Processed Calls
A. Chemical Carrier/Tanker	2	0 (0%)
B. Conventional Cargo Vessel	25	7 (28%)
F. Fully Cellular Container Vessel	116	55 (47.4%)
I. Oil Tanker	12	5 (41.7%)
Total	**155**	**67 (43.2%)**

Note: Nil calls for Cruise/ Ferry, Dry Bulk Carrier, Fishing/ Fish Processing Vessel, Gas Carrier/ Tanker, Lighter/ Barge/Cargo Junk, Pleasure Vessel, Roll On/ Roll Off, Semi-container Vessel, Tug, and Others.
Figures in bracket are percentage share.

Marine Vessel Survey

2.5.10. RTVs – In the marine vessels survey conducted mainly for OGVs, four survey forms were returned from RVs, including one container vessel, two conventional cargo vessels, and one oil tanker.

2.5.11. In addition, a tailor-made survey form in Chinese was designed and sent to container feeder operators via the Guangdong Hong Kong Feeder Association (GHKFA), representing 45 operators or 50 to 60% of the river trade industry. Survey forms were also sent to Chu Kong Shipping, a major operator in river trade. The operators were asked to complete survey forms based on typical voyages. A sample of the survey form is attached to this Final Report as Appendix B.

2.5.12. The response rate was low, despite the effort made by GHKFA's secretariat to promote the survey and the Study. In total, only ten survey forms were returned from GHKFA members and Chu Kong Shipping. Information collected from the survey was used in conjunction with data gathered from other sources.

2.5.13. Macau Ferry – A set of two survey forms (see Appendix C) was designed for ferries operating between Hong Kong and Macau, one to collect vessel information, and another one to collect operation information. The forms were distributed to the three Macau Ferry operators, namely, Shun Tak – China Travel Ship Management Limited (TurboJet), New World First Ferry (Macau) Company Limited, and Cotai Ferries (CotaiJet). Operators were asked to submit information for typical voyages based on service route and vessel class.

2.5.14. Vessel information was received from all three operators, either as return of individual vessels or a sample vessel from the same vessel class/model.

2.5.15. As for vessel operation, 10 survey forms were received from the three operators, covering all service routes for each operator by vessel class/model.

2.5.16. Vessel time-in-mode data, vessel speed by mode, fuel use and engine information were all provided in the survey forms.

2.5.17. However, only one survey return had provided load factor data by operation mode (Table 2-16). As the sample was small, load factor data was sought from other sources for verification.

Table 2-16 Surveyed Main Engine Load Factor by Mode, Macau Ferry

Operation Mode	Total Main Engine Load (kW)	Load Factor (Total Power = 9,280 kW)
Berthing in Hong Kong	1,861	0.20
Outward maneuvering from terminal	3,789	0.41
Slow cruise in Victoria Harbour	6,856	0.74
Cruising after Victoria Harbour	7,361	0.79
Slow cruise approaching Macau	4,199	0.45
Inward maneuvering (Macau)	2,784	0.30
Berthing in Macau	1,856	0.20
Outward maneuvering from terminal	2,320	0.25
Slow cruise in Macau breakwater	3,506	0.38
Cruising after breakwater	6,934	0.74
Slow cruise approaching Hong Kong	3,380	0.36
Inward maneuvering (Hong Kong)	2,691	0.29

2.5.18. Pearl River Delta Ferry – Similarly, a set of two survey forms (Appendix D) was designed for ferry services operating between Hong Kong and PRD ports. However, no operators had participated in the survey. Instead, one major operator agreed to provide general information through an interview. See paragraphs 2.5.20 and 2.5.21 for more information.

Interviews with Marine Trade

2.5.19. To supplement information collected from published sources and local surveys, personal interviews with major operators and trade associations were arranged to gather more information.

2.5.20. Pearl River Delta Ferry – Major PRD Ferry operators were contacted in the Study, but only one operator responded to the request. A meeting was held in August 2009, and general vessel information of 32 PRD ferries was provided.

2.5.21. However, PRD ferry operation information, such as engine activity information, was not available according to the operator.

2.5.22. Container Feeders – Feeder service provided by RVs formed a significant part of river trade activity in Hong Kong. Hundreds of RTVs visit Hong Kong on a daily basis.

2.5.23. Many of these are scheduled services operating between Hong Kong and PRD ports. In 2007, the largest operator offered over 25 regular routes, operating over 1,000 trips per month.

2.5.24. Major berthing locations of container feeders include RTT in Tuen Mun, PCWAs, privately operated wharves, and mid-stream locations. RVs usually berth at more than one location over one single call.

2.5.25. According to members of the trade, container feeders burn marine diesel oil (MDO) purchased in Hong Kong.

Other Data Sources

2.5.26. Web-based Information – As RV data like AE power was difficult to gather, credible web-based information were also considered in the Study as alternative sources.

2.5.27. For example, China Classification Society's register of ships was consulted for information of vessels classified by the Society. In some cases, information of RVs plying Hong Kong waters was found in the database. Otherwise, information of vessels of the same type and of similar tonnage were used as a surrogate.

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PART III EMISSION INVENTORY 2007

3. OCEAN-GOING VESSELS INVENTORY 2007

3.1. Overview

Major Vessel Types

3.1.1. The following paragraphs provide an overview of the five major OGVs types in Hong Kong according to arrival number and emission level: (a) fully cellular container vessel; (b) conventional cargo vessel; (c) cruise/ferry; (d) oil tanker; and (e) dry bulk carrier. Chemical carrier, fishing/fish processing vessel, gas carrier, lighter/barge/cargo junk, pleasure vessel, roll on/roll off, semi-container vessel, tug, and others are not included in this overview.

3.1.2. Fully Cellular Container Vessel – Container vessels are specialized ships built to carry 20-foot and 40-foot containers on their decks. They are the largest and most frequent visitors to the Port of Hong Kong. In 2007, a total of 23,563 FCCV called Hong Kong, and their size varied from below 1,000 tonnes to over 100,000 tonnes in DWT, carrying up to about 15,000 container boxes in TEU. About 60% of FCCV berth at KCCT, whereas the rest berth at mid-stream or other locations. Apart from the long-haul routes to North America, Europe and other continents using larger vessels, there are also short-haul, intra-Asia routes deploying smaller and older container ships. On average, FCCV spent 22 hours in port. The turnaround time at KCCT was 13 hours in 2007. Figure 3-1 below shows a container vessel at KCCT.

Figure 3-1 Fully Cellular Container Vessel

3.1.3. For FCCVs calling Hong Kong alone, most ships use East Lamma Channel to approach KCCT or the other mid-stream anchorage areas west of Victoria Harbour. Vessels from Shekou enter from the west via Urmston Road, whereas vessels from Yantian sail near the eastern boundary of Hong Kong waters, south of Po Toi Islands, and enter Hong Kong waters also via East Lamma Channel.

3.1.4. Usually one hour before entering Hong Kong waters, the vessel starts slowing down from cruise speed (could be up to 26 knots depending on the service speed of the vessel) to slow cruise speed (below 12 knots). The vessel slows down further to

about 3 to 5 knots near Ngan Chau to pick up the pilot, and then raise the speed again to about 8 to 10 knots to head towards Kwai Chung. Vessel speed is maintained below 8 knots as it approaches Tsing Yi Island and turns into Kwai Chung Basin. With the help of tug boats as the vessel is pushed into the berth, vessel speed is down to just a couple of knots. Once the vessel is pulled alongside, ME is switched off. AE and AB are kept on during hotelling.

3.1.5. Some container ships choose not to berth at KCCT because of the high terminal charges. Instead, they anchor mid-steam and be serviced by up to 6 to 8 barges installed with loading and unloading equipment. (Figure 3-2) Vessels operating mid-stream may stay for up to 12 to 20 hours, or 7 to 8 hours minimum. Mid-stream operation is concentrated near Western Harbour Anchorage and North Lamma Anchorage.

Figure 3-2 Mid-stream Operation

3.1.6. There are also FCCVs (and same for other vessel types such as tankers) that berth for a fairly short period of time south of Lamma Island (or even in other anchorages). According to MD's record, it can be half an hour or less. This is common for vessels trading between mainland China and Taiwan, and these vessels enter Hong Kong to switch documents for port clearance.

3.1.7. Conventional Cargo Vessel – Conventional or general cargo vessels are able to carry a diverse type of cargo, such as food, footwear, machinery, garments, and other packaged goods. Most of the conventional cargo ships are equipped with electric boom cranes for loading or unloading, and are typically configured with direct drive propulsion engines and separate auxiliary engines to supply electrical needs. In 2007, there were 4,664 conventional cargo vessel calls in Hong Kong, with DWT ranging from about 1,000 tonnes to over 70,000 tonnes. Private wharves such as China Merchants Wharf in Kennedy Town and in Tsing Yi were major shoreside berthing locations. Besides, general cargo vessels also berthed mid-stream in Western Harbour Anchorage, south of Lamma Island, as well as in other anchorages. Average berthing time for conventional cargo vessel was 38 hours according to *PHKST*. A typical conventional cargo vessel is shown in Figure 3-3.

Figure 3-3 Conventional Cargo Vessel

3.1.8. Cruise/Ferry – In general, cruise ships that visit Hong Kong fall under two major categories. First, the majority are regular, and relatively smaller callers using Hong Kong as home port. Each of them will typically make not less than 100 calls in a year. Second, there are larger, non-regular callers that visit Hong Kong as one of their stops. Non-regular callers usually make only a handful of calls each year. In 2007, there were 3,562 cruise/ferry calls in Hong Kong. 13 regular high sea routes were offered by 10 regular, home-based vessels, and they accounted for 3,466 or over 97% of the total number of calls. These vessels either berthed at shoreside locations such as Ocean Terminal and China Hong Kong Terminal, or at mid-stream locations near Hung Hom or Kowloon Bay. The remaining 96 calls were split among 30 non-regular vessels. Most of them berthed at Ocean Terminal. Cruise ships that berthed mid-stream often have launches running regular connection services to/from the shoreside for embarking and disembarking passengers. Unlike the other vessel types, all cruise ships enter Victoria Harbour from the East through Tathong Channel. Figure 3-4 shows a typical cruise ship.

Figure 3-4 Cruise Ship

3.1.9. AE demands are usually heavy for cruise ships, since they often have to provide heating and electricity for over a thousand passengers at a time. Typically, new cruise ships work on a diesel-electric configuration with some using turbines to generate electricity, while old cruise ships use direct drive and AE.

3.1.10. Regular callers often operate as casino cruise, offering one-night high sea cruise every day. Some of the regular callers also offer one-day high sea cruise during daytime. For the non-regular callers, they call Hong Kong as one of their stops over the entire cruise voyage.

3.1.11. Regular callers berthing at Ocean Terminal normally take 40 minutes to Lei Yue Mun. Thereafter, the vessels operate at full speed to sail to international waters. Once they are in international waters, they start drifting with all ME off. If the weather is rough, they keep one ME on. ME is started up again about one hour before sailing home.

3.1.12. During hotelling mode at the terminal, ME is switched off. AE is kept on to provide electricity for air conditioning and lighting. AB remains in operation to provide hot water for passengers (as they can stay onboard for a few hours after the vessel berthed in the morning), and to keep the heavy fuel warm.

3.1.13. Oil Tanker – In 2007, there were 1,400 oil tanker calls in Hong Kong, majority of which were product tankers carrying petroleum products. The size of these oil tankers ranged from a few thousand tonnes to over 200,000 tonnes in DWT (Very Large Crude Carrier or VLCC). The main berthing locations for oil tankers are the oil terminals in Tsing Yi, the aviation fuel loading facility in Sha Chau, and the receiving terminal of TownGas in Tolo Harbour (for naphtha). Oil tankers also berth at mid-stream locations, such as Western Harbour Anchorage, mainly for waiting. The average time-in-port for oil tankers was 22 hours in 2007, according to *PHKST*. Figure 3-5 is a picture of a typical oil product tanker at a receiving terminal.

Figure 3-5 Oil Tanker

3.1.14. According to the trade and oil suppliers, some tankers wait in the dangerous goods anchorage area near Tsing Yi if a berthing slot at the terminal is not yet available or if the tidal level is not suitable to berth a vessel. If the waiting period is short, the tanker normally operates in an idling mode, that is, keeps the ME on and off with minimal power. If the waiting time is long, anchor is lowered and the ME turned off. The AB, however, is switched on in order to keep the fuels (marine and product fuels) warm.

3.1.15. Tankers often berth in an anchorage zone (south of Lamma being the most common one) for a short period of time for documentation purpose.

3.1.16. Once the tanker is at berth, AB is used to provide steam for the steam-driven pump for crude oil tanker type, found to have some calling though Hong Kong has no refinery to receive crude oil. As for other product oil, less AB energy is required during unloading.

3.1.17. Due to pre-agreed discharge time at terminals and discharge rate from the pump, oil tankers seldom spend over 36 hours at berth.

3.1.18. Dry Bulk Carrier – Dry bulk carriers (Figure 3-6) are designed to carry unpackaged bulk cargo, such as coal, ore and cement. They usually have open cargo holds and giant hatches for loading and unloading. In 2007, there were 1,362 dry bulk carrier calls in Hong Kong. The size of carriers ranged from a couple of thousands to over 180,000 tonnes in DWT. Major berthing locations are the two power stations at Castle Peak and Lamma Island, Green Island Cement Wharf, and Siu Wing Wharf at Tap Shek Kok. Dry bulk carriers also spend time at mid-stream locations, such as Western Harbour Anchorage. On average, dry bulk carrier spent 36 hours in port in 2007.

Figure 3-6 Dry Bulk Carrier

Vessel Arrival Number

3.1.19. Vessel arrival information for 2007, without vessel name, was provided by Statistics Section of MD through EPD. Additional vessel arrival information, with vessel name, was acquired from Vessel Traffic Centre of MD. In addition, vessel arrival and departure reports, as well as port activity reports published by MD were collected and consolidated. All the above information were cross-matched, and a list of OGV calling Hong Kong in 2007 was compiled with the vessel call information as described in paragraph 2.2.9.

3.1.20. Unfortunately, not all the calls could be matched with a vessel name. The number of unidentified calls by vessel type is listed in Table 3-1 below:

Table 3-1 Unidentified OGV Calls by Vessel Type, 2007

Vessel Type	Number of Call	Percentage
A. Chemical Carrier/Tanker	0	
B. Conventional Cargo Vessel	265	5.7%
C. Cruise/Ferry	0	
D. Dry Bulk Carrier	0	
E. Fishing/Fish Processing Vessel	143	28.1%
F. Fully Cellular Container Vessel	0	
G. Gas Carrier/Tanker	0	
H. Lighter/Barge/Cargo Junk	149	98.0%
I. Oil Tanker	0	
J. Pleasure Vessel	112	88.2%
K. Roll On/Roll Off	0	
L. Semi-container Vessel	1	0.5%
M. Tug	153	61.4%
N. Others	5	4.2%
Total	**828**	**2.2%**

OGV Calls by Vessel Type

3.1.21. In total, there were 37,152 OGV calls in 2007. As shown in Table 3-2, FCCV accounted for over 60% of all OGV calls. The other main vessel types were conventional cargo vessel, cruise/ferry, oil tanker, and dry bulk carrier. The top five vessel types together made up 93% of all OGV calls.

Table 3-2 Ocean-going Vessels Arrival by Vessel Type, 2007

Vessel Type	Number of Call	Percentage
A. Chemical Carrier/Tanker	452	1.2%
B. Conventional Cargo Vessel	4,664	12.6%
C. Cruise/Ferry	3,562	9.6%
D. Dry Bulk Carrier	1,362	3.7%
E. Fishing/Fish Processing Vessel	509	1.4%
F. Fully Cellular Container Vessel	23,563	63.4%
G. Gas Carrier/Tanker	342	0.9%
H. Lighter/Barge/Cargo Junk	152	0.4%
I. Oil Tanker	1,400	3.8%
J. Pleasure Vessel	127	0.3%
K. Roll On/Roll Off	461	1.2%
L. Semi-container Vessel	190	0.5%
M. Tug	249	0.7%
N. Others	119	0.3%
Total	**37,152**	**100%**

Fully Cellular Container Vessel

3.1.22. Tables 3-3, 3-4 and 3-5 show a further breakdown of the largest vessel type, FCCV by GRT, DWT and by TEU carrying capacity.

Table 3-3 Ocean FCCV Arrival by GRT Class, 2007

GRT Class	Number of Call	Percentage
Below 500	116	0.5%
500 – 999	3,859	16%
1,000 – 4,999	2,835	12%
5,000 – 9,999	2,368	10%
10,000 – 29,999	7,186	30%
30,000 – 49,999	2,964	13%
≥ 50,000	4,235	18%
Total	**23,563**	**100%**

Table 3-4 Ocean FCCV Arrival by DWT Class, 2007

DWT Class	Number of Call	Percentage
Below 10,000	7,505	31.9%
10,000 – 19,999	4,190	17.8%
20,000 – 29,999	3,217	13.7%
30,000 – 39,999	2,120	9.0%
40,000 – 49,999	1,485	6.3%
50,000 – 74,999	3,309	14.0%
75,000 – 99,999	888	3.8%
≥ 100,000	849	3.6%
Total	**23,563**	**100%**

Table 3-5 Ocean FCCV Arrival by TEU Carrying Capacity, 2007

Category	TEU Carrying Capacity	Number of Call[16]	Percentage
Small Handysize	<1,000	8,890	37.7%
Handysize	1,000 – 2,999	8,528	36.2%
Sub-panamax	3,000 – 3,999	1,499	6.4%
Panamax	4,000 – 4,999	1,328	5.6%
Post-panamax	5,000 – 7,999	2,419	10.3%
Super-post-panamax	8,000 – 9,999	839	3.6%
Suezmax	10,000 – 12,999	51	0.2%
Malaccamax	≥ 13,000	9	0.04%
Total		**23,563**	**100%**

[16] There were 5,488 calls of unknown TEU. 5,486 calls fell in DWT Class <10,000 and the other two in DWT Class 10,000–20,000. Thus, 5,486 and 2 were assigned to TEU Classes <1,000 and 1,000–2,999 respectively.

3.1.23. While FCCV that visited Hong Kong came in different sizes, vessels below 30,000 DWT accounted for over 60% of all FCCV calls in 2007. (Table 3-4) Amongst the 7,505 FCCVs with DWT below 10,000, actually 6,404 (or 85%) of them were DWT 5,000 or below, and 4,679 (or 62%) were DWT 2,000 or below. They were mainly feeder container vessels that served the mainland coastal ports, as well as some that served the intra-Asia routes.

3.1.24. OGVs of DWT 5,000 or below were uncommon in PoLA. They adopted 5,000 DWT as the threshold to define OGVs that visit their port. In Hong Kong, FCCVs with DWT below 10,000 had an average ME power rating of 1,310 kW, most of which is classified by USEPA as OGV AE, engine for harbour craft, and small OGV propulsion engine. In this Study, special attention had been paid to the smaller OGVs, which were quite common in Hong Kong, in particular the type of fuel they used according to their size and engine power rating. See paragraph 3.2.33 for more elaboration.

Deadweight Tonnage

3.1.25. Table 3-6 below shows that average DWT of all OGVs calling Hong Kong in 2007 was 23,282 tonnes. Dry bulk carrier had the highest average DWT of about 40,000, to be followed by oil tanker and container vessel.

Table 3-6 Average DWT of OGVs by Vessel Type, 2007

Vessel Type	Number of Call	Average DWT
A. Chemical Carrier/Tanker	452	10,833
B. Conventional Cargo Vessel	4,664	8,682
C. Cruise/Ferry	3,562	6,089
D. Dry Bulk Carrier	1,362	40,042
E. Fishing/Fish Processing Vessel	509	No information
F. Fully Cellular Container Vessel	23,563	28,709
G. Gas Carrier/Tanker	342	6,967
H. Lighter/Barge/Cargo Junk	152	4,693
I. Oil Tanker	1,400	30,394
J. Pleasure Vessel	127	372
K. Roll On/Roll Off	461	9,105
L. Semi-container Vessel	190	12,661
M. Tug	249	559
N. Others	119	21,877
Total	**37,152**	**23,282***

***** Excluding fishing/fish processing vessel

Vessel Age

3.1.26. Table 3-7 summarizes average fleet age by vessel type, for vessels that called Hong Kong in 2007.

Table 3-7 Average Age of Vessels Calling Hong Kong, 2007

Vessel Type	Average Year Built	Average Age (Years)	Lower End (Years)	Upper End (Years)
A. Chemical Carrier/Tanker	1998	9	0	28
B. Conventional Cargo Vessel	1993	14	0	42
C. Cruise/Ferry	1983	31	5	52
D. Dry Bulk Carrier	1983	24	0	51
E. Fishing/Fish Processing Vessel	n/a	n/a	n/a	n/a
F. Fully Cellular Container Vessel	1997	10	0	51
Below 10,000 DWT	1993	14	1	51
10,000 – 19,999 DWT	1996	11	0	30
20,000 – 29,999 DWT	1996	11	0	38
30,000 – 39,999 DWT	1997	10	0	36
40,000 – 49,999 DWT	1994	13	0	37
50,000 – 74,999 DWT	1999	8	0	29
75,000 – 99,999 DWT	2003	4	0	12
≥ 100,000 DWT	2004	3	0	10
G. Gas Carrier/Tanker	1994	13	1	31
H. Lighter/Barge/Cargo Junk	n/a	n/a	n/a	n/a
I. Oil Tanker	1996	11	0	31
J. Pleasure Vessel	2004	3	1	5
K. Roll On/Roll Off	1991	16	1	34
L. Semi-container Vessel	1996	11	0	25
M. Tug	1993	14	0	37
N. Others	1985	22	0	41

n/a = not available

3.1.27. According to Table 3-7, cruise/ferry (31 years), dry bulk carrier (24 years), others (22 years) and roll on/roll off (16 years) have the oldest average fleet age. On the contrary, FCCV of the largest DWT sub-classes are the most recently built vessels, and so they have the youngest average age.

Frequent Caller

3.1.28. Table 3-8 illustrates that the 37,152 OGV calls were actually made by 4,738 unique vessels [17] representing 36,324 identified calls, with the remaining 828 being unidentified calls. In other words, some vessels visited Hong Kong more than once during 2007.

Table 3-8 Unique Vessels Calling Hong Kong by Ocean Vessel Type, 2007

Vessel Type	Identified Call	Unique Vessel	Unidentified Call
A. Chemical Carrier/Tanker	452	164	0
B. Conventional Cargo Vessel	4,399	948	265

[17] Unique vessels are vessels with vessel names, excluding those without vessel names.

C. Cruise/Ferry	3,562	40	0
D. Dry Bulk Carrier	1,362	490	0
E. Fishing/Fish Processing Vessel	366	39	143
F. Fully Cellular Container Vessel	23,563	2,178	0
G. Gas Carrier/Tanker	342	70	0
H. Lighter/Barge/Cargo Junk	3	1	149
I. Oil Tanker	1,400	535	0
J. Pleasure Vessel	15	11	112
K. Roll On/Roll Off	461	129	0
L. Semi-container Vessel	189	33	1
M. Tug	96	41	153
N. Others	114	59	5
Total	**36,324**	**4,738**	**828**

3.1.29. The number of frequent callers, which is defined as vessels that visited Hong Kong six times or more over a year, is tabulated by vessel type in Table 3-9. In 2007, about 36% of vessels that visited Hong Kong were frequent callers. This is more than double the corresponding percentage in the PoLA in 2008 (17%). Most frequent callers were found among FCCV (60%), fishing vessel (59%), and cruise ship (30%). In total, about 80% of all OGV calls were made by frequent callers. Amongst different vessel types, cruise ship (~99%) and FCCV (89%) had the highest percentage of calls made by frequent callers. (Table 3-10)

Table 3-9 Frequent Caller by Ocean Vessel Type, 2007

Vessel Type	Unique Vessel	Frequent Caller	Percentage of Frequent Caller
A. Chemical Carrier/Tanker	164	20	12.2%
B. Conventional Cargo Vessel	948	220	23.2%
C. Cruise/Ferry	40	12	30.0%
D. Dry Bulk Carrier	490	41	8.4%
E. Fishing/Fish Processing Vessel	39	23	59.0%
F. Fully Cellular Container Vessel	2,178	1,304	59.9%
G. Gas Carrier/Tanker	70	15	21.4%
H. Lighter/Barge/Cargo Junk	1	0	n.a.
I. Oil Tanker	535	45	8.4%
J. Pleasure Vessel	11	0	n.a.
K. Roll On/Roll Off	129	24	18.6%
L. Semi-container Vessel	33	6	18.2%
M. Tug	41	1	2.4%
N. Others	59	1	1.7%
Total	**4,738**	**1,712**	**36.1%**

n.a. = not applicable

Table 3-10 Number of Frequent Calls by Ocean Vessel Type, 2007

Vessel Type	Total Call	Frequent Call	Percentage of Frequent Call
A. Chemical Carrier/Tanker	452	158	35.0%
B. Conventional Cargo Vessel	4,664	3,016	64.7%
C. Cruise/Ferry	3,562	3,516	98.7%
D. Dry Bulk Carrier	1,362	772	56.7%
E. Fishing/Fish Processing Vessel	509	329	64.6%
F. Fully Cellular Container Vessel	23,563	21,001	89.1%
G. Gas Carrier/Tanker	342	240	70.2%
H. Lighter/Barge/Cargo Junk	152	0	n.a.
I. Oil Tanker	1,400	508	36.3%
J. Pleasure Vessel	127	0	n.a.
K. Roll On/Roll Off	461	291	63.1%
L. Semi-container Vessel	190	129	67.9%
M. Tug	249	46	18.5%
N. Others	119	13	10.9%
Total	**37,152**	**30,019**	**80.8%**

n.a. = not applicable

Berthing Locations

3.1.30. OGVs calling Hong Kong may berth at different locations depending on vessel type, cargo or passenger carried, and the purpose of call. In general, berthing / cargo handling locations are classified by MD as anchorages/buoys (A+B), or container terminals, berths and wharves (including public cargo working areas) (CT+B/W).

3.1.31. A vessel may also berth at more than one location within Hong Kong waters. For the port statistical tables published by MD, main berthing/cargo handling location refers to the most costly location if the purpose of call of the vessel is for loading or unloading cargoes. For vessels with other reasons of call, the main berthing location refers to the one with the longest stay.

3.1.32. In this Study, berthing location information was mainly extracted from MD's VARs and cross-referenced with other statistical reports published and provided by MD. Main OGV berthing location for 2007 is listed by vessel type in Table 3-11. Of the 37,152 calls, 57% berthed at shore-side, and 43% berthed at mid-stream as main location.

Table 3-11 Main Berthing Location by Ocean Vessel Type

Vessel Type	Anchorages / Buoys (A+B)	Container Terminals / Berths / Wharves (CT+B/W)
A. Chemical Carrier/Tanker	203	249
B. Conventional Cargo Vessel	3,296	1,368
C. Cruise/Ferry	1,878	1,684
D. Dry Bulk Carrier	1,192	170
E. Fishing/Fish Processing Vessel	392	117
F. Fully Cellular Container Vessel	8,000	15,563
G. Gas Carrier/Tanker	85	257
H. Lighter/Barge/Cargo Junk	11	141
I. Oil Tanker	339	1,061
J. Pleasure Vessel	56	71
K. Roll On/Roll Off	77	384
L. Semi-container Vessel	137	53
M. Tug	64	185
N. Others	105	14
Total	**15,835**	**21,317**

3.1.33. According to Table 3-12, large container ships preferred container terminals over mid-stream locations for loading and unloading cargoes. Mid-stream operation was more popular among smaller vessels.

Table 3-12 Ocean FCCV Berthing Location by DWT Class

DWT Class	A+B	CT+B/W
Below 10,000	4,585	2,920
10,000 – 19,999	1,542	2,648
20,000 – 29,999	1,012	2,205
30,000 – 39,999	368	1,752
40,000 – 49,999	133	1,352
50,000 – 74,999	274	3,035
75,000 – 99,999	42	846
≥ 100,000	44	805
Total	**8,000**	**15,563**

3.2. Methodology

3.2.1. As stated in paragraph 1.3.5 of Chapter 1, the activity-based approach was used in this Study to estimate marine vessels emission. Emissions were estimated by individual calls based on a list of 37,152 OGV calls for 2007, compiled from sources explained in paragraph 3.1.19. The main equation is included below again for emission estimation of a single vessel call:

$$\textbf{\textit{Total Emission}}_{(pollutant)} = \sum \textbf{\textit{Emission}}_{(pollutant,\ activity\ mode,\ equipment)}$$

$$\textbf{\textit{Emission}}_{(pollutant,\ activity\ mode,\ equipment)} = P \times FL \times T \times EF$$

where P is the installed power of equipment;
FL is fractional load of equipment in a specific mode;
T is operation time-in-mode; and
EF is fractional load emission factor of equipment.

Main Engine Power

3.2.2. The list of 4,738 unique vessels was used to extract engine and boiler information from LRS, among other relevant data. Data fields related to ME were listed in paragraph 2.4.18.

3.2.3. Total ME power extracted from LRS was used as a surrogate for maximum continuous rated power of the propulsion engine. In cases where identified vessels were not listed in LRS, or the vessels were unidentified, total ME power (and other engine information such as engine speed and number of stroke) of another vessel belonging to the same vessel type and tonnage class were used as a surrogate.

3.2.4. Special attention was taken in this Study for vessels using diesel-electric engines, with large generator sets installed on board to provide electric power for both propulsion and ship-board electricity. Such engine configuration is different from conventional ships whose propeller is driven directly by diesel propulsion engine. Maximum combined ME power as listed in LRS for these vessels were split between propulsion and auxiliary use. 78.25%[18] of the combined power was assigned for propulsion, and the remainder as AE power. Table 3-13 shows that 28 vessels (or less than 1% of unique vessel) that visited Hong Kong in 2007 were installed with diesel-electric engine system. Tables 3-13 and 3-14 show that ME information of 7% of vessel number and 20% of vessel calls in 2007 were unknown. Their ME types were assumed to be the most frequent, motor diesel.

[18] Derived based on page 2-8, section 2.3 of *ICF 2009 Report*.

Table 3-13 Vessel Number by OGV Main Engine Type and Vessel Type, 2007

Vessel Type	Unique Vessel	Motor Diesel	Diesel Electric	Steam Turbine	Unknown
A. Chemical Carrier/Tanker	164	161	3	0	0
B. Conventional Cargo Vessel	948	793	0	2	153
C. Cruise/Ferry	40	30	10	0	0
D. Dry Bulk Carrier	490	487	1	0	2
E. Fishing/Fish Processing Vessel	39	39	0	0	0
F. Fully Cellular Container Vessel	2,178	1,993	6	8	171
G. Gas Carrier/Tanker	70	69	0	1	0
H. Lighter/Barge/Cargo Junk	1	0	0	0	1
I. Oil Tanker	535	524	5	0	6
J. Pleasure Vessel	11	10	1	0	0
K. Roll On/Roll Off	129	129	0	0	0
L. Semi-container Vessel	33	30	0	0	3
M. Tug	41	41	0	0	0
N. Others	59	57	2	0	0
Total	**4,738**	**4,363**	**28**	**11**	**336**

Table 3-14 Vessel Calls by OGV Main Engine Type and Vessel Type, 2007

Vessel Type	Vessel Call	Motor Diesel	Diesel Electric	Steam Turbine	Unknown
A. Chemical Carrier/Tanker	452	449	3	0	0
B. Conventional Cargo Vessel	4,664	2,879	0	6	1,779
C. Cruise/Ferry	3,562	3,544	18	0	0
D. Dry Bulk Carrier	1,362	1,357	1	0	4
E. Fishing/Fish Processing Vessel	509	509	0	0	0
F. Fully Cellular Container Vessel	23,563	18,123	48	22	5,370
G. Gas Carrier/Tanker	342	341	0	1	0
H. Lighter/Barge/Cargo Junk	152	0	0	0	152
I. Oil Tanker	1,400	1,350	8	0	42
J. Pleasure Vessel	127	125	2	0	0
K. Roll On/Roll Off	461	461	0	0	0
L. Semi-container Vessel	190	100	0	0	90
M. Tug	249	249	0	0	0
N. Others	119	116	3	0	0
Total	**37,152**	**29,603**	**83**	**29**	**7,437**

3.2.5. Based on the above consideration, ME power was determined for each OGV. Table 3-15 summarizes average ME power for 2007 OGVs by vessel class. FCCV and

cruise ship had the highest average ME power among all the vessel types. Average ME power of FCCV also varied among different DWT classes (Table 3-16).

Table 3-15 Average Main Engine Power (kW) of OGVs, 2007

Vessel Type	Average ME Power
A. Chemical Carrier/Tanker	3,515
B. Conventional Cargo Vessel	2,313
C. Cruise/Ferry	15,184
D. Dry Bulk Carrier	7,555
E. Fishing/Fish Processing Vessel	420
F. Fully Cellular Container Vessel	18,104
G. Gas Carrier/Tanker	3,364
H. Lighter/Barge/Cargo Junk	0
I. Oil Tanker	5,652
J. Pleasure Vessel	786
K. Roll On/Roll Off	7,250
L. Semi-container Vessel	3,404
M. Tug	2,344
N. Others	7,832
All Vessel Types	**14,032**

Table 3-16 Average Main Engine Power (kW) of Ocean FCCV, 2007

DWT Class	Average ME Power
Below 10,000 (MDO)	617
Below 10,000 (HFO)	3,756
10,000 – 19,999	9,107
20,000 – 29,999	13,925
30,000 – 39,999	20,845
40,000 – 49,999	25,474
50,000 – 74,999	43,464
75,000 – 99,999	59,629
≥ 100,000	64,780
All Classes	**18,104**

Main Engine Speed

3.2.6. Main engine speed was also an important parameter considered in the Study. Table 3-17 below summarizes the distribution OGV calls according to main engine speed – slow speed diesel (SSD), medium speed diesel (MSD), high speed diesel (HSD) and steam turbine engine (ST). This is a key factor in determining the selection of emission factors for emission estimation (see paragraphs 3.2.36 and 3.2.37 for more discussion). It is worth noting that the 7,285 unknown calls,

excluding 152 calls of lighter/barge/cargo junk which do not have main engine, were assigned to respective main engine speed types as mentioned in paragraph 3.2.3.

Table 3-17 Vessel Calls by OGV Main Engine Speed and Vessel Type, 2007

Vessel Type	SSD	MSD	HSD	ST
A. Chemical Carrier/Tanker	119	313	20	0
B. Conventional Cargo Vessel	571	4,045	42	6
C. Cruise/Ferry	3	3,559	0	0
D. Dry Bulk Carrier	1,225	99	38	0
E. Fishing/Fish Processing Vessel	0	509	0	0
F. Fully Cellular Container Vessel	15,807	2,080	5,654	22
G. Gas Carrier/Tanker	55	276	10	1
H. Lighter/Barge/Cargo Junk	0	0	0	0
I. Oil Tanker	682	645	73	0
J. Pleasure Vessel	0	0	127	0
K. Roll On/Roll Off	246	215	0	0
L. Semi-container Vessel	30	160	0	0
M. Tug	1	27	221	0
N. Others	52	53	14	0
Total	**18,791**	**11,981**	**6,199**	**29**

Main Engine Load Factor

3.2.7. In this Study, ME load factors by vessel type and then by operation mode were mainly derived from vessel track data acquired from MD, which contained information such as vessel name, vessel type identifier, vessel position, vessel speed, and data update time. Based on the speed profile of individual vessels, time-in-modes was then determined (see Table 3-24 about the definition of time-in-mode). Figure 3-7 below shows a typical speed profile of a container vessel, and how time-in-mode was assigned according to vessel speed.

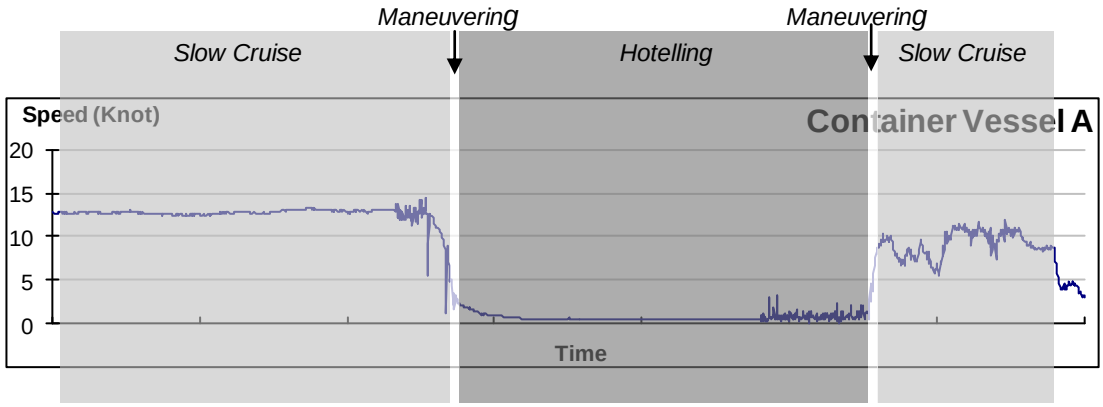

Figure 3-7 Typical Vessel Speed and Time-in-mode Characterization

3.2.8. Movement track of individual vessels was analyzed and grouped together by vessel type, and then by DWT sub-class for cargo ships or PAX sub-class for cruise/ferry. Average time duration, speed and ME load factors were then estimated for each of the five operation modes – cruise, fairway cruise, slow cruise, maneuvering, and hotelling.

3.2.9. Actual speed of the vessel was provided by the vessel track data. Instead of using maximum speed for the equation below, it was decided that service speed was used in this Study to account for de-rating of the ME. In general, most of the vessel speed information provided in LRS was service speed. If only maximum speed information was provided, a factor of 0.94 was then applied to the vessel's maximum speed to estimate its service speed[19].

3.2.10. ME load factor of any data point (a vessel at a particular location during a 30-second snapshot) was estimated by the Propeller Law according to the following equation:

$$\textit{Load Factor} = (\textit{Actual Speed}/\textit{Maximum Speed})^3$$

3.2.11. Table 3-18 below shows a set of average ME load factors derived for OGVs. All OGVs, except cruise/ferry and FCCV, operate within HKW at speed not more than 12 knots and thus ME load factor at fairway cruise mode are not applicable. During maneuvering, ME load factor are 0.02 for many vessel subtypes, which is the minimum value that corresponds to idling. At hotelling mode, ME will be switched off and its load factor was assumed to be zero, except during idling when ME load factor was assumed to be 0.02.

Table 3-18 Averaged Main Engine Load Factors for OGVs, 2007

Vessel Type	Fairway Cruise	Slow Cruise	Maneuvering
A. Chemical Carrier/Tanker			
DWT < 5,000	n.a.	0.418	0.025
DWT 5,000 – 9,999	n.a.	0.418	0.024
DWT 10,000 – 19,999	n.a.	0.403	0.024
DWT 20,000 – 39,999	n.a.	0.416	0.024
DWT ≧40,000	n.a.	0.396	0.024
B. Conventional Cargo Vessel			
DWT < 2,000	n.a.	0.360	0.027
DWT 2,000 – 4,999	n.a.	0.361	0.030
DWT 5,000 – 9,999	n.a.	0.361	0.030
DWT 10,000 – 29,999	n.a.	0.362	0.033
DWT ≧30,000	n.a.	0.361	0.031
C. Cruise/Ferry			
PAX < 300	0.422	0.127	0.020
PAX 300 – 699	0.366	0.169	0.021
PAX 700 – 1,399	0.397	0.063	0.020
PAX 1,400 – 2,599	0.397	0.126	0.020

[19] Based on page 2-9, Table 2-5, *ICF 2009 Report*.

PAX ≧2,600	0.422	0.127	0.020
D. Dry Bulk Carrier			
DWT < 10,000	n.a.	0.267	0.028
DWT 10,000 – 29,999	n.a.	0.326	0.023
DWT 30,000 – 59,999	n.a.	0.309	0.024
DWT 60,000 – 99,999	n.a.	0.306	0.023
DWT ≧100,000	n.a.	0.299	0.022
E. Fishing/Fish Processing Vessel	n.a.	0.650	0.095
F. Fully Cellular Container Vessel			
DWT < 10,000 (MDO)	0.524	0.140	0.020
DWT < 10,000 (HFO)	0.516	0.137	0.020
DWT 10,000 – 19,999	0.515	0.136	0.020
DWT 20,000 – 29,999	0.513	0.135	0.020
DWT 30,000 – 39,999	0.500	0.128	0.020
DWT 40,000 – 49,999	0.486	0.121	0.020
DWT 50,000 – 74,999	0.475	0.110	0.020
DWT 75,000 – 99,999	0.478	0.108	0.020
DWT ≧100,000	0.473	0.109	0.020
G. Gas Carrier/Tanker			
DWT < 5,000	n.a.	0.375	0.025
DWT 5,000 – 9,999	n.a.	0.375	0.024
DWT 10,000 – 19,999	n.a.	NR	NR
DWT 20,000 – 39,999	n.a.	0.375	0.025
DWT ≧40,000	n.a.	0.375	0.025
H. Lighter/Barge/Cargo Junk	n.a.	n.a.	n.a.
I. Oil Tanker			
DWT < 10,000	n.a.	0.446	0.025
DWT 10,000 – 29,999	n.a.	0.384	0.023
DWT 30,000 – 59,999	n.a.	0.362	0.023
DWT 60,000 – 119,999	n.a.	0.337	0.022
DWT ≧120,000	n.a.	0.382	0.023
J. Pleasure Vessel	n.a.	0.210	0.020
K. Roll On/Roll Off	n.a.	0.178	0.020
L. Semi-container Vessel	n.a.	0.224	0.020
M. Tug	n.a.	0.569	0.020
N. Others	n.a.	0.247	0.037

n.a. = Not applicable
NR = No arrival recorded, i.e. VAN = 0
*In effect, if ME fractional load is 2%, there is almost no power for propulsion and the vessel will be virtually idling. Therefore, ME load factor will not be set lower than 0.02.

Auxiliary Engine Power

3.2.12. AE power refers to total installed power of AE and was a major information gap in past marine vessels emission inventories. Most of the vessel records in LRS do not

provide AE information. In 2005, CARB conducted a survey of ocean-going vessels and developed an AE to ME power ratio (Table 3-19). This ratio was adapted and used in this Study to derive AE power for each vessel based on ME power information provided by LRS. Where AE power ratio was not provided for a particular vessel type, the ratio of a similar vessel type was used (see Table 3-20).

Table 3-19 Auxiliary Engine to Main Engine Power Ratios for OGVs

Vessel Type	Average Propulsion Engine (kW)	Auxiliary to Propulsion Ratio
Auto Carrier	10,700	0.266
Bulk Carrier	8,000	0.222
Container Ship	30,900	0.220
Cruise Ship	39,600	0.278
General Cargo Ship	9,300	0.191
Roll On/Roll Off	11,000	0.259
Reefer	9,600	0.406
Tanker	9,400	0.211

Source: CARB, 2005.

Table 3-20 Adapted AE to ME Power Ratios and Rating (kW) for OGVs

Vessel Type	AE Power Ratio	CARB Vessel Type	AE Power Rating
A. Chemical Carrier/Tanker	0.211	Tanker	745
B. Conventional Cargo Vessel	0.191	General Cargo Ship	442
C. Cruise/Ferry	0.278	Cruise Ship	4,221
D. Dry Bulk Carrier	0.222	Bulk Carrier	1,677
E. Fishing/Fish Processing Vessel	0.222	Bulk Carrier	93
F. Fully Cellular Container Vessel	0.220	Container Ship	3,983
G. Gas Carrier/Tanker	0.211	Tanker	710
H. Lighter/Barge/Cargo Junk	AE power estimated based on local crafts (see paragraph 3.2.13 for elaboration)		551
I. Oil Tanker	0.211	Tanker	1,197
J. Pleasure Vessel	AE power estimated based on local crafts (see paragraph 3.2.13 for elaboration)		60
K. Roll On/Roll Off	0.259	Roll On/Roll Off	1,878
L. Semi-container Vessel	0.191	General Cargo Ship	650
M. Tug	0.222	Bulk Carrier	520
N. Others	0.222	Bulk Carrier	1,739

3.2.13. Not all AE power was estimated by the above ratio. For lighter/barge/cargo junk, AE power of individual vessel was estimated for each vessel by making reference to local dumb lighters of similar GRT or NRT. As for pleasure vessel, AE power was estimated based on pleasure crafts of similar GRT or NRT listed in LRS. Finally, vessels with diesel electric-engine configuration would have their AE power allocated from the combined ME power. (See paragraph 3.2.4)

Auxiliary Engine Load Factors and Load Defaults

3.2.14. AE load factor is the fractional load of the AE power. AE load default is the AE power demand at different mode which is an important parameter for marine vessels emission calculation. Unfortunately, AE load factors could not be derived from MD's vessel track data.

3.2.15. In this Study, a set of AE load factors was derived from *PoLA 2009 Report*[20]. Table 3-21 below summarizes all the average AE load factors used in this Study for all vessel types, except container vessel. AE load factor at fairway cruise mode are not applicable as all OGVs, except cruise/ferry and FCCV, operate within HKW at speed not more than 12 knots.

Table 3-21 Adapted Auxiliary Engine Load Factors for OGVs except FCCV

Vessel Type	Cruise / Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
A. Chemical Carrier/Tanker	n.a.	0.297	0.350	0.265
B. Conventional Cargo Vessel	n.a.	0.310	0.517	0.224
C. Cruise/ Ferry	0.416	0.541	0.666	0.416
D. Dry Bulk Carrier	n.a.	0.242	0.403	0.121
E. Fishing/Fish Processing Vessel	n.a.	0.270	0.450	0.223
G. Gas Carrier/Tanker	n.a.			
5,000 < DWT < 40,000	n.a.	0.174	0.206	0.156
DWT ≧40,000	n.a.	0.273	0.322	0.244
H. Lighter/Barge/Cargo Junk	n.a.	0.135	0.135	0.655
I. Oil Tanker	n.a.			
DWT < 10,000	n.a.	0.174	0.206	0.156
DWT 10,000 – 29,999	n.a.	0.174	0.206	0.156
DWT 30,000 – 59,999	n.a.	0.268	0.315	0.239
DWT 60,000 – 119,999	n.a.	0.279	0.329	0.249
DWT ≧120,000	n.a.	0.283	0.334	0.253
J. Pleasure Vessel	n.a.	0.320	0.320	0.320
K. Roll On/Roll Off	n.a.	0.300	0.450	0.260
L. Semi-container Vessel	n.a.	0.242	0.403	0.121
M. Tug	n.a.	0.270	0.450	0.216
N. Others	n.a.	0.270	0.450	0.223

n.a. = Not applicable

[20] Based on the AE load defaults in Table 3.12 and power rating listed in Table 3.24 of *PoLA 2009 Report*.

3.2.16. As for container vessel, AE load defaults based on *PoLA 2009 Report* were used in this Study. They referred to specific DWT classes which were assumed applicable to those calling Hong Kong. In fact, container vessel traffic between the US and Hong Kong is frequent, and container vessels surveyed on the West Coast were assumed to be similar to those calling Hong Kong.

3.2.17. As the AE load defaults of *PoLA 2009 Report* were classified by TEU carrying capacity, they were re-classified by DWT classes in this Study (Table 3-22).

Table 3-22 Adapted Auxiliary Engine Load Defaults (kW) for FCCV

DWT Class	Cruise	Fairway Cruise	Slow Cruise	Maneu vering	Hotel-ling	Ave. TEU	PoLA Class by TEU
<10,000 (MDO)	17	17	25	41	15	430	<1,000
<10,000 (HFO)	106	106	156	252	93	430	
10,000 – 19,999	443	443	651	1,051	388	1,060	1,000 – 1,999
20,000 – 29,999	666	666	956	1,512	650	1,621	
30,000 – 39,999	888	888	1,260	1,973	913	2,503	2,000 – 2,999
40,000 – 49,999	692	692	1,268	2,372	643	3,233	3,000 – 3,999
50,000 – 74,999	1,544	1,544	2,195	3,444	1,307	4,801	4,000 – 4,999
75,000 – 99,999	1,544	1,544	2,195	3,444	1,307	6,905	6,000 – 6,999
≥ 100,000	1,560	1,560	2,218	3,480	1,320	8,596	7,000 – 7,999

* MDO = marine diesel oil; HFO = heavy fuel oil; Average TEU is based on LRS

3.2.18. For vessels that visited a dockyard for service, it was assumed that AE was shut down and AE load factor during hotelling was therefore zero.

Boiler Energy Defaults

3.2.19. AB are installed on board of vessels for a number of purposes: (a) provides hot water for crew, and for passengers in case of cruise ships; (b) provides heat for steam-driven pumps on oil tankers to unload oil products; and (c) heats up bunker fuel for use. Based on the need of on-board AB to heat up bunker fuel, it was assumed in this Study that all vessels burning HFO also had AB installed on board. On the other hand, vessels burning distillate fuel were not equipped with AB.

3.2.20. AB energy default values of vessels operating within Hong Kong waters were not available for this Study, and hence AB energy defaults of *PoLA 2009 Report* were adapted for this Study (Table 3-23), with the following assumptions and adjustments:

- During fairway cruise and most of slow cruise modes, propulsion system loads were high (assumed to be higher than 20% load factor). It was assumed that economizers were on and AB were switched off;

- For each vessel type except crude oil tanker, AB energy defaults were assumed to be the same during manuevering, hotelling, as well as slow cruise mode when ME load factor was 0.2 or below. Crude oil tankers use steam to drive pump for unloading products at berth, and so a set of higher AB energy defaults was assigned to them for hotelling at berth. Tankers other than crude oil type were assumed to use the electric pump which has become increasingly popular, with a lower AB energy defaults value;

- As PoLA's vessel profile is different from that of Hong Kong, such as DWT sub-class range and distribution, adjustments were made for major vessel types so that AB energy defaults corresponded better with vessel size and tonnage. For example, PoLA used a boiler energy default of 252 kW for general cargo vessel, with an average DWT of 42,011. However, most of the conventional cargo vessels that visited Hong Kong in 2007 were smaller in size. To reflect this, AB energy defaults were scaled down according to DWT. Such adjustment better represents smaller cargo vessels that are more common in Hong Kong (see Table 3-23); and

- Vessels installed with diesel-electric engine were assumed to not use their boilers.

Table 3-23 Adapted Auxiliary Boiler Energy Defaults (kW) for OGVs

Vessel Type and Sub-class	Slow Cruise & Maneuvering	Hotelling at Berth	Hotelling at Anchorage	PoLA Reference Vessel Type (DWT)
B. Conventional Cargo Vessel & L. Semi-container Vessel				
DWT < 5,000	17	17	17	
DWT 5,000 – 9,999	40	40	40	
DWT 10,000 – 29,999	98	98	98	
DWT ≥ 30,000	252	252	252	←General Cargo (42,011)
C. Cruise/Ferry (passenger carrying capacity = PAX)				
PAX < 300	73	73	73	
PAX 300 – 699	254	254	254	
PAX 700 – 1,399	410	410	410	
PAX 1,400 – 2,599	869	869	869	
PAX ≥ 2,600	1,000	1,000	1,000	←Cruise Ship (7,496)
D. Dry Bulk Carrier & N. Others				
DWT < 10,000	11	11	11	
DWT 10,000 – 29,999	57	57	57	
DWT 30,000 – 59,999	109	109	109	←Bulk (46,781)
DWT 60,000 – 99,999	183	183	183	
DWT ≥ 100,000	403	403	403	
F. Fully Cellular Container Vessel				
DWT < 10,000	136	136	136	
DWT 10,000 – 19,999	232	232	232	←Container (1,000 TEU)
DWT 20,000 – 29,999	313	313	313	
DWT 30,000 – 39,999	393	393	393	←Container (2,000 TEU)
DWT 40,000 – 49,999	534	534	534	←Container (3,000 TEU)
DWT 50,000 – 74,999	586	586	586	←Container (≥ 6,000 TEU)
DWT 75,000 – 99,999	586	586	586	

DWT ≥ 100,000	586	586	586	
K. Roll On/Roll Off				
DWT < 5,000	45	45	45	
DWT 5,000 – 9,999	87	87	87	
DWT 10,000 – 19,999	167	167	167	
DWT ≥ 20,000	282	282	282	←Auto Carrier (22,608)
I. Oil Tanker (Crude oil tanker)				
DWT < 10,000	48	321	48	
DWT 10,000 – 29,999	144	970	144	
DWT 30,000 – 59,999	371	2500	371	←Tanker (45,606)
DWT 60,000 – 119,999	371	2500	371	
DWT ≥ 120,000	371	2500	371	
A/ G/ I. Chem./Gas/Other Oil Tanker				
DWT < 10,000	48	48	48	
DWT 10,000 – 29,999	144	144	144	
DWT 30,000 – 59,999	371	371	371	←Tanker (45,606)
DWT 60,000 – 119,999	371	371	371	
DWT ≥ 120,000	371	371	371	

n.a. not applicable, as there is no boiler for E. Fishing/Fish Processing Vessel, H. Lighter/Barge/Cargo Junk, J. Pleasure Vessel, and M. Tug.

Time-in-mode

3.2.21. Vessel activity information and time-in-mode (TIM) data were collected from various MD's publications and archived reports. Vessel activity was divided into 5 operation modes as explained in Table 3-24, namely: cruise, fairway cruise, slow cruise, maneuvering, and hotelling. Cruise and fairway cruise share the same vessel speed range but are differentiated based on vessel operation outside or inside Hong Kong waters. The vessel speed limits for slow cruise and maneuvering are determined based on *ICF 2009 Report*. Whilst hotelling speed is theoretically zero, 1 knot is assigned as its maximum detectable value of MD's vessel track data.

Table 3-24 Time-in-mode Definition by Vessel Speed of OGVs

Operation Mode	Description	Vessel Speed
Cruise	Vessel operating at service speed, usually outside Hong Kong waters	Over 12 knots
Fairway Cruise	Vessel operating at speed higher than slow cruise speed inside Hong Kong waters	Over 12 knots
Slow Cruise	Vessel operating at reduced speed inside Hong Kong waters, in line with speed limit requirements	8 to 12 knots
Maneuvering	Vessel operating at lower speed as it approaches berth/pier/dock or anchorage	1 to below 8 knots
Hotelling	Vessel at berth or anchored with propulsion engines switched off	Below 1 knot

3.2.22. For vessels operating within Hong Kong waters, cruise mode was non-existent. Fairway cruise mode was limited to cruise ships and container vessels over a certain stretch of waters.

3.2.23. ATA and ATD provided by MD statistics were useful in determining TIM for each call. According to MD's definition, ATA is the time when a vessel arrives at its first berthing location, and ATD is the time when a vessel departs from its last berthing location. For a vessel that only berths at one location, the difference between ATA and ATD is total hotelling time.

Total hotelling time (for all calls) = ATD - ATA

3.2.24. If a vessel berths at more than one location, then the difference between ATA and ATD will become total hotelling time plus combined shifting time between different berthing locations. As vessel berthing information was incomplete to define TIM of shifting time, it was assumed that all shifting time was in hotelling mode.

3.2.25. ENT and EXR was another pair of arrival and departure time in this Study. ENT and EXT times were embedded in MD's VAR. The full set of 2007 VARs was analyzed. Vessel calls with complete ENT and EXR time, berthing start and end time, and a combined inbound/outbound sailing time of not more than 8 hours were selected for emission estimation. The "8 hour" criterion was selected based on analysis of radar track records.[21] These were defined as the 'good calls'. (see paragraph 2.4.10)

3.2.26. The difference between ENT and EXR times equals total time a vessel spent within Hong Kong waters (total port stay). By definition, total port stay includes total slow cruise time (inbound and outbound), total maneuvering time (inward and outward), and total berthing time. Combined slow cruise and maneuvering time was derived by deducting total hotelling time from total port stay.

3.2.27. From the vessel track data, typical maneuvering time at major berthing locations was estimated. Experienced members of the marine trade[22] were also consulted to verify the estimates. With maneuvering time determined, total slow cruise time was also derived by deduction. To summarize, for 'good calls':

Slow cruise time = Port stay – Hotelling time – Maneuvering time

where Port stay = ENT – EXR

Maneuvering time = estimate based on vessel track data

3.2.28. Each OGV call, except cruise/ferry, was matched with the 'good calls' identified from VAR. For the matched calls, exact TIM were derived for emission estimation. For the remaining unmatched calls, exact berthing time (ATD minus ATA) and maneuvering time (from vessel track data) were still available. However, there was no ENT and EXT time information to deduce slow cruise time. Slow cruise time was instead estimated by averaging all slow cruise time of vessels (same vessel type) visiting the same berthing location.

[21] Vessels entering and leaving Hong Kong via East Lamma Channel typically had a combined inbound/outbound sailing time of 2 to 4 hours. Vessels coming from Yantian typically took 4 to 5 hours to reach KCCT. An 8-hour criterion was set to capture vessel calls with Yantian as the last/next port. OGV roundtrip between Hong Kong and Yantian was rare.

[22] They are members of the Hong Kong Liners Shipping Association.

3.2.29. For hotelling time, four different cases were identified in this Study:

- Loading/unloading – this was the most common practice;
- Shut-down – Except for tankers and cruise/ferry, there were vessels that stayed in the port with unreasonably long berthing time, but not for docking. Total loading/unloading time was therefore capped at the 98 percentile, which varied among vessel types. Hotelling time exceeding the 98 percentile time was re-classified as shut-down, during which all engines including AB was assumed to have shut down;
- Preparation – For tankers (chemical/gas/oil), total berthing time was capped by typical berthing time allowed at terminals, based on information gathered from the trade. Typical maximum unloading time was set at 36 hours for oil tankers, and 10 hours for chemical/gas tankers[23]. Once again, berthing time in excess of these limits was re-classified as preparation time. Provision for such preparation time for crude oil tanker is meaningful as all other tanker types have same boiler energy defaults whether at terminal or anchorage (see Table 3-23) (crude oil tanker uses large steam boilers for product delivery); and
- Idling – For vessels with total berthing time of less than or equal to one hour at a mid-stream location, such as south of Lamma Island (SLA) or western harbour area (WHA), it was assumed that the lowering of anchor was unlikely, as it would take about 15 minutes each to lower and to raise the anchor. Instead, it was assumed that the vessels would operate in an idling mode, with ME load factor assumed to be 0.02.

3.2.30. Table 3-25 below summarizes the practical meaning of the four hotelling modes explained above, namely idling, unloading/loading, preparation and shut down.

Table 3-25 Practical Meaning of Different Hotelling Modes

Hoteling mode	Idling	(Un)loading	Preparation	Shut-down
OGV Types	All	All	Tankers	All except tankers
Main Engine	On	Off	Off	Off
Auxiliary Engine	On	On	On	Off
Boiler	On	On	On	Off

3.2.31. For cruise/ferry, TIM of regular cruise was determined by information derived from the vessel track data. Similarly, fairway cruise time and maneuvering time of non-regular cruise were determined by vessel track data, whereas berthing time was provided by MD's VAR, and slow cruise time was derived by deducting fairway cruise, maneuvering and berthing time from total call duration provided by MD.

3.2.32. Table 3-26 below summarizes all weighted average TIM information by vessel type, and for FCCV also by DWT sub-class and berthing location.

[23] Information provided by local fuel suppliers.

Table 3-26 Summary of OGVs Time-in-mode (hour)

Vessel Type	Fairway Cruise	Slow Cruise	Maneu-vering	Hotelling *	Total Call Duration
A. Chemical Carrier/Tanker	n.a.	2.08	0.94	12.18	15.19
B. Conventional Cargo Vessel	n.a.	3.75	0.54	38.00	42.28
C. Cruise/Ferry	0.51	2.11	0.42	9.02	12.07
D. Dry Bulk Carrier	n.a.	2.39	0.65	26.86	29.90
E. Fishing/Fish Processing Vessel	n.a.	3.36	0.50	98.00	101.86
F1. FCCV at KCCT	1.10	2.97	1.05	13.78	18.91
DWT < 10,000 (MDO)	1.10	2.97	1.05	13.78	44.28
DWT < 10,000 (HFO)	0.71	2.35	1.06	40.16	17.33
DWT 10,000 – 19,999	0.72	2.42	1.12	13.08	19.28
DWT 20,000 – 29,999	0.85	2.69	1.15	14.58	17.79
DWT 30,000 – 39,999	0.86	2.81	1.05	13.07	18.38
DWT 40,000 – 49,999	0.98	2.98	1.02	13.40	15.74
DWT 50,000 – 74,999	1.08	3.10	1.02	10.54	18.38
DWT 75,000 – 99,999	1.45	3.25	1.02	12.67	20.30
DWT ≧ 100,000	1.56	3.26	1.01	14.46	20.68
F2. FCCV at Other Terminals	0.82	2.60	0.58	43.89	47.89
DWT < 10,000 (MDO)	0.83	2.60	0.51	36.68	40.61
DWT < 10,000 (HFO)	0.80	2.50	0.88	35.61	39.78
DWT 10,000 – 19,999	0.80	2.71	0.88	48.28	52.69
DWT 20,000 – 29,999	0.80	2.90	0.67	43.88	48.25
DWT 30,000 – 39,999	0.81	2.77	1.00	184.68	189.26
DWT 40,000 – 49,999	NR	NR	NR	NR	NR
DWT 50,000 – 74,999	0.93	2.47	1.00	351.26	355.66
DWT 75,000 – 99,999	1.25	2.03	1.00	812.38	816.66
DWT ≧ 100,000	NR	NR	NR	NR	NR
F3. FCCV at Anchorages	0.80	2.64	0.50	27.59	31.54
DWT < 10,000 (MDO)	0.82	2.61	0.50	34.99	38.92
DWT < 10,000 (HFO)	0.79	2.63	0.51	29.59	33.52
DWT 10,000 – 19,999	0.83	2.71	0.51	21.26	25.30
DWT 20,000 – 29,999	0.82	2.72	0.51	20.48	24.53
DWT 30,000 – 39,999	0.79	2.67	0.50	16.64	20.60
DWT 40,000 – 49,999	0.55	2.48	0.50	13.55	17.09
DWT 50,000 – 74,999	0.59	2.56	0.50	10.60	14.25
DWT 75,000 – 99,999	0.52	2.11	0.50	6.35	9.48
DWT ≧ 100,000	0.57	2.85	0.50	4.22	8.14
G. Gas Carrier/Tanker	n.a.	2.46	0.71	40.88	44.05
H. Lighter/Barge/Cargo Junk	n.a.	4.00	1.00	112.00	117.00
I. Oil Tanker	n.a.	2.50	1.03	22.01	25.54
J. Pleasure Vessel	n.a.	2.00	1.00	66.00	69.00
K. Roll On/Roll Off	n.a.	3.56	1.04	14.61	19.21

L. Semi-container Vessel	n.a.	3.40	0.79	28.52	32.70
M. Tug	n.a.	3.59	0.50	92.00	96.09
N. Others	n.a.	3.43	1.00	66.00	70.43

n.a. = Not applicable; NR = No arrival recorded, i.e. VAN = 0
* Including four hotelling modes: idling, unloading/loading, preparation and shut down.

Marine Fuel Type and Quality

3.2.33. Fuel type is an important determinant of emission factors. It was assumed in this Study that vessels with ME power greater than 1,100 kW would burn HFO. Otherwise, distillate fuel such as MDO and marine gas oil (MGO) would be used. Based on Table 2-2 of *ICF 2009 Report,* Cat. 2 engine used in small OGV propulsion has approximate power rating of 1,000 to 3,000 kW. Engine rating of 1,100 kW is thus a conservative cut-off point, supported by (a) its corresponding 3,000 DWT, which is less than *PoLA 2009 Report* in defining OGVs as vessels of DWT over 5,000; (b) RVs which use distillate could have engine rating up to 1,565 kW (except tug, which also uses distillate), based on RVs information collected from Marine Offices of MD.

3.2.34. In terms of fuel sulphur content, findings of the marine vessel survey indicated that effective sulphur contents of fuel used by OGV visiting Hong Kong for ME, AE and AB were 2.83%, 2.64% and 2.77%, respectively. This combines the effect of (a) average sulphur contents of primary fuel for ME, AE and AB at 2.95%, 2.78% and 2.80% respectively; and (b) fuel switching within Hong Kong water at 4% for ME, 5% for AE and 1% for AB.

3.2.35. As for distillate fuel, effective sulphur content was set at 0.5%, maximum regulatory value for industrial diesel oil initially introduced for industrial and commercial sectors in the past but also applies to marine application.

Emission Factors and Low Load Adjustment Factors

3.2.36. Based on the type of fuel (HFO, MDO and MGO), type and speed[24] of engine (SSD, MSD, HSD, ST and GT) installed, emission factors (EFs) and brake specific fuel consumption (BSFC) were selected for different equipments to estimate the quantity of different air pollutants emitted and fuel consumed from the vessel during a call.

3.2.37. EFs used in this Study were based on *ICF 2009 Report* (except PM of GT and ST) and *PoLA 2009 Report* (for PM of GT and ST). The former incorporates those of the *Entec 2002 Study*, except for PM EFs. CARB provided the PM EFs for SSD and MSD. The latter adopted PM EFs for GT and ST by IVL 2004 Study[25]. Tables 3-27 to 3-29 summarizes emission factors used for ME, AE, and AB. Steam turbine propulsion emission factors were used for calculating boiler emissions, in line with practice in overseas studies.

[24] Slow and medium speed refer to engine RPM < 130 and 130 – 1,400 respectively. Their respective engine stroke types are 2 and 4. See Table 2-3 in *ICF 2009 Report*.
[25] IVL, (2004) Methodology for Calculating Emissions from Ships: Update on Emission Factors, prepared by IVL Swedish Environmental Research Institute for the Swedish Environmental Protection Agency.

Table 3-27 OGV Main Engine Emission Factors (g/kWh)

Engine Type	Fuel Type	Sulphur %	SO_2	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	BSFC
SSD	HFO	2.70%	10.29	18.10	1.42	1.31	0.60	1.40	195
SSD	MDO	1.00%	3.62	17.00	0.45	0.42	0.60	1.40	185
SSD	MGO	0.50%	1.81	17.00	0.31	0.28	0.60	1.40	185
MSD	HFO	2.70%	11.24	14.00	1.43	1.32	0.50	1.10	213
MSD	MDO	1.00%	3.97	13.20	0.47	0.43	0.50	1.10	203
MSD	MGO	0.50%	1.98	13.20	0.31	0.29	0.50	1.10	203
GT	HFO	2.70%	16.10	6.10	0.05	0.04	0.10	0.20	305
GT	MDO	1.00%	5.67	5.70	0.02	0.02	0.10	0.20	290
GT	MGO	0.50%	2.83	5.70	0.01	0.01	0.10	0.20	290
ST	HFO	2.70%	16.10	2.10	0.80	0.60	0.10	0.20	305
ST	MDO	1.00%	5.67	2.00	0.31	0.24	0.10	0.20	290
ST	MGO	0.50%	2.83	2.00	0.19	0.14	0.10	0.20	290

Table 3-28 OGV Auxiliary Engine Emission Factors (g/kWh)

Fuel Type	Sulphur %	SO_2	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	BSFC
HFO	2.70%	11.98	14.70	1.44	1.32	0.40	1.10	227
MDO	1.00%	4.24	13.90	0.49	0.45	0.40	1.10	217
MGO	0.50%	2.12	13.90	0.32	0.29	0.40	1.10	217

Table 3-29 OGV Boiler Emission Factors (g/kWh)

Fuel Type	Sulphur %	SO_2	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	BSFC
HFO	2.70%	16.10	2.10	0.80	0.60	0.10	0.20	305
MDO	1.00%	5.67	2.00	0.31	0.24	0.10	0.20	290
MGO	0.50%	2.83	2.00	0.19	0.14	0.10	0.20	290

3.2.38. The low load adjustment factor was applied to ME emission factors when load factor was lower than 20% (Table 3-30) to account for lower combustion efficiency when engines are used at low load.

Table 3-30 Low Load Adjustment Multipliers for OGV Emission Factors

Load	SO_2	NO_X	PM	HC	CO
0.02	1.00	4.63	7.29	21.18	9.68
0.03	1.00	2.92	4.33	11.68	6.46
0.04	1.00	2.21	3.09	7.71	4.86
0.05	1.00	1.83	2.44	5.61	3.89
0.06	1.00	1.60	2.04	4.35	3.25
0.07	1.00	1.45	1.79	3.52	2.79
0.08	1.00	1.35	1.61	2.95	2.45
0.09	1.00	1.27	1.48	2.52	2.18
0.10	1.00	1.22	1.38	2.18	1.96
0.11	1.00	1.17	1.30	1.96	1.79
0.12	1.00	1.14	1.24	1.76	1.64
0.13	1.00	1.11	1.19	1.60	1.52
0.14	1.00	1.08	1.15	1.47	1.41
0.15	1.00	1.06	1.11	1.36	1.32
0.16	1.00	1.05	1.08	1.26	1.24
0.17	1.00	1.03	1.06	1.18	1.17
0.18	1.00	1.02	1.04	1.11	1.11
0.19	1.00	1.01	1.02	1.05	1.05
0.20	1.00	1.00	1.00	1.00	1.00

Emission Reduction Technologies

3.2.39. In this Study, special attention was paid to vessels constructed (keel-laying date) on or after 1st January 2000 and before 1st January 2011 (2000+ vessels), as they were required to satisfy Tier 1 standard of IMO Regulation 13 on NO_X emission with each of their marine diesel engine with a power output of over 130 kW.

3.2.40. For vessels constructed between 2000 and 2003, and installed with any 2-stroke MAN B&W diesel engines (vessels with engine make of "MAN", "B&W" or "MAN B&W" inclusive) of less than 10,000 kW power, they were assumed to be still using conventional valve, and their NO_X emissions would be reduced by 20%.[26]

3.2.41. For vessels constructed between 2000 and 2003, and installed with any 2-stroke MAN B&W diesel engines of more than 10,000 kW power, and all vessels constructed after 2003 using 2-stroke MAN B&W diesel engine, they were assumed to be using slide fuel valve. As a result, these vessels would have their NO_X emissions reduced by 20%, PM emissions reduced by 25%, and HC/VOC emissions reduced by 30%.[27]

3.2.42. For vessels constructed on or after 2000 and installed with MAN B&W 4-stroke diesel engine, they would have their NO_X emissions reduced by 25%.[28]

3.2.43. For vessels constructed on or after 2000 and installed with engines manufactured by

[26] Based on reply email from Svend Henningsen of MAN to Billy Cheung of EPD, dated 15th January 2010.
[27] Based on above email, and 1st February 2010's return of MAN providing Engine_Make of "MAN B&W" and launched date in 2002_03, showing the conventional valve has Engine total small than 10,000 kW and the slide fuel valve equal or greater than 10,000 kW in general. All MAN engines of keel laid date from 1st January 2004 onwards are assumed to be equipped with slide fuel valves, consistent with *PoLA 2009 report*.
[28] Based on reply email from Fritz Fleischer of MAN to Billy Cheung of EPD, dated 25th February 2010.

companies other than MAN B&W, they would have their NO_X emissions from ME and AE both reduced by 11%.[29]

3.3. Results and Discussions

3.3.1. The following paragraphs summarize OGV emissions by vessel type, equipment and mode for each pollutant (Tables 3-31 to 3-33). Further breakdowns are made for detailed analysis per vessel type, using FCCV as an example in Tables 3-34 and 3-35. To estimate VOC[30] emissions consistent with current EPD's emissions inventory system, an adjustment factor of 1.053 was applied to the HC outputs[31].

Emission by Vessel Type

3.3.2. A summary of 2007 OGV emissions by vessel type for all pollutants is presented in Table 3-31.

Table 3-31 2007 OGV Emissions (tonne) by Vessel Type

Vessel Type	No. of Call	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
A. Chemical Carrier/Tanker	452	45.7	44.1	5.1	4.6	1.9	3.9
B. Conventional Cargo Vessel	4,664	322.7	374.9	37.0	33.6	13.9	31.8
C. Cruise/Ferry	3,562	1,144.9	1,598.2	131.9	119.1	61.3	136.5
D. Dry Bulk Carrier	1,362	304.0	289.0	31.7	28.3	1.5	25.0
E. Fishing/Fish Processing Vessel	509	3.3	21.5	0.5	0.5	0.7	1.7
F. Fully Cellular Container Vessel	23,563	9,886.4	11,479.8	1,172.8	1,062.5	520.8	1,166.1
G. Gas Carrier/ Tanker	342	40.5	37.3	4.3	3.8	1.4	3.1
H. Lighter/ Barge/ Cargo Junk	152	13.2	86.3	2.0	1.8	2.6	6.8
I. Oil Tanker	1,400	542.2	338.4	45.6	40.2	13.6	30.3
J. Pleasure Vessel	127	0.5	2.6	0.1	0.1	0.1	0.2
K. Roll On/Roll Off	461	75.8	89.8	9.3	8.4	3.8	8.0
L. Semi-container Vessel	190	12.5	14.0	1.4	1.3	0.6	1.3
M. Tug	249	8.4	41.7	1.2	1.1	1.3	3.1
N. Others	119	38.3	44.0	4.5	4.1	1.5	3.6
Total	**37,152**	**12,438**	**14,462**	**1,447**	**1,309**	**635**	**1,421**

[29] Based on page 2-15, section 2.6 of *ICF 2009 Report*.
[30] Total HC plus oxygenated components such as alcohols and aldehydes that take part in ozone formation reactions are defined as VOC.
[31] Based on USEPA (2007) Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotives Engines and Marine Compression Ignition Engines less than 30 litres per Cylinder. EPA 420-D-07-001, March 2007.

3.3.3. Top five emitters of SO_2 were container vessels (79.5%), cruise/ferry (9.2%), oil tanker (4.4%), conventional cargo vessel (2.6%), and dry bulk carrier (2.4%). In total, they accounted for 98.1% of SO_2 emissions in 2007. (Figure 3-8)

3.3.4. Top five emitters of NO_X were container vessels (79.4%), cruise/ferry (11.1%), conventional cargo vessel (2.6%), oil tanker (2.3%), and dry bulk carrier (2.0%). In total, they accounted for 97.4% of NO_X emissions in 2007. (Figure 3-9)

3.3.5. Top five emitters of PM_{10} were container vessels (81.0%), cruise/ferry (9.1%), oil tanker (3.2%), conventional cargo vessel (2.6%), and dry bulk carrier (2.2%). In total, they accounted for 98.0% of PM_{10} emissions in 2007. (Figure 3-10)

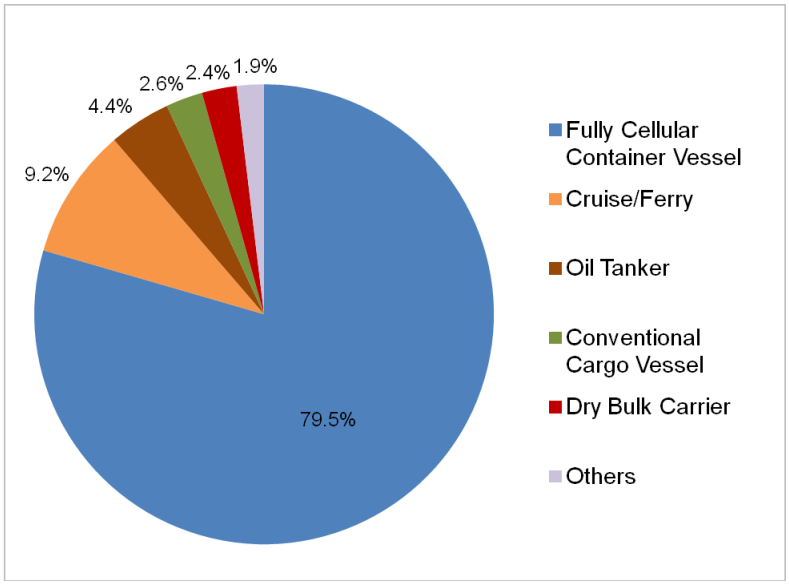

Figure 3-8 OGV SO_2 Emission by Vessel Type (%)

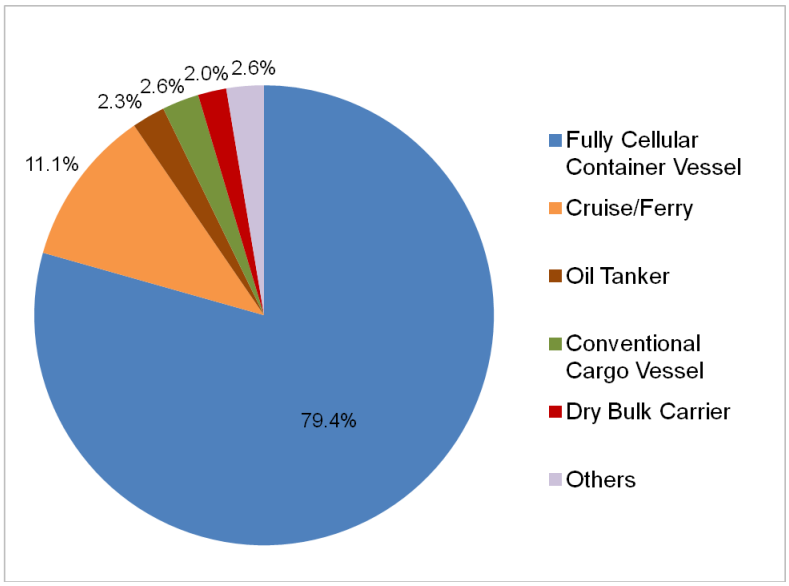

Figure 3-9 OGV NO_X Emission by Vessel Type (%)

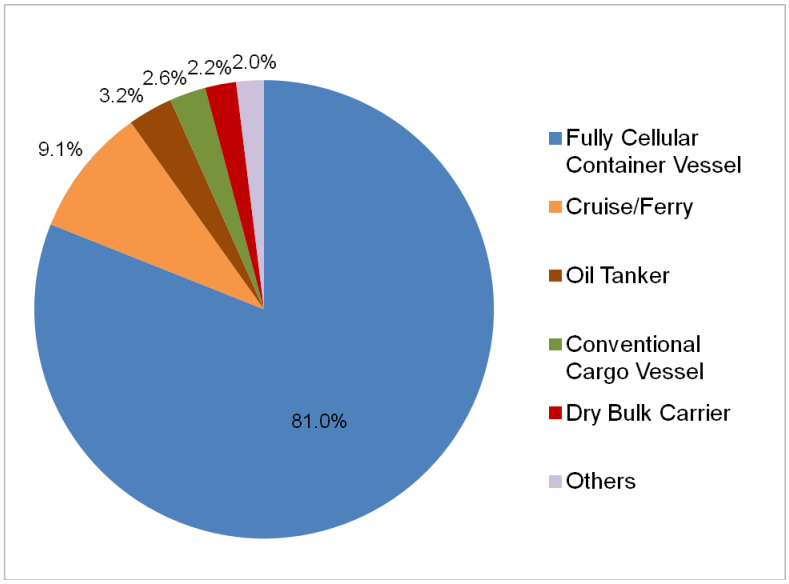

Figure 3-10 OGV PM_{10} Emission by Vessel Type (%)

Emission by Equipment

3.3.6. 2007 OGV emissions by equipment for all pollutants is summarized in Table 3-32.

Table 3-32 2007 OGV Emissions (tonne) by Equipment

Equipment	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Main Engine	5,020.0	7,960.6	740.8	682.4	431.5	902.7
Auxiliary Engine	4,713.0	6,143.4	571.8	526.1	185.5	484.6
Boiler	2,705.2	357.4	134.5	100.9	17.9	34.1
Total	**12,438**	**14,462**	**1,447**	**1,309**	**635**	**1,421**

3.3.7. For SO_2, 40.4% was emitted from ME, 37.9% from AE, and 21.7% from AB. For NO_X, 55 % was emitted from ME, and 42.5% from AE. AB only accounted for 2.5%. For PM_{10}, the corresponding percentages were 51.2%, 39.5% and 9.3%, respectively. (Figure 3-11)

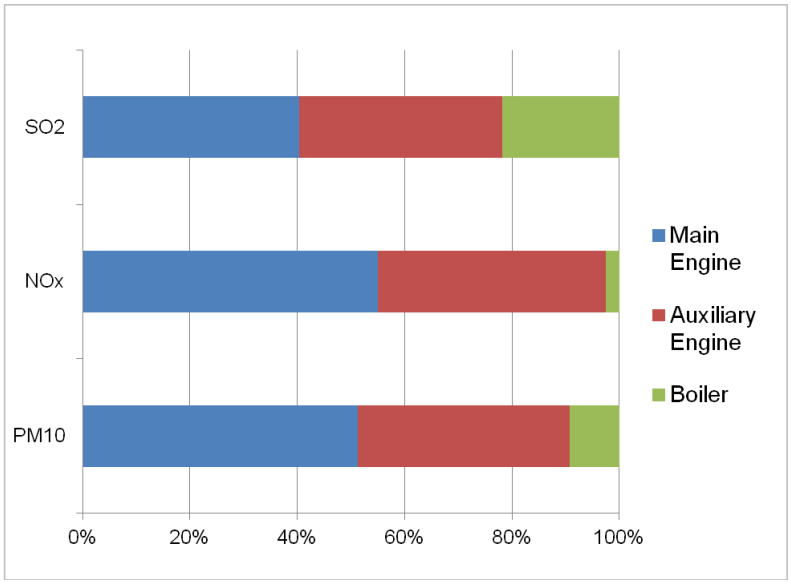

Figure 3-11 OGV Emission by Equipment (%)

3.3.8. Figures 3-12 to 3-14 show a further breakdown of OGV emission by equipment and major vessel type. Contribution of AB to SO_2 emission ranged from over 50% for oil tanker to just short of 20% for conventional cargo vessel. For NO_X, emission produced by AE was dominant for cruise/ferry. For PM_{10}, AB was once again a key emission source for oil tanker and dry bulker carrier.

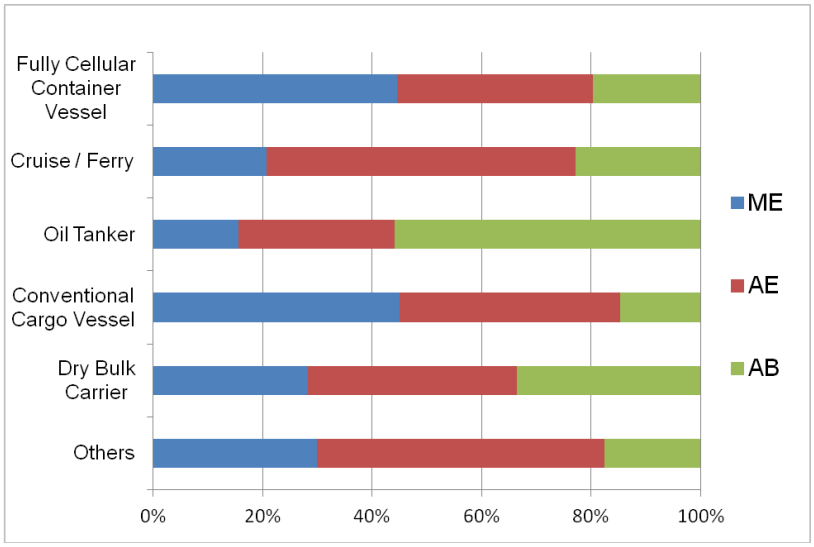

Figure 3-12 OGV SO_2 Emission by Equipment by Vessel Type (%)

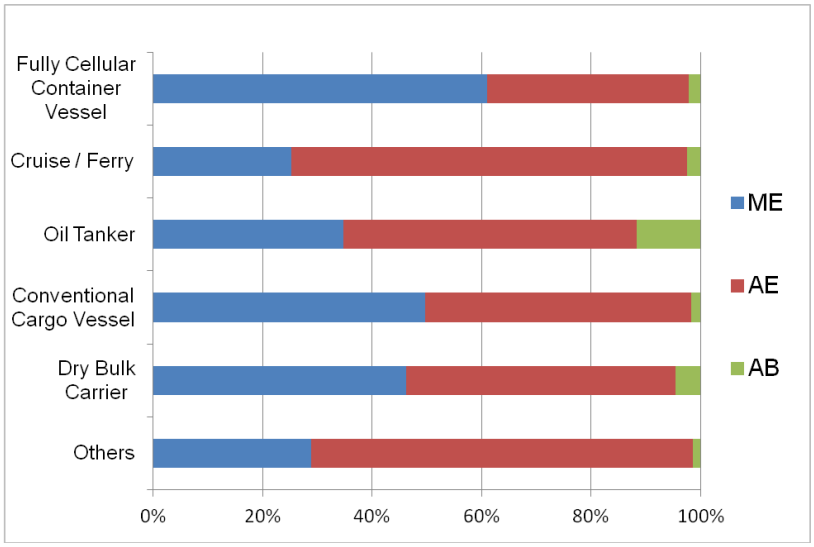

Figure 3-13 OGV NO_X Emission by Equipment by Vessel Type (%)

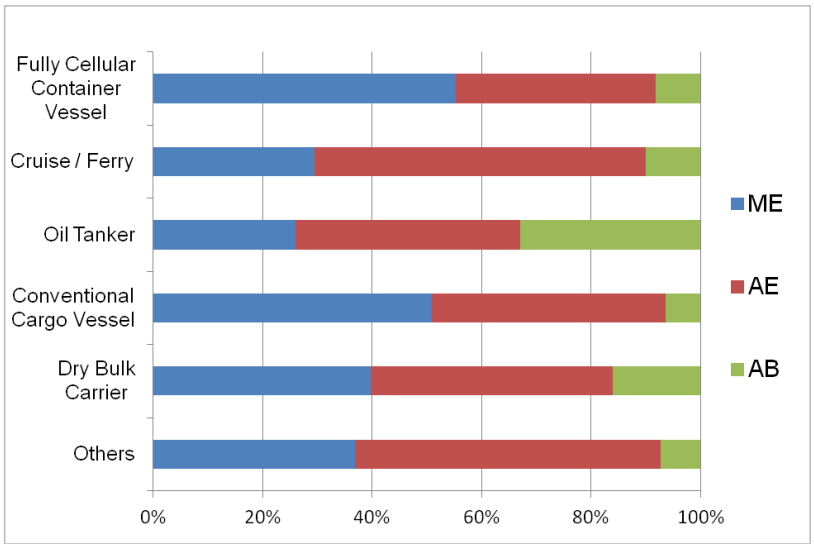

Figure 3-14 OGV PM_{10} Emission by Equipment by Vessel Type (%)

Emission by Operation Mode

3.3.9. A summary of 2007 OGV emissions by activity mode for all pollutants is presented in Table 3-33.

Table 3-33 2007 OGV Emissions (tonne) by Mode

Activity Mode	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Fairway Cruise	3,043.1	4,246.2	368.0	338.5	150.7	381.2
Slow Cruise	3,476.9	4,657.4	452.1	413.5	224.1	525.7
Maneuvering	680.7	1,210.0	148.5	135.7	122.7	166.6
Hotelling	5,237.4	4,348.0	478.6	421.7	137.4	347.9
Total	**12,438**	**14,462**	**1,447**	**1,309**	**635**	**1,421**

3.3.10. In 2007, hotelling accounted for 42.1% of SO_2 emissions from OGVs and followed by slow cruise of 28%. Fairway cruise accounted for 24.5%, and maneuvering for 5.5%. (Figure 3-15)

3.3.11. As for NO_X, 32.3% was emitted during slow cruise and 30.1% during hotelling. Fairway cruise accounted for 29.4%, and maneuvering for 8.4%.

3.3.12. For PM_{10}, 33.1% was emitted during hotelling and 31.2% during slow cruise. The remainder was emitted during fairway cruise (25.4%) and maneuvering (10.3%).

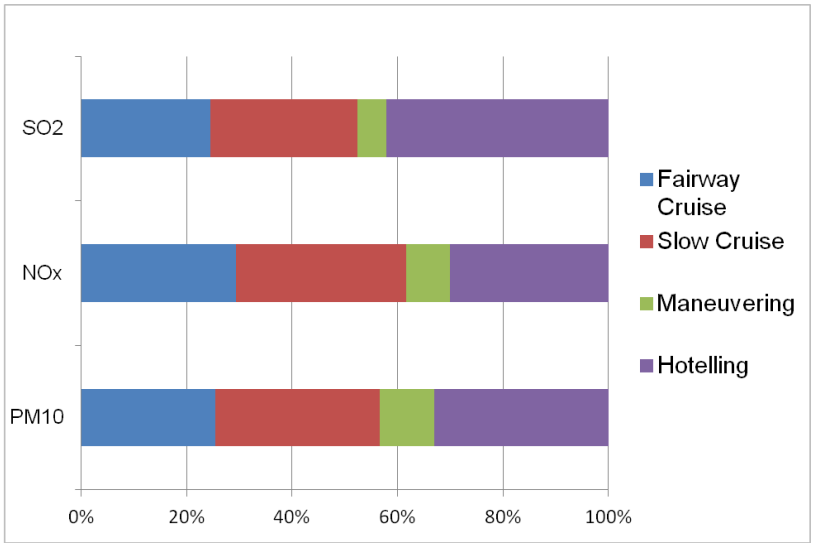

Figure 3-15 OGV Emission by Operation Mode (%)

3.3.13. Figures 3-16 to 3-18 show that OGV emission by operation mode varied amongst major vessel type and from one pollutant to another. First, emission during fairway cruise mode only happened with FCCV and ocean/ferry. Second, emission of SO_2 during hotelling ranged from about 80% for oil tanker to about 40% for FCCV. The range for NO_X was from about 60% to 20%, and from about 70% to 30% for PM_{10}. Third, over half of conventional cargo vessel's emission was produced by ME.

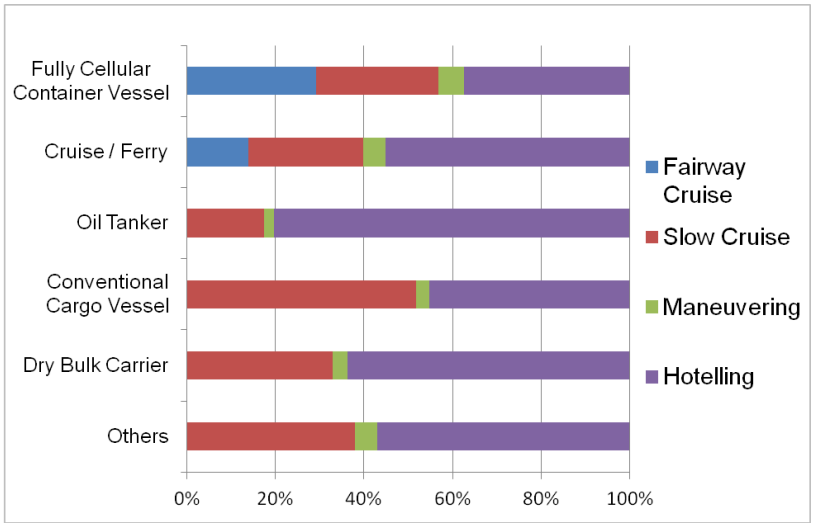

Figure 3-16 OGV SO_2 Emission by Mode by Vessel Type (%)

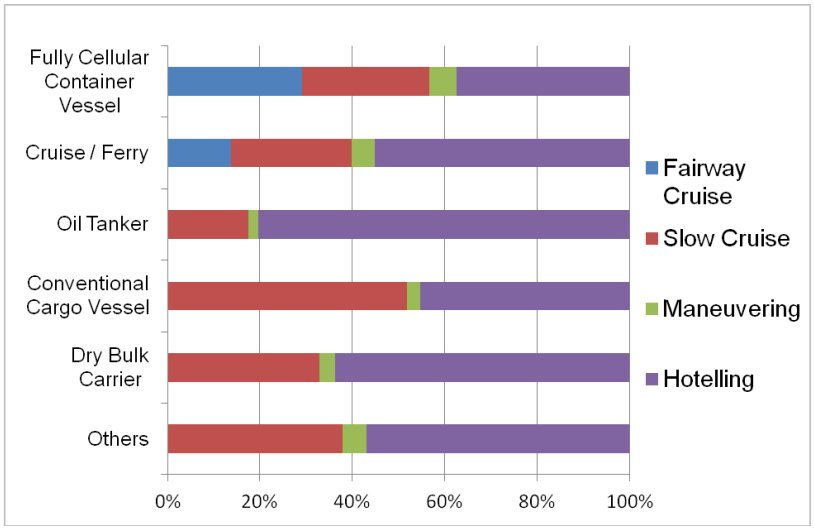

Figure 3-17 OGV NO_X Emission by Mode by Vessel Type (%)

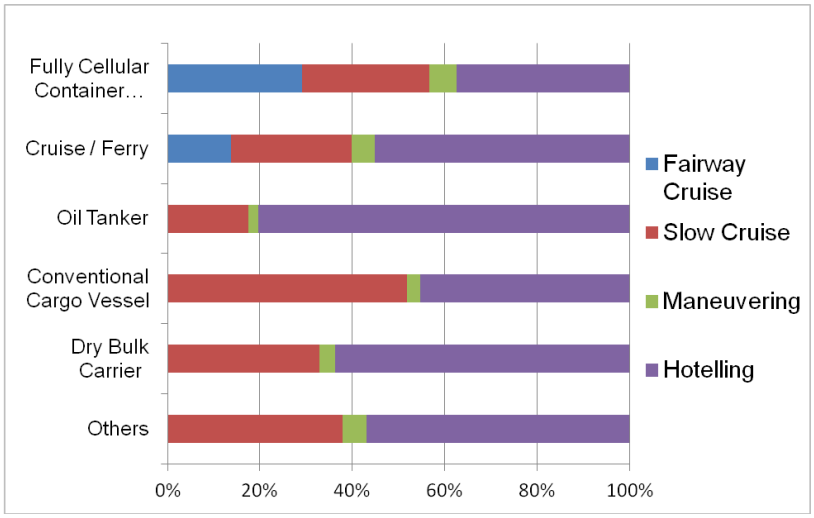

Figure 3-18 OGV PM_{10} Emission by Mode by Vessel Type (%)

Detailed Analysis of FCCV Emissions

3.3.14. FCCV was the largest emitter among OGV types. Table 3-34 shows that FCCV at KCCT contributed about 83% to 87% of total air emissions, compared to the 13% to 17% emitted from FCCV that operated elsewhere, that is, at other terminals or anchorages. Emissions from the former group mainly come from larger ships (DWT 50,000 or above), which was understandable as larger container vessels cannot operate at anchorages and KCCT was their preferred terminal location.

3.3.15. For FCCV that operated elsewhere at other terminals and anchorages, smaller container vessels (DWT below 10,000) contributed relatively little emission, despite their large numbers (6,635). For example, 135.6 tonnes of SO_2 was emitted out of 1,432.7 from all anchorages FCCVs, or 9.5%. There were a few reasons for this. Firstly, ME power of these FCCVs was much lower, with an average of 617 and 3,756 kW of vessel burning MDO and HFO respectively (see Table 3-16). Secondly, it was assumed in this Study that vessels with ME power of 1,100 kW or below would use distillate fuel, with lower sulphur content and thus small SO_2 emissions.

Table 3-34 2007 Ocean FCCV Emissions (tonne) by DWT and Berthing Location

FCCV	Calls	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
KCCT	13,305	8,227.5	9,775.9	993.2	901.2	451.5	1,006.0
DWT < 10,000 (MDO)	264	0.7	3.4	0.1	0.1	0.1	0.3
DWT < 10,000 (HFO)	606	56.1	44.0	5.9	5.3	2.2	4.2
DWT 10,000 – 19,999	2,527	637.1	661.1	73.7	66.3	30.8	63.7
DWT 20,000 – 29,999	2,175	802.7	874.0	93.4	84.4	39.3	85.5
DWT 30,000 – 39,999	1,731	900.1	1,009.4	104.4	94.5	44.3	100.8
DWT 40,000 – 49,999	1,352	734.1	857.6	88.7	80.2	41.3	86.8
DWT 50,000 – 74,999	3,000	2,989.7	3,695.2	367.6	334.2	170.2	380.0
DWT 75,000 – 99,999	845	1,043.7	1,312.7	129.7	118.1	61.9	140.4
DWT ≧ 100,000	805	1,063.2	1,318.5	129.6	118.0	61.6	144.3
Other Terminals	2,258	226.2	217.4	23.4	20.9	8.4	19.0
DWT < 10,000 (MDO)	1,833	34.0	42.8	3.6	3.2	0.6	3.4
DWT < 10,000 (HFO)	218	19.8	20.7	2.2	1.9	1.1	1.9
DWT 10,000 – 19,999	121	31.7	27.7	3.3	2.9	1.5	2.5
DWT 20,000 – 29,999	30	7.5	6.9	0.8	0.7	0.7	0.6
DWT 30,000 – 39,999	21	29.6	26.7	3.1	2.7	1.0	2.4
DWT 40,000 – 49,999	-	-	-	-	-	-	-
DWT 50,000 – 74,999	35	100.6	89.9	10.2	9.1	3.3	8.0
DWT 75,000 – 99,999	1	3.0	2.7	0.3	0.3	0.1	0.3
DWT ≧ 100,000	-	-	-	-	-	-	-
Anchorages	8,000	1,432.7	1,486.5	156.2	140.4	60.8	141.1
DWT < 10,000 (MDO)	3,755	63.5	84.1	6.7	6.0	1.4	6.8
DWT < 10,000 (HFO)	829	72.1	60.5	7.3	6.4	2.9	5.6
DWT 10,000 – 19,999	1,542	439.1	416.9	46.6	41.7	17.6	38.6
DWT 20,000 – 29,999	1,012	414.5	418.0	44.3	39.8	16.8	38.1
DWT 30,000 – 39,999	368	187.1	201.6	21.0	18.9	8.3	19.3
DWT 40,000 – 49,999	133	50.7	56.2	5.9	5.3	2.6	5.6
DWT 50,000 – 74,999	274	153.4	181.9	18.2	16.5	8.2	19.3
DWT 75,000 – 99,999	42	24.2	30.1	2.8	2.6	1.3	3.5
DWT ≧ 100,000	44	28.2	37.1	3.5	3.2	1.8	4.3
Total	**23,563**	**9,886.4**	**11,479.8**	**1,172.8**	**1,062.5**	**520.8**	**1,166.1**

3.3.16. Table 3-35 gives an insight about emissions from FCCV by equipment and operating modes. Using SO_2 as an example, main sources of emission were ME during fairway cruise (27%), AE during hotelling (22%), ME during slow cruise (16%), and AB during hotelling (15%).

Table 3-35 2007 Ocean FCCV Emissions (tonne) by Equipment and Mode

FCCV	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Main Engine	4397.6	7011.1	648.4	596.5	379.6	806.4
Fairway Cruise	2681.2	3798.1	323.6	297.7	135.6	345.0
Slow Cruise	1628.3	2637.8	247.6	227.8	150.3	352.0
Maneuvering	87.8	573.5	77.0	70.8	93.5	109.1
Hotelling	0.3	1.7	0.2	0.2	0.3	0.3
Auxiliary Engine	3540.1	4214.5	427.5	393.3	128.5	335.4
Fairway Cruise	203.5	239.9	24.6	22.6	7.3	19.2
Slow Cruise	771.6	913.6	93.2	85.7	27.9	72.8
Maneuvering	386.9	457.9	46.7	43.0	14.0	36.4
Hotelling	2178.2	2603.1	263.1	242.1	79.3	207.0
Boiler	1948.7	254.2	96.8	72.6	12.7	24.2
Fairway Cruise	0.0	0.0	0.0	0.0	0.0	0.0
Slow Cruise	327.6	42.7	16.3	12.2	2.1	4.1
Maneuvering	102.9	13.4	5.1	3.8	0.7	1.3
Hotelling	1518.2	198.0	75.4	56.6	9.9	18.9
Total	**9886.4**	**11479.8**	**1172.8**	**1062.5**	**520.8**	**1166.1**

3.3.17. Table 3-35 also shows that most FCCV SO_2 was mainly emitted from ME (44%) and AE (36%). In terms of mode, 37% of SO_2 was emitted during hotelling, followed by fairway cruise (29%) and slow cruise (28%).

3.4. Comparison with Overseas Studies

Overview

3.4.1. Overseas studies on marine vessel emissions are mostly developed by either the US or European Union (EU). Studies for PoLA, the UK, Rotterdam and Kaohsiung were selected for comparison with this Study. PoLA and Rotterdam are the busiest ports in North America and Europe respectively. Studies for the UK ports and Kaohsiung port are the most recently completed ones, and were selected in this analysis for benchmarking purpose.

Emission Factors

3.4.2. Although EFs used in this Study were based on two US documents (*PoLA 2009 Report* and *ICF 2009 Report*), they in turn made reference to two documents of the EC (*Entec 2002 Study* and *2004 IVL Studies*), except for EFs of PM which were provided by CARB. CARB had collected own measurement data for PM and thus offered up-to-date figures.

3.4.3. One of the two US documents, *ICF 2009 Report*, represents USEPA. Its EFs are found to be comparable with those of the *Entec 2005* Report,[32] representing the EU. EFs for OGV ME and AE are comparable. Entec has higher ME EFs for

[32] See Entec UK Limited (2007).

maneuvering and hotelling. Yet, when EFs are adjusted with low load adjustment multipliers (see Table 3-30), results of *ICF 2009 Report* are similar to those of *Entec 2002 Report*.

3.4.4. The other US document, *PoLA 2009 Report*, has parameters down to different TEU throughput classes for container vessels derived from Vessel Boarding Program that collects actual operational data.

Emissions Inventory of Port of Los Angeles

3.4.5. PoLA has been compiling annual port-related emission inventories for 2001 base year and subsequent years since 2005.[33] Container vessel was selected for comparison because it is a major emitter for both PoLA and Port of Hong Kong. Container vessels in PoLA and Hong Kong are classified by TEU capacity and DWT class respectively. Three pollutants in 2007 are selected for comparison.

3.4.6. Table 3-36 below shows that emissions per container vessel call are higher in LA than Hong Kong, about 2-3 times higher for most of the comparable vessel classes.

Table 3-36 Emission per FCCV Call, PoLA and Port of Hong Kong, 2007

Port of LA Emission Inventory 2007*										
TEU Class	**No. of Arrival**	**Total Emissions (tonne)**			**Emissions per call (tonne/call)**					
		SO_2	**NO_X**	**PM_{10}**	**SO_2**	**NO_X**	**PM_{10}**			
1,000	234	133.5	201.8	15.3	0.57	0.86	0.07			
2,000	104	101.2	116.6	9.3	0.97	1.12	0.09			
3,000	127	150.3	260.0	19.2	1.18	2.05	0.15			
4,000	537	685.3	1348.9	96.3	1.28	2.51	0.18			
5,000	329	555.9	897.0	69.2	1.69	2.73	0.21			
6,000	160	296.7	648.3	40.6	1.85	4.05	0.25			
7,000	80	122.3	304.2	15.8	1.53	3.80	0.20			
8,000	4	7.1	10.3	0.8	1.77	2.56	0.20			
Total	***1,575***	***2,052***	***3,787***	***267***	***1.30***	***2.40***	***0.17***			
Port of Hong Kong Emission Inventory 2007										
DWT Class	**No. of Arrival**	**Total Emissions (tonne)**			**Emissions per call (tonne/call)**			**Tonne/call ratio (LA/HK)**		
		SO_2	**NO_X**	**PM_{10}**	**SO_2**	**NO_X**	**PM_{10}**	**SO_2**	**NO_X**	**PM_{10}**
<10k	7,505	190.3	204.1	19.7	0.03	0.03	0.00			
10-19k	4,190	1,136.2	1,127.6	126.6	0.27	0.27	0.03	2.1	3.2	2.2
20-29k	3,217	1,252.2	1,328.5	141.5	0.39	0.41	0.04			
30-39k	2,120	1,116.9	1,237.8	128.4	0.53	0.58	0.06	1.8	1.9	1.5
40-49k	1,485	784.8	913.9	94.6	0.53	0.62	0.06	2.2	3.3	2.5
50-74k	3,308	3,243.8	3,967.0	396.0	0.98	1.20	0.12	1.5	2.2	1.6
75-99k	889	1,070.8	1,345.5	132.8	1.20	1.51	0.15	1.5	2.6	1.6
≥100k	849	1,091.4	1,355.6	133.1	1.29	1.60	0.16	1.4	1.6	1.3
Total	***23,563***	***9,886***	***11,480***	***1,173***	***0.42***	***0.49***	***0.05***			

* Starcrest Consulting Group (2008b)

3.4.7. There is a couple of reasons for the difference. First, hotelling time in PoLA ranged from 29.8 hour for container vessels of 1,000 TEU to 71.4 hours for those of 8,000 TEU, compared to about 13 hours on average at KCCT in Hong Kong. Second, fairway distance is also much longer while approaching PoLA. These two factors

[33] See http://www.portoflosangeles.org/environment/studies_reports.asp.

combined to explain the higher emission per call in PoLA. To the contrary, the use of low sulphur fuel in some vessels calling PoLA may reduce emission per vessel call to some extent.

Emissions Inventory of the United Kingdom

3.4.8. In November 2010, the Final Report on UK Ship Emissions Inventory was published by Entec.[34] Two sets of emission inventory, one for "UK waters" and one for a much smaller region of 12 nm off UK coastline were compiled for 2007. Emissions from ME and AE (but not AB) were extracted from this Study for comparison with the UK inventory, which does not include AB emissions.

3.4.9. Table 3-37 shows that emission per call in the UK is higher for SO_2 by 53%, NO_X by 147% and PM_{10} by 12%. First, average hotelling time in the UK was 30 hours, compared to 22.7 hours in Hong Kong. Second, the UK inventory covered areas up to 12 nm off the coast, whereas Hong Kong has a smaller sea area (approximately 8 nm off the coast). The above combined effect on a higher emission per call in the UK, however, was offset by fact that more than 50% of the UK coastline falls in an Emission Control Area (ECA) where fuel switching to 1.5% sulphur fuel is required.

Table 3-37 Comparison of Key UK and HK Inventory Parameters, 2007

UK Ship Emission Inventory 2007* (VAN = 106,887)						
	Emissions (tonne)**			**Emission** per call (tonne/call)**		
Operation Mode	**SO_2**	**NO_X**	**PM_{10}**	**SO_2**	**NO_X**	**PM_{10}**
At Sea	28,000	62,000	2,400			
Maneuvering	2,000	4,000	300			
At Berth	13,000	35,000	1,500			
Total	**43,000**	**100,000**	**4,200**	0.402	0.936	0.039
Port of Hong Kong Emission Inventory 2007 (VAN = 37,152)						
	Emissions (tonne)**			**Emission** per call (tonne/call)**		
Operation Mode	**SO_2**	**NO_X**	**PM_{10}**	**SO_2**	**NO_X**	**PM_{10}**
Underway	6,141	8,854	801			
Maneuvering	557	1,194	142			
Hotelling	3,035	4,057	369			
Total	**9,733**	**14,104**	**1,313**	0.262	0.380	0.035
Tonne/call Ratio (UK/HK)				**SO_2**	**NO_X**	**PM_{10}**
				1.53	2.47	1.12

* Entec UK Limited (2010)
** ME and AE emissions only.

[34] See http://www.airquality.co.uk/reports/cat15/1012131459_21897_Final_Report_291110.pdf

Emissions Inventory of Rotterdam

3.4.10. Ship emission estimates in Rotterdam in 2005[35] were selected to compare with findings of this Study. Emission per call was used as the basis of comparison, but only at-berth emission was chosen due to data availability.

3.4.11. Among OGVs, container vessel was selected for comparison because first, it is a major vessel type in both ports: container vessel is the top emitter in Hong Kong, representing about 80% of total calls and emissions, whereas in Rotterdam it also comes first in total gross tonnage and second in call number and emissions. Second, other vessel types such as general cargo vessel and oil tanker are significantly different between Rotterdam and Hong Kong, thus making comparison difficult: majority of general cargo vessels are operated mid-stream in Hong Kong, and gross tonnage of oil tankers in Rotterdam is on average 2.5 times of those calling Hong Kong.

3.4.12. Table 3-38 shows that at-berth emission per call in Rotterdam and Hong Kong are comparable, with its ratios ranging from 0.5 to 2.8. The difference can be explained by (a) the higher at-berth engine EF used in Rotterdam, except PM (thus lower PM emission in Rotterdam); (b) much higher at-berth boiler HC and CO EF in Rotterdam, thus higher HC and CO emissions; and (c) slightly higher gross tonnage (1.2 times of Hong Kong) and berthing time (1.1 times of Hong Kong) in Rotterdam.

Table 3-38 Comparison of Key Rotterdam (2005) and HK (2007) Inventory Parameters

Rotterdam 2005 (VAN = 6,309)					
At berth emissions	**SO_2**	**NO_X**	**PM_{10}**	**HC**	**CO**
Tonne/year	909	890	49	44	172
Tonne/call	0.144	0.141	0.008	0.007	0.027
Port of Hong Kong 2007 (VAN = 23,563)					
At berth emissions	**SO_2**	**NO_X**	**PM_{10}**	**HC**	**CO**
Tonne/year	3,697	2,803	339	85	226
Tonne/call	0.157	0.119	0.014	0.004	0.010
Tonne/call Ratio (Rotterdam/HK)					
	SO_2	**NO_X**	**PM_{10}**	**HC**	**CO**
	0.9	1.2	0.5	1.9	2.8

Emissions Inventory of Kaohsiung Port

3.4.13. In July 2010, a report on emission inventory for Keelung, Taichung, Kaohsiung and Hualien with 2009 as base year was completed[36] under a partnership program between EPA Taiwan and US. The inventory was compiled basically following the

[35] See Hulskotte et al. (2010).
[36] Establishment of Port Air Pollutant Emissions Inventory and Drafting of Management Strategies. See http://epq.epa.gov.tw/project/projectcp.aspx?proj_id=RMKVBNSHGU

USEPA methodology. Among the four Taiwan ports, Kaohsiung had the largest emission and its OGV emissions were selected for comparison with Hong Kong. Kaohsiung is the largest port in Taiwan, representing about 75% of the total container throughput.

3.4.14. Table 3-39 below summarizes the comparison. Emission per call in Kaohsiung port is similar to the figures in Hong Kong, with the Kaohsiung/Hong Kong ratios ranging from 0.8 to 1.38 for different pollutants.

Table 3-39 Comparison of Key Kaohsiung (2009) and HK (2007) Inventory Parameters

Year	Emissions (tonne/call)					
	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
A. Kaohsiung port in harbour and 20 nm outside harbour						
2009	0.461	0.485	0.036	0.028	0.020	0.043
B. Kaohsiung port in harbour						
2009	0.300	0.226	0.021	0.016	0.011	0.023
C. Hong Kong ports in harbour and about 8 nm outside harbour						
2007	0.335	0.389	0.039	0.035	0.017	0.038
Tonne/call Ratio (A/C)	**1.38**	**1.25**	**0.92**	**0.8**	**1.18**	**1.13**

Discussion

3.4.15. Based on the comparisons conducted in this section, it is apparent that the emission estimates for OGVs derived in this Study are consistent with and comparable to results of other overseas studies carried out in America, Europe and Asia.

4. RIVER VESSELS INVENTORY 2007

4.1. Overview

4.1.1. In 2007, a total of 190,860 RVs arrived in Hong Kong, including both RTVs and passenger ferries. RTVs covered chemical carrier, conventional cargo vessel, dry bulk carrier, container vessel, gas carrier, lighter and barge, oil tanker, roll-on and roll-off vessel, semi-container-vessel, and tug boats. Passenger ferries, on the other hand, were further classified into Macau Ferry and PRD Ferry.

Vessel Arrival Number (VAN) and Vessel Departure Number (VDN)

4.1.2. Table 4-1 below shows that there were 108,930 RTV arrivals in 2007, accounting for 57% of all RVs. The rest was passenger ferries, made up of 43,850 Macau Ferry arrivals (23%) and 38,080 PRD Ferry arrivals (20%). It is useful to note that only VAN is available for RTVs whilst Macau Ferry and PRD Ferry have both VAN and VDN, as shown in the following paragraphs.

Table 4-1 Arrival Number of River Vessels in 2007

Vessel Type	Vessel Arrival Number
1. River Trade Vessel	108,930
Chemical Carrier	*250*
Conventional Cargo	*16,004*
Dry Bulk Carrier	*1,305*
Fishing / Fish Processing Vessel	*0*
Fully Cellular Container Vessel	*70,880*
Gas Carrier	*32*
Lighter/Barge/Cargo Junk	*10,225*
Oil Tanker	*1,083*
Pleasure Vessel	*0*
Roll on/ Roll off	*6*
Semi-container Vessel	*957*
Tug	*7,577*
Others	*611*
2. Passenger Ferry	
Macau Ferry	*43,850*
PRD Ferry	*38,080*
River Vessels Total	**190,860**

Source: MD

4.1.3. Amongst RTVs, fully cellular container vessel was the major vessel type, accounting for 65% of all RTV arrivals. Majority of them served as feeder vessels among different PRD ports. (Figure 4-1) In addition, there were plenty of conventional cargo vessels, lighter/barge/cargo junks, and tug boats.

Figure 4-1 Container Feeder

4.1.4. Macau Ferry is operated regularly between Hong Kong and Macau. In 2007, services were provided by three operators: (a) Shun Tak-China Travel Ship Management Limited (operating under the brand name of TurboJET), (b) New World First Ferry Services (Macau) Limited (First Ferry (Macau))[37], and (c) Cotai Jet. (Figures 4-2 to 4-4) Based on information provided by the operators and statistics published by MD, Table 4-2 consolidates 2007 annual arrival and departure numbers of Macau Ferry.

Figure 4-2 TurboJet

[37] In September 2011, Shun Tak-China Travel Ship Management Limited acquired First Ferry Macau.

Figure 4-3 New World First Ferry Macau

Figure 4-4 Cotai Jet

Table 4-2 Arrival and Departure Number of Macau Ferry, 2007

Hong Kong Terminal	Operator	No. of Arrival	No. of Departure
China Ferry Terminal / SkyPier at Hong Kong International Airport / Hong Kong Macau Ferry Terminal	NWFF / TurboJET / Cotai Jet	43,850	44,110

4.1.5. Regular services were provided by several operators[38] between Hong Kong and various PRD ports. In terms of frequency of service, the most important ports were Shekou, Zhuhai, Shenzhen, Zhongshan, Humen, Shunde, and Nansha. Table 4-3

[38] Such as Chu Kong Shipping Enterprises (Holdings) Co. Ltd., Zhuhai High-Speed Passenger Ferry Co. Ltd., Panyu Nansha Port Passenger Transport, Shenzhen Pengxing Shipping Co. Ltd., and Shenzhen Xunlong Shipping Co. Ltd.

below consolidates arrival and departure number of PRD Ferry (Figure 4-5) by PRD port, as well as by terminals in Hong Kong, classified as either 'Central' or 'SkyPier'. 'Central' refers to Hong Kong Macau Ferry Terminal (MFT) in Sheung Wan and China Ferry Terminal (CFT) in Tsim Sha Tsui, both with similar distance from PRD ports. 'SkyPier' refers to the terminal facilities at the Hong Kong International Airport. Services to and from Tuen Mun Ferry Terminal (TMFT) is considered negligible.

Table 4-3 Arrival and Departure Number of PRD Ferry, 2007

PRD Port	Number of Arrival	Number of Departure
Doumen	80	80
Gaoming	390	390
Humen	3,180	3,170
Jiangmen	1,120	1,120
Lianhuashan	1,480	1,480
Nansha	2,020	2,010
Sanbu	170	170
Shekou	9,710	9,710
Shenzhen	6,020	5,670
Shunde	2,350	2,350
Zhongshan	4,800	4,450
Zhuhai	6,760	6,750
Total Number of Arrival:	**38,080**	**37,340**
Hong Kong Terminal		
Central	25,410	25,570
SkyPier	12,670	11,780

Figure 4-5 Pearl River Delta Ferry

Gross Registered Tonnage of River Trade Vessels

4.1.6. Based on information provided by MD to EPD, the number of RTV arrivals was further classified by GRT. Table 4-4 shows that over half of the RTVs falls within the range of 500 to 999 in GRT.

Table 4-4 RTV Arrival by GRT Class, 2007

Vessel Type	GRT 0-499	GRT 500-999	GRT ≥1,000	Vessel Arrival Number
Chemical Carrier	16	107	127	250
Conventional Cargo	6,520	6,788	2,696	16,004
Dry Bulk Carrier	1	273	1,031	1,305
Fishing / Fish Processing Vessel	0	0	0	0
Fully Cellular Container Vessel	2,147	54,729	14,004	70,880
Gas Carrier	0	0	32	32
Lighter/Barge/Cargo Junk	382	1,054	8,789	10,225
Oil Tanker	68	438	577	1,083
Pleasure Vessel	0	0	0	0
Roll on/ Roll off	0	0	6	6
Semi-container Vessel	2	876	79	957
Tug	7,552	11	14	7,577
Others	220	123	268	611
Total	**16,908**	**64,399**	**27,623**	**108,930**

Source: MD

Berthing Locations

4.1.7. Similar to OGVs, RVs also operated both at shore-side and mid-stream. However, berthing location information for RTVs was not published by MD. According to the trade, common shore-side locations include PCWAs and private berths. On the other hand, container feeders and barges often operated alongside ocean-going FCCVs that anchored mid-stream.

4.1.8. For passenger ferries, including both Macau Ferry and PRD Ferry, major berthing locations include MFT, CFT and SkyPier at the Hong Kong International Airport. There were also a few PRD Ferry services from TMFT to Zhuhai in 2007 until October that year. Table 4-2 above also shows Macau Ferry arrival number by berthing location.

Frequent Caller

4.1.9. Although individual vessel particulars are generally not available, the percentage of frequent callers as defined in paragraph 3.1.29 is believed to be high. This is based on personal interviews with various members of the trade that most vessels are assigned to pre-arranged schedules and routes.

4.2. Methodology

4.2.1. Information of RVs is not well-documented and vessel particulars are often

unknown. As a result, it is impractical to calculate emission for each river vessel in the way similar to OGVs. In this Study, emission of RTVs was estimated by main vessel types as listed in paragraph 4.1.1 and Table 4-1 above. For passenger ferries, emission was estimated by major vessel class, based on the corresponding engine power rating, time-in-mode and load factor information available.

4.2.2. The same activity-based approach was used to estimate RV emissions, as discussed in paragraph 1.3.4. The main equation for emission estimation of each RV type, modified from the one in paragraph 3.2.1, is included below:

$$\textbf{\textit{Total Emission}}_{(pollutant,\ ship\ type)} = \sum \textbf{\textit{Emission}}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment)}$$

$$\textbf{\textit{Emission}}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment)} = P \times FL \times T \times EF \times VAN$$

where P is the typical / average installed power of equipment;
FL is the typical / average fractional load of equipment in a specific mode;
T is the typical / average operation time-in-mode;
EF is the typical / average fractional load emission factor of equipment; and
VAN is vessel arrival number.

Main Engine Power

4.2.3. Unlike OGVs, RVs are not listed in LRS, which is the main source of OGV ME power information for this Study. Most RVs that operate in the PRD are registered with different maritime safety administrations in mainland China, and some are registered in Hong Kong. Unfortunately, a comprehensive database for all RVs was not available at the time of this Study.

4.2.4. However, RTVs that enter Hong Kong are required to submit a hard copy of their trading certificates to MD for port formalities, and the records will be kept at various Marine Offices for one year before disposal. Basic vessel information such as vessel name and tonnage are fairly complete, while engine power information is also included in some records.

4.2.5. Table 4-5 summarizes ME power based on the information of 1,210 RTVs samples extracted from MD's various Marine Offices that visited Hong Kong from March 2008 to March 2009, supplemented with the following assumptions when ME data were not available:

- Chemical/gas carrier – same as oil tanker;
- Mechanized lighter/barge/cargo junk – those of GRT 0-499 class same as that of conventional cargo vessel;
- Roll on/roll off (RORO) – those of GRT 500-999 and ≥ 1,000 classes same as that of RORO GRT 0-499;
- Semi-container vessel – those of GRT 0-499 class same as GRT 0-499 class of RV FCCV;

- Tug – those of GRT 0-499 class same as the average of Grade II tug boat of locally licensed vessel, those of GRT ≥ 1,000 class same as the average of Grade I tug boat, and those of GRT 500-999 class to be the average of Grade I and Grade II tugs; and

- Others – those of GRT 500-999 be the average of GRT 0-499 and ≥ 1,000 classes.

Table 4-5 Main Engine Power (kW) of RTVs

Vessel Type	GRT		
	0-499	500-999	≥ 1,000
Chemical Carrier	629	714	1,565
Conventional Cargo Vessel	245	379	654
Dry Bulk Carrier	124	491	744
Fully Cellular Container Vessel	232	485	704
Gas Carrier	629	775	1,565
Oil Tanker	629	775	1,565
Mechanised Lighter/Barge/Cargo Junk	245	480	727
Roll on/ Roll off	596	596	596
Semi-container Vessel	232	427	626
Tug	625	840	2,371
Others	643	675	707

4.2.6. It was assumed that all RTVs are installed with diesel engines.

4.2.7. For Macau Ferry, ME power information by major vessel class and engine type was collected directly from the three operators through survey forms and interviews. It ranged from 4,080 to 9,280 kW per vessel, consisting of diesel engine and gas turbine.

4.2.8. ME power information of PRD Ferry by major vessel model was obtained from two major sources: (a) a PRD Ferry operator, and (b) internet resources[39]. Average ME power of PRD Ferry by major routes ranges from 2,280 to 5,490 kW per vessel, with an average of 3,150 kW.

Auxiliary Engine (AE) Power

4.2.9. AE of RTVs are usually used for starting up main engines, and for providing on-board lighting and air conditioning. For tankers and lighter/barge/cargo junk vessels, AE power is also utilized for pumping liquid cargoes (e.g. oil and liquefied gases) and for handling container boxes.

4.2.10. AE power information collected from MD's RTV trading certificates was very limited. Thus, the following assumptions were made:

- Conventional cargo vessel, dry bulk carrier, fully cellular container vessel, RORO, semi-container vessel and others – it was assumed that their AE power was the same, used for lighting and air conditioning. Their average AE power by GRT class were derived from 59 samples of similar vessel types;

[39] Such as http://www.barcaferry.com which specializes in local ferry, Macau ferry and PRD ferry.

- Chemical/gas carrier and oil tanker – information of 94 tankers, including ME and AE power where available, was collected from the China Classification Society database as a sample. A ME/AE power ratio was derived from the sample for the three GRT classes. The ratios for GRT 0-499, 500-999 and ≥1,000 classes were 0.19, 0.23 and 0.24 respectively. These ratios were then applied to the ME power of the three tanker types to obtain the AE power values;

- Lighter/barge/cargo junk – average AE power was based on the 5 samples recorded by MD, and it was applied to GRT classes of both mechanized and non-mechanized lighter/barge/cargo junk; and

- Tug – reference was again made with local tug boats licensed in Hong Kong. AE power of GRT 0-499 class was assumed the same as the average of Hong Kong's Grade II tug boat, and AE power of GRT ≥1,000 class was assumed to be the same as the average of Hong Kong's Grade I tug boat. AE power of GRT 500-999 class was assumed to be their weighted average.

4.2.11. Table 4-6 below summarizes all the AE power information of RTVs:

Table 4-6 Auxiliary Engine Power (kW) of RTVs

Vessel Type	GRT		
	0-499	500-999	≥ 1,000
Chemical Carrier	116	175	375
Conventional Cargo	66	74	115
Dry Bulk Carrier	66	74	115
Fully Cellular Container Vessel	66	74	115
Gas Carrier	116	175	375
Oil Tanker	116	175	375
Lighter/Barge/Cargo Junk	116	116	116
Roll on / Roll off	66	74	115
Semi-container Vessel	66	74	115
Tug	33	56	220
Others	66	74	115

4.2.12. For Macau Ferry, AE power information was collected directly from the operators, ranging from 120 to 326 kW per vessel, consisting of diesel engines and gas turbines.

4.2.13. AE power rating of PRD Ferry, gathered from an operator and internet resources, range from 174 to 208 kW per vessel, with an average of 188 kW.

Load Factor

4.2.14. Using the Propeller Law to estimate ME load factors is not applicable to RVs. ME load factors for RTVs were adopted from a set of harbour vessel load factors published in Table 4.9 of *PoLA 2009 Report*, which were assumed to apply for fairway cruise and slow cruise modes. All vessel types were adopting a load factor of 0.45 for work boats, except for tug boat which adopted a load factor of 0.31. For maneuvering, a load factor of 0.3 was taken from *An evaluation of potential control measures to reduce emissions from in-use ferries in Hong Kong* dated October 2008

(*MSG 2008 Report*) as a surrogate. ME was assumed to be shut down during hotelling, and hence the load factor was zero. (See Table 4-7)

Table 4-7 Main Engine Load Factors of RTVs

Vessel Type	Fairway Cruise / Slow Cruise	Maneuvering	Hotelling
All except tug	0.45	0.3	0
Tug	0.31	0.3	0

4.2.15. In order to determine ME load factors for Macau Ferry, fuel consumption and BSFC data for one round trip from (a) Hong Kong Macau Ferry Terminal and (b) SkyPier at the Hong Kong International Airport was considered based on advice of one of the operators for their four vessel models. (Table 4-8) Load factors of all diesel engine powered vessels were assumed to be the same as a vessel model called Flying Cat.

Table 4-8 Main Engine Load Factors of Macau Ferry

ME Power (kW)	ME	Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
4,080-9,280	DE/GT	0.60-0.95	0.60-0.95	0.60-0.70	0

4.2.16. For PRD Ferry, load factors of 0.8, 0.6 and 0.3 were adopted from the *MSG 2008 Report* for cruise, slow cruise and maneuvering modes, respectively. (Table 4-9)

Table 4-9 Main Engine Load Factors of PRD Ferry

Vessel Type	Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
PRD Ferry	0.8	0.6	0.3	0

4.2.17. For AE load factor, 0.43 was adopted from the PoLA 2009 Report for all RTVs under all operating modes. (see Table 4-10) For Macau Ferry and PRD Ferry, AE load factor was estimated to be 0.45, based on the approach explained in paragraph 4.2.15 for ME load factors.

Table 4-10 Auxiliary Engine Load Factors of RTVs, Macau and PRD Ferry

Vessel Type	Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
All RTVs	0.43	0.43	0.43	0.43
Macau / PRD Ferry	0.45	0.45	0.45	0.45

Time-in-mode

4.2.18. Generally speaking, the same TIM definition by OGV speed was used for RVs. Please refer to paragraph 3.2.21 and Table 3-24 for more information.

4.2.19. As discussed in paragraph 4.1.2, VAN is available for RTVs whilst Macau and PRD Ferry have both VAN and VDN. Thus, TIM for RTVs refers to a two-way trip of vessels, or 2 times of VAN. TIM for Macau and PRD Ferry are separately accounted for VAN and VDN. MD's *PHKST* published average time in port for RVs by vessel type (Table 4-11). This is the average time clocked for a river vessel from the time it arrives at the first berthing location to the time it departs from the last berthing location. However, this is not the total call duration of a river vessel, as the sailing time from Hong Kong waters boundary to the first berthing location and the time from the last berthing location to the boundary of Hong Kong waters are not included. To estimate total call duration, an extra 4 hours, based on radar data, were added to average time in port for each vessel type:

Total Call Duration (hours) = Time in Port (hours) + 4 (hours)

Table 4-11 Time in Port and Total Call Duration (hour) of RTVs

Vessel Type	Average Time in Port	Total Call Duration
Chemical Carrier	28	32
Conventional Cargo Vessel	30	34
Dry Bulk Carrier	22	26
FCCV	34	38
Gas Carrier	9	13
Oil Tanker	59	63
Lighter/Barge/Cargo Junk	69	73
Roll on / Roll off	9	13
Semi-container Vessel	43	47
Tug	68	72
Others	19	23

Source: MD

4.2.20. The three operation modes of underway (fairway cruise/slow cruise), maneuvering, and hotelling were assigned to the total call duration of RTVs by vessel type, based on findings obtained from the analysis of vessel track data sample of FCCVs, conventional cargo vessels, and oil tankers that operated within Hong Kong waters, as shown in Table 4-12.

Table 4-12 Time-in-mode Apportionment of Sample RTVs

Vessel Type	Underway	Maneuvering	Hotelling
Conventional Cargo Vessel	21%	5%	74%
FCCV	24%	4%	72%
Oil Tanker	25%	3%	72%

4.2.21. For vessel types that were not represented in the analysis, TIM ratios of a similar vessel type were adopted as follows:

- TIM split of chemical and gas carrier was assumed to be the same as oil tanker;
- TIM split of semi-container vessel was assumed to be the same as FCCV; and

- TIM split of other RTVs was assumed to be the same as conventional cargo vessel.

4.2.22. A summary of TIM by vessel type is shown in Table 4-13.

Table 4-13 Time-in-mode (hour) of RTVs by Vessel Type

Vessel Type	Slow Cruise	Maneuvering	Hotelling	Total Duration
Chemical Carrier	7.92	1.12	22.96	32
Conventional Cargo	7.12	1.85	25.03	34
Dry Bulk Carrier	5.45	1.41	19.14	26
Fully Cellular Container Vessel	9.16	1.50	27.33	38
Gas Carrier	3.50	0.50	9.00	13
Oil Tanker	15.59	2.20	45.21	63
Lighter/Barge/Cargo Junk	15.29	3.97	53.75	73
Roll on / Roll off	3.50	0.50	9.00	13
Semi-container Vessel	11.33	1.86	33.81	47
Tug	15.08	3.91	53.01	72
Others	4.82	1.25	16.93	23

4.2.23. For Macau Ferry, TIM information based on major vessel models and ferry terminal was estimated for both arrival and departure journeys through vessel track data analysis. The only exception was for hotelling time, which was estimated to be 0.5 hours based on surveys conducted with one of the operators, which was considered to be more representative. Distance and cruise time from Macau to Central is longer than those to SkyPier. Other than that, the difference between Central and SkyPier is small. (Table 4-14)

Table 4-14 Time-in-mode (hour) of Macau Ferry

Terminal		Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
Central	*Arrival*	0.48-0.66	0.01-0.03	0.01-0.09	0.50
	Departure	0.48-0.66	0.01-0.03	0.02-0.03	0.50
SkyPier	*Arrival*	0.15-0.18	0.02	0.01-0.02	0.50
	Departure	0.15-0.17	0.01-0.02	0.01-0.02	0.50

4.2.24. For PRD Ferry, TIM information (fairway cruise, slow cruise and maneuvering) was estimated by major routing for both arrival and departure journeys based on radar track data analysis. Again, hotelling time was estimated based on survey findings from operators. Similar to Macau Ferry, cruise time of PRD Ferry to Central is longer than that to SkyPier. (Table 4-15)

Table 4-15 Time-in-mode (hour) of PRD Ferry

Main PRD Route and Terminal	Fairway Cruise	Slow Cruise	Maneuvering	Hotelling
PRD/ Shekou to SkyPier	0.20-0.35	0.03	0.03	0.38
PRD/ Shekou to Central	0.60-0.75	0.03	0.03	0.38
SkyPier to PRD/ Shekou	0.20-0.34	0.02	0.02	0.38
Central to PRD/ Shekou	0.61-0.77	0.02	0.02	0.38

Emission Factor

4.2.25. Generally speaking, emission factors are determined by a number of factors, including fuel type, fuel quality, engine type and operating conditions.

4.2.26. It was assumed in this Study that marine fuel used by all RVs (including RTVs, Macau Ferry and PRD Ferry) was MGO, with a sulphur content of 0.5%.

4.2.27. For RTVs, it was assumed that all ME are MSD. The BSFC was assumed to be 213 g/kWh, according to *MSG 2008 Report*.

4.2.28. It was assumed that no boiler was installed on-board of RTV, hence there was no boiler emissions.

4.2.29. Emission factors (NO_X, PM_{10}, VOC and CO) for ME with minimum power between 130 and 560 kW of Tier 0 Engines (Category 1) were adopted from *ICF 2009 Report* and apply to all RTVs, except (a) chemical/gas/oil tankers with GRT $\geq$ 1,000 and (b) tug boats.

4.2.30. With a minimum power of over 1,000 kW, MEs of chemical/gas/oil tankers with GRT $\geq$ 1,000 and of all tug boats were classified as Category 2 engines. Emission factors of Tier 0, Category 2 Engines were therefore adopted.

4.2.31. Emission factors of SO_2 and PM_{10} for all RTVs were estimated by the following formula according to *ICF 2009 Report*:

SO_2 EF = BSFC x 2 x 0.97753 x Fuel Sulphur Fraction

PM_{10} EF = 0.23 + BSFC x 7 x 0.02247 x (Fuel Sulphur Fraction – 0.0024)

4.2.32. $PM_{2.5}$ emissions were estimated to be 97% of PM_{10} emissions for both Categories 1 and 2 engines, according to *ICF 2009 Report*.

4.2.33. Emission factors (NO_X, PM_{10}, VOC and CO) for engine with a minimum power of 75 kW of Tier 0 Engines (Category 1) were adopted from *ICF 2009 Report* for AE of all RTVs. AE emission factor of SO_2 was estimated by the formula stated in paragraph 4.2.31.

4.2.34. Table 4-16 below summarizes all the emission factors used in this Study for RTVs.

Table 4-16 ME and AE Emission Factors (g/kWh) for RTVs

Engine Type	Fuel Used	S%	Emission Factor (g/kWh)						
			SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO	BSFC
ME (Cat.1)	MGO	0.50	2.08	10.0	0.30	0.29	0.27	1.5	213
ME (Cat.2)	MGO	0.50	2.08	13.2	0.72	0.70	0.50	1.1	213
AE	MGO	0.50	2.08	10.0	0.40	0.39	0.27	1.7	213

Notes: ME (Cat.1) – All RTVs except (a) chemical/gas/oil tankers with GRT ≥ 1,000 and (b) all tugs
ME (Cat.2) – Chemical/gas/oil tankers with GRT ≥ 1,000 and all tug boats.

4.2.35. Similar derivations and assumptions were made for emission factors of Macau and PRD Ferry, except that gas turbine (GT) was also used in some ME and AE. GT manufacturers and a Macau Ferry operator were consulted to derive BSFC and thus SO_2 and PM emissions. All emission factors of Macau Ferry and PRD Ferry are listed below in Table 4-17.

Table 4-17 ME and AE Emission Factors (g/kWh) for Macau and PRD Ferry

Engine Type	Fuel Used	S%	Emission Factor (g/kWh)						
			SO_2	NO_X	PM_{10}	$PM_{2.5}$	HC	CO	BSFC
ME (DE)	MGO	0.50	2.08	13.2	0.31	0.29	0.47	1.1	213
ME/AE (GT)	MGO	0.50	2.93	5.7	0.35	0.32	0.10	0.2	300
AE (DE)	MGO	0.50	2.12	10.0	0.31	0.29	0.26	1.5	217

4.3. Results and Discussions

4.3.1. Tables 4-18 to 4-21 below summarize emissions from RVs by vessel type, equipment and operation mode for major air pollutants. In summary, 1,848 tonnes of SO_2, 7,779 tonnes of NO_X, 287 tonnes on PM_{10}, 275 tonnes of $PM_{2.5}$, 230 tonnes of VOC and 882 tonnes of CO were emitted from RV sources in 2007. (Table 4-18)

Table 4-18 2007 RV Emissions (tonne) by Vessel Type

Vessel Type	No. of Call	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Chemical Carrier	250	4	23	1	1	1	3
Conventional Cargo	16,004	84	406	14	14	11	64
Cruise/Ferry							
Macau Ferry	*43,850*	*757*	*2,248*	*97*	*91*	*63*	*138*
PRD Ferry	*38,080*	*241*	*1,341*	*36*	*34*	*49*	*112*
Dry Bulk Carrier	1,305	9	41	1	1	1	7
FCCV	70,880	550	2,640	89	86	71	415
Gas Carrier	32	0	2	0	0	0	0
Lighter/Barge/Cargo Junk	10,225	78	374	15	14	10	64
Oil Tanker	1,083	38	202	9	9	6	26
Roll on/ Roll off	6	0	0	0	0	0	0
Semi-container Vessel	957	8	39	1	1	1	6
Tug	7,577	74	446	23	23	16	44
Others	611	3	16	1	1	0	2
Total	**190,860**	**1,848**	**7,779**	**287**	**275**	**230**	**882**

Emission by Vessel Type

4.3.2. Of all vessel types, Macau Ferry was the largest emitter, contributing 757 tonnes of SO_2 (41%), 2,248 tonnes of NO_X (29%) and 97 tonnes of PM_{10} (34%). FCCV was a close second, emitting 550 tonnes of SO_2 (30%), 2,640 tonnes of NO_X (34%) and 89 tonnes of PM_{10} (31%). Other key emitters were PRD Ferry, conventional cargo vessels and lighter/barge/cargo junk (see Figures 4-5 to 4-7 and Table 4-19).

Table 4-19 Top 5 RV Emitters in 2007

Vessel Type	No. of Call	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Macau Ferry	43,850	757	2,248	97	91	63	138
FCCV	70,880	550	2,640	89	86	71	415
PRD Ferry	38,080	241	1,341	36	34	49	112
Conventional Cargo	16,004	84	406	14	14	11	64
Lighter/Barge/Cargo Junk	10,225	78	374	15	14	10	64

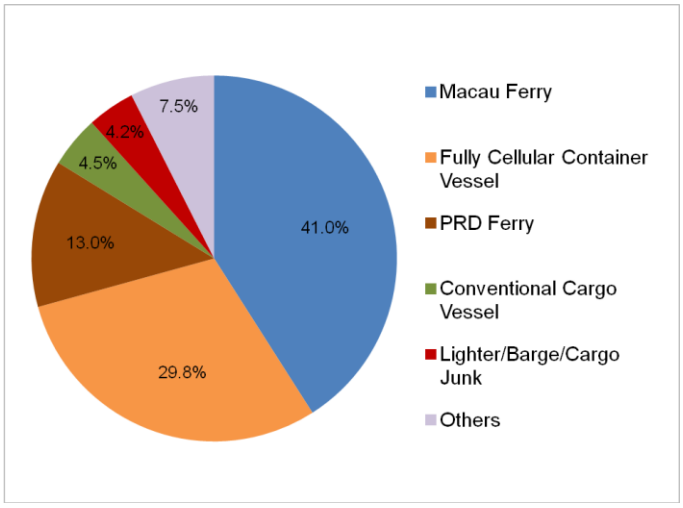

Figure 4-5 RV SO_2 Emission by Vessel Type (%)

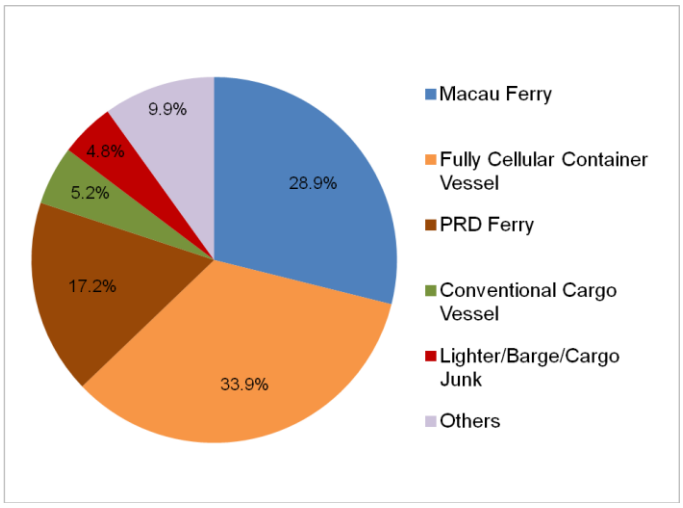

Figure 4-6 RV SO_2 Emission by Vessel Type (%)

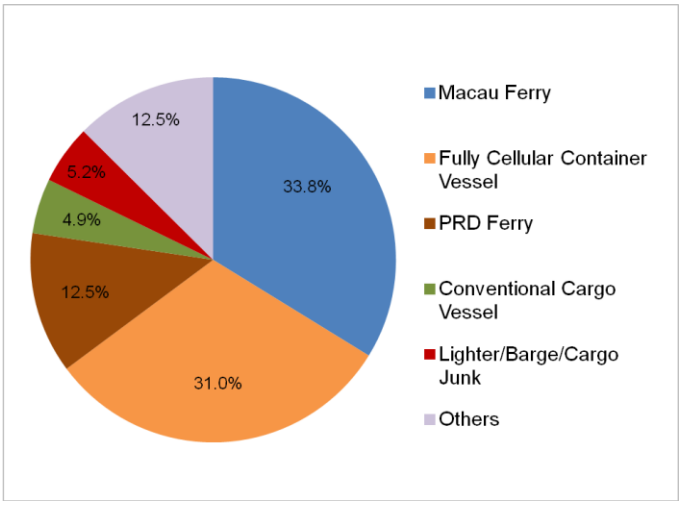

Figure 4-7 RV SO_2 Emission by Vessel Type (%)

Emission by Equipment

4.3.3. Table 4-20 below shows that ME contributed not only about three quarters of SO_2, NO_X and VOC emissions, but also two-thirds of PM_{10}, $PM_{2.5}$ and CO emissions.

Table 4-20 2007 RV Emissions (tonne) by Equipment

Vessel Type	SO_2		NO_X		PM_{10}		$PM_{2.5}$		VOC		CO	
	ME	AE	ME	AE	ME	AE	ME	AE	ME	AE	ME	AE
Chemical Carrier	2	2	14	9	1	0	1	0	0	0	1	2
Conventional Cargo Vessel	46	38	223	182	7	7	6	7	6	5	33	31
Cruise/Ferry												
Macau Ferry	*742*	*15*	*2,175*	*73*	*95*	*2*	*88*	*2*	*60*	*3*	*127*	*11*
PRD Ferry	*229*	*13*	*1,280*	*61*	*34*	*2*	*32*	*2*	*47*	*2*	*103*	*9*
Dry Bulk Carrier	5	3	26	16	1	1	1	1	1	0	4	3
FCCV	352	198	1688	952	51	38	49	37	46	26	253	162
Gas Carrier	0	0	1	1	0	0	0	0	0	0	0	0
Lighter/Barge/ Cargo Junk	1	77	4	371	0	15	0	14	0	10	1	63
Oil Tanker	21	17	121	81	6	3	6	3	4	2	12	14
Roll on/ Roll off	0	0	0	0	0	0	0	0	0	0	0	0
Semi-container	5	3	24	15	1	1	1	1	1	0	4	3
Tug	58	16	367	79	20	3	19	3	14	2	31	13
Others	2	1	11	5	0	0	0	0	0	0	2	1
Total	**1,463**	**385**	**5,934**	**1,845**	**215**	**72**	**204**	**71**	**180**	**50**	**571**	**311**
% in Total	**79%**	**21%**	**76%**	**24%**	**75%**	**25%**	**74%**	**26%**	**78%**	**22%**	**65%**	**35%**

4.3.4. Figure 4-8 below shows a typical breakdown of RV emission by equipment, whereas Figure 4-9 goes one step further to demonstrate the emission of SO_2 by equpiment and major vessel type. For RTV, the ratio of SO_2 emission produced by

ME to AE was 60% to 40%. For passenger ferries, emission was predominantly produced by ME. The diagrams for NO_X and PM_{10} are almost identical.

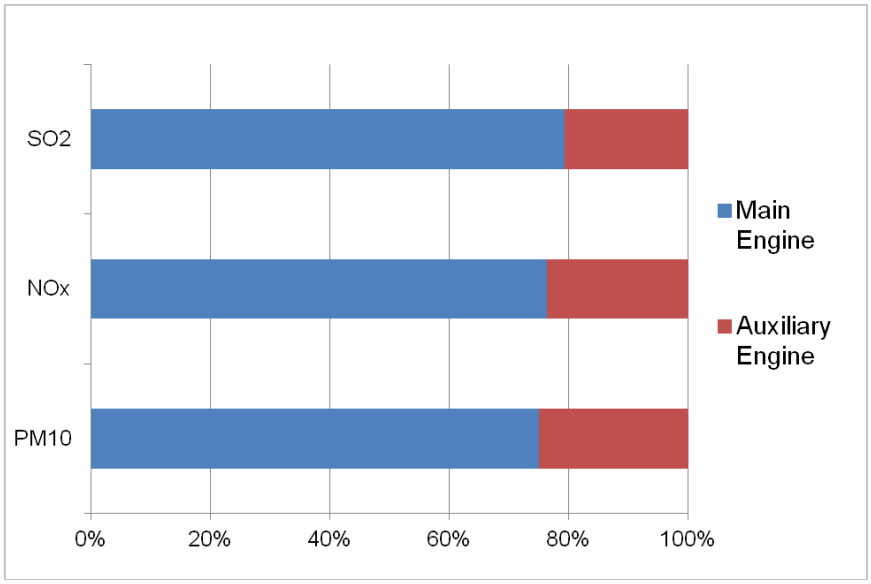

Figure 4-8 RV Emission by Equipment (%)

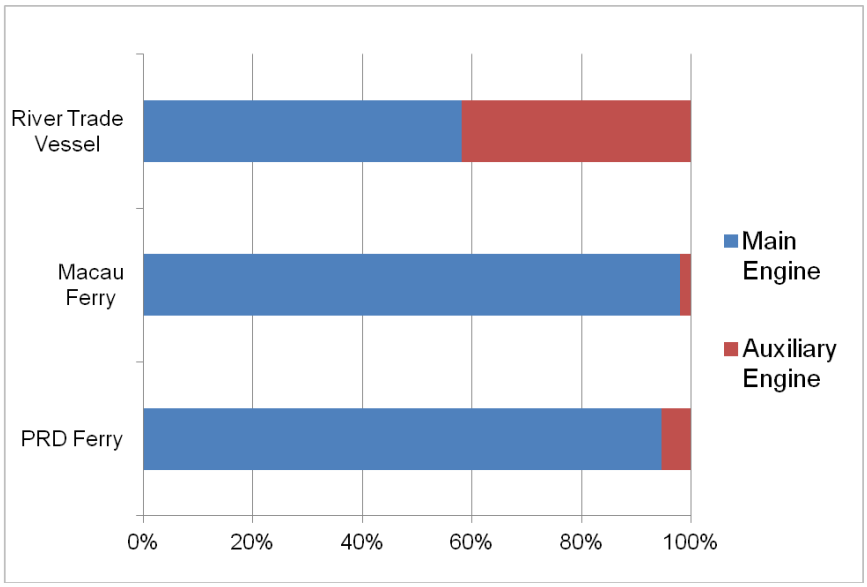

Figure 4-9 RV SO_2 Emission by Equipment and Vessel Type (%)

Emission by Mode

4.3.5. According to Table 4-21, a significant proportion of air pollutants were emitted during fairway cruise mode. They were solely emitted from Macau Ferry and PRD Ferry, which would operate in high speed in part of their journey within Hong Kong waters. For example, 49% of SO_2 and 42% of PM were produced during fairway cruise mode. Besides, emission during slow cruise was also important. With these two modes combined, RVs while underway contributed roughly 70% to 80% of emissions in 2007. (Figure 4-10)

Table 4-21 2007 RV Emissions (tonne) by Mode

	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Fairway Cruise	913.7 (49.5%)	3,289.6 (42.3%)	121.1 (42.2%)	114.1 (41.6%)	102.5 (44.7%)	225.6 (25.6%)
Slow Cruise	557.7 (30.2%)	2,710.8 (34.8%)	96.1 (33.5%)	93.0 (33.9%)	77.8 (33.9%)	377.4 (42.8%)
Maneuvering	105.1 (5.7%)	477.9 (6.1%)	18.1 (6.3%)	17.4 (6.4%)	14.1 (6.2%)	58.7 (6.7%)
Hotelling	271.0 (14.7%)	1,300.6 (16.7%)	51.5 (18.0%)	50.0 (18.2%)	35.1 (15.3%)	219.9 (24.9%)
Total	**1,847.5**	**7,778.9**	**286.9**	**274.5**	**229.5**	**881.7**

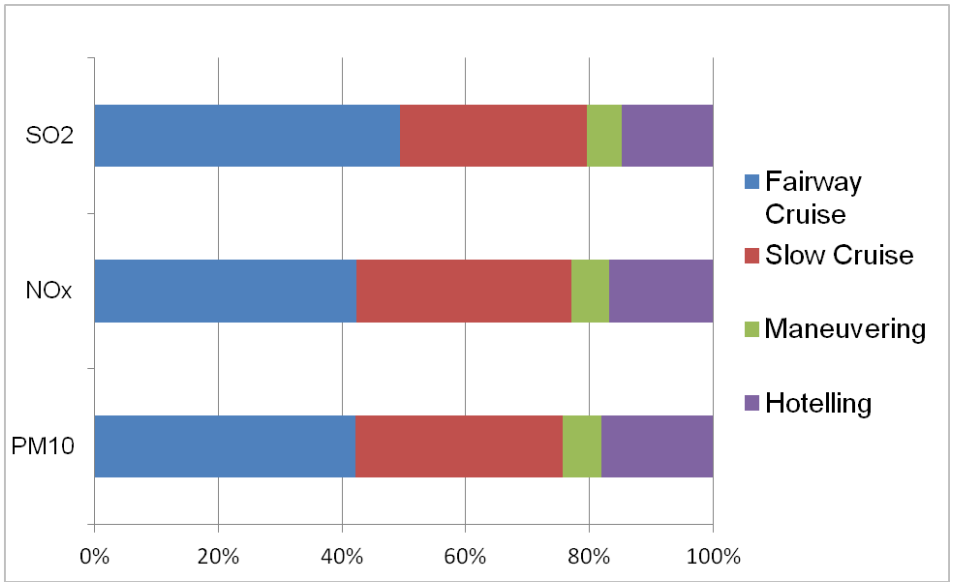

Figure 4-10 RV Emission by Mode (%)

4.3.6. It is found in Figure 4-11 that the patterns of RV emission by mode were different between cargo and passenger vessels. Using SO_2 emission as an illustration, the pattern of emission by operation mode for RTV was typical of cargo-carrying vessels, with most emission produced during slow cruise and hotelling modes. On the other hand, the emission pattern by operation mode for Macau Ferry and PRD Ferry was dominated by fairway cruise mode, during which about 90% of the emissions were produced. The same patterns are observed for NO_X and PM_{10}.

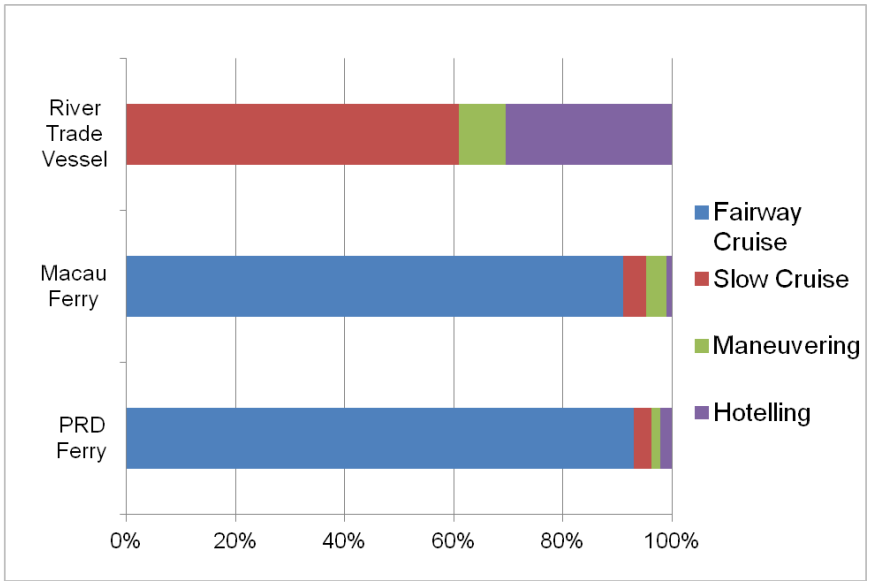

Figure 4-11 RV SO_2 Emission by Mode and Vessel Type (%)

4.4. Comparison with Overseas Studies

4.4.1. RVs play a key role in transporting goods and carrying passengers within the PRD. Vessel mix and vessel operation characteristics are quite unique in Hong Kong, which is a major hub in this region. Whilst harbour crafts in other ports share some common vessel types like oil carriers and tugs, RTVs in Hong Kong also cover fully cellular container vessels, conventional cargo vessels, lighter/barge/cargo junk that are not commonly defined as harbour crafts elsewhere in the world. Difference in vessel types and operation characteristics may lead to different emission levels. Although RVs in Shanghai and the Yangtze River Delta might have similar operations as in Hong Kong, there was limited information at the time of writing to compare their emission inventory with the findings of this Study.

4.4.2. In order to provide a sense about the scale of Hong Kong's RV emissions in this Report, harbour craft emissions in PoLA and Kaohsiung port were selected and compared in the next paragraph, where information was available, for illustrative purpose. It is important to note that harbour craft in the two selected ports cannot be seen as a direct comparison to RVs in Hong Kong, as mentioned in paragraph 4.4.1. However, some of the harbour crafts in both PoLA and Kaohsiung also operate in similar fashion to RVs in Hong Kong, such as the ferries in PoLA. In addition, the same sets of emission factors and load factors were used in the emission inventory for PoLA, Kaohsiung and Hong Kong.

4.4.3. Table 4-22 shows that RV emissions in Hong Kong is far greater in terms of total quantity than PoLA and Kaohsiung. The relatively high emissions is perceivable due to the substantial cargo and passenger movements in the PRD region that are supported by RTVs and river passenger ferries such as Macau Ferry and PRD Ferry. Another relevant explanation to the difference is that harbour crafts in PoLA are using diesel with 15 ppm, whereas RVs in Hong Kong are using 0.5% sulphur diesel..

Table 4-22 Comparison of Hong Kong RV and PoLA/Kaohsiung Harbour Craft Emissions (tonne)

	SO_2	NO_X	PM_{10}	VOC	CO
Hong Kong 2007					
River vessel total	1,848	7,779	287	230	882
River passenger ferry	999	3,589	132	111	250
River trade vessel	849	4,190	154	118	631
Port of Los Angeles 2007					
Harbor craft total	0.6	1,162.4	47.8	77.3*	315.5
Ferry	0.1	138.1	6.1	9.8*	39.0
Others	0.5	1,24.3	41.7	67.5*	276.5
Kaohsiung 2009					
Harbor craft total	54.7	249.8	7.8	7.0*	83.2
Ferry	0.0	0.0	0.0	0.0	0.0
Others	54.7	249.8	7.8	7.0*	83.2

* HC

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5. TOTAL MARINE VESSELS INVENTORY 2007

5.1. Local Vessel 2007

5.1.1. LVs refer to Hong Kong licensed vessels and government vessels (exempted from licensing by MD). Since 2007, licensed vessels were re-classified with a number of sub-classes as follows: (a) Class I LVs are passenger related with 6 sub-classes; (b) Class II LVs are cargo related with 22 sub-classes; (c) Class III LVs are fishing vessels with 4 sub-classes; (d) Class IV LVs are pleasure vessels with 3 sub-classes; and (e) dwelling vessels. There were also 744 government vessels licensed in 2007 under 14 different government departments. However, some government vessels are considered to have negligible emissions due to their small numbers or engine power. Only 124 are major mechanized vessels, with the remaining 620 government vessels being small ones.

5.1.2. In 2007, Local Vessels contributed 1,433 tonnes of SO_2, 10,503 tonnes of NO_X, and 405 tonnes of PM_{10}. (Table 5-1) Classes I, II and government vessels are mostly equipped with diesel internal combustion engines. Class III and IV vessels have both engines of diesel and petrol inboard/outboard engines, thus having significant VOC and CO emissions. Class IV and government vessels used low sulphur diesel fuel and thus have minimal SO_2 and reduced PM_{10} emissions.

Table 5-1 LV Emissions in Hong Kong (tonne), 2007

Vessel Type	SO_2	NO_X	PM_{10}	VOC	CO
Class I	425 (30%)	3,077 (29%)	98 (24%)	61 (2%)	537 (7%)
Class II	674 (47%)	4,270 (41%)	179 (44%)	153 (6%)	743 (9%)
Class III	332 (23%)	1,898 (18%)	83 (21%)	1,608 (61%)	2,968 (36%)
Class IV	1 (0%)	429 (4%)	22 (5%)	768 29%)	3,524 (43%)
Government	1 (0%)	830 (8%)	22 (5%)	35 (1%)	460 (6%)
Total	**1,433**	**10,503**	**405**	**2,625**	**8,232**

Notes: Percentage share in brackets.
Class I: mainly consisted of passenger vessels of which ferries and launches were the major emitters.
Class II: mainly consisted of cargo and marine works vessels of which tugs, dumb lighters, dry cargo vessels, oil carriers and dredgers were the major emitters. Other vessels in this class included pilot boats, crane barges and dangerous goods vessels.
Class III: mainly consisted of fishing vessels and outboard open sampans. The high VOCs and CO emissions were from petrol engines.
Class IV: consisted of pleasure crafts such as cruisers, open cruisers and auxiliary powered yachts. Ultra-low sulphur diesel with sulphur content of 50 ppm and Euro V diesel with sulphur content of 10 ppm was used in diesel engines before and after December 2007 respectively. Petrol engines were major emitters of VOCs and CO.
Government: consisted of vessels used by various government departments including the Police, Customs, Immigration, etc. Ultra-low sulphur diesel with sulphur content of 50 ppm and Euro V diesel with sulphur content of 10 ppm was used in diesel engines before and after December 2007 respectively.

5.2. Summary of Total Marine Vessels Inventory 2007

5.2.1. In 2007, all marine vessels (including OGVs, RVs and LVs, but not transit vessels) contributed 15,719 tonnes of SO_2, 32,744 tonnes of NO_X 2,139 tonnes of PM_{10}, 3,489 tonnes of VOC and 10,535 tonnes of CO. (Table 5-2)

Table 5-2 Total Marine Emissions (tonne), 2007

Vessel Type	SO_2	NO_X	PM_{10}	VOC	CO
OGV	12,438	14,462	1,447	635	1,421
RV	1,848	7,779	287	230	882
LV	1,433	10,503	405	2,625	8,232
Total	**15,719**	**32,744**	**2,139**	**3,489**	**10,535**

5.2.2. Given the size and tonnage of OGVs and the high sulphur content of the fuel they burnt, OGVs were responsible for 79% of SO_2 and 68% of PM_{10} emitted from marine source. (Table 5-3) On the other hand, it is noteworthy that RVs contributed 44% of NO_X emission. LV also contributed significantly for the emission of VOC (75%) and CO (78%) in 2007.

Table 5-3 Total Marine Emissions (percentage share), 2007

Vessel Type	SO_2	NO_X	PM_{10}	VOC	CO
OGV	79%	44%	68%	18%	13%
RV	12%	24%	13%	7%	8%
LV	9%	32%	19%	75%	78%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

6. UNCERTAINTY OF OCEAN-GOING AND RIVER VESSELS INVENTORY 2007

6.1. Methodology

6.1.1. Efforts were undertaken in this Study to ensure the accuracy of emission calculations, for examples, bottom-up individual cell and workbook checking, rotation of staff in conducting review, top-down reasonable checking among results of different pollutants, years and with other overseas studies.

6.1.2. In addition, a quantitative approach was used to characterize uncertainties in estimating OGV and RV emissions as explained in Chapters 3 and 4, in which bootstrap simulation and empirical judgment were applied to quantify uncertainty in input parameters and the Monte Carlo simulation was performed to propagate uncertainties (Frey and Zheng, 2002; IPCC 2006). In the Monte Carlo simulation, random values of the input parameters, such as engine power, load factors, time-in-mode and emission factors by engine type, operation mode and pollutant, were selected within their individual probability density functions representing their uncertainties, and the corresponding emission values for different categories were calculated. This process was repeated 10,000 times to build up the probability density functions of emission estimates by category level and category aggregation (IPCC 2006; Cullen and Frey, 1999; Rypdal and Winiwarter, 2001).

6.2. Identification and Characterization of Uncertainties for Ocean-going Vessels

6.2.1. Uncertainty sources are determined based on the equation used in estimating marine emissions as follows:

$$\textbf{\textit{Emission}} = P \times LF \times TIM \times EF$$

Input parameters of uncertainties include engine power (P) and load factors (LF) of ME and AE, boiler energy, time-in-mode (TIM) and emission factors (EF) for the three equipment. Each input parameter is discussed in the following paragraphs.

Engine Power

6.2.2. Some of the vessels covered in this Study did not have power rating information (either main or auxiliary, or both), which were then assumed to be similar to those installed by vessels of the same or similar size. Therefore, uncertainties of main/auxiliary engine power regarding emission estimation did exist. However, this Study did not carry out uncertainty analysis on power, because:

- Most of these calls without engine power belong to vessels with relatively small power rating, and emission uncertainties caused by these calls will result in a minimal contribution to total uncertainties; and
- On the other hand, technical computerization for implementing Monte Carlo simulation is time-consuming if power rating uncertainty of each call is taken into account.

Load Factor

6.2.3. ME LFs by mode were derived from limited radar data analysis due to data availability. (Table 6-1)

Table 6-1 Uncertainties of ME Load Factors by OGV Vessel Type

Vessel Type by Mode	Mean of Load	Uncertainty (mean as 1)
Fairway Cruise		
FCCV	0.47	N (1.0002, 0.0391)
Cruise/Ferry	0.40	N (1.0000, 0.0564)
Slow Cruise		
FCCV	0.11	N (0.9968, 0.0608)
Cruise/Ferry	0.13	N (1.0000, 0.0317)
Oil Tanker	0.38	N (0.9524, 0.0732)
Conventional Cargo Vessel	0.36	N (1.0093, 0.0684)
Dry Bulk Carrier	0.34	N (0.9983, 0.0709)
Chemical Carrier	0.37	N (0.9940, 0.0901)
Gas Carrier	0.37	N (1.0139, 0.0981)
Fishing/Fish Processing Vessel	0.65	U (0.72, 1.28)
Pleasure Vessel		N (1.0000, 0.2430)*
Roll On/Roll Off	0.25	U (0.26, 2.65)
Semi-container Vessel	0.22	U (0.87, 1.09)
Tug	0.52	U (0.97, 1.03)
Others	0.25	U (0.96, 1.04)

* Same as ocean cruise; N = Normal; U = Uniform

6.2.4. AE LFs and boiler energy by mode were collected from the PoLA (2006-2009) as this Study mainly adopted figures of *PoLA 2009 Report*, and typical loads applied in a series of annual inventories were used to derive uncertainties of AE and AB loads. (Tables 6-2 and 6-3) As this emission inventory basically adopted LFs by vessel type and mode of the *PoLA 2009 Report*, lower and upper bounds of uncertainty were determined based on the annually reported figures. Such approach would under-estimate the uncertainty since the reported figures are likely averages of the many unreported raw data.

Table 6-2 Uncertainties of AE Load Factors by OGV Vessel Type

Vessel Type	At Sea		Maneuvering		Berth		Anchorage	
	L	Un	L	Un	L	Un	L	Un
Chemical Carrier/Tanker	768	U(0.93,1.12)	1056	U(0.93,1.12)	832	U(0.93,1.12)	768	U(0.95,1)
Conventional Cargo Vessel	429	U(0.84,1.07)	1137	U(0.83,1.06)	556	U(0.85,1.06)	429	U(1,1.07)
Cruise/Ferry		U(1,1.17)		U(1,1.17)		U(1,1.17)		U(1,1.17)
Dry Bulk Carrier	283	U(0.83,1.22)	750	U(0.83,1.22)	167	U(0.83,2.67)	283	U(0.83,1)
Fishing/Fish Processing Vessel		U(0.82,1.21)	0	U(0.82,1.21)	0	U(0.79,1.38)	0	U(0.88,1.13)

Fully Cellular Container Vessel	813	U(0.72,1.08)	2140	U(0.98,1.43)	701	U(0.96,1.65)	813	U(0.98, 1.01)
Gas Carrier/Tanker	543	U(0.96,1.41)	746	U(0.96,1.41)	588	U(0.96,1.41)	543	U(0.98,1.37)
Lighter/Barge/ Cargo Junk		U(0.82,1.21)		U(0.82,1.21)		U(0.79,1.38)		U(0.88,1.13)
Oil Tanker	543	U(0.96,1.41)	746	U(0.96,1.41)	588	U(0.96,1.41)	543	U(0.98,1.37)
Pleasure Vessel		U(1,1.17)		U(1,1.17)		U(1,1.17)		U(1,1.17)
Roll On/Roll Off	369	U(1,1.5)	1108	U(1,1.51)	616	U(1,1.57)	369	U(1,1.19)
Semi-container Vessel		U(0.84,1.07)		U(0.83,1.06)		U(0.85,1.06)		U(1,1.07)
Tug	111	U(0.29,1)	293	U(0.29,1)	145	U(0.29,1)	111	U(0.79,1)
Others	410	U(0.57,1)	1085	U(0.57,1)	538	U(0.26,1)	538	U(0.43,1)

L = Mean of Load; Un = Uncertainty (mean as 1); U = Uniform
Sources: Starcrest Consulting Group (2007, 2008a, 2008b, 2009)

Table 6-3 Uncertainties of Boiler Energy by OGV Vessel Type

Vessel Type	L	Un	Remark
Chemical Carrier/Tanker	371	U(1,1.2)	Mean of load excludes loading/unloading
Conventional Cargo Vessel	252	U(0.42,1)	
Cruise/Ferry		U(1,1.39)	
Dry Bulk Carrier	109	U(1,1.26)	
Fishing/Fish Processing Vessel		U(0.83,1.20)	Assumed to be similar as the average
Fully Cellular Container Vessel	409	U(0.83, 1.04)	Weighted by DWT
Gas Carrier/Tanker	371	U(1,1.2)	Mean of load excludes loading/unloading
Lighter/Barge/Cargo Junk		U(0.83,1.20)	Assumed to be similar as the average
Oil Tanker	371	U(1,1.2)	Mean of load excludes loading/unloading
Pleasure Vessel		U(0.83,1.20)	Assumed to be similar as the average
Roll On/Roll Off	282	U(0.87,1.32)	
Semi-container Vessel	252	U(0.42,1)	Same as Conventional Cargo
Tug		U(0.83,1.20)	Assumed to be similar as the average
Others	371	U(0.37,1)	

L = Mean of Load; Un = Uncertainty (mean as 1); U = Uniform
Sources: Starcrest Consulting Group (2007, 2008a, 2008b, 2009)

Time-in-mode

6.2.5. For TIM, there were minimal uncertainties, as most of the information was extracted from MD's vessel arrival records and vessel track data. A variability of +10% and -10% was assigned to this parameter, that is, "triangle (0.9, 1, 1.1)".

Emission Factor

6.2.6. Uncertainty information of SO_2, NO_X, HC and CO (assume same as CO_2) for vessels at sea, maneuvering and in port were collected from the *Entec 2002 Report*. Uncertainty information of PM for vessels operating heavy fuel oil and distillate fuel were collected from Sax and Alexis (2007). (Table 6-4)

Table 6-4 Uncertainties of Emission Factors

Mode	SO_2	NO_X	PM (HFO)	PM (Distillate)	HC	CO
Cruise/ Slow Cruise	N(1, 0.05)	N(1, 0.1)	U(0.80, 1.07)	U(0.67, 1.33)	N(1, 0.125)	N(1, 0.05)
Maneuvering	N(1, 0.15)	N(1, 0.2)	U(0.80, 1.07)	U(0.67, 1.33)	N(1, 0.25)	N(1, 0.15)
Hotelling	N(1, 0.1)	N(1, 0.15)	U(0.80, 1.07)	U(0.67, 1.33)	N(1, 0.2)	N(1, 0.1)

N = Normal; U = Uniform

6.3. Identification and Characterization of Uncertainties for River Vessels

6.3.1. Like OGVs, uncertainties of emission estimates of RVs may arise from engine power, load factors of ME and AE, time-in-mode and emission factors.

Engine Power

6.3.2. Power information of ME and AE collected for different vessel types varied and thus their derived uncertainties were different. For example, limited engine power data of RTVs were collected from MD. On the other hand, all engine power data for Macau Ferry and the majority of data for PRD Ferry were collected from the operators. Therefore, it was assumed that engine power rating information of both Macau Ferry and PRD Ferry had no uncertainty.

Load Factor

6.3.3. Load factors of ME and AE by mode were derived as follows: (a) RTVs based on *PoLA 2009 Study* and local marine studies; (b) Macau Ferry based on local vessel track data analysis; and (c) PRD Ferry based on local marine studies and Macau Ferry vessel track data analysis results. A +10% and -10% variability was assumed for the lower and upper bounds of uncertainties of the load factors.

Time-in-mode

6.3.4. TIM by vessel type were derived based on vessel track data analysis. Percentage of processed RTV track data over total 2007 calls were small and they were confined to RTVs with GRT over 1,000 that are required to install AIS. Thus, data derived have significant uncertainty.

Emission Factor

6.3.5. Uncertainties of emission factor by pollutant were assumed to be same as those of OGVs.

6.4. Results and Discussions

Ocean-going Vessel

6.4.1. Table 6-5 shows that uncertainties of OGV emission ranged from -23% to 26% for SO_2, -26% to 29% for NO_X and -23% to 26% for PM_{10}. Overall uncertainties of OGVs were highest for VOC (-36% to 40%) and lowest for CO (-22% to 25%). The higher VOC range was due to EF uncertainty.

Table 6-5 Uncertainties of Emissions from OGVs

Pollutant	Mean	Uncertainty	
SO_2	13,126	-23%	26%
NO_X	15,371	-26%	29%
PM_{10}	1,435	-23%	26%
$PM_{2.5}$	1,300	-23%	27%
VOC	663	-36%	40%
CO	1,492	-22%	25%

6.4.2. As FCCVs played the major role in OGVs' emissions (around 80% of SO_2, NO_X, and PM), uncertainties of FCCVs' emissions dominated total uncertainties, followed by cruise/ferry, oil tanker, conventional cargo vessel and dry bulk carrier. (Table 6-6) The top 5 emitters contributed about 98% of SO_2, NO_X and PM produced by OGVs. Dry bulk carrier with relatively higher uncertainties was due to uncertainties of AE LF and boiler energy.

Table 6-6 Uncertainties of Emissions by OGV Type

Vessel Type	SO_2				NO_X				PM_{10}			
	Mean	% in total	Uncertainty		Mean	% in Total	Uncertainty		Mean	% in total	Uncertainty	
FCCV	10,403	79%	-23%	26%	12,234	80%	-25%	28%	1,164	81%	-23%	26%
Cruise / Ferry	1,183	9%	-21%	23%	1,629	11%	-28%	30%	125	9%	-19%	21%
Oil Tanker	598	5%	-24%	26%	370	2%	-32%	36%	47	3%	-22%	25%
Dry Bulk Carrier	383	3%	-34%	39%	370	2%	-41%	50%	38	3%	-35%	40%
Conventional Cargo Vessel	305	2%	-23%	25%	367	2%	-27%	30%	33	2%	-22%	25%
Other OGVs	255	2%	-34%	39%	400	3%	-41%	48%	28	2%	-34%	39%
Total	**13,126**	**100%**	**-23%**	**26%**	**15,371**	**100%**	**-26%**	**29%**	**1,435**	**100%**	**-23%**	**26%**

6.4.3. In terms of equipment, emissions from AE had the highest uncertainties, due to uncertainties of AE LFs by mode. (Table 6-7) Emissions from ME had the lowest

uncertainties as it was assumed that the ME LFs can be estimated accurately using the Propeller Law with actual and maximum speeds derived from radar data and LRS respectively.

Table 6-7 Uncertainties of OGV Emissions by Engine Type

Engine/Vessel Type	SO_2				NO_X				PM_{10}			
	mean	% in Total	Uncertainty		mean	% in Total	Uncertainty		mean	% in Total	Uncertainty	
Main Engine	5,027	38%	-16%	18%	7,961	52%	-21%	23%	693	48%	-19%	21%
FCCV	*4,397*	*33%*	*-16%*	*17%*	*7,008*	*46%*	*-21%*	*22%*	*606*	*42%*	*-19%*	*21%*
Cruise / Ferry	*235*	*2%*	*-15%*	*17%*	*182*	*3%*	*-24%*	*25%*	*36*	*3%*	*-18%*	*20%*
Oil Tanker	*80*	*1%*	*-20%*	*21%*	*113*	*1%*	*-26%*	*29%*	*11*	*1%*	*-21%*	*24%*
Other OGVs	*314*	*2%*	*-25%*	*27%*	*447*	*3%*	*-31%*	*35%*	*41*	*3%*	*-27%*	*30%*
Aux. Engine	5,450	42%	-30%	34%	6,055	46%	-32%	37%	618	43%	-28%	33%
FCCV	*4,186*	*32%*	*-31%*	*35%*	*4,203*	*32%*	*-31%*	*36%*	*473*	*33%*	*-29%*	*34%*
Cruise / Ferry	*644*	*5%*	*-21%*	*22%*	*1,091*	*8%*	*-29%*	*31%*	*74*	*5%*	*-19%*	*21%*
Oil Tanker	*183*	*1%*	*-27%*	*31%*	*181*	*1%*	*-35%*	*39%*	*21*	*1%*	*-25%*	*28%*
Other OGVs	*437*	*3%*	*-36%*	*41%*	*580*	*4%*	*-40%*	*49%*	*50*	*3%*	*-34%*	*40%*
Boiler	2,649	20%	-23%	26%	355	2%	-26%	29%	123	9%	-21%	24%
FCCV	*1,820*	*14%*	*-23%*	*25%*	*254*	*2%*	*-23%*	*26%*	*85*	*6%*	*-21%*	*23%*
Cruise / Ferry	*304*	*2%*	*-25%*	*29%*	*38*	*0%*	*-33%*	*36%*	*14*	*1%*	*-24%*	*27%*
Oil Tanker	*334*	*3%*	*-23%*	*25%*	*39*	*0%*	*-32%*	*34%*	*16*	*1%*	*-19%*	*21%*
Other OGVs	*192*	*1%*	*-28%*	*32%*	*25*	*0%*	*-35%*	*40%*	*9*	*1%*	*-25%*	*29%*
Total	**13,126**	**100%**	**-23%**	**26%**	**14,159**	**100%**	**-26%**	**29%**	**1,435**	**100%**	**-23%**	**26%**

6.4.4. In terms of operation mode, emissions in hotelling and maneuvering modes had relatively higher uncertainties, mainly due to uncertainties related to AE LFs and boiler energy. (Table 6-8)

Table 6-8 Uncertainties of OGV Emissions by Operation Mode

Mode and Vessel Type	SO_2				NO_X				PM_{10}			
	mean	% in Total	Uncertainty		mean	% in Total	Uncertainty		mean	% in Total	Uncertainty	
Fairway cruise	3,031	23%	-15%	16%	4,228	28%	-22%	24%	342	24%	-18%	21%
FCCV	*2,869*	*22%*	*-15%*	*16%*	*4,017*	*26%*	*-22%*	*24%*	*323*	*23%*	*-18%*	*20%*
Cruise / Ferry	*162*	*1%*	*-16%*	*17%*	*212*	*1%*	*-23%*	*25%*	*19*	*1%*	*-20%*	*21%*
Slow cruise	3,403	26%	-19%	21%	4,584	30%	-20%	22%	416	29%	-22%	25%
FCCV	*2,623*	*20%*	*-19%*	*21%*	*3,489*	*23%*	*-18%*	*20%*	*324*	*23%*	*-22%*	*25%*
Cruise / Ferry	*315*	*2%*	*-16%*	*17%*	*482*	*3%*	*-22%*	*23%*	*37*	*3%*	*-19%*	*20%*

Oil Tanker	*93*	*1%*	*-20%*	*21%*	*117*	*1%*	*-25%*	*28%*	*11*	*1%*	*-23%*	*25%*
Others	*372*	*3%*	*-24%*	*26%*	*496*	*3%*	*-30%*	*34%*	*44*	*3%*	*-27%*	*31%*
Maneuvering	761	6%	-33%	37%	1,312	9%	-33%	36%	148	10%	-20%	22%
FCCV	*650*	*5%*	*-33%*	*38%*	*1,139*	*7%*	*-32%*	*35%*	*129*	*9%*	*-20%*	*23%*
Cruise / Ferry	*65*	*0%*	*-31%*	*34%*	*95*	*1%*	*-39%*	*40%*	*10*	*1%*	*-18%*	*20%*
Oil Tanker	*14*	*0%*	*-33%*	*36%*	*21*	*0%*	*-41%*	*44%*	*3*	*0%*	*-20%*	*22%*
Others	*33*	*0%*	*-34%*	*38%*	*57*	*0%*	*-41%*	*45%*	*6*	*0%*	*-20%*	*22%*
Hotelling	5,931	45%	-29%	33%	5,246	34%	-33%	39%	529	37%	-28%	33%
FCCV	*4,261*	*32%*	*-29%*	*34%*	*3,589*	*23%*	*-32%*	*38%*	*388*	*27%*	*-29%*	*34%*
Cruise / Ferry	*641*	*5%*	*-24%*	*26%*	*840*	*5%*	*-31%*	*33%*	*58*	*4%*	*-20%*	*22%*
Oil Tanker	*491*	*4%*	*-24%*	*27%*	*232*	*2%*	*-34%*	*39%*	*34*	*2%*	*-22%*	*25%*
Others	*538*	*4%*	*-35%*	*40%*	*585*	*4%*	*-42%*	*51%*	*49*	*3%*	*-35%*	*40%*
Total	**13,126**	**100%**	**-23%**	**26%**	**15,371**	**100%**	**-26%**	**29%**	**1,435**	**100%**	**-23%**	**26%**

6.4.5. For FCCV, uncertainties of EFs were most sensitive to emissions of each pollutant, followed by ME LFs in slow and fairway cruise modes for SO_2, NO_X and CO emissions. At hotelling, AE LF adopted from PoLA 2008 study results included onboard reefer container load, which varies with ports and could be quite different from Hong Kong. For the ocean cruise, AE and AB EFs and energy defaults in hotelling mode were the most important factors that affect emission estimation. For oil tankers, AE LF in hotelling mode had the largest sensitivity to SO_2, NO_X and PM_{10} emissions, while ME LF in slow cruise mode dominated VOC and CO emissions.

River Vessel

6.4.6. Uncertainties of RV emission of SO_2, NO_X and PM_{10} estimated in this Study were found within the range of -21% to 24%, -31% to 34% and -37% to 42% respectively. (Table 6-9) Amongst the main RV vessel types, Macau Ferry and container feeder contributed most uncertainties. (Table 6-10)

Table 6-9 Uncertainties of Emissions from River Vessels

Pollutant	Mean	Uncertainty	
SO_2	1,858	-21%	24%
NO_X	7,825	-31%	34%
PM_{10}	288	-37%	42%
$PM_{2.5}$	276	-37%	42%
VOC	239	-34%	38%
CO	894	-25%	29%

Table 6-10 Uncertainties of Emissions by RV Type

RV Type	SO_2				NO_X				PM_{10}			
	Mean	% in total	Uncertainty		Mean	% in Total	Uncertainty		Mean	% in total	Uncertainty	
Macau Ferry	766	41%	-13%	14%	2,286	29%	-29%	30%	98	34%	-32%	35%
FCCV	549	30%	-23%	27%	2,469	32%	-28%	32%	89	31%	-35%	40%
PRD Ferry	241	13%	-15%	17%	1,431	18%	-27%	29%	36	12%	-33%	37%
Others	302	16%	-42%	50%	1,639	21%	-43%	53%	66	23%	-50%	61%
Total	**1,858**	**100%**	**-21%**	**24%**	**7,825**	**100%**	**-31%**	**34%**	**288**	**100%**	**-37%**	**42%**

6.4.7. In terms of equipment, emissions from AE carried the highest uncertainties (Table 6-11), due to limited data about RTV AE power rating. Uncertainties related to RTV ME power rating were also high. In contrast, engine power of Macau Ferry and PRD Ferry carried lower uncertainties as data were provided by the operators. (see also paragraph 6.3.2)

Table 6-11 Uncertainties of RV Emissions by Engine Type

Engine/Vessel Type	SO_2				NO_X				PM_{10}			
	mean	% in Total	Uncertainty		mean	% in Total	Uncertainty		mean	% in Total	Uncertainty	
Main Engine	1,465	79%	-19%	21%	7,622	80%	-29%	31%	214	74%	*-31%*	*35%*
RTV	*487*	*26%*	*-29%*	*32%*	*2,163*	*23%*	*-31%*	*35%*	*84*	*29%*	*-39%*	*46%*
Macau Ferry	*750*	*40%*	*-13%*	*14%*	*3,744*	*39%*	*-29%*	*30%*	*96*	*33%*	*-26%*	*28%*
PRD Ferry	*229*	*12%*	*-15%*	*16%*	*1,715*	*18%*	*-27%*	*29%*	*34*	*12%*	*-27%*	*29%*
Aux. Engine	393	21%	-31%	37%	1,883	20%	-37%	44%	74	26%	-43%	52%
RTV	*364*	*20%*	*-32%*	*38%*	*1,748*	*18%*	*-38%*	*45%*	*70*	*24%*	*-44%*	*53%*
Macau Ferry	*16*	*1%*	*-18%*	*20%*	*74*	*1%*	*-26%*	*28%*	*2*	*1%*	*-33%*	*35%*
PRD Ferry	*13*	*1%*	*-19%*	*20%*	*61*	*1%*	*-26%*	*28%*	*2*	*1%*	*-33%*	*35%*
Total	**1,858**	**100%**	**-21%**	**24%**	**9,505**	**100%**	**-31%**	**34%**	**288**	**100%**	**-34%**	**39%**

6.4.8. In terms of operation mode, emissions in maneuvering, hotelling and slow cruise modes had higher uncertainties, due to limited information about RV movements inside Hong Kong waters tracked by AIS. (see paragraph 6.3.4) This is different from fairway cruise, as the only two vessel types that operate in this mode, Macau Ferry and PRD Ferry, were well represented by the vessel track data. (Table 6-12)

Table 6-12 Uncertainties of RV Emissions by Operation Mode

Mode and Vessel Type	SO_2				NO_X				PM_{10}			
	mean	% in Total	Uncertainty		mean	% in Total	Uncertainty		mean	% in Total	Uncertainty	
Fairway cruise	937	50%	-13%	14%	3,454	36%	-21%	23%	125	43%	-26%	27%
Macau Ferry	*705*	*38%*	*-12%*	*13%*	*2,160*	*23%*	*-21%*	*22%*	*91*	*32%*	*-25%*	*26%*
PRD Ferry	*232*	*12%*	*-15%*	*16%*	*1,294*	*14%*	*-22%*	*24%*	*34*	*12%*	*-26%*	*28%*
Slow cruise	544	29%	-27%	30%	2,646	28%	-32%	37%	94	33%	-36%	42%
RTV	*515*	*28%*	*-27%*	*31%*	*2,564*	*27%*	*-32%*	*37%*	*90*	*31%*	*-36%*	*43%*
Macau Ferry	*29*	*2%*	*-18%*	*20%*	*80*	*1%*	*-24%*	*27%*	*4*	*1%*	*-28%*	*31%*
PRD Ferry	*0*	*0%*	*-15%*	*17%*	*2*	*0%*	*-23%*	*24%*	*0*	*0%*	*-27%*	*29%*
Maneuvering	99	5%	-46%	55%	2,075	22%	-40%	43%	17	6%	-61%	77%
RTV	*71*	*4%*	*-51%*	*62%*	*76*	*1%*	*-60%*	*80%*	*13*	*5%*	*-64%*	*83%*
Macau Ferry	*25*	*1%*	*-33%*	*38%*	*1,542*	*16%*	*-40%*	*41%*	*3*	*1%*	*-50%*	*56%*
PRD Ferry	*4*	*0%*	*-31%*	*33%*	*457*	*5%*	*-40%*	*42%*	*1*	*0%*	*-50%*	*52%*
Hotelling	277	15%	-30%	35%	1,331	14%	-36%	43%	53	18%	-44%	51%
RTV	*265*	*14%*	*-30%*	*35%*	*1,272*	*13%*	*-36%*	*43%*	*51*	*18%*	*-44%*	*51%*
Macau Ferry	*7*	*0%*	*-22%*	*24%*	*35*	*0%*	*-31%*	*33%*	*1*	*0%*	*-40%*	*43%*
PRD Ferry	*5*	*0%*	*-23%*	*24%*	*24*	*0%*	*-31%*	*33%*	*1*	*0%*	*-40%*	*43%*
Total	**1,858**	**100%**	**-21%**	**24%**	**9,505**	**100%**	**-31%**	**34%**	**288**	**100%**	**-34%**	**39%**

Discussion

6.4.9. Whilst some overseas marine vessels emission studies quantified uncertainties of emission factors[40], quantification for uncertainties of marine vessel emissions like this Study could be one of the few pioneers[41]. Two possible contributing factors to the seemingly low uncertainty level associated with emission estimates derived for Hong Kong are the activity-based, bottom-up approach adopted, as well as improved data quality in this Study. Discussion on data improvement can be found in Chapter 17.

[40] Entec UK Limited (2002, 2010); Sax and Alexis (2007).

[41] One example of quantitative analysis of uncertainties of marine vessel emissions is Zheng, et.al. (2009). Uncertainty ranges for marine sources in the PRD were estimated from -70% to 80% for SO_2, -40% to 65% for NO_X and -70% to 110% for PM_{10}.

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PART IV BACKCASTING EMISSIONS FOR 1990-2006

7. OCEAN-GOING VESSELS INVENTORY 1990-2006

7.1. Methodology

7.1.1. Annual emissions of OGVs from 1990 to 2006 were estimated by vessel type and air pollutant, based on the 2007 inventory. Parameters and emission figures for 1990, 1997 and 2003[42] were highlighted, together with their trends during the whole backcasting period. Emission estimates for FCCV were further broken down by berthing locations (either at KCCT or elsewhere) and by DWT sub-class.

7.1.2. To estimate emissions of a certain air pollutant from a certain vessel type in a particular year, the following parameters were considered:

- Vessel activity including vessel arrival number and average time-in-mode;
- Engine power rating, load/energy defaults or load factors of ME, AE and AB;
- Emission factor, which in turn was affected by (a) fuel sulphur content and (b) adjustment factors to reflect emission reduction technology implemented under IMO requirements since 2000.

7.1.3. 2007 was the base year from which emissions were calculated backward. All the parameters listed above were considered to reflect changes over time relative to 2007. An index value of 1.00 was assigned to all the parameters for year 2007. The index value of the same parameter of a different year was determined by comparing the value with its corresponding 2007 value.

7.1.4. Generally speaking, emissions were back calculated by the following main equation:

$$\textit{Total Emission}_{(pollutant,\ ship\ type,\ year)} = \sum \textit{Emission}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)}$$

$$\textit{Emission}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)} = VAN \times P \times FL \times T \times EF \times AdjF$$

where VAN is vessel arrival number;
P is the typical / average installed power of equipment;
FL is the typical / average fractional load of equipment in a specific mode;
T is the typical / average operation time-in-mode;
EF is the typical / average fractional load emission factor of equipment; and
AdjF is the weighted adjustment factor for emission reduction technology adopted under IMO requirement since 2000.

Trends in Vessel Activity

7.1.5. Change in vessel activity over time was considered in several aspects, including vessel arrival numbers, and the average time a vessel stayed in the port of Hong Kong.

[42] Year 1990 is the first year in which emissions inventory of HKSAR was comprehensively reported. Years 1997 and 2003 were selected as the reference years for reporting emissions in the Mid-term Review of the Joint Agreement between HKSAR and Guangdong provincial governments in emission reduction.

7.1.6. Historical OGV arrival numbers were collected through statistical reports such as *PHKST*, published annually by MD. Figure 7-1 below shows the long-term trend of OGV arrival number by major vessel type from 1990 to 2007. Total number of OGVs grew sharply since 1990 and peaked in 1997. After 1997, vessel arrival numbers had dropped in line with global economic condition and trade performance. The trend picked up again since 2004, but saw another dip in 2007. Amongst different vessel types, it is apparent that the number of FCCV calling Hong Kong has grown significantly over the backcasting period, while the number of conventional cargo vessels and semi-container vessels both dropped below their 1990 level after enjoying a booming period in the mid-1990s. It is also worthwhile to note that while a large proportion of FCCV that called Hong Kong over the period was smaller vessels with DWT of 10,000 or below, the number of large containerships (DWT over 100,000) has increased continuously since 1997. (Figure 7-2) Effect of such DWT splits over time is reflected in engine power ratings, as discussed in paragraph 7.1.9..

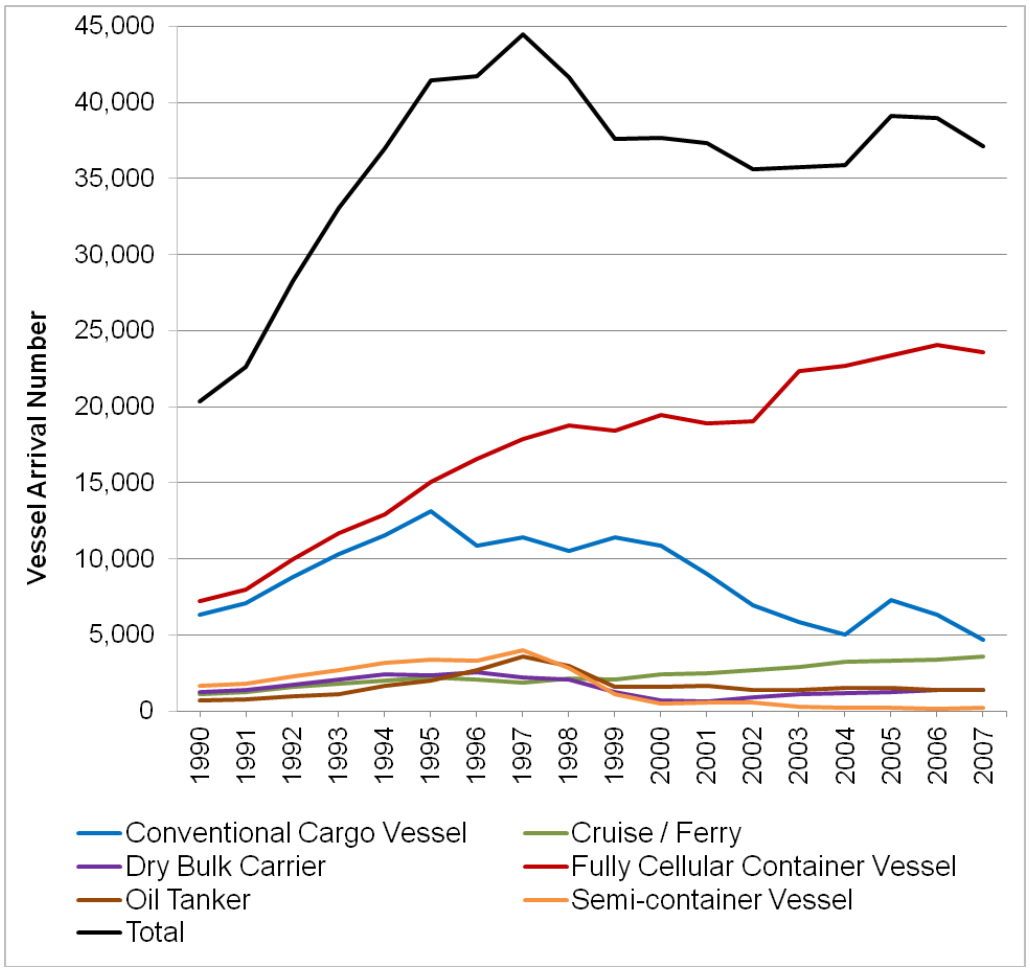

Figure 7-1 OGV Arrival Number by Main Vessel Type, 1990-2007

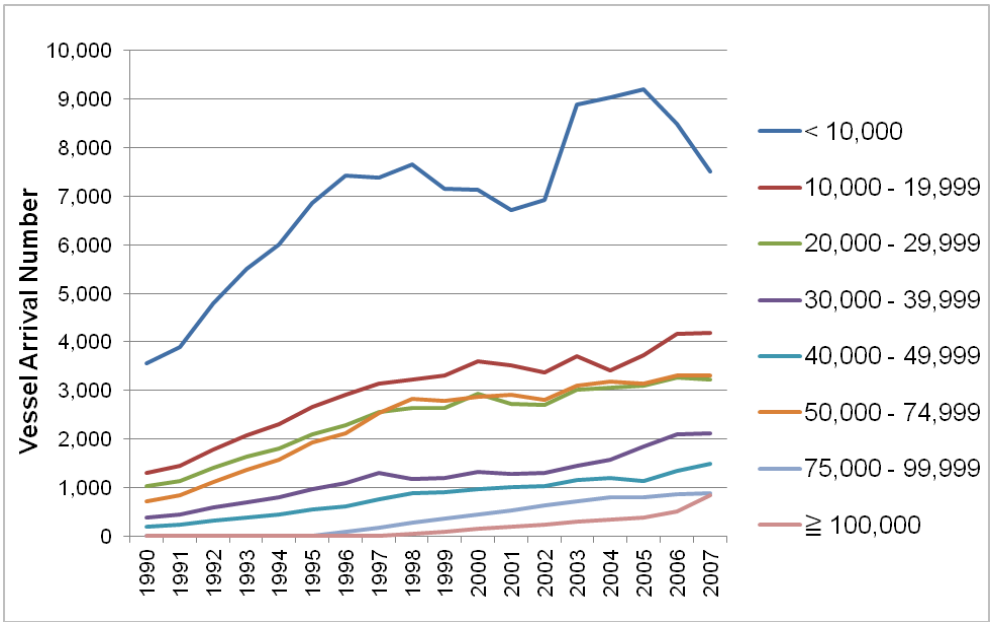

Figure 7-2 OGV FCCV Arrival Number by DWT Class, 1990-2007

7.1.7. Average time-in-port, time spent from the first berthing to the last berthing which may be assumed to be average hotelling time, was also gathered from *PHKST* for 1992 to 2006 by major vessel type. As no time-in-port information was available for 1990 and 1991, it was assumed to be the same as 1992. Table 7-1 illustrates changing average hotelling time of major vessel types in selected years since 1990. In general, most vessel types reduced their time in port over the years. For FCCV, reduction in hotelling was mainly achieved through shorter turnaround time at KCCT (Figure 7-3). As FCCV has become larger in size, loading and unloading at KCCT also improved enormously in term of efficiency.

Table 7-1 Average OGV Hotelling Time (hour) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
A. Chemical Carrier/Tanker	39	51	11	13
B. Conventional Cargo Vessel	73	71	65	38
C. Cruise/Ferry	14	14	12	9
D. Dry Bulk Carrier	104	93	59	36
E. Fishing/Fish Processing Vessel	159	153	144	98
F. Fully Cellular Container Vessel	30	28	23	22
G. Gas Carrier/Tanker	41	44	27	46
H. Lighter/Barge/Cargo Junk	109	110	170	112
I. Oil Tanker	58	42	25	22
J. Pleasure Vessel	66	31	81	66
K. Roll On/Roll Off	20	18	9	16
L. Semi-container Vessel	52	48	28	29
M. Tug	97	149	209	92
N. Others	98	91	81	66

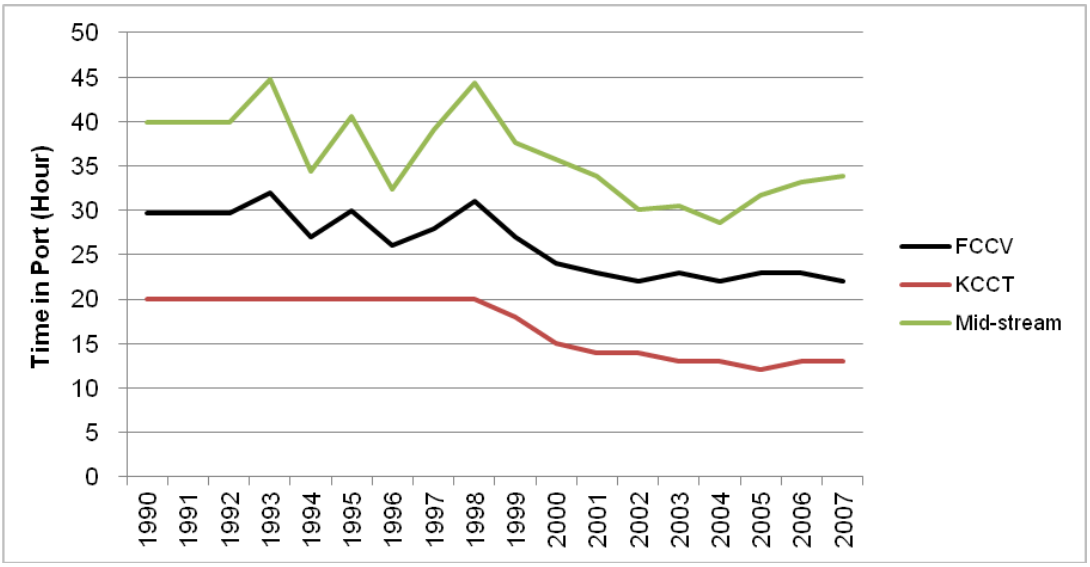

Figure 7-3 Average Hotelling Time by Berthing Location, 1990-2007

7.1.8. The other time-in-mode in historic years, including cruising, fairway cruise, slow cruise and maneuvering, would also affect emission estimation. As there was no valid information about how the average time-in-mode has changed over time, and given the sailing distance from the boundary of Hong Kong waters to the main berthing locations remains the same, it was assumed that average time-in-mode for each vessel type and DWT sub-class was identical to the corresponding 2007 value.

Trends in Engine Power Ratings, Load Defaults or Factors

7.1.9. Change in ME, AE and AB power ratings over time was another determining factor on historical vessel emission estimation, which can be reflected by vessel size with GRT as an indicator. Even though ME information of individual vessels could be retrieved from LRS, information about the identity of the vessels that entered Hong Kong in historical years was not retrievable. As a result, average engine power ratings by vessel type (except FCCV) were derived from the vessel call by GRT data made available by MD to EPD in the past. For FCCV, average ME power ratings are estimated with 2007 power ratings surveyed per DWT class at container terminals or elsewhere weighted with their corresponding arrival calls. Figure 7-4 is a snapshot of average ME power ratings by main vessel type from 1990 to 2007.

7.1.10. Adjustment to ME load factor for FCCV and cruise/ferry on or before 1999 was made. The current vessel speed limit system within Hong Kong waters came into force on 1 July 2000. These two vessel types probably sailed at higher speed before 2000, meaning higher ME load factor. Assuming that they sailed at a speed 20% higher, their ME load factor on or before 1999 were adjusted upward accordingly (by 1.2 to the power 3). No adjustment to other OGV types are anticipated as their maximum speed would be lower than the speed limit.

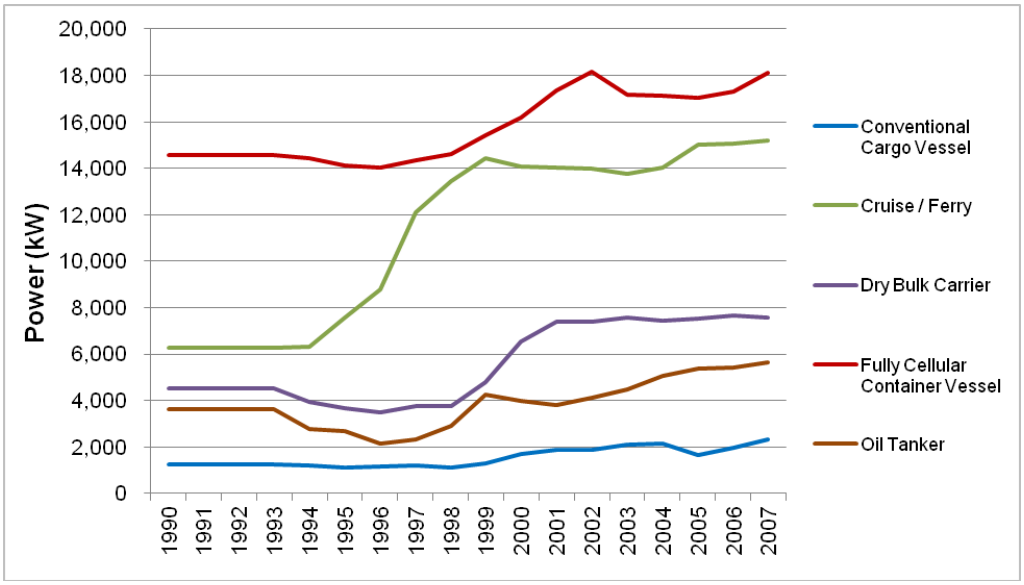

Figure 7-4 Average ME Power Rating by Main Vessel Type, 1990-2007

7.1.11. For FCCV, emissions from AE were estimated based on the auxiliary engine load defaults adapted from *PoLA 2009 Report*. It was assumed that the load default values for each DWT sub-class remained unchanged from 1990 to 2006. Similarly, the fleet average boiler energy defaults adapted also from *PoLA 2009 Report* for the 2007 emission inventory were also used to estimate historical emissions.

Trends in Fuel Sulphur Content

7.1.12. Marine fuel used by OGVs includes residual oil (also called heavy fuel oil or HFO) and distillate fuel. Majority of OGVs use residual oil with high sulphur content. In this Study, irrespective of vessel type, OGVs with ME power not more than 1,100 kW were assumed to use distillate fuel. Sulphur content of residual oil and distillate in historical years were estimated based on Endresen, et.al. (2005) and DNV (2009). For residual oil, Hong Kong's 2002 value was assumed the same as the average value for Asia, and average fuel sulphur content for the past years was estimated based on the ratio of average Asia value over DNV's global average in 2002. (Table 7-2) For distillate, the 2002 average Asia value of 0.63% was once again adopted as the 2002 Hong Kong average fuel sulphur content. It was assumed that the average value for Hong Kong remained as 0.63% in all the pre-2002 years. The values from 2003 to 2006 were interpolated, given the 2007 effective fuel sulphur content for distillate was set as 0.5 (Table 7-3)

Table 7-2 Average Fuel Sulphur Content of Residual Oil, Selected Years

	1990	1997	2002	2003	2007
Hong Kong	3.54%	3.31%	3.07%	3.25%	2.90%*
Asia[1]			3.07%		
Global[2]	2.95%	2.76%	2.56%	2.71%	2.53%

1 Endresen, et.al. (2005); 2 DNV (2009).
* Assume 2.90% to represent average sulphur contents of primary fuel for ME, AE and AB at 2.95%, 2.78% and 2.80% respectively. See paragraph 2.4.36.

Table 7-3 Average Fuel Sulphur Content of Distillate Fuel, Selected Years

	1990	1997	2002	2003	2007
Hong Kong	0.63%*	0.63%*	0.63%	0.60%#	0.50%
Asia			0.63%		

* Same as 2002
# Estimated by interpolation between 2002 and 2007

7.1.13. Another consideration related to fuel use was the split in vessel call number and ratio between those using residual oil and distillate fuel during past years. As there was no such record, the 2007 fuel split by vessel type was applied to the historical years. A series of weighted fuel sulphur content was derived as shown in Table 7-4 below.

Table 7-4 Weighted Fuel Sulphur Content by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007 Fuel Split	
				HFO	Distillate
A. Chemical Carrier/Tanker	3.34%	3.13%	3.07%	0.93	0.07
B. Conventional Cargo Vessel	2.32%	2.19%	2.15%	0.58	0.42
C. Cruise/Ferry	2.71%	2.55%	2.50%	0.71	0.29
D. Dry Bulk Carrier	3.46%	3.24%	3.18%	0.97	0.03
E. Fishing/Fish Processing Vessel	0.63%	0.63%	0.60%	0.00	1.00
F. Fully Cellular Container Vessel	2.82%	2.64%	2.59%	0.75	0.25
G. Gas Carrier/Tanker	3.54%	3.31%	3.25%	1.00	0.00
H. Lighter/Barge/Cargo Junk	0.63%	0.63%	0.60%	0.00	1.00
I. Oil Tanker	3.49%	3.27%	3.21%	0.99	0.02
J. Pleasure Vessel	0.63%	0.63%	0.60%	0.00	1.00
K. Roll On/Roll Off	3.35%	3.14%	3.08%	0.93	0.07
L. Semi-container Vessel	1.79%	1.70%	1.66%	0.40	0.60
M. Tug	0.63%	0.63%	0.60%	0.00	1.00
N. Others	3.51%	3.29%	3.23%	0.99	0.01

Trends in Emission Factor and Adjustment Factor

7.1.14. Emission factors were affected over time by several factors, namely fuel sulphur content, mix of fuel type, and the rate of progress of NO_X emission reductions from MEs since 2000 due emission reduction technology changes in line with IMO's requirements.

7.1.15. Change in average or typical fuel sulphur content (see paragraph 7.1.12 and Table 7-2) in turn affects the calculation of the SO_2 and PM emission factors.

7.1.16. Change in the type of fuel used by OGVs over time (see paragraph 7.1.13), which saw vessels switching from residual oil to distillate during specific operation modes or locations, also led to the use of emission factors derived for distillate fuels for part of the emission estimation.

7.1.17. As explained in paragraphs 3.2.39 to 3.2.43, an adjustment factor reflecting emission reduction technology installed onboard, and hence emission reduction from ME achieved for NO_X, PM and HC/VOC, was applied to individual vessels calling Hong Kong in 2007, with a keel-laying date between 1st January 2000 and 31st December 2010 (both dates inclusive). Due to the different vessel age profile amongst different vessel types, a weighted adjustment factor was derived for the three pollutants for each vessel type according to its fleet mix and age profile in 2007. Similar adjustment factors were derived for the years between 1999 (no adjustment) and 2007 by interpolation. Tables 7-5 to 7-7 display the adjustment factors for NO_X, PM and VOC respectively.

Table 7-5 Emission Reduction Adjustment Factor (ME) for NO_X by Vessel Type, Selected Years

Vessel Type	1990-1999	2003	2007
A. Chemical Carrier/Tanker	1.000	0.972	0.944
B. Conventional Cargo Vessel	1.000	0.990	0.981
C. Cruise/Ferry	1.000	1.000	1.000
D. Dry Bulk Carrier	1.000	0.994	0.987
E. Fishing/Fish Processing Vessel	1.000	1.000	1.000
F. Fully Cellular Container Vessel	1.000	0.982	0.963
G. Gas Carrier/Tanker	1.000	0.988	0.976
H. Lighter/Barge/Cargo Junk	1.000	1.000	1.000
I. Oil Tanker	1.000	0.977	0.955
J. Pleasure Vessel	1.000	0.998	0.997
K. Roll On/Roll Off	1.000	0.992	0.984
L. Semi-container Vessel	1.000	0.985	0.969
M. Tug	1.000	0.994	0.988
N. Others	1.000	0.993	0.986

Table 7-6 Emission Reduction Adjustment Factor (ME) for PM_{10} by Vessel Type, Selected Years

Vessel Type	1990-1999	2003	2007
A. Chemical Carrier/Tanker	1.000	0.988	0.980
B. Conventional Cargo Vessel	1.000	0.995	0.992
C. Cruise/Ferry	1.000	1.000	1.000
D. Dry Bulk Carrier	1.000	0.991	0.985
E. Fishing/Fish Processing Vessel	1.000	1.000	1.000
F. Fully Cellular Container Vessel	1.000	0.972	0.951
G. Gas Carrier/Tanker	1.000	0.999	0.999
H. Lighter/Barge/Cargo Junk	1.000	1.000	1.000
I. Oil Tanker	1.000	0.978	0.956
J. Pleasure Vessel	1.000	1.000	1.000

K. Roll On/Roll Off	1.000	0.991	0.982
L. Semi-container Vessel	1.000	0.991	0.983
M. Tug	1.000	0.999	0.999
N. Others	1.000	0.999	0.998

Table 7-7 Emission Reduction Adjustment Factor (ME) for VOC by Vessel Type, Selected Years

Vessel Type	1990-1999	2003	2007
A. Chemical Carrier/Tanker	1.000	0.986	0.972
B. Conventional Cargo Vessel	1.000	0.995	0.989
C. Cruise/Ferry	1.000	1.000	1.000
D. Dry Bulk Carrier	1.000	0.990	0.979
E. Fishing/Fish Processing Vessel	1.000	1.000	1.000
F. Fully Cellular Container Vessel	1.000	0.966	0.933
G. Gas Carrier/Tanker	1.000	0.999	0.998
H. Lighter/Barge/Cargo Junk	1.000	1.000	1.000
I. Oil Tanker	1.000	0.974	0.947
J. Pleasure Vessel	1.000	1.000	1.000
K. Roll On/Roll Off	1.000	0.989	0.979
L. Semi-container Vessel	1.000	0.990	0.979
M. Tug	1.000	0.999	0.999
N. Others	1.000	0.999	0.997

Backcasting

7.1.18. Once all the key parameters (by year, vessel type, DWT sub-class, operation mode and equipment where appropriate) were determined as a factor of their corresponding 2007 value, past emissions were then back calculated by applying all the factors to the corresponding emission numbers in 2007.

7.2. Results and Discussions

7.2.1. Figure 7-5 below plots the historical emission of three major pollutants, namely SO_2, NO_X and PM_{10}, from 1990 to 2006. Emission of all three pollutants grew tremendously since 1990: SO_2 by a factor of 2.2, NO_X by 3, and PM_{10} by 2.6. There is also a notable drop in SO_2 emission, between the peak in 1998 and the low point in 2002. This was the combined effect of the lowering of fuel sulphur content from 3.39% in 1998 to 3.07% in 2002 (see paragraph 7.1.12), and a decrease in vessel arrival number to Hong Kong due to the impact of the 1997 Asian financial crisis on the economy and trade (paragraph 7.1.6 and Figure 7-1).

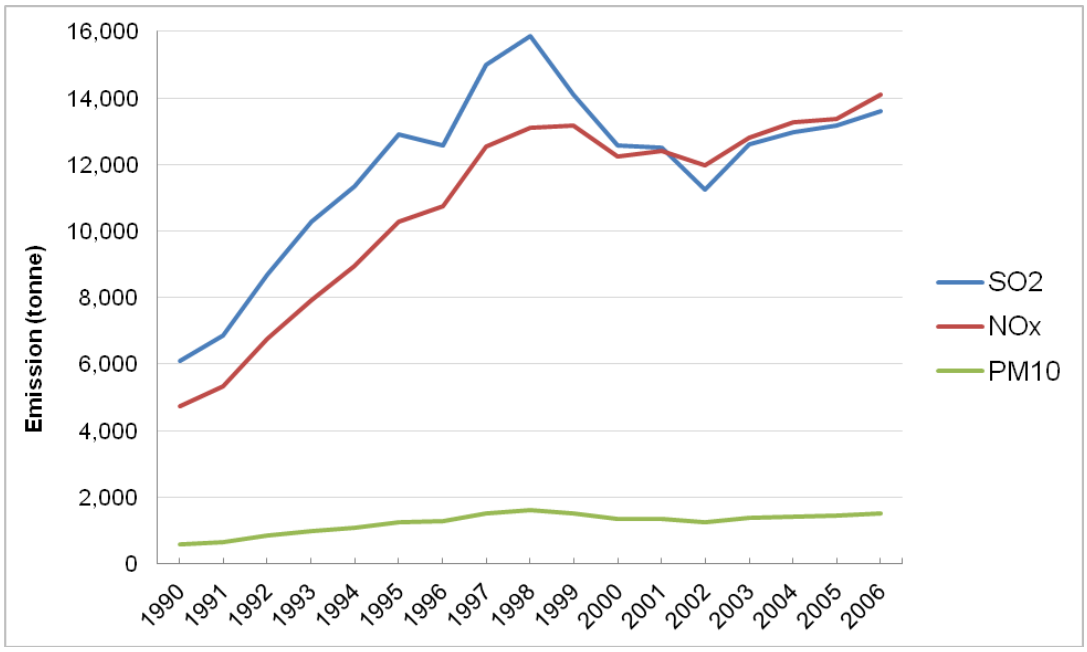

Figure 7-5 Historical OGV Emissions in Hong Kong, 1990-2006

7.2.2. Figures 7-6 to 7-8 below show further breakdown of historical emissions of SO_2, NO_X and PM_{10} by major vessel type.

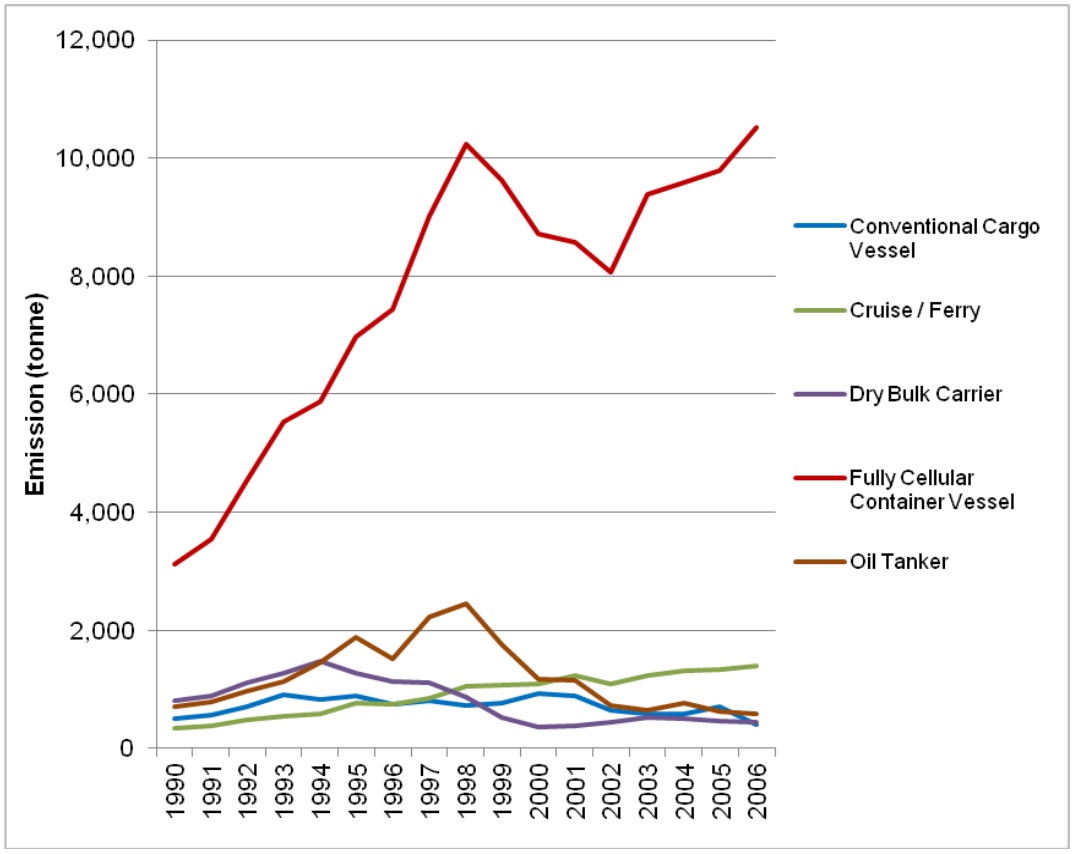

Figure 7-6 Historical OGV Emissions of SO_2 by Main Vessel Type, 1990-2006

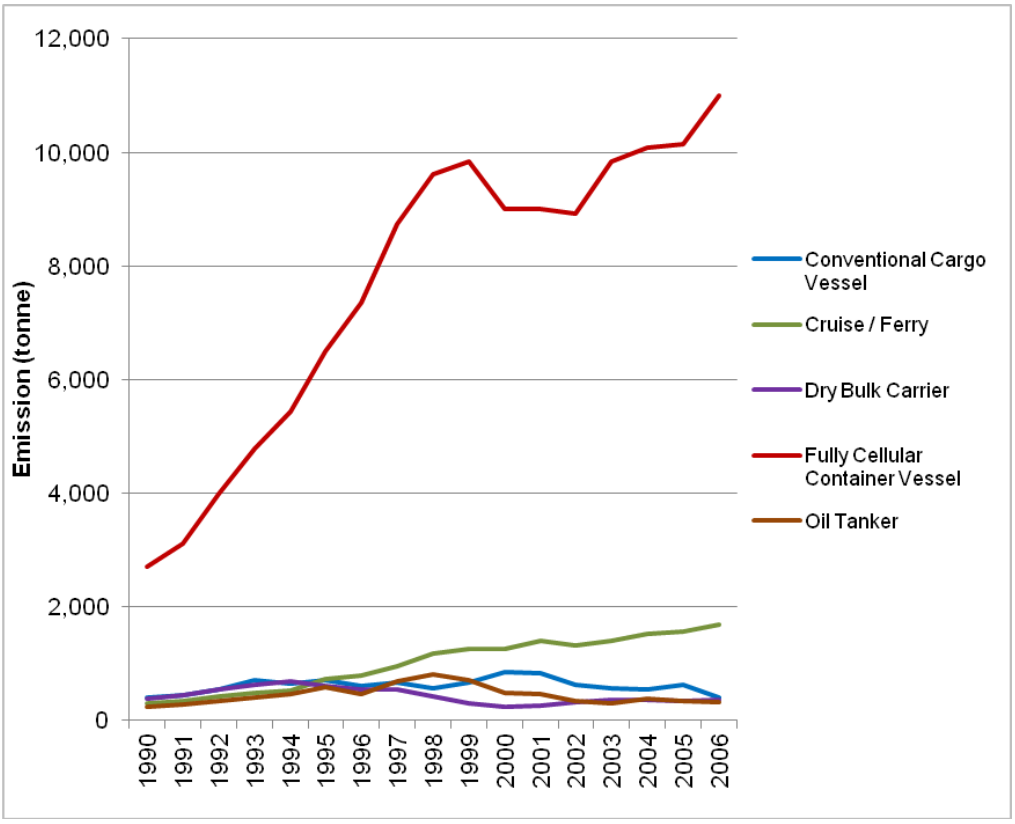

Figure 7-7 Historical OGV Emissions of NO_X by Main Vessel Type, 1990-2006

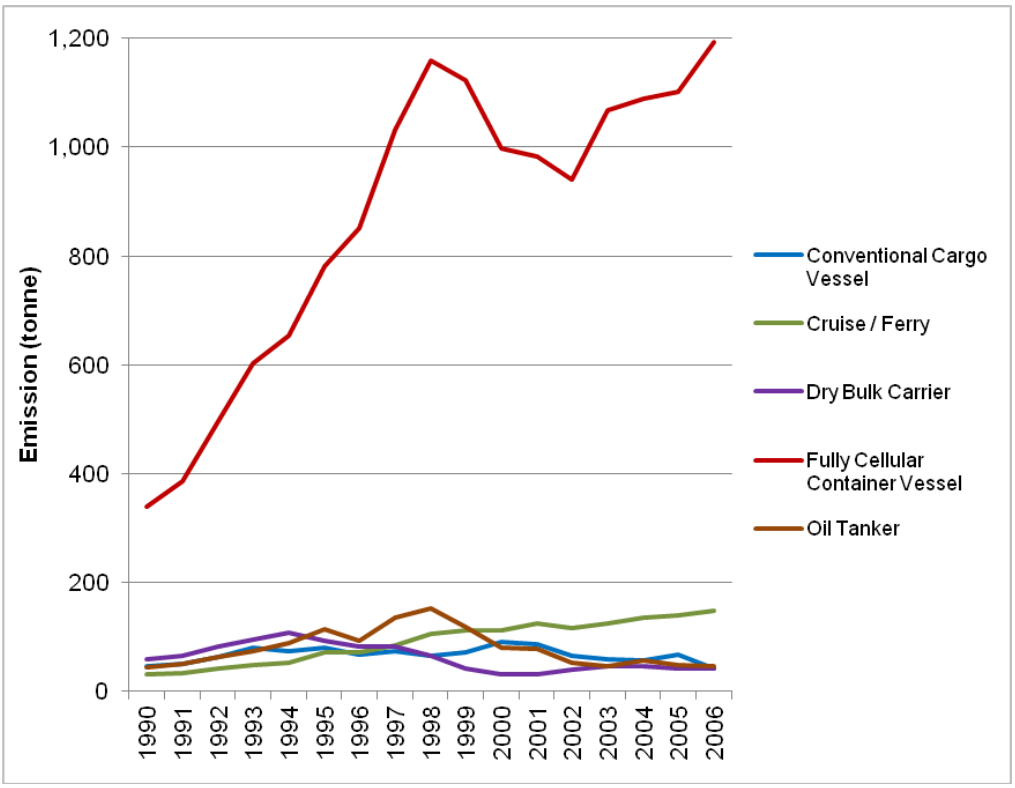

Figure 7-8 Historical OGV Emissions of PM_{10} by Main Vessel Type, 1990-2006

7.2.3. A common observation from the three diagrams is that FCCV has made the most significant contribution to the increase of emissions in quantity. Emissions of SO_2, NO_X and PM_{10} from FCCV were 3.4 time, 4.2 times and 3.5 times of the respective 1990 values. This is largely due to the continuous increase in FCCV arrivals and the growing size of containerships.

7.2.4. In terms of percentage growth, emissions of SO_2, NO_X and PM_{10} from cruise ships recorded even higher growth from 1990 to 2006. Their emissions in 2006 were 4 times, 5.6 times and 4.8 times of the respective 1990 values. The strong growth is mainly due to a much higher average ME power rating for the new and larger cruise ships. (see Figure 7-4)

7.2.5. For the other major vessel types included in the diagrams, such as conventional cargo vessel, dry bulk carrier and oil tanker, they have recorded either modest increase or decrease in emissions over the same period.

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8. RIVER VESSELS INVENTORY 1990-2006

8.1. Methodology

8.1.1. Annual emissions of RVs from 1990 to 2006 were estimated by vessel type and air pollutant, based on the 2007 inventory. Similar to the RV emission inventory of 2007, historical emission inventory of RV was prepared in three components, namely RTVs, Macau Ferry and PRD Ferry.

River Trade Vessels

8.1.2. Historical emission of RTVs from 1990 to 2006 was estimated by the following equation:

$$\textbf{\textit{Total Emission}}_{(pollutant,\ ship\ type,\ year)} = \sum \textbf{\textit{Emission}}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)}$$

$$\textbf{\textit{Emission}}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)} = VAN \times P \times FL \times T \times EF$$

where VAN is vessel arrival number;
P is the typical / average installed power of equipment;
FL is the typical / average fractional load of equipment in a specific mode;
T is the typical / average operation time-in-mode; and
EF is the typical / average fractional load emission factor of equipment

8.1.3. Among all the parameters listed above, ME and AE power by vessel type and GRT sub-class[43], fuel sulphur content, ME and AE load factors by mode, and emission factors were assumed to remain unchanged during the backcasting period, and so the 2007 values were used.

8.1.4. Change in RTV activity over time was considered in terms of vessel arrival number and average time-in-port.

8.1.5. Past vessel arrival number of RTVs by year and GRT class was collected from various past issues of *PHKST* and from EPD's data archive provided by MD.

8.1.6. Figure 8-1 below illustrates the long-term trend of RTV arrival number by major vessel type from 1990 to 2007. Total number of RTVs grew strongly since 1990 and peaked in 1997 and 1998, similar to the trend of OGV arrival numbers. After 1998, vessel arrival numbers dropped modestly to the level of about 115,000 to 119,000 each year and remained fairly constant until 2006. There was a dip in 2007 to below 110,000 arrivals. Amongst the main vessel types, the growth of FCCV arrivals was the strongest, especially after 1999. FCCV's increase in number from 1999 to 2006 was virtually offset by the reduction of conventional cargo vessel arrivals over the same period. In 1990, five vessel types each contributed over 1,000 arrivals to Hong Kong. They were conventional cargo vessel, lighter/barge/cargo junk, tug, FCCV and oil tanker. In 2006, they remained in the top five in terms of arrival number. Dry bulk carrier also had over 1,000 arrivals in 2006 and was ranked in sixth.

[43] Although average ME and AE power based on MD's GRT sub-class varied from one year to another, the most important types of RTVs such as FCCV and conventional cargo vessel only had minimal variations. Also, Macau and PRD Ferries have relatively constant GRT. Thus, average ME and AE powers per vessel type were assumed constant.

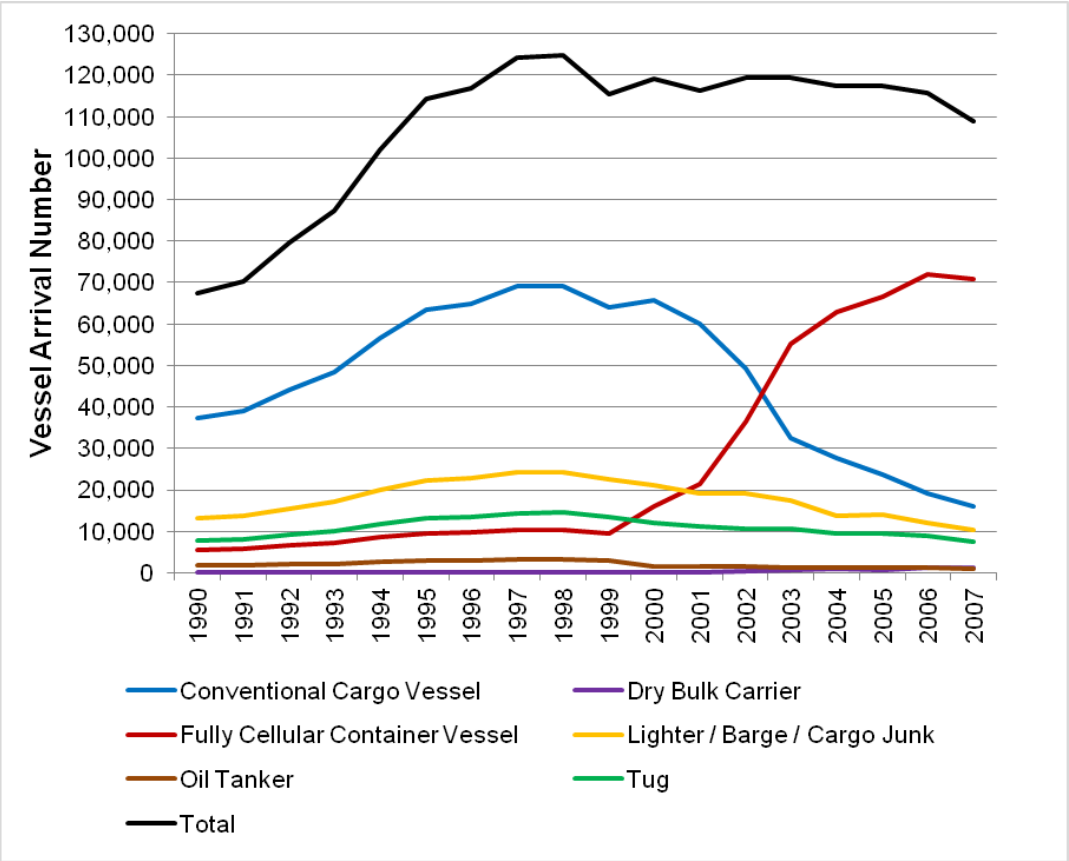

Figure 8-1 Historical RTV Arrival Number by Main Vessel Type, 1990-2007

8.1.7. Average time-in-port by vessel type between 2000 and 2006 was collected from *PHKST*. The arithmetic means of the 2000 to 2006 average time-in-port were used as surrogates for the years between 1990 and 1999, as information was not available. (Table 8-1) Four hours were added to each of the average time-in-port to become average call duration to reflect sailing time to and from boundary of Hong Kong waters and between different berthing locations. (Table 8-2)

Table 8-1 RTV Average Time-in-port (hour) by Vessel Type, Selected Years

Vessel Type	1990-1999	2000	2003	2007
A. Chemical Carrier/Tanker	24	28	21	28
B. Conventional Cargo Vessel	28	28	27	30
D. Dry Bulk Carrier	38	66	29	22
F. Fully Cellular Container Vessel	28	23	27	34
G. Gas Carrier/Tanker	17	9	11	9
H. Lighter/Barge/Cargo Junk	63	65	61	69
I. Oil Tanker	50	40	51	59
K. Roll On/Roll Off	9	16	10	9
L. Semi-container Vessel	25	29	19	43
M. Tug	56	56	51	68
N. Others	50	57	72	19

Table 8-2 RTV Average Call Duration (hour) by Vessel Type, Selected Years

Vessel Type	1990-1999	2000	2003	2007
A. Chemical Carrier/Tanker	28	32	25	32
B. Conventional Cargo Vessel	32	32	31	34
D. Dry Bulk Carrier	42	70	33	26
F. Fully Cellular Container Vessel	32	27	31	38
G. Gas Carrier/Tanker	21	13	15	13
H. Lighter/Barge/Cargo Junk	67	69	65	73
I. Oil Tanker	54	44	55	63
K. Roll On/Roll Off	13	20	14	13
L. Semi-container Vessel	29	33	23	47
M. Tug	60	60	55	72
N. Others	54	61	76	23

Macau Ferry

8.1.8. Historical emission of Macau Ferry from 1990 to 2006 was estimated by two key parameters, namely (a) annual arrival and departure number of Macau Ferry, and (b) average emission per Macau Ferry trip.

8.1.9. Past Macau Ferry arrival numbers were obtained from various past issues of *PHKST*. Past departure numbers, however, were only available from *PHKST* since 1999. Macau Ferry departure numbers before 1999 were estimated based on the average arrival and departure ratio from 1999 to 2007, which is about 0.997. (Table 8-3)

Table 8-3 Historical Macau Ferry Arrival and Departure Number, Selected Years

	1990	1997	2003	2007
Arrivals	36,544	40,588	34,600	43,850
Departures	36,663	40,720	34,510	44,110

8.1.10. Once the arrival and departure numbers were determined, they were further classified under diesel engine ferry and gas turbine engine ferry. Engine type was specified in emission estimation as different parameters such as emission factor were selected.

8.1.11. The split between diesel engine ferry trip and gas turbine engine ferry trip was only available for 2007, based on information provided by the operators. For arrivals, 27% of ferries were powered by diesel engine, and for departures the percentage was 28%. As such, these ratios were maintained throughout the backcasting period, except all arrival and departure numbers before 1993 were assigned to diesel engine ferry, as gas turbine engine ferry was only introduced to Hong Kong since 1993. (Table 8-4)

Table 8-4 Historical Macau Ferry Arrival and Departure Number by Engine Type, Selected Years

	1990	1993	1997	2003	2007
Arrivals	36,544	37,566	40,588	34,600	43,850
Diesel Engine	*36,544*	*10,309*	*11,138*	*9,495*	*12,033*
Gas Turbine Engine	*0*	*27,257*	*29,450*	*25,105*	*31,817*
Departures	36,663	37,688	40,720	34,510	44,110
Diesel Engine	*36,663*	*10,502*	*11,347*	*9,617*	*12,292*
Gas Turbine Engine	*0*	*27,186*	*29,373*	*24,893*	*31,818*

8.1.12. Average emission per trip was estimated based on the emission number produced for Macau Ferry in 2007 (Chapter 4). Average emission per trip was further classified by engine type, namely diesel engine and gas turbine engine as explained above.

8.1.13. An additional factor was considered as new ferry services were commissioned since 2003 between SkyPier at the Hong Kong International Airport and Macau. In order to reflect lower emissions due to the shorter distance between SkyPier and boundary of Hong Kong waters to the west, two sets of average emission per trip numbers were developed. The first set covers the period from 2003 to 2006, which incorporated the trips to and from SkyPier. The second set covers the period prior to 2003. Tables 8-5 and 8-6 below show that average emission per Macau Ferry trip for 2003 to 2006 and pre-2003, with the former slightly lower caused by the shorter distance and hence lower emission of the SkyPier trips.

Table 8-5 Average Emission per Macau Ferry Trip (tonne), 2003-2006

	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Arrivals						
Diesel Engine	*0.0072*	*0.0451*	*0.0011*	*0.0011*	*0.0017*	*0.0038*
Gas Turbine Engine	*0.0092*	*0.0182*	*0.0011*	*0.0010*	*0.0003*	*0.0007*
Departures						
Diesel Engine	*0.0071*	*0.0445*	*0.0011*	*0.0010*	*0.0017*	*0.0038*
Gas Turbine Engine	*0.0092*	*0.0182*	*0.0011*	*0.0010*	*0.0003*	*0.0007*

Table 8-6 Average Emission per Macau Ferry Trip (tonne), pre-2003

	SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Arrivals						
Diesel Engine	*0.0076*	*0.0478*	*0.0012*	*0.0011*	*0.0018*	*0.0041*
Gas Turbine Engine	*0.0093*	*0.0185*	*0.0011*	*0.0010*	*0.0003*	*0.0007*
Departures						
Diesel Engine	*0.0075*	*0.0472*	*0.0011*	*0.0011*	*0.0018*	*0.0040*
Gas Turbine Engine	*0.0094*	*0.0186*	*0.0011*	*0.0010*	*0.0003*	*0.0007*

PRD Ferry

8.1.14. Similar to Macau Ferry, the two major parameters considered were (a) annual arrival and departure number of PRD Ferry, and (b) average emission per PRD Ferry trip.

8.1.15. Historical PRD Ferry arrival and departure numbers since 1999 by PRD ports were obtained from various past issues of *PHKST*. Arrival and departure numbers prior to 1999 were collected from EPD's data archive, in which information was previously provided by MD. Past PRD Ferry arrival and departure numbers were summarized in Table 8-7.

Table 8-7 Historical PRD Ferry Arrival and Departure Number by PRD Ports, Selected Years

	1990		1997		2003		2007	
	Arr.	*Dep.*	*Arr.*	*Dep.*	*Arr.*	*Dep.*	*Arr.*	*Dep.*
Guangzhou	1,821	1,821	5,059	5,053	4,060	4,050	3,500	3,490
Dongguan	406	405	1,111	1,113	1,320	1,330	3,180	3,170
Foshan	1,115	1,114	2,817	2,810	2,970	2,960	2,740	2,740
Jiangmen	364	362	766	764	1,240	1,250	1,120	1,120
Zhongshan	1,956	1,958	2,744	2,746	3,660	3,660	4,970	4,620
Zhuhai	1,082	1,082	4,215	4,230	5,460	5,460	6,840	6,830
Shenzhen	0	0	2,343	2,343	3,570	3,670	6,020	5,670
Shekou	2,983	2,982	4,089	4,086	5,540	5,550	9,710	9,710
Others	2,031	2,034	2,485	2,485	360	360	0	0
Total	11,758	11,758	25,629	25,630	28,180	28,290	38,080	37,350

8.1.16. Average emission per PRD trip was estimated based on the emission number produced for PRD Ferry in 2007 (see Chapter 4). Average emission per trip was further broken down into two sets: (a) average emission per trip for 2003 to 2006, accounting for the new PRD Ferry services to and from SkyPier since 2003, and (b) pre-2003 average emission per trip. (see Tables 8-8 and 8-9 below)

Table 8-8 Average Emission per PRD Ferry Trip (tonne), 2003-2006

		SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Arrivals							
	Guangzhou	*0.0061*	*0.0325*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Dongguan	*0.0018*	*0.0113*	*0.0003*	*0.0003*	*0.0004*	*0.0010*
	Foshan	*0.0051*	*0.0182*	*0.0007*	*0.0006*	*0.0006*	*0.0013*
	Jiangmen	*0.0039*	*0.0243*	*0.0006*	*0.0006*	*0.0009*	*0.0021*
	Zhongshan	*0.0037*	*0.0169*	*0.0005*	*0.0005*	*0.0006*	*0.0013*
	Zhuhai	*0.0031*	*0.0193*	*0.0005*	*0.0005*	*0.0007*	*0.0017*
	Shenzhen	*0.0024*	*0.0152*	*0.0004*	*0.0004*	*0.0006*	*0.0013*
	Shekou	*0.0023*	*0.0146*	*0.0004*	*0.0003*	*0.0005*	*0.0013*
	Others	*0.0051*	*0.0182*	*0.0007*	*0.0006*	*0.0006*	*0.0013*
Departures							
	Guangzhou	*0.0060*	*0.0320*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Dongguan	*0.0019*	*0.0117*	*0.0003*	*0.0003*	*0.0004*	*0.0010*
	Foshan	*0.0049*	*0.0178*	*0.0007*	*0.0006*	*0.0005*	*0.0012*
	Jiangmen	*0.0037*	*0.0231*	*0.0006*	*0.0005*	*0.0009*	*0.0020*
	Zhongshan	*0.0036*	*0.0169*	*0.0005*	*0.0005*	*0.0006*	*0.0013*
	Zhuhai	*0.0031*	*0.0194*	*0.0005*	*0.0005*	*0.0007*	*0.0017*
	Shenzhen	*0.0026*	*0.0160*	*0.0004*	*0.0004*	*0.0006*	*0.0014*
	Shekou	*0.0023*	*0.0145*	*0.0004*	*0.0003*	*0.0005*	*0.0013*
	Others	*0.0049*	*0.0178*	*0.0007*	*0.0006*	*0.0005*	*0.0012*

Table 8-9 Average Emission per PRD Ferry Trip (tonne), pre-2003

		SO_2	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO
Arrivals							
	Guangzhou	*0.0061*	*0.0325*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Dongguan	*0.0061*	*0.0325*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Foshan	*0.0051*	*0.0182*	*0.0007*	*0.0006*	*0.0006*	*0.0013*
	Jiangmen	*0.0039*	*0.0243*	*0.0006*	*0.0006*	*0.0009*	*0.0021*
	Zhongshan	*0.0042*	*0.0191*	*0.0006*	*0.0006*	*0.0007*	*0.0015*
	Zhuhai	*0.0032*	*0.0201*	*0.0005*	*0.0005*	*0.0008*	*0.0017*
	Shenzhen	*0.0035*	*0.0219*	*0.0005*	*0.0005*	*0.0008*	*0.0019*
	Shekou	*0.0032*	*0.0197*	*0.0005*	*0.0005*	*0.0007*	*0.0017*
	Others	*0.0051*	*0.0182*	*0.0007*	*0.0006*	*0.0006*	*0.0013*
Departures							
	Guangzhou	*0.0060*	*0.0320*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Dongguan	*0.0060*	*0.0320*	*0.0009*	*0.0008*	*0.0012*	*0.0026*
	Foshan	*0.0050*	*0.0181*	*0.0007*	*0.0006*	*0.0006*	*0.0013*
	Jiangmen	*0.0037*	*0.0231*	*0.0006*	*0.0005*	*0.0009*	*0.0020*
	Zhongshan	*0.0040*	*0.0188*	*0.0006*	*0.0005*	*0.0006*	*0.0015*
	Zhuhai	*0.0033*	*0.0204*	*0.0005*	*0.0005*	*0.0008*	*0.0018*
	Shenzhen	*0.0036*	*0.0224*	*0.0005*	*0.0005*	*0.0008*	*0.0019*
	Shekou	*0.0032*	*0.0199*	*0.0005*	*0.0005*	*0.0007*	*0.0017*
	Others	*0.0050*	*0.0181*	*0.0007*	*0.0006*	*0.0006*	*0.0013*

8.2. Results and Discussions

8.2.1. Historical RV emission was plotted in Figure 8-2 below. In 2006, emission of SO_2, NO_X, PM_{10}, VOC and CO increased from their 1990 levels by 62%, 21%, 49%, 4% and 29% respectively.

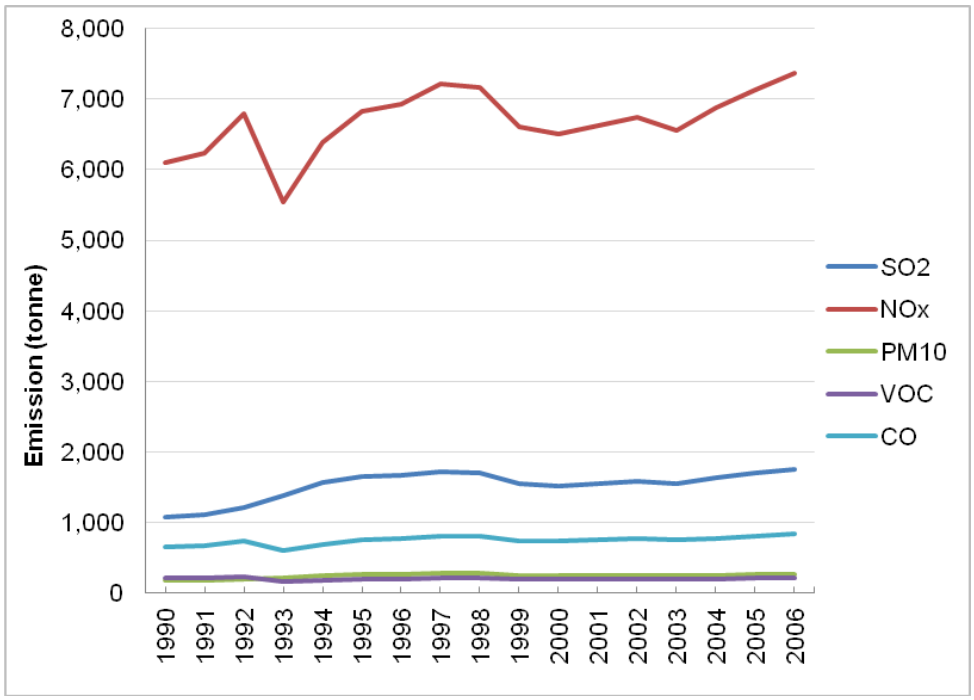

Figure 8-2 Historical RV Emissions in Hong Kong, 1990-2006

8.2.2. Figures 8-3 to 8-5 below display further breakdown of historical emissions of SO_2, NO_X and PM_{10} by major RV type.

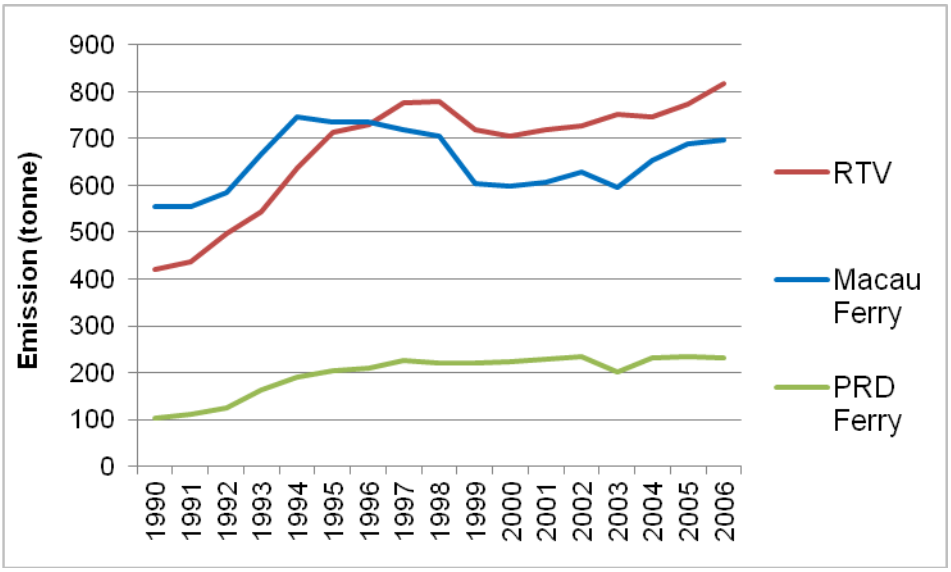

Figure 8-3 Historical RV Emission of SO_2 by Vessel Type, 1990-2006

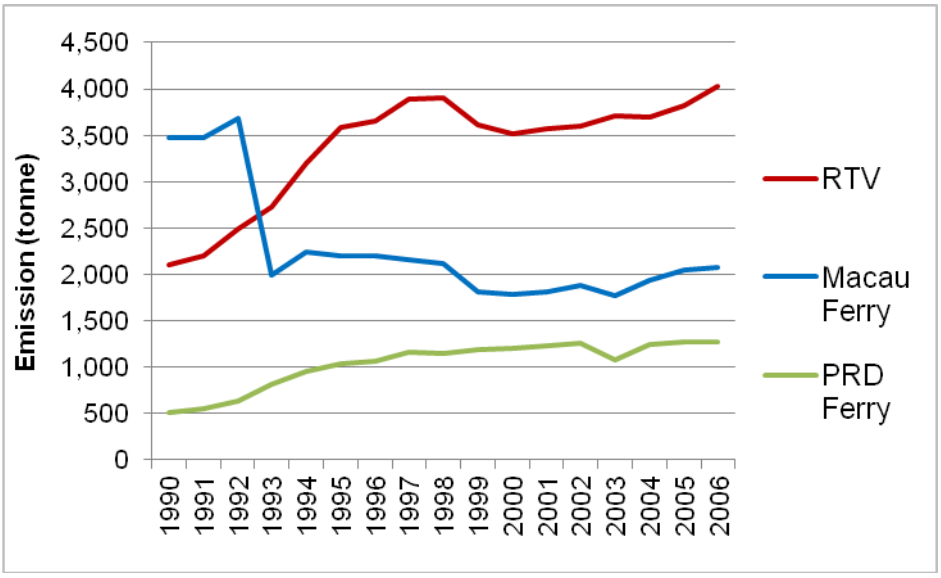

Figure 8-4 Historical RV Emission of NO_X by Vessel Type, 1990-2006

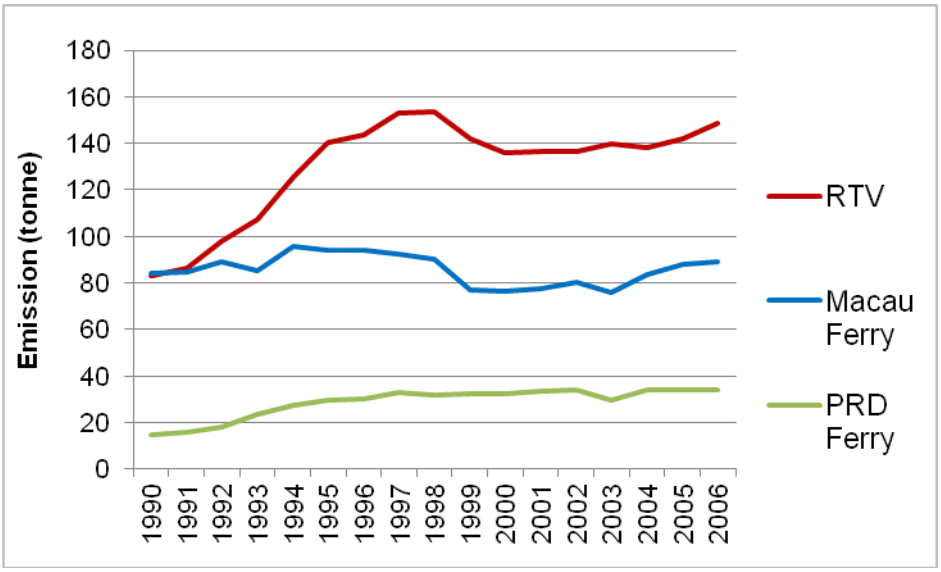

Figure 8-5 Historical RV Emission of PM_{10} by Vessel Type, 1990-2006

8.2.3. From the three diagrams, it is apparent that the growing number of RTV arrivals was the key driver of increasing RV emission during the backcasting period. The number of Macau Ferry trips also increased, but the growth rate was much smaller.

8.2.4. The emission curves of both RTV and PRD Ferry are very consistent amongst the three pollutants. The most noticeable difference is found among the three Macau Ferry curves. The sharp drop of NO_X emission from Macau Ferry as shown in Figure 8-4 explains the sudden decrease of total RV NO_X emission in 1993, which was due to the introduction of gas turbine engine Macau Ferry and hence the significant reduction of diesel engine ferries.

9. TOTAL MARINE VESSELS INVENTORY 1990-2006

9.1. Local Vessels 1990-2006

9.1.1. According to EPD's in-house estimation, historical emissions of SO_2, NO_X, PM_{10}, VOC and CO by vessel type are highlighted below in selected years. (Tables 9-1 to 9-5)

Table 9-1 Historical LV Emission of SO_2 (tonne) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
Class I	485	588	406	425
Class II	825	909	938	674
Class III	1,948	764	885	332
Class IV	43	6	1	1
Government	113	129	2	1
Total	**3,414**	**2,396**	**2,232**	**1,433**

Table 9-2 Historical LV Emission of NO_X (tonne) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
Class I	3,522	4,230	2,877	3,077
Class II	5,191	5,751	6,174	4,270
Class III	11,003	4,345	5,025	1,898
Class IV	351	351	355	429
Government	697	797	1,021	830
Total	**20,765**	**15,474**	**15,452**	**10,503**

Table 9-3 Historical LV Emission of PM_{10} (tonne) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
Class I	112	136	95	98
Class II	241	239	228	179
Class III	347	165	180	83
Class IV	21	18	18	22
Government	29	34	27	22
Total	**751**	**592**	**549**	**405**

Table 9-4 Historical LV Emission of VOC (tonne) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
Class I	70	86	62	61
Class II	233	200	200	153
Class III	1,992	2,297	2,094	1,608
Class IV	629	629	635	768
Government	27	30	40	35
Total	**2,949**	**3,242**	**3,029**	**2,625**

Table 9-5 Historical LV Emission of CO (tonne) by Vessel Type, Selected Years

Vessel Type	1990	1997	2003	2007
Class I	615	693	498	537
Class II	1,017	1,977	1,100	743
Class III	4,616	4,417	4,139	2,968
Class IV	2,886	2,912	2,912	3.524
Government	317	362	484	460
Total	**9,451**	**9,399**	**9,133**	**8,232**

9.1.2. Historical LV emission was plotted in Figure 9-1 below. In 2006, emission of SO_2, NO_X, PM_{10} and CO decreased from their 1990 levels by 51%, 43%, 39% and 6% respectively. VOC emissions from LV were fairly steady throughout the years.

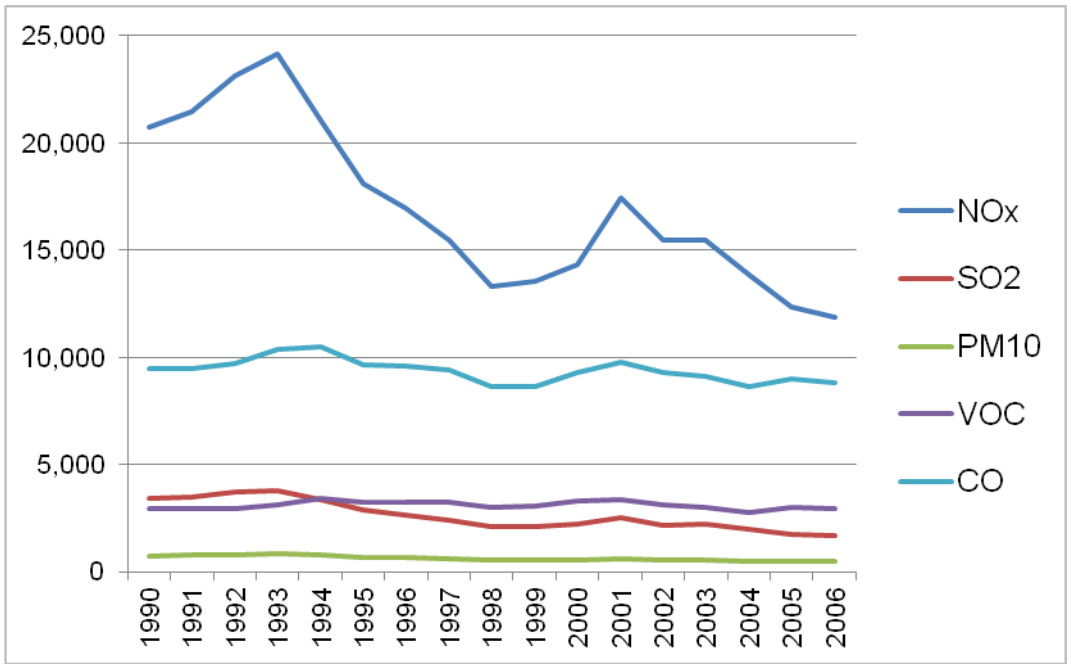

Figure 9-1 Historical LV Emissions (tonne) in Hong Kong, 1990-2006

9.1.3. Figures 9-2 to 9-6 below display further breakdown of historical emissions of SO_2, NO_X, PM_{10}, VOC and CO by major LV class, namely Class I, Class II, Class III, Class IV and government vessel.

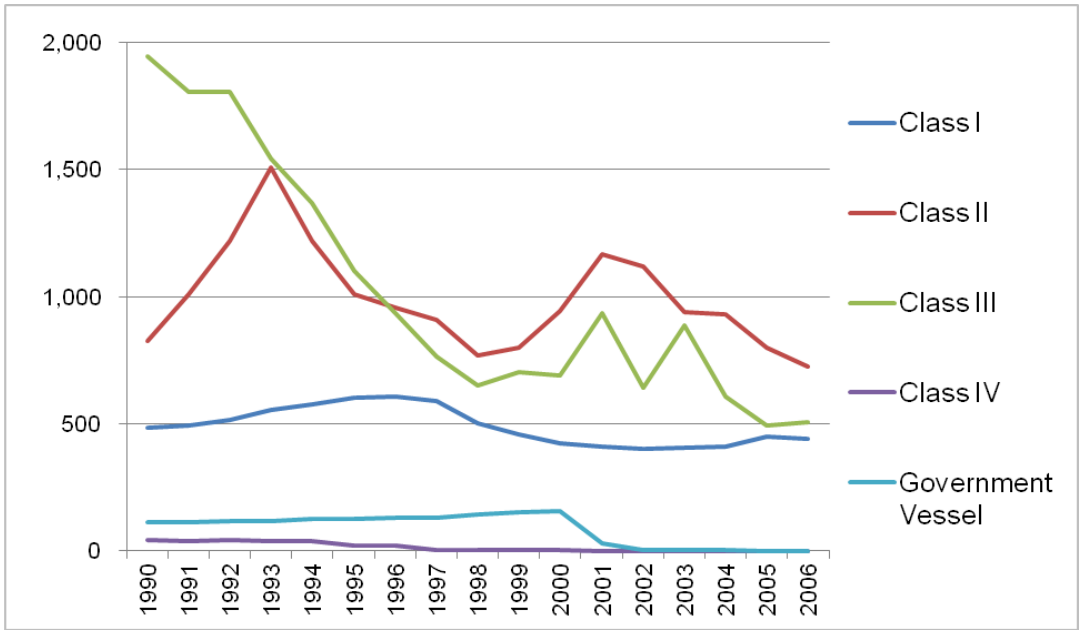

Figure 9-2 Historical LV Emission of SO_2 (tonne) by Vessel Type, 1990-2006

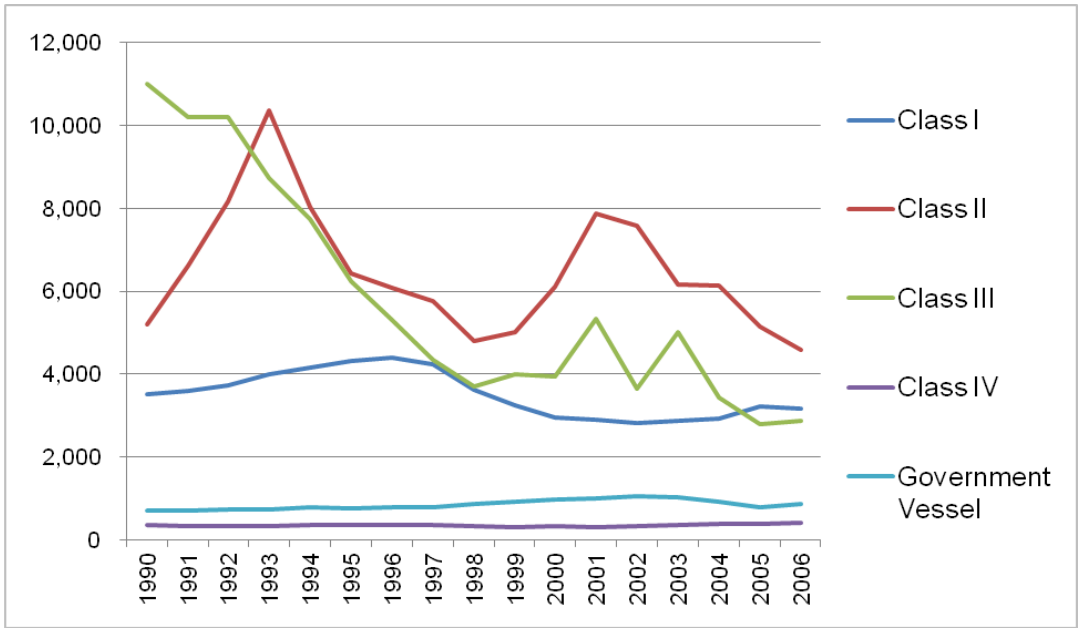

Figure 9-3 Historical LV Emission of NO_X (tonne) by Vessel Type, 1990-2006

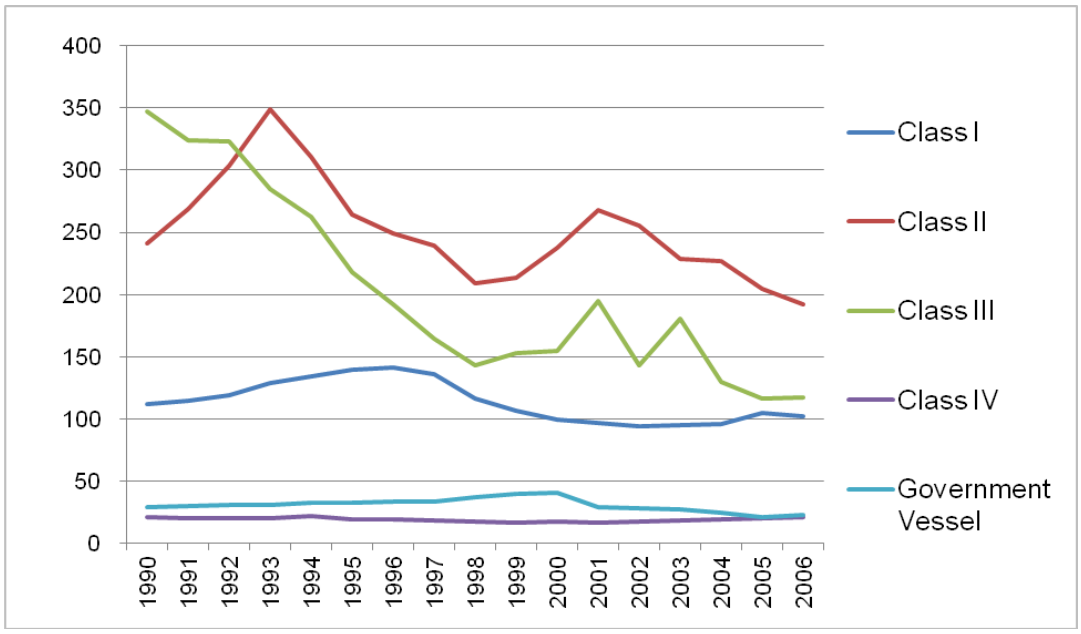

Figure 9-4 Historical LV Emission of PM_{10} (tonne) by Vessel Type, 1990-2006

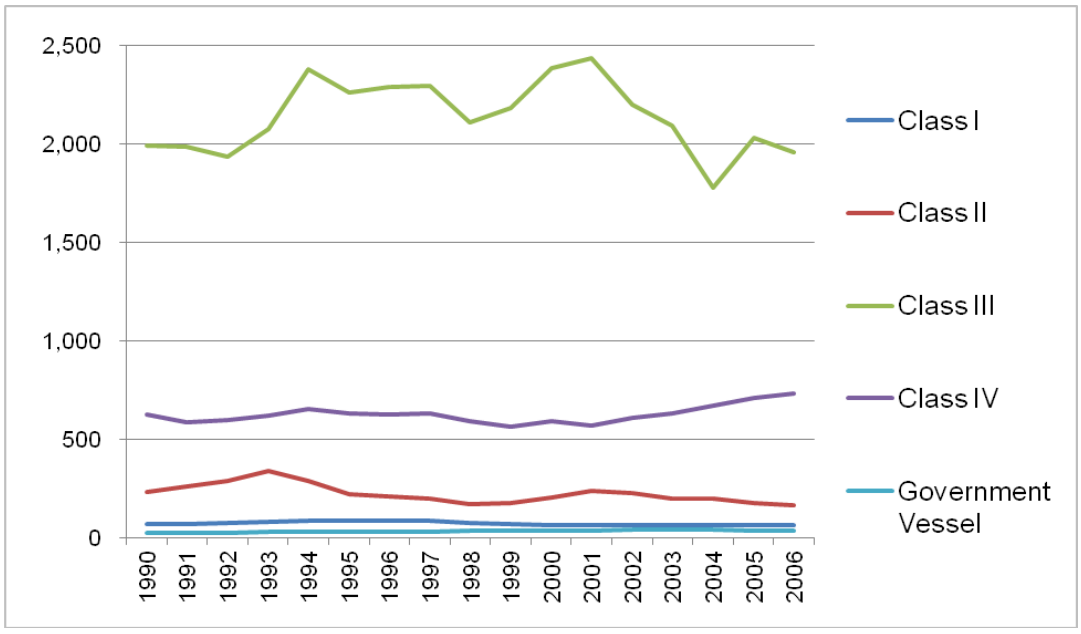

Figure 9-5 Historical LV Emission of VOC (tonne) by Vessel Type, 1990-2006

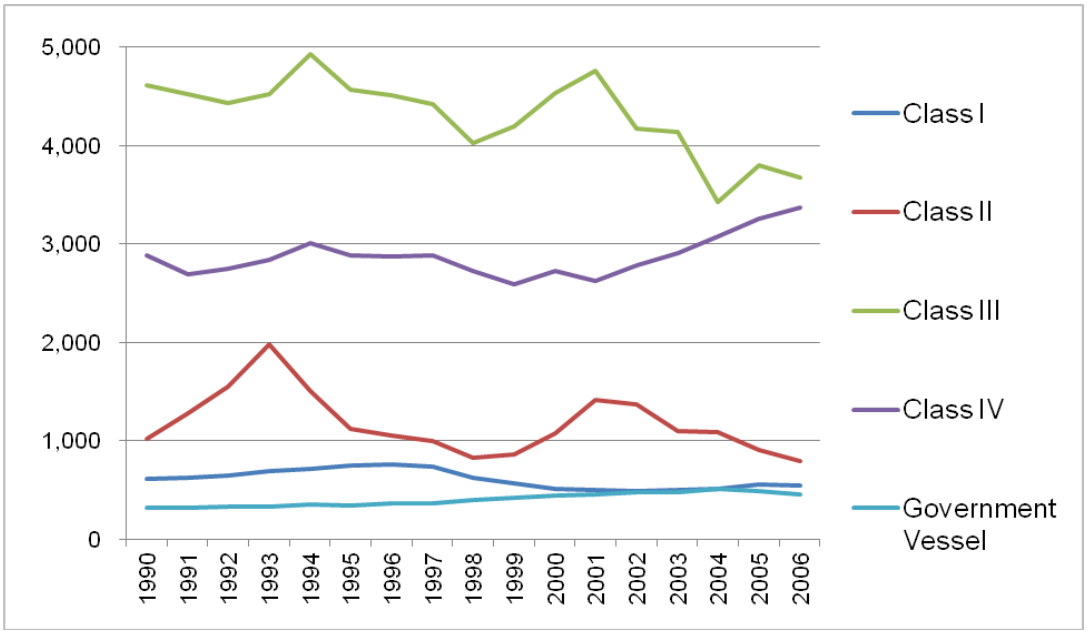

Figure 9-6 Historical LV Emission of CO (tonne) by Vessel Type, 1990-2006

9.1.4. From the diagrams above, it is observed that air pollutant emissions from different classes of local vessel have in general demonstrated a downward trend between 1990 and 2006. In particular, SO_2, NO_X and PM_{10} of Class III has shown a very significant reduction caused by decreasing fleet size and smaller fuel consumption per vessel of diesel engine. The only exceptions are pleasure vessel (Class IV) and government vessel, both with higher NO_X, VOC and CO emissions in 2006 as compared to 1990.

9.1.5. For SO_2, NO_X and PM, the major emitters during this period were Classes I, II and III vessels. For VOC and CO, emission from Classes III and IV vessels were significant.

9.1.6. Emission trends of Class I, II and III vessels were dominated with historical activity of local ferry, dredger, fish carrier/ fishing vessel (SO_2, NO_X and PM) and outboard open sampan (VOC and CO) respectively. SO_2/PM, NO_X, and VOC/CO trends of Class IV follows historical trend of marine diesel sulphur content, cruiser and outboard open cruiser respectively. Emission trends of government vessels were affected by marine diesel sulphur content and their activity.

9.2. Summary of Total Marine Vessels Inventory 1990-2006

9.2.1. Incorporating EPD's in-house estimation for LV emission during the period between 1990 and 2006, Tables 9-6 to 9-10 below displayed total emissions of SO_2, NO_X, PM_{10}, VOC and CO from marine vessels in selected years.

Table 9-6 Total Historical SO_2 Emissions (tonne), Selected Years

	1990	1997	2003	2007
OGV	6,103 (58%)	14,991 (78%)	12,613 (77%)	12,438 (79%)
RV	1,078 (10%)	1,722 (9%)	1,546 (9%)	1,848 (12%)
LV	3,414 (32%)	2,396 (13%)	2,232 (14%)	1,433 (9%)
Total	**10,596**	**19,110**	**16,392**	**15,719**

Note: percentage share in brackets

Table 9-7 Total Historical NO_X Emissions (tonne), Selected Years

	1990	1997	2003	2007
OGV	4,718 (15%)	12,546 (36%)	12,816 (37%)	14,462 (44%)
RV	6,099 (19%)	7,219 (20%)	6,563 (19%)	7,779 (24%)
LV	20,765 (66%)	15,474 (44%)	15,452 (44%)	10,503 (32%)
Total	**31,583**	**35,240**	**34,831**	**32,744**

Note: percentage share in brackets

Table 9-8 Total Historical PM_{10} Emissions (tonne), Selected Years

	1990	1997	2003	2007
OGV	583 (38%)	1,506 (63%)	1,373 (63%)	1,447 (68%)
RV	182 (12%)	278 (12%)	245 (11%)	287 (13%)
LV	751 (50%)	592 (25%)	549 (25%)	405 (19%)
Total	**1,516**	**2,375**	**2,167**	**2,139**

Note: percentage share in brackets

Table 9-9 Total Historical VOC Emissions (tonne), Selected Years

	1990	1997	2003	2007
OGV	199 (6%)	556 (14%)	543 (14%)	635 (18%)
RV	209 (6%)	214 (5%)	193 (5%)	230 (7%)
LV	2,949 (88%)	3,242 (81%)	3,029 (80%)	2,625 (75%)
Total	**3,358**	**4,012**	**3,766**	**3,489**

Note: percentage share in brackets

Table 9-10 Total Historical CO Emissions (tonne), Selected Years

	1990	1997	2003	2007
OGV	430 (4%)	1,176 (10%)	1,172 (11%)	1,421 (13%)
RV	651 (6%)	807 (7%)	758 (7%)	882 (8%)
LV	9,451 (90%)	9,399 (83%)	9,133 (83%)	8,232 (78%)
Total	**10,533**	**11,382**	**11,064**	**10,535**

Note: percentage share in brackets

9.2.2. The contribution of OGV to the emission of SO_2, NO_X and PM_{10} has grown significantly between 1990 and 2007, from 58% to 79% for SO_2, 15% to 44% for NO_X, and 38% to 68% for PM_{10}. OGV's growing contribution was largely offset by the diminishing contribution of LVs over the same period.

9.2.3. The situation for VOC and CO was slightly different. While the contribution of OGV to these two pollutants has also risen, the increase was quite modest, and LV has remained the major emitter of VOC and CO over the backcasting period, accounted for at least 75% and 78% respectively.

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PART V FORECASTING EMISSIONS FOR 2008-2020

10. OCEAN-GOING VESSELS INVENTORY 2008-2020

10.1. Methodology

10.1.1. Annual emissions of OGVs from 2008 to 2020 were projected by vessel type and air pollutant on a business-as-usual (BAU) basis, based on the 2007 inventory and 2010 as reference for forecasting. Parameters and emission estimates for 2015 and 2020 were highlighted, together with their trends over the entire projection period. Emission forecasts were further broken down by DWT sub-class for cargo-carrying vessels, and by PAX sub-class for cruise/ferry.

10.1.2. While 2007 was the base year for projection, MD's statistics of vessel activities for 2008 to 2010 were used to compile emissions. In other words, 2008-10 emissions were in fact historical emissions. For all the post-2010 years, emissions were estimated solely based on projected parameters and thus forecasted emissions.

10.1.3. Since September and October 2010 respectively, two container lines namely Maersk Line and APL voluntarily started fuel switch at berth. They were forerunners of the Fair Winds Charter (FWC)[44], a pledge for 17 international carriers committing to switching to a fuel container 0.50% sulphur content or less while at berth in Hong Kong from 1st January 2011 to 31st December 2012. However, the 2010-12 emissions herewith do NOT include the effect of FWC as data of participating vessels are not available. In any case, preliminary estimate of the 2010 emission reduction by the two forerunners was found to be not significant and the focus on emission projection in this Report is on the years 2015 and 2020.

10.1.4. To project emissions in future years, the equation below was considered:

$$\textit{Total Emission}_{(\textit{pollutant, ship type, year})} = \sum \textit{Emission}_{(\textit{pollutant, ship type, activity mode, equipment, year})}$$

$$\textit{Emission}_{(\textit{pollutant, ship type, activity mode, equipment, year})} = VAN \times P \times FL \times T \times EF \times AdjF$$

where VAN is vessel arrival number;
P is the typical / average installed power of equipment;
FL is the typical / average fractional load of equipment in a specific mode;
T is the typical / average operation time-in-mode;
EF is the typical / average fractional load emission factor of equipment; and
AdjF is the weighted adjustment factor for emission reduction technology adopted under IMO requirement since 2000.

10.1.5. Of all the parameters included above, it was assumed that the average power rating, load factors or load defaults of ME and AE, and energy default of AB, determined by DWT sub-class or PAX sub-class, would remain constant. In other words, their respective 2007 values were used to forecast emissions.

10.1.6. In the following paragraphs, the trends of the other parameters in future years will be discussed, including:

[44] For details see http://www.civic-exchange.org/wp/fair-winds-charter/

- Vessel arrival number;
- Time-in-mode;
- Engine power ratings, reflected in split to DWT or PAX subclasses;
- Emission factor, which in turn was affected by (a) fuel sulphur content; and (b) adjustment factor due to anticipated development of emission reduction technologies in line with forthcoming IMO requirements.

Predicted Trend in Vessel Arrival Number and DWT/PAX Split

10.1.7. In terms of vessel arrival numbers, published statistics for 2008 to 2010 were collected from various issues of the *PHKST*, whereas vessel arrival numbers for post-2010 years were projected under three vessel categories: (a) FCCV, (b) Cruise/Ferry, and (c) Others.

10.1.8. For FCCV, projected growth of the number of TEU handled was used as a surrogate for the growth of vessel arrival number, and the growth rate at KCCT was distinguished from the growth rate at other berthing locations. According to the *Hong Kong Port Cargo Forecast 2005/2006*[45], the growth rates at KCCT were estimated at 2.6% for 2011-2015, and 4.7% for 2016-2020. On the other hand, TEU throughputs at other berthing locations were projected to reduce by 5.7% from 2011 to 2015, and by 8.1% from 2016 to 2020.

10.1.9. Cruise/Ferry arrival numbers were estimated according to the size of vessel as determined by PAX, main service function of the vessel (regular or non-regular callers), as well as berthing location.

10.1.10. In general, regular callers are smaller in size and operate as casino cruise (see paragraphs 3.1.8 to 3.1.12). Irrespective of berthing location, the predicted average GDP growth rates of 5.5% for 2011 and 4% for 2012 to 2015[46] were assumed, with the latter also assumed for years between 2016 and 2020.

10.1.11. For non-regular callers, which visit Hong Kong as a stop of the voyage, their growth rate was determined based on the size of vessel and berthing location as follow.

10.1.12. Non-regular cruise ships that berth at buoys have only 2 calls in 2010. In any case, their arrivals were estimated to grow each year by 5.1% from 2011 to 2020, reflecting worldwide conventional cruise passenger growth rate and the Asia Pacific region passenger forecast.[47] (Table 10-1)

10.1.13. The arrival numbers of non-regular cruise ships that berth at terminals are

[45] See GHK (2008). The percentages were taken from Scenario A (base case of no major additional policy intervention). These were then the best available data provided by the Transport and Housing Bureau, HKSAR Government.

[46] 2010 Budget for 2012-15 and http://www.hkeconomy.gov.hk/tc/forecasts/content.htm for 2011

[47] Annual average growth rate for worldwide conventional cruise passenger was estimated at 4.7% and passenger annual forecast for Asia Pacific region was predicted at 5.4%. 5.1% was the average of the two. Consultancy studies of the Tourism Commission and Hong Kong Tourism Board. See LegCo Panel on Economic Services - Development of New Cruise Terminal Facilities in Hong Kong CB(1)161/06-07(01) dated 27th November 2006.

differentiated into PAX below 2,600 and at 2,600 or above. For PAX below 2,600, it was assumed that arrival number each year from 2011 to 2020 will remain at 104, which was the number in 2010. As the New Cruise Terminal at Kai Tak (KTCT) is designed to accommodate the largest PAX class of ocean cruise, arrivals of non-regular cruise ship with PAX at 2,600 or above were estimated to grow at a higher rate considering the completion of KTCT in stages: the first and second berths coming into operation in mid-2013 and by 2014/2015 respectively. (Table 10-1)

Table 10-1 Non-regular Cruise Ship Arrivals, 2007-2020

Year	Buoys	Terminals		Total	Remarks for Terminals and PAX ≥ 2600
		PAX < 2,600	PAX ≥ 2,600		
2007	2	88	6	96	Use 2007-2010 actual figures
2008	12	79	3	94	
2009	3	73	8	84	
2010	2	104	8	114	
2011	2	104	8	114	Same as 2010
2012	2	104	8	114	
2013	2	104	132	238	Based on 1st berth by mid-2013, 70% utilization rate
2014	2	104	321	428	Average of 2013-2015
2015	3	104	511	618	Two berths and 70% utilization rate
2016	3	104	548	654	5% annual increment for utilization rate up to 90% ceiling
2017	3	104	584	691	
2018	3	104	621	727	
2019	3	104	657	764	
2020	3	104	657	764	Capped at 2019

10.1.14. Lastly, vessel types other than FCCV and Cruise/Ferry, which were predominantly cargo-carrying vessels, were predicted to grow at an annual rate of 1.7% to 1.9% from 2011 to 2015, and a rate of 3.7% to 4.1% from 2016 to 2020, which is the overall growth rate (at KCCT and elsewhere) for TEU throughputs.

10.1.15. In addition, in view of the growing number of larger vessels, which in turn will have installed engines with higher power rating, the split of DWT class for cargo-carrying vessels and passenger-carrying capacity for cruise ships was also considered for future years.

10.1.16. DWT/PAX splits for 2007 and 2010 are based on MD's statistics per vessel call, assuming the 2008-9 splits based on interpolation. Without data, DWT/ PAX splits for the post-2010 years are assumed to be maintained at 2010 level. To illustrate, the most important FCCV at KCCT and non-regular cruise/ferry at Terminal are shown in Table 10-2.

Table 10-2 DWT/PAX Split of FCCV at KCCT and Non-regular Cruise/Ferry at Terminal, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
FCCV at KCCT						
DWT < 10,000	*7%*	*6%*	*6%*	*5%*	*5%*	*5%*
DWT 10,000 - 19,999	*19%*	*17%*	*15%*	*13%*	*13%*	*13%*
DWT 20,000 - 29,999	*16%*	*16%*	*16%*	*16%*	*16%*	*16%*
DWT 30,000 - 39,999	*13%*	*12%*	*11%*	*10%*	*10%*	*10%*
DWT 40,000 - 49,999	*10%*	*9%*	*8%*	*6%*	*6%*	*6%*
DWT 50,000 - 74,999	*23%*	*25%*	*27%*	*29%*	*29%*	*29%*
DWT 75,000 - 99,999	*6%*	*7%*	*8%*	*9%*	*9%*	*9%*
DWT ≥ 100,000	*6%*	*8%*	*9%*	*11%*	*11%*	*11%*
Non-regular Cruise/Ferry at Terminal						
PAX < 300	*9%*	*6%*	*9%*	*29%*	*5%*	*4%*
PAX 300 - 699	*7%*	*17%*	*16%*	*20%*	*4%*	*3%*
PAX 700 - 1,399	*57%*	*49%*	*43%*	*11%*	*2%*	*2%*
PAX 1,400 - 2,599	*20%*	*24%*	*23%*	*33%*	*6%*	*5%*
PAX ≥ 2,600	*6%*	*4%*	*10%*	*7%*	*83%*	*86%*

10.1.17. Table 10-3 below summarizes OGV arrival numbers, actual and predicted, in selected years:

Table 10-3 OGV Arrival Numbers, Selected Years

Vessel Type	Actual				Projected	
	2007	2008	2009	2010	2015	2020
Tanker (chemical/gas/oil)	2,194	2,190	2,145	1,932	2,111	2,558
Conventional Cargo Vessel	4,664	5,150	5,951	3,880	4,240	5,137
Cruise/Ferry	3,562	2,915	2,347	2,134	3,110	3,797
Regular (buoy)	*1,876*	*1,554*	*1,157*	*1,039*	*1,282*	*1,560*
Regular (berth/terminal)	*1,590*	*1,267*	*1,106*	*981*	*1,211*	*1,473*
Non regular (buoy)	*2*	*12*	*3*	*2*	*3*	*3*
Non regular (berth/terminal)	*94*	*82*	*81*	*112*	*615*	*761*
Dry Bulk Carrier	1,362	1,240	1,222	1,357	1,483	1,796
FCCV	23,563	22,730	20,061	21,717	21,112	22,451
KCCT	*13,305*	*12,941*	*11,516*	*12,569*	*14,290*	*17,979*
DWT Under 10,000	*870*	*788*	*650*	*653*	*742*	*934*
DWT 10,000 - 19,999	*2,527*	*2,199*	*1,726*	*1,632*	*1,855*	*2,334*
DWT 20,000 - 29,999	*2,175*	*2,119*	*1,889*	*2,065*	*2,348*	*2,954*
DWT 30,000 - 39,999	*1,731*	*1,561*	*1,281*	*1,279*	*1,454*	*1,830*
DWT 40,000 - 49,999	*1,352*	*1,156*	*888*	*815*	*927*	*1,166*
DWT 50,000 - 74,999	*3,000*	*3,195*	*3,089*	*3,640*	*4,138*	*5,207*
DWT 75,000 - 99,999	*845*	*941*	*943*	*1,145*	*1,302*	*1,638*
DWT ≥100,000	*805*	*982*	*1,051*	*1,340*	*1,523*	*1,917*
Elsewhere	*10,258*	*9,789*	*8,545*	*9,148*	*6,822*	*4,472*
DWT Under 10,000	*6,635*	*6,041*	*5,010*	*5,071*	*3,782*	*2,479*
DWT 10,000 - 19,999	*1,663*	*1,550*	*1,319*	*1,373*	*1,024*	*671*
DWT 20,000 - 29,999	*1,042*	*1,113*	*1,080*	*1,277*	*952*	*624*
DWT 30,000 - 39,999	*389*	*484*	*526*	*677*	*505*	*331*
DWT 40,000 - 49,999	*133*	*163*	*174*	*222*	*166*	*109*

DWT 50,000 - 74,999	*309*	*327*	*315*	*371*	*277*	*181*
DWT 75,000 - 99,999	*43*	*49*	*50*	*62*	*46*	*30*
DWT ≥100,000	*44*	*61*	*71*	*95*	*71*	*46*
Others	1,807	1,650	1,433	1,625	1,776	2,151
Total	**37,152**	**35,875**	**33,159**	**32,645**	**33,831**	**37,890**

Predicted Trend in Time-in-mode

10.1.18. Similar to backcasting (paragraphs 7.1.7 and 7.1.8), hotelling time was assumed to be the only variable among different time-in-modes for emission forecast. Average hotelling time by vessel type for the years between 2008 and 2010 were gathered from *PHKST* as published information. The only exception was cruise/ferry (with its sub-classes): breakdown of 2007 and 2010 was derived from MD VAR data, which then used to intrapolate 2008-2009.

10.1.19. From the historical data, it was observed that there is no conclusive trend or pattern for hotelling time. There was also no concrete evidence to suggest a significant change in hotelling time for any vessel type. As a result, it was determined that average hotelling time for the years 2011 to 2020 would remain constant as 2010. (see Table 10-4)

Table 10-4 Average OGV Hotelling Time (hour) by Vessel Type, 2007-2020

Vessel Type	**2007**	**2008**	**2009**	**2010**	**2011-20**
Chemical Carrier/Tanker	13	12	18	15	15
Conventional Cargo Vessel	38	30	31	34	34
Cruise/Ferry					
Regular (buoy)	*12.6*	*14.9*	*17.4*	*19.9*	*19.9*
Regular (berth/terminal)	*3.9*	*4.7*	*5.5*	*6.0*	*6.0*
Non Regular (buoy)	*107.6*	*88.7*	*69.7*	*50.8*	*50.8*
Non Regular (berth/terminal)	*22.2*	*23.2*	*22.4*	*20.3*	*20.3-14.1#*
Dry Bulk Carrier	36	40	35	27	27
Fishing/Fish Processing Vessel	98	98	78	93	93
Fully Cellular Container Vessel	22	22	22	23	23
KCCT	*13*	*14*	*14*	*14*	*14*
Mid-stream	*34*	*34*	*35*	*35*	*35*
Gas Carrier/Tanker	46	46	55	48	48
Lighter/Barge/Cargo Junk	112	158	209	173	173
Oil Tanker	22	25	30	34	34
Pleasure Vessel*	66	0	0	0	0
Roll On/Roll Off`	16	27	15	11	11
Semi-container Vessel	29	37	42	47	47
Tug	92	122	166	146	146
Others	66	48	71	136	136
All Vessel Type	**26**	**26**	**27**	**27**	**27**

*MD advised that hotelling time of pleasure vessel was zero in 2008-10, meaning the time was less than 1 hour. Same hotelling time was assumed for 2011-20.

#The average hotelling time forecast decreases from 20.3 hours in 2011 to 14.1 hours in 2020. More non-regular ocean cruises of the largest PAX class (which have less hotelling time on average) is expected to call Hong Kong and berth at KTCT by the completion of its 1st berth in mid-2013.

Predicted Trend in Fuel Sulphur Content

10.1.20. In this Study, sulphur content of residual oil and distillate fuel in future years was estimated based on Endresen, et.al.(2005) and DNV (2009).

10.1.21. As in the backcasting exercise, Hong Kong's 2002 fuel sulphur content for residual oil was assumed to be same as the value for Asia provided by Endresen, et.al. (2005), which in turn was adjusted by comparing global vs Asia values, except years 2007-2008. The 2007-2008 values (3.03% and 2.95%) were higher than the surveyed value of 2.90% (based on average sulphur contents of primary fuel for ME, AE and AB at 2.95%, 2.78% and 2.80% respectively); the latter were adopted instead. As discussed in paragraph 2.4.38, the effective sulphur contents after considering fuel switching within Hong Kong water became 2.83%, 2.64% and 2.77% for ME, AE and AB respectively. On pro-rata basis, average fuel sulphur content for ME, AE and AB in subsequent years was projected as shown in Table 10-5.

Table 10-5 Projected and Effective Fuel Sulphur Content, Selected Years

	2002	2007	2008	2009	2010-20
Projected Residual Oil Sulphur Content					
Asia[1]	*3.07%*	*3.03%*	*2.95%*	*2.87%*	*2.82%**
Global[2]	*2.56%*	*2.53%*	*2.46%*	*2.39%*	
Hong Kong	*3.07%*	*2.90%*	*2.90%*	*2.87%*	*2.82%*
Effective Fuel Sulphur Content per engine					
ME		*2.83%*	*2.83%*	*2.80%*	*2.75%*
AE		*2.64%*	*2.64%*	*2.61%*	*2.57%*
AB		*2.77%*	*2.77%*	*2.74%*	*2.69%*

1 Endresen, et.al., 2005; 2 DNV, 2009; * Trended figure based on years 2003-9

10.1.22. The 2007 ratio by vessel type of fuel split between residual oil and distillate fuel (see paragraph 7.1.13) was also applied to the future years. Based on the fuel sulphur contents determined above (Table 10-5), Table 10-6 below shows the weighted fuel sulphur content of selected years.

Table 10-6 Weighted Fuel Sulphur Content of Residual Oil, Selected Years

Vessel Type	2007-08			2010-20		
	ME	AE	AB	ME	AE	AB
A. Chemical Carrier/Tanker	2.67%	2.49%	2.61%	2.60%	2.43%	2.54%
B. Conventional Cargo Vessel	1.86%	1.75%	1.82%	1.81%	1.70%	1.78%
C. Cruise/Ferry	2.17%	2.03%	2.12%	2.11%	1.98%	2.07%
D. Dry Bulk Carrier	2.77%	2.58%	2.71%	2.69%	2.51%	2.63%
E. Fishing/Fish Processing Vessel	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
F. Fully Cellular Container Vessel	2.25%	2.11%	2.21%	2.19%	2.05%	2.15%
G. Gas Carrier/Tanker	2.83%	2.64%	2.77%	2.75%	2.57%	2.69%
H. Lighter/Barge/Cargo Junk	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
I. Oil Tanker	2.80%	2.61%	2.74%	2.72%	2.54%	2.66%
J. Pleasure Vessel	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%

K. Roll On/Roll Off	2.68%	2.50%	2.62%	2.61%	2.43%	2.55%
L. Semi-container Vessel	1.43%	1.36%	1.41%	1.40%	1.33%	1.38%
M. Tug	0.50%	0.50%	0.50%	0.50%	0.50%	0.50%
N. Others	2.81%	2.62%	2.75%	2.73%	2.55%	2.68%

10.1.23. It is necessary to note that the global fuel sulphur cap at 0.5% by 2020 as proposed in Marine Environment Protection Committee (MEPC) 57 of IMO is not adopted. Such a conservative approach is consistent with uncertainty of the measure which is subject to a feasibility review no later than 2018. If the review is found to be infeasible, the cap will be deferred to 2025. Recent discussions in international community have been pessimistic.

10.1.24. Sulphur content of distillate fuel was assumed to be constant at 0.5% throughout the forecast period.

Predicted Trend in Adjustment Factor

10.1.25. Adjustment factors were derived for the past years to reflect emission reduction technology developed under IMO regulations (see paragraphs 3.2.39 to 3.2.43 and 7.1.17). However, effects of recent MEPC 62 meeting on July 2011 were not incorporated in this Study. The meeting agreed to adopt the Energy Efficiency Design Index (EEDI) regulation for new ships. The EEDI will require new ships to meet a minimum level of energy efficiency with ships built between 2015 and 2019 needing to improve their efficiency by 10%, rising to 20% between 2020 and 2024 and 30% for ships delivered after 2024. Apart from the EEDI for new ships, it makes the Ship Energy Efficiency Management Plan (SEEMP) mandatory for both new and existing ships, regardless of flag.

10.1.26. For the forecast period, two additional factors were considered. First, the Tier 1 NO_X limit was replaced with the Tier 2 limit on 1 January 2011, representing a further 20% NO_X reduction below Tier 1.

10.1.27. Second, marine diesel engines built between 1990 and 1999 that are 90 liters per cylinder or more require retrofitting to meet Tier 1 emission standards. In general, all SSD engines are 90 liters per cylinder or more, but only 35% of MSD propulsion engines are greater than 90 liters per cylinder. Based on the age profiles of OGVs calling Hong Kong in 2007 and advice from USEPA[48], Hong Kong-based NO_X adjustment factors were derived for projecting emissions as indicated in Table 10-7. Without committed emission reduction technologies in place, no adjustment factors were assumed for PM and HC/VOC.

Table 10-7 NO_X Adjustment Factors for Emission Projection

Engine Type	2010	2015	2020
Main Engine	0.8829	0.8152	0.7802
Auxiliary Engine	0.8829	0.8250	0.7891

[48] Emails from Penny Carey of USEPA to Billy Cheung of HKEPD on 4th May 2010 and 1st June 2010.

10.2. Results and Discussions

10.2.1. Annual OGV emissions from 2008 to 2020 were projected and emission estimates of selected years were summarized in Table 10-8. Generally speaking, emissions were projected to increase in the next decade, after a drop of around 4% to 8% from 2008 to 2009 due to the global financial crisis. (Figure 10-1) Growing emissions were mainly caused by growing vessel arrival numbers, although the lowering of fuel sulphur content and NO_X control measures would slightly offset the increase.

Table 10-8 Projected OGV Emissions (tonne), Selected Years

(2010 = 100%)	2007	2008	2009	2010	2015	2020
SO_2	12,438	13,128	12,259	13,526	15,636	18,674
	92%	97%	91%	100%	116%	138%
NO_X	14,462	15,010	13,846	15,377	17,174	19,795
	94%	98%	90%	100%	112%	129%
PM_{10}	1,447	1,487	1,416	1,577	1,847	2,216
	92%	94%	90%	100%	117%	141%
$PM_{2.5}$	1,309	1,379	1,280	1,426	1,672	2,007
	92%	97%	90%	100%	117%	141%
VOC	635	666	622	700	818	987
	91%	95%	89%	100%	117%	141%
CO	1,421	1,497	1,403	1,586	1,845	2,223
	90%	94%	88%	100%	116%	140%

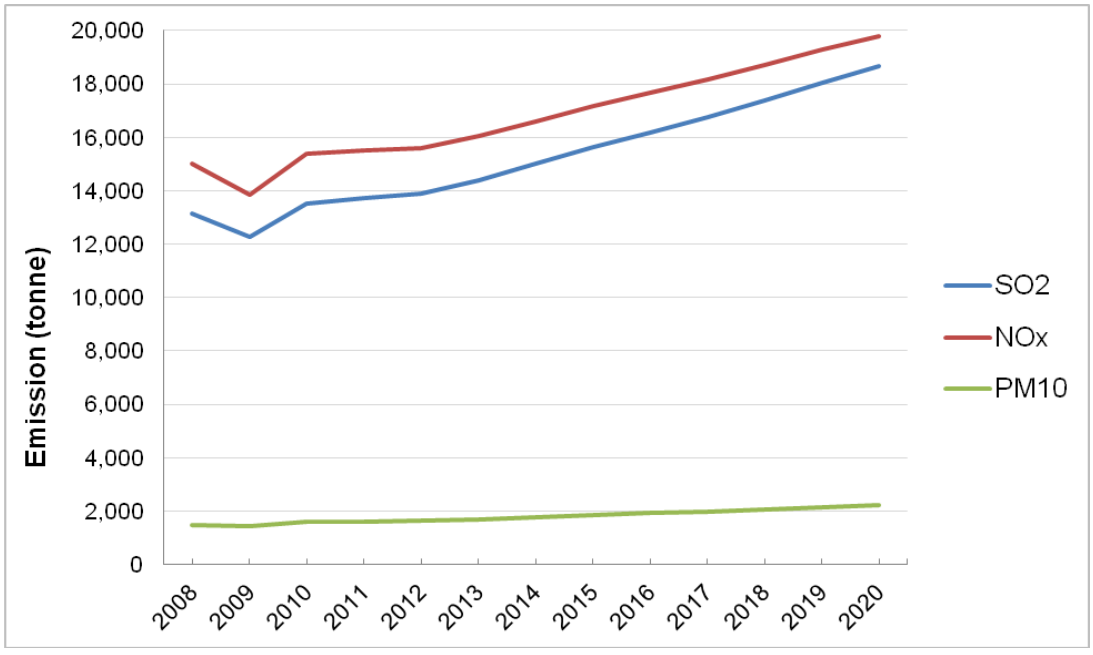


Figure 10-1 Projected OGV Emissions (tonne), 2008-2020

10.2.2. Projected growth was fairly uniform amongst the pollutants, except for NO_X with a relatively slower growth rate due to tighter IMO requirements during the forecast period. Emissions were projected to increase by 12% to 17% between 2010 and 2015, and by 29% to 41% from 2010 to 2020. (Table 10-8)

10.2.3. Figure 10-2 and Tables 10-9 to 10-11 summarize projected SO_2, NO_X and PM_{10} emissions by top five emitters. FCCV is by far the largest emitter of the three pollutants, accounted for around 80% of SO_2, 83% of NO_X and 83% of PM_{10} in 2010. It was estimated that by 2020, FCCV will remain the largest emitter of SO_2, NO_X and PM_{10}, even though its percentage share was predicted to drop slightly.

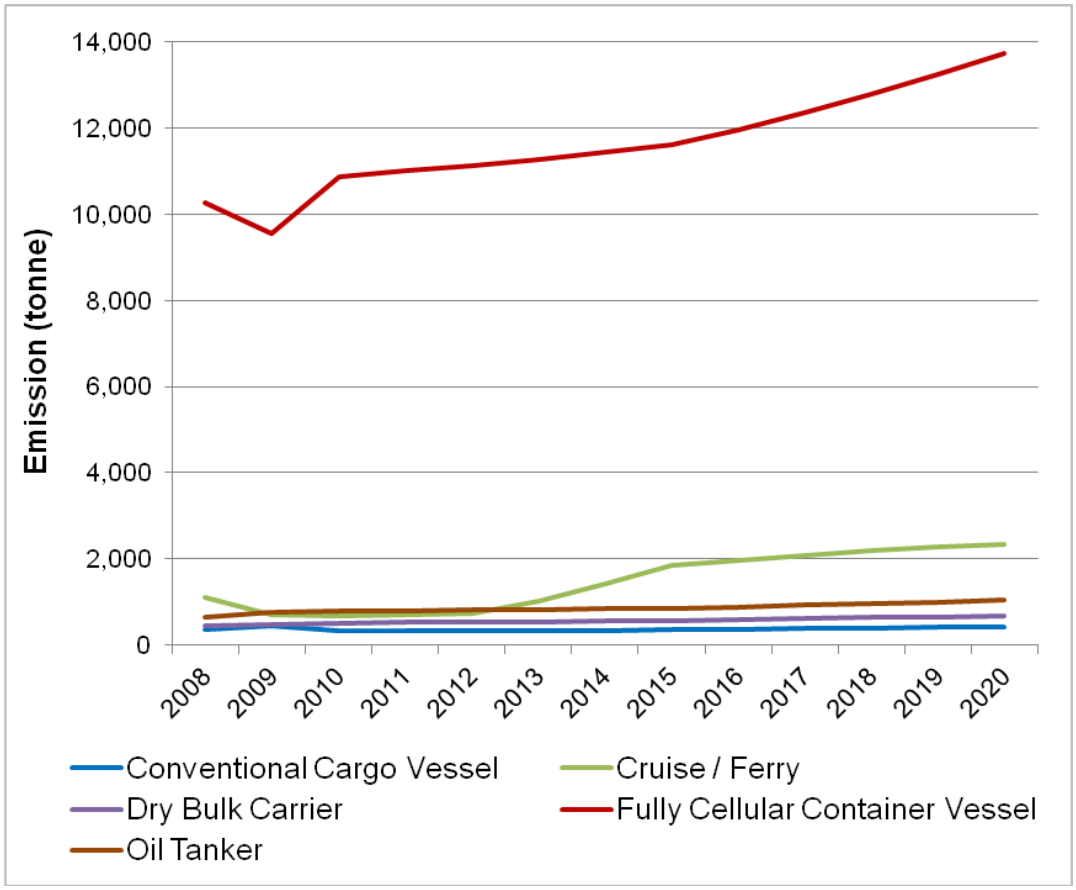


Figure 10-2 Projected OGV SO_2 Emission (tonne) by Vessel Type, 2008-2020

Table 10-9 Projected OGV SO_2 Emission (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
Fully Cellular Container Vessel	9,886 79%	10,270 78%	9,557 78%	10,875 80%	11,603 74%	13,723 73%
Cruise/Ferry	1,145 9%	1,098 8%	701 6%	668 5%	1,867 12%	2,326 12%
Oil Tanker	542 4%	644 5%	771 6%	785 6%	858 5%	1,039 6%
Conventional Cargo Vessel	323 3%	355 3%	449 4%	324 2%	354 2%	429 2%
Dry Bulk Carrier	304 2%	460 4%	492 4%	521 4%	570 4%	690 4%
Others	237 2%	301 2%	289 2%	352 3%	384 2%	466 2%
Total	**12,438**	**13,128**	**12,259**	**13,526**	**15,636**	**18,674**

Table 10-10 Projected OGV NO_X Emission (tonne) by Main Emitters, Selected Years

	2007	2008	2009	2010	2015	2020
Fully Cellular Container Vessel	11,480	11,830	11,064	12,711	13,157	15,052
	79%	79%	80%	83%	77%	76%
Cruise/Ferry	1,598	1,564	1,072	991	2,281	2,719
	11%	10%	8%	6%	13%	14%
Oil Tanker	338	385	443	442	460	537
	2%	3%	3%	3%	3%	3%
Conventional Cargo Vessel	375	400	492	346	355	412
	3%	3%	4%	2%	2%	2%
Dry Bulk Carrier	289	383	405	443	461	537
	2%	3%	3%	3%	3%	3%
Others	381	448	371	444	460	538
	3%	3%	3%	3%	3%	3%
Total	**14,462**	**15,011**	**13,847**	**15,377**	**17,174**	**19,795**

Table 10-11 Projected OGV PM_{10} Emission (tonne) by Main Emitters, Selected Years

	2007	2008	2009	2010	2015	2020
Fully Cellular Container Vessel	1,173	1,219	1,141	1,309	1,405	1,671
	81%	82%	81%	83%	76%	75%
Cruise/Ferry	132	93	79	74	230	288
	9%	6%	6%	5%	12%	13%
Oil Tanker	46	53	63	64	70	84
	3%	4%	4%	4%	4%	4%
Conventional Cargo Vessel	37	41	52	37	41	50
	3%	3%	4%	2%	2%	2%
Dry Bulk Carrier	32	45	48	52	57	69
	2%	3%	3%	3%	3%	3%
Others	28	35	33	40	44	54
	2%	2%	2%	3%	2%	2%
Total	**1,447**	**1,487**	**1,416**	**1,577**	**1,847**	**2,216**

10.2.4. Emissions from cruise/ferry were projected to increase during the period, due to the opening of the new cruise terminal and the growing number of larger cruise ships. The contribution of cruise/ferry for SO_2, NO_X and PM_{10} were projected to rise from 5%, 6% and 5% to 12%, 14% and 13%, respectively. Oil tankers, conventional cargo vessels and dry bulk carriers were predicted to remain the other major emitters in the future. (Figure 10-2)

11. RIVER VESSELS INVENTORY 2008-2020

11.1. Methodology

11.1.1. Annual emissions of RVs between 2008 and 2020 were projected by vessel type and air pollutant on a business-as-usual (BAU) basis, based on the 2007 inventory and 2010 as reference for forecasting. Parameters and emission estimates for 2015 and 2020 were highlighted, together with their trends over the entire projection period. Emission forecasts were compiled under RTVs, Macau Ferry and PRD Ferry.

11.1.2. For RTVs, future emissions were projected based on this equation:

$$\textit{Total Emission}_{(pollutant,\ ship\ type,\ year)} = \sum \textit{Emission}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)}$$

$$\textit{Emission}_{(pollutant,\ ship\ type,\ activity\ mode,\ equipment,\ year)} = VAN \times P \times FL \times T \times EF$$

where VAN is vessel arrival number;
P is the typical / average installed power of equipment;
FL is the typical / average fractional load of equipment in a specific mode;
T is the typical / average operation time-in-mode; and
EF is the typical / average fractional load emission factor of equipment

11.1.3. Key parameters considered for emission forecast from 2008 to 2020 were vessel arrival number and average time-in-mode by vessel type. Other factors such as average power rating of ME and AE, effective sulphur content of marine fuel, and emission factors were assumed to be unchanged as 2007.

11.1.4. For Macau Ferry and PRD Ferry, future emissions were calculated by multiplying projected annual VAN by average emission per trip. The latter was developed for 2007 by major Macau Ferry and PRD Ferry terminals.

Predicted Trend in Vessel Arrival Number

11.1.5. Like OGVs, VAN of RTVs during 2008 to 2010 were extracted from various issues of *PHKST*. As for passenger ferries, both the arrival and departure numbers of Macau Ferry and PRD Ferry by main engine type (gas turbine and diesel engine) and terminal location from 2008 to 2010 were either provided by the operator or extracted from *PHKST*.

11.1.6. For the post-2010 years, different assumptions were made with respect to the annual growth rate of VAN.

11.1.7. Based on river container throughput provided by THB[49], the annual growth rate of RTV arrivals during 2011 to 2015 was 0.1%, and the growth rate during 2016 to 2020 was 5.1% per annum. Table 11-1 below summarizes projected VAN of RTV in selected years.

[49] Same as footnote 45, assuming annual growth rate of river container throughput same as RTV arrival.

Table 11-1 Projected VAN of RTV, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Chemical Carrier/Tanker	250	210	227	317	319	409
Conventional Cargo Vessel	16,004	13,580	12,543	11,144	11,200	14,362
Dry Bulk Carrier	1,305	1,500	2,017	2,769	2,783	3,569
Fully Cellular Container Vessel	70,880	65,900	60,343	63,093	63,409	81,314
Gas Carrier/Tanker	32	20	28	78	78	101
Lighter/Barge/Cargo Junk	10,225	9,510	6,825	6,463	6,495	8,329
Oil Tanker	1,083	1,120	1,018	724	728	933
Roll On/Roll Off	6	10	26	28	28	36
Semi-container Vessel	957	1,590	1,816	2,004	2,014	2,583
Tug	7,577	6,600	4,626	4,160	4,181	5,361
Others	611	600	281	352	354	454
Total River Trade Vessels	**108,930**	**100,640**	**89,750**	**91,132**	**91,589**	**117,450**

11.1.8. For Macau Ferry, the average annual growth rate of 3.7% between 1999 and 2010 was used as the basic growth rate for future VAN from 2011 to 2020. However, considering the planned opening of the Zhuhai-Hong Kong-Macau Bridge in 2016 and the shifting of some Macau Ferry passengers to road-based transport mode via the Bridge, a 25% reduction in VAN was applied to the projection from 2016 onwards (Table 11-2). The split between diesel engine ferry trip and gas turbine engine ferry trip for 2010 to 2020 was assumed to be the same as 2009, which was about 53% to 47% for both arrivals and departures.

Table 11-2 Projected VAN of Macau Ferry, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Arrivals	43,850	49,220	54,183	59,810	71,836	64,711
Diesel Engine	*12,033*	*19,207*	*28,592*	*31,561*	*37,908*	*34,147*
Gas Turbine Engine	*31,817*	*30,014*	*25,591*	*28,249*	*33,929*	*30,563*
Departures	44,110	49,880	54,378	60,689	71,836	64,711
Diesel Engine	*12,292*	*19,797*	*28,787*	*32,128*	*38,029*	*34,257*
Gas Turbine Engine	*31,818*	*30,084*	*25,591*	*28,561*	*33,807*	*30,454*

11.1.9. Arrival and departure numbers of PRD Ferry by PRD ports and Hong Kong terminals between 2010 and 2020 were assumed constant as the 2010 figures. Similar to Macau Ferry, PRD Ferry will also be affected by the planned opening of the Zhuhai-Hong Kong-Macau Bridge in 2016. Hence a 25% reduction was applied to the VAN projection of Zhuhai, Jiangmen and Zhongshan from 2016 onwards. In addition, the Guangzhou-Shenzhen-Hong Kong Express Rail Link is expected to be in operation in 2015, and it will draw passengers from PRD Ferry. In order to reflect such passenger shift, a 25% reduction was also applied to the projected VAN of Guangzhou and Dongguan starting from 2015. Table 11-3 displays projected VAN for PRD Ferry in selected years.

Table 11-3 Projected VAN of PRD Ferry by PRD Port, Selected Years

PRD Port	2007	2008	2009	2010	2015	2020
Doumen	80	-	-	-	-	-
Gaoming	390	370	375	370	370	370
Humen	3,180	2,650	1,855	1,830	1,373	1,373
Jiangmen	1,120	970	753	803	803	602
Lianhuashan	1,480	1,440	1,612	1,826	1,370	1,370
Nansha	2,020	1,870	2,026	2,140	1,605	1,605
Sanbu	170	-	-	-	-	-
Shekou	9,710	8,720	7,609	7,590	7,590	7,590
Shenzhen	6,020	3,400	2,398	2,231	2,231	2,231
Shunde	2,350	2,200	2,212	2,195	2,195	2,195
Zhongshan	4,800	3,710	3,219	3,007	3,007	2,255
Zhuhai	6,760	6,340	6,356	6,327	6,327	4,745
Total	**38,080**	**31,670**	**28,415**	**28,319**	**26,870**	**24,336**

Note: PRD Ferry services to/from Doumen and Sanbu ceased operation after 2007.

Predicted Trend in Average Time-in-mode for RTVs

11.1.10. Average time-in-port of RTVs by vessel type from 2008 to 2010 was collected from *PHKST*. Average time-in-port for post-2010 years was assumed to be the same as 2010. In order to calculate average call duration of RTV within Hong Kong waters, four hours were added to reflect sailing time between boundary of Hong Kong waters and berthing locations. (Table 11-4)

Table 11-4 Projected RTV Average Time-in-port (hour) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Chemical Carrier/Tanker	28	49	49	71	71	71
Conventional Cargo Vessel	30	29	30	31	31	31
Dry Bulk Carrier	22	30	38	35	35	35
Fully Cellular Container Vessel	34	32	33	35	35	35
Gas Carrier/Tanker	9	34	28	64	64	64
Lighter/Barge/Cargo Junk	69	71	76	72	72	72
Oil Tanker	59	47	56	66	66	66
Roll on/roll off	9	12	8	12	12	12
Semi-container Vessel	43	37	39	45	45	45
Tug	68	69	81	87	87	87
Others	19	23	51	46	46	46
All ship type	**39**	**38**	**39**	**40**	**40**	**40**

Projected Average Emission per Trip

11.1.11. For the projection of Macau Ferry and PRD Ferry emissions, the emission per Macau Ferry trip and PRD Ferry trip calculated for 2007 were used, as there was no reason to suggest that emission per trip in future years would be significantly different.

11.2. Results and Discussions

11.2.1. Projected annual emissions from RVs in selected years from 2008 to 2020 are shown in Figure 11-1 and Table 11-5 below. In general, emissions are projected to increase as vessel arrivals also increase. It is estimated that emissions in 2015 and 2020 will increase by 5% to 9% and 12% to 18% respectively over the 2010 levels.

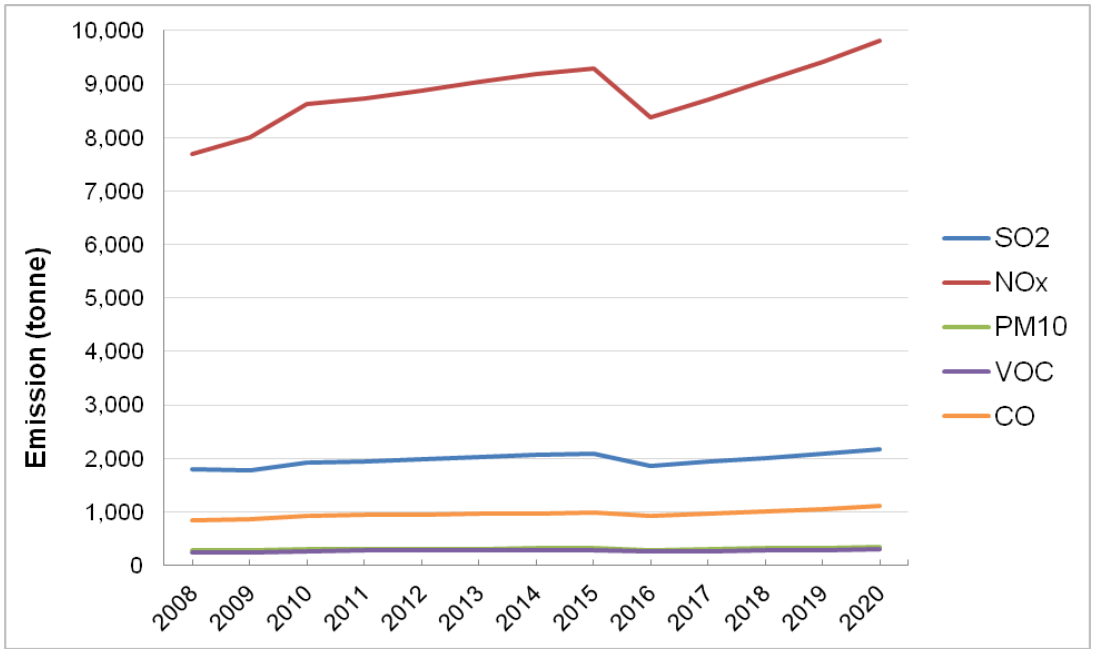


Figure 11-1 Projected RV Emissions (tonne), 2008-2020

Table 11-5 Projected RV Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
SO_2	1,848	1,792	1,775	1,920	2,095	2,179
	96%	93%	92%	100%	109%	114%
NO_X	7,779	7,703	8,007	8,619	9,299	9,808
	90%	89%	93%	100%	108%	114%
PM_{10}	287	277	274	295	319	339
	97%	94%	93%	100%	108%	115%
$PM_{2.5}$	275	265	263	283	305	326
	97%	94%	93%	100%	108%	115%
VOC	230	232	249	267	289	300
	86%	87%	93%	100%	108%	112%
CO	882	850	869	932	982	1102
	95%	91%	93%	100%	105%	118%

2010 = 100%

11.2.2. Macau Ferry was top emitter in 2010, contributed about 51% of SO_2, 45% of NO_X and 45% of PM_{10} respectively. (Tables 11-6 to 11-8) It was predicted that Macau Ferry would remain top emitter during the forecast period, even though its percentage share would drop slightly by a few percentage points from 2010 to 2020.

Table 11-6 Projected RV Emissions of SO_2 (tonne) by Vessel Type, Selected Years

	2007	2008	2009	2010	2015	2020
Macau Ferry	757	830	879	976	1,163	1,048
	41%	46%	50%	51%	56%	48%
Fully Cellular Container Vessel	550	484	456	502	505	647
	30%	27%	26%	26%	24%	30%
PRD Ferry	241	202	183	184	168	152
	13%	11%	10%	10%	8%	7%
Conventional Cargo Vessel	84	70	66	61	61	78
	5%	4%	4%	3%	3%	4%
Lighter/Barge/Cargo Junk	78	74	57	51	52	66
	4%	4%	3%	3%	2%	3%
Tug	74	66	54	52	52	67
	4%	4%	3%	3%	2%	3%
Others	62	67	80	94	94	121
	3%	4%	5%	5%	5%	6%
Total SO_2	**1,848**	**1,792**	**1,775**	**1,920**	**2,095**	**2,179**

Table 11-7 Projected RV Emissions of NO_X (tonne) by Vessel Type, Selected Years

	2007	2008	2009	2010	2015	2020
Macau Ferry	2,248	2,840	3,501	3,886	4,633	4,174
	29%	37%	44%	45%	50%	43%
Fully Cellular Container Vessel	2,640	2,326	2,189	2,412	2,424	3,109
	28%	24%	21%	21%	20%	25%
PRD Ferry	1,341	1,109	995	995	909	817
	17%	14%	12%	12%	10%	8%
Conventional Cargo Vessel	406	334	318	291	292	375
	4%	3%	3%	3%	2%	3%
Lighter/Barge/Cargo Junk	374	358	274	246	248	317
	4%	4%	3%	2%	2%	3%
Tug	446	394	322	310	311	399
	5%	4%	3%	3%	3%	3%
Others	324	342	408	479	481	617
	3%	3%	4%	4%	4%	5%
Total NO_X	**7,779**	**7,703**	**8,007**	**8,619**	**9,299**	**9,808**

Table 11-8 Projected RV Emissions of PM_{10} (tonne) by Vessel Type, Selected Years

	2007	2008	2009	2010	2015	2020
Macau Ferry	97	109	119	132	157	142
	34%	39%	43%	45%	49%	42%
Fully Cellular Container Vessel	89	78	74	81	81	104
	31%	28%	27%	27%	26%	31%
PRD Ferry	36	30	27	27	25	22
	12%	11%	10%	9%	8%	7%
Tug	23	20	17	16	16	21
	8%	7%	6%	5%	5%	6%
Lighter/Barge/Cargo Junk	15	14	11	10	10	13
	5%	5%	4%	3%	3%	4%
Conventional Cargo Vessel	14	12	11	10	10	13
	5%	4%	4%	3%	3%	4%
Others	14	14	16	19	19	24
	5%	5%	6%	6%	6%	7%
Total PM_{10}	**287**	**277**	**274**	**295**	**319**	**339**

11.2.3. Among the RTVs, FCCV contributed most emissions in 2010, and it was predicted that FCCV would remain an important emitter in the future.

12. TOTAL MARINE VESSELS INVENTORY 2008-2020

12.1. Local Vessels 2008-2020

12.1.1. According to EPD's in-house projection, future emissions of SO_2, NO_X, PM_{10}, VOC and CO by vessel type are tabulated below in selected years. (Tables 12-1 to 12-5) Emissions for 2008-10 are based on data collected from survey, TD, EPD, AFCD, EMSD as in 2007. Emissions for 2011-20 are projected based on MD's report *Assessment of Typhoon Shelter Space Requirements 2009-2025* and assumed constant emission of local ferry and government vessels.

Table 12-1 Projected LV Emissions of SO_2 (tonne) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Class I	425	396	363	368	361	356
Class II	674	640	674	735	778	808
Class III	332	310	359	335	331	324
Class IV	1	1	1	1	1	1
Government	1	0	0	0	0	0
Total	**1,433**	**1,347**	**1,397**	**1,439**	**1,472**	**1,490**

Table 12-2 Projected LV Emissions of NO_X (tonne) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Class I	3,077	2,877	2,694	2,733	2,692	2,660
Class II	4,270	4,145	4,416	4,931	5,223	5,425
Class III	1,898	1,772	2,057	1,914	1,893	1,855
Class IV	429	442	479	512	533	555
Government	830	752	824	879	879	879
Total	**10,503**	**9,988**	**10,470**	**10,970**	**11,220**	**11,374**

Table 12-3 Projected LV Emissions of PM_{10} (tonne) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Class I	98	90	84	85	84	83
Class II	179	162	165	171	182	189
Class III	83	77	95	82	81	79
Class IV	22	23	25	26	27	28
Government	22	20	22	23	23	23
Total	**405**	**371**	**390**	**388**	**397**	**402**

Table 12-4 Projected LV Emissions of VOC (tonne) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Class I	61	56	53	54	53	52
Class II	153	144	148	158	167	173
Class III	1,608	1,467	2,014	1,518	1,500	1,470
Class IV	768	807	872	928	966	1,006
Government	35	32	35	37	37	37
Total	**2,625**	**2,505**	**3,122**	**2,694**	**2,723**	**2,739**

Table 12-5 Projected LV Emissions of CO (tonne) by Vessel Type, Selected Years

Vessel Type	2007	2008	2009	2010	2015	2020
Class I	537	503	472	477	470	465
Class II	743	744	790	895	948	985
Class III	2,968	2,712	3,681	2,816	2,784	2,728
Class IV	3,524	3,696	3,998	4,254	4,429	4,611
Government	460	415	455	486	486	486
Total	**8,232**	**8,068**	**9,395**	**8,928**	**9,117**	**9,275**

12.1.2. Future LV emissions by air pollutant were plotted in Figure 12-1 below. Emissions of SO_2, NO_X, PM_{10}, VOC and CO in 2020 increased modestly from their 2010 levels by 1.6% to 3.9%.

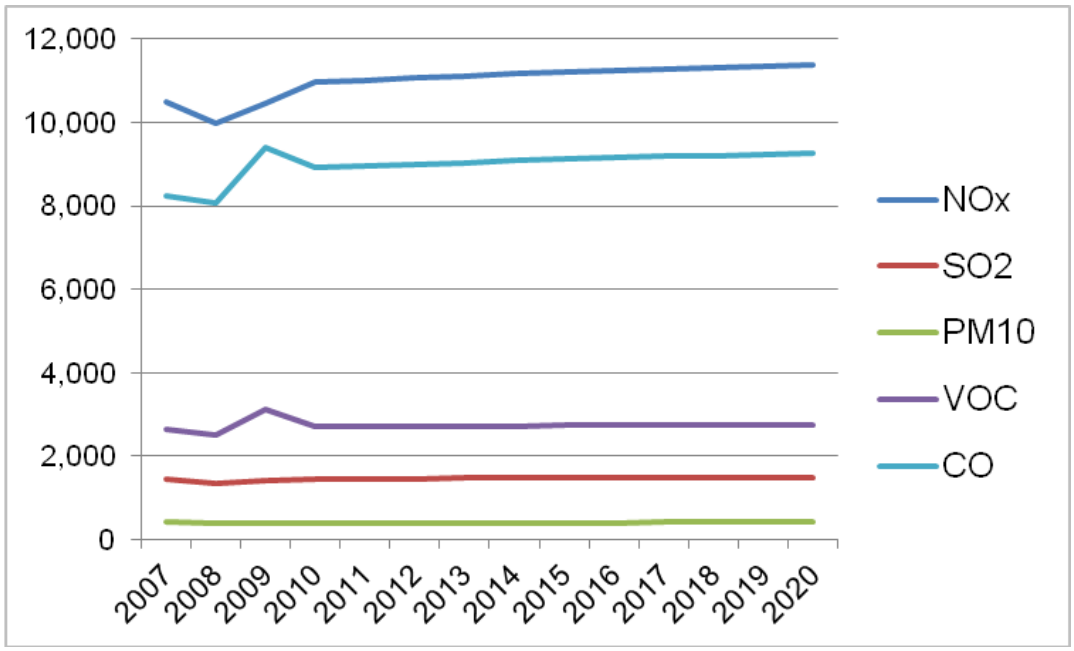


Figure 12-1 Forecast LV Emissions (tonne) in Hong Kong, 2007-2020

12.2. Summary of Total Marine Vessels Inventory 2008-2020

12.2.1. Tables 12-6 to 12-10 below illustrate total projected emissions of SO_2, NO_X, PM_{10}, VOC and CO from marine vessels in selected years, by combining projected estimates for OGVs (Chapter 10), RVs (Chapter 11) and EPD's in-house estimates for LVs during the period between 2007 and 2020.

Table 12-6 Total Projected SO_2 Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
OGV	12,438	13,128	12,259	13,526	15,636	18,674
RV	1,848	1,792	1,775	1,920	2,095	2,179
LV	1,433	1,347	1,397	1,439	1,472	1,490
Total	**15,719**	**16,267**	**15,431**	**16,885**	**19,202**	**22,343**

Table 12-7 Total Projected NO_X Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
OGV	14,462	15,010	13,846	15,377	17,174	19,795
RV	7,779	7,703	8,007	8,619	9,299	9,808
LV	10,503	9,988	10,470	10,970	11,220	11,374
Total	**32,744**	**32,701**	**32,324**	**34,966**	**37,693**	**40,978**

Table 12-8 Total Projected PM_{10} Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
OGV	1,447	1,487	1,416	1,577	1,847	2,216
RV	287	277	274	295	319	339
LV	405	371	390	388	397	402
Total	**2,139**	**2,135**	**2,081**	**2,260**	**2,563**	**2,958**

Table 12-9 Total Projected VOC Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
OGV	635	666	622	700	818	987
RV	230	232	249	267	289	300
LV	2,625	2,505	3,122	2,694	2,723	2,739
Total	**3,489**	**3,403**	**3,992**	**3,662**	**3,830**	**4,026**

Table 12-10 Total Projected CO Emissions (tonne), Selected Years

	2007	2008	2009	2010	2015	2020
OGV	1,421	1,497	1,403	1,586	1,845	2,223
RV	882	850	869	932	982	1,102
LV	8,232	8,068	9,395	8,928	9,117	9,275
Total	**10,535**	**10,416**	**11,667**	**11,445**	**11,944**	**12,600**

12.2.2. Table 12-11 converts projected emission numbers into percentage shares. The share of RVs remained very constant over the projection period.

Table 12-11 Total Projected Marine Vessel Emissions in Percentage Share, Selected Years

	Vessel Type	2007	2008	2009	2010	2015	2020
SO_2	OGVs	79%	81%	79%	80%	81%	84%
	RVs	12%	11%	12%	11%	11%	10%
	LVs	9%	8%	9%	9%	8%	7%
NO_X	OGVs	44%	46%	43%	44%	46%	48%
	RVs	24%	24%	25%	25%	25%	24%
	LVs	32%	31%	32%	31%	30%	28%
PM_{10}	OGVs	68%	70%	68%	70%	72%	75%
	RVs	13%	13%	13%	13%	12%	11%
	LVs	19%	17%	19%	17%	15%	14%
$PM_{2.5}$	OGVs	66%	69%	67%	68%	71%	74%
	RVs	14%	13%	14%	14%	13%	12%
	LVs	20%	18%	20%	18%	16%	14%
VOC	OGVs	18%	20%	16%	19%	21%	25%
	RVs	7%	7%	6%	7%	8%	7%
	LVs	75%	74%	78%	74%	71%	68%
CO	OGVs	13%	14%	12%	14%	15%	18%
	RVs	8%	8%	7%	8%	8%	9%
	LVs	78%	77%	81%	78%	76%	74%

12.2.3. It is apparent that OGVs dominated SO_2, PM_{10} and $PM_{2.5}$ emissions over the projection period. In fact, the share of OGV was predicted to grow slightly by a few percentage points. The share of LV, on the other hand, was predicted to drop.

12.2.4. However, LVs contributed the most in terms of VOC and CO emissions. Their percentage shares were predicted to decrease modestly from 2007 to 2020, and the gains were taken up by OGVs.

12.2.5. In terms of NO_X emission, the split among OGV, RV and LV was 44%, 24% and 32% in 2007. In 2020, OGV would increase its share to 48%, whereas the share of LV would be reduced to 28%.

PART VI SPATIAL & TEMPORAL EMISSION DISTRIBUTION OF 2007

13. MAPPED EMISSION ESTIMATES 2007

13.1. Methodology

13.1.1. The spatial distribution of marine vessel emissions of 2007 within Hong Kong waters was prepared in the Study on a 500 meter x 500 meter grid square resolution, in order to identify emission hot spots or corridors. The spatial dimension of marine emission is also an input parameter for air modeling, which in turn an important tool for formulating and implementing effective emission control measures.

13.1.2. For an accurate spatial presentation of vessel emissions in 2007, the best method would be to collect and analyze radar track data of each individual vessel that visited Hong Kong in 2007, so that its emissions could be plotted on its own track. However, the analysis of a full-year radar track data would be very resource-intensive and time-consuming. Majority of vessels are regular callers and their aggregate patterns should be relatively steady. In addition, only the portion of the 2007 radar track data that recorded marine accidents was kept in MD with the majority already erased when this Study was commissioned.

13.1.3. In light of the limitation explained above, two weeks' of vessel track data in 30-second intervals covering the period from 27th August to 9th September 2007 were used to analyze the spatial pattern of vessel movements, down to major vessel class and DWT sub-class levels where appropriate. A number of steps were taken to clean and verify the data as follows:

- Data points without vessel name or other vessel identification, such as IMO number, were filtered away as noise;
- Data points on land were filtered; and
- Remaining data points were cross-referenced with LRS to verify vessel type, DWT class, vessel service speed, and other information.

13.1.4. Based on the actual vessel speed information embedded in the radar track data and the vessel service speed information collected from LRS, the operation mode of each data point among a series of points representing a vessel sailing along its track was determined by Propeller Law (see paragraphs 3.2.8 and 3.2.9). Moving average speed was used to smooth out abrupt and unrealistic change of speed.

13.1.5. Once time-in-mode was determined for each data point, all the data points were then gridded into 500 meter x 500 meter squares covering Hong Kong waters. They were classified by vessel type, DWT class and time-in-mode. Data points outside Hong Kong waters were screened out.

13.1.6. A 95% frequency filter was further applied to each vessel type, DWT sub-class and time-in-mode distribution, so as to remove outliers in the spatial domain. The 95% criterion was found to give the best balance between retaining most useful data and screening out noises.

13.1.7. Surrogate values were then generated for the following vessel type and DWT

sub-class, by the four operation modes of fairway cruise, slow cruise, maneuvering and hotelling:

- OGV Chemical Carrier;
- OGV Conventional Cargo Vessel;
- OGV Cruise/Ferry;
- OGV Dry Bulk Carrier;
- OGV FCCV DWT < 10,000;
- OGV FCCV DWT 10,000 – 19,999;
- OGV FCCV DWT 20,000 – 29,999;
- OGV FCCV DWT 30,000 – 39,999;
- OGV FCCV DWT 40,000 – 49,999;
- OGV FCCV DWT 50,000 – 74,999;
- OGV FCCV DWT 75,000 – 99,999;
- OGV FCCV DWT ≥ 100,000;
- OGV Gas Carrier;
- OGV Oil Tanker;
- OGV Others;
- RTV;
- Macau Ferry; and
- PRD Ferry

13.1.8. Annual emission estimates of 2007 by air pollutant, vessel type, DWT sub-class and time-in-mode were then assigned to their corresponding surrogate matrix, hence producing a series of gridded emission maps.

13.1.9. For completeness purpose, emission maps were also produced for local vessels. Among the five local vessel classes, the movements of local ferries (the major subclass of Class I) were readily captured by MD's radar track data and are assumed to represent all Class I vessels. Similar steps as listed above (paragraphs 13.1.3 to 13.1.7) were used to prepare the surrogate values for Class I LVs.

13.1.10. For the other LV classes that do not have radar data, different data were considered to represent their respective spatial distribution, as explained below:

- For Class II LVs, which are cargo-related work boats, the surrogate matrices of

RTV were used as substitutes, due to similarity in operation characteristics;

- For Class III LVs, which are fishing boats, a distribution map of fishing operations based on a survey carried out by the Agriculture, Fisheries and Conservation Department in 2006[50] was adapted for this purpose;

- For Class IV LVs, which are pleasure vessels, the eight pleasure vessel sheltered anchorages, major marinas, and a couple of typhoon shelters which provide sheltered space for pleasure vessels were marked as their main berthing locations;[51] and

- For government vessels, it was assumed they operated all over Hong Kong waters.

It is important to note that with the exception of local ferries, surrogate matrix of LVs do not differentiate among time-in-mode, as there was no such information.

13.1.11. With representative spatial pattern determined for the five LV classes, emission estimates of LV for 2007 prepared by EPD's in-house study were assigned accordingly to produce the emission maps for LV.

13.2. Results and Discussions

Ocean-going Vessels

13.2.1. FCCV was the top OGV emitter of the six air pollutants covered in this Study in 2007. Figures 13-1 to 13-3 show the spatial distribution of SO_2, NO_X and PM_{10} emissions from FCCV as an illustration. $PM_{2.5}$ has the same pattern as PM_{10}.

13.2.2. From the three diagrams above, it is apparent that KCCT was an emission hot spot in 2007 for SO_2, NO_X and PM_{10}, much related to the berthing activity of FCCV at the terminals. The East Lamma Channel – Western Fairway – Ma Wan Fairway – Urmston Road axis was another major marine emission corridor, as this is the main route for OGV calling Hong Kong from open sea, as well as from ports in western Shenzhen such as Shekou.

13.2.3. However, it is also important to notice emissions east and southeast of Hong Kong, which was largely related to vessel movements between Hong Kong and Yantian.

13.2.4. Figure 13-4 below shows the spatial distribution of SO_2 emission from Cruise/Ferry, the second largest OGV emitter, which is quite different from that of FCCV (Figure 13-1). First of all, emission hot spots for Ocean Cruise/Ferry were found at Ocean Terminal and at the government buoys off Kowloon Bay. Once again, this was related to berthing activity. Secondly, an emission trail extended from the berthing locations to the southeastern part of Hong Kong waters via Hung Hom Fairway and Eastern Fairway in Victoria Harbour and Tathong Channel. This is the popular route for the regular ocean cruises.

[50] See http://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_latest/fish_cap_latest.html for information about the Port Survey 2006 carried out by Agriculture, Fisheries and Conservation Department.

[51] They are marinas in Clearwater Bay, Discovery Bay, Marina Cove, and Gold Coast; typhoon shelters in Causeway Bay and Aberdeen South; and pleasure vessel sheltered anchorages in Middle Island, Pak Sha Wan, Sai Kung, St. Stephen's Bay, Tai Mei Tuk, Tai Tam Harbour, Ting Kau, and Tsam Chuk Wan. For more information , see MD (2009), *Assessment of Typhoon Shelter Space Requirements, 2009-2025.*

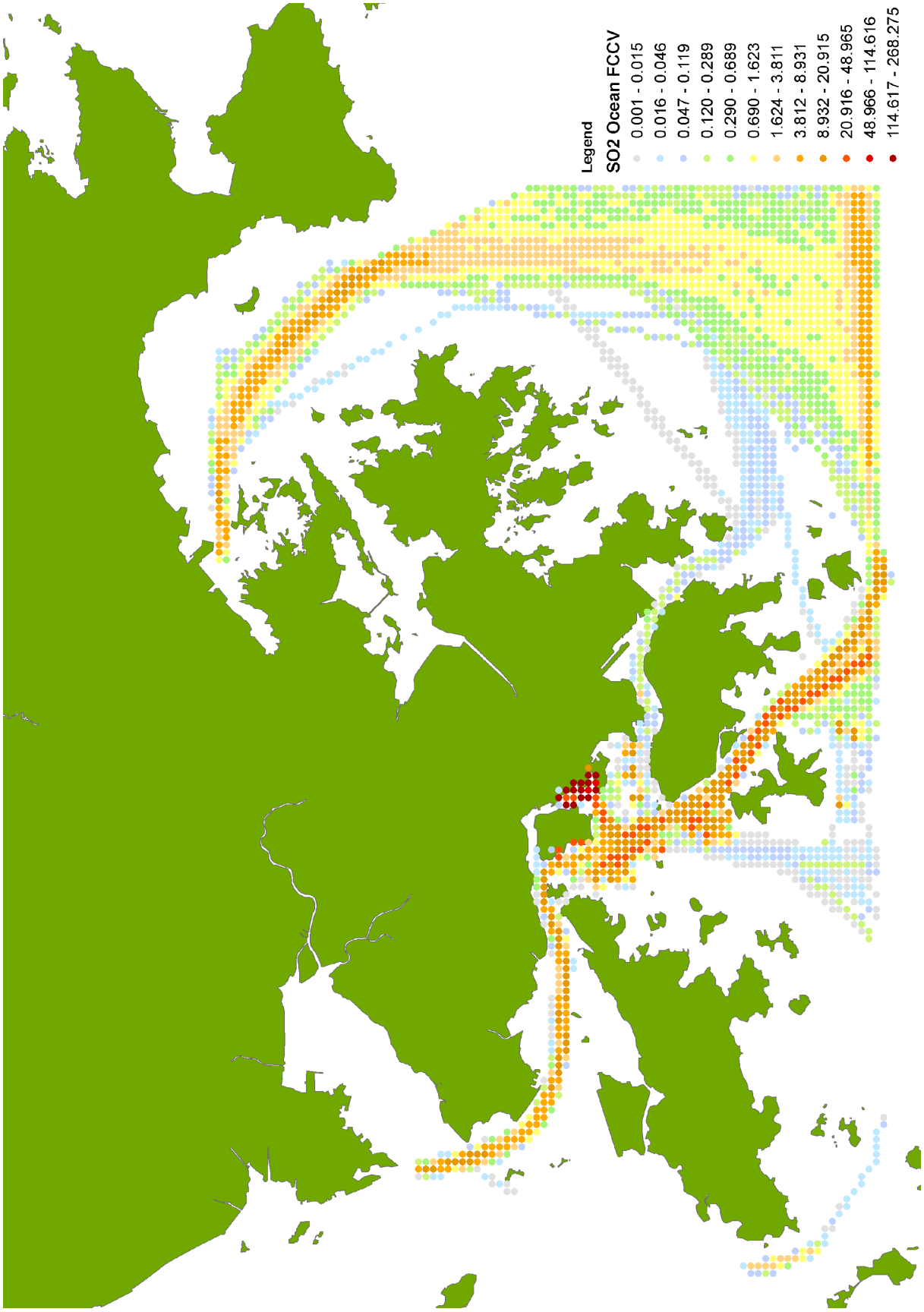


Figure 13-1 Spatial Distribution of SO_2 Emission (tonne) from FCCV, 2007

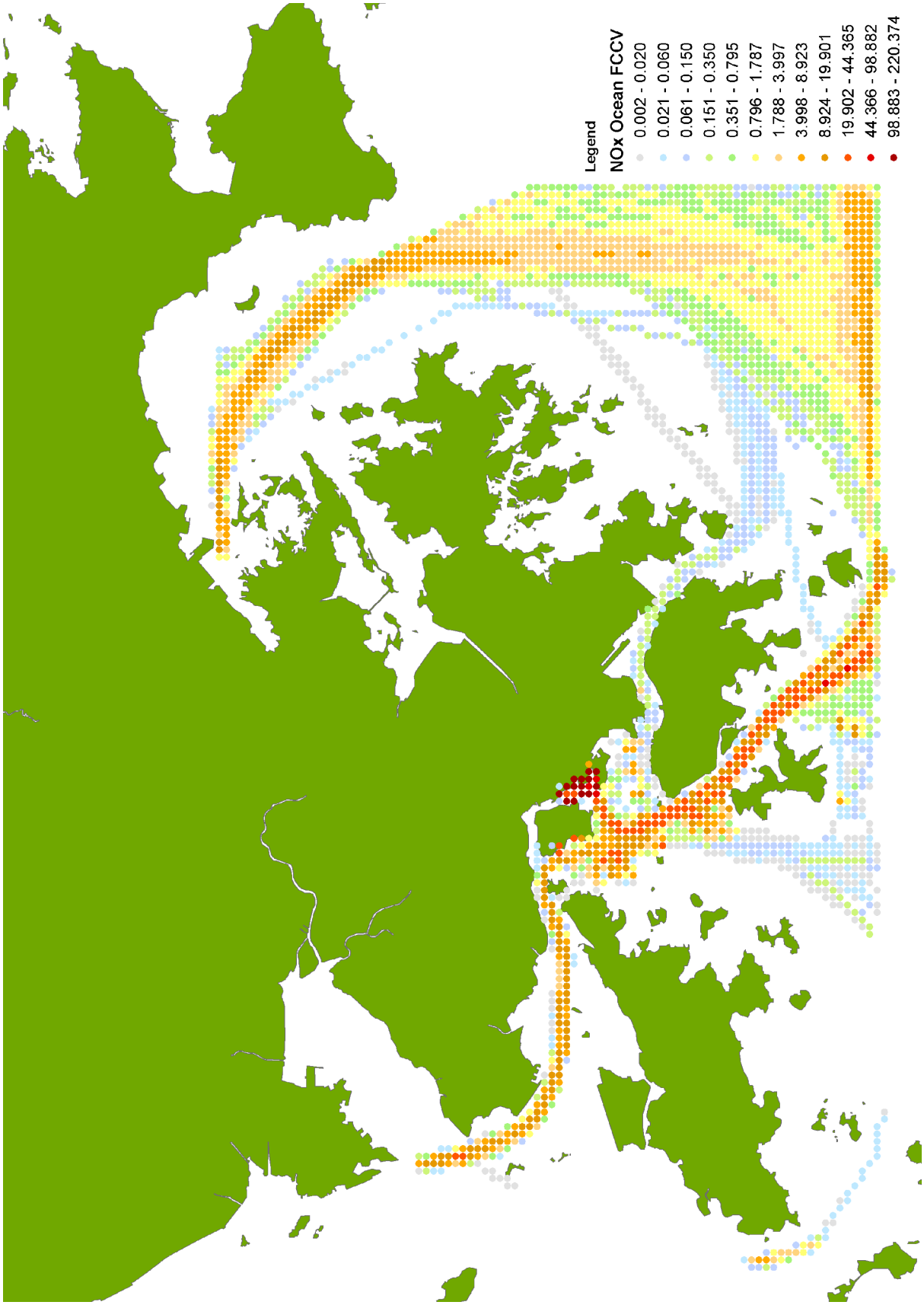


Figure 13-2 Spatial Distribution of NO_X Emission (tonne) from FCCV, 2007

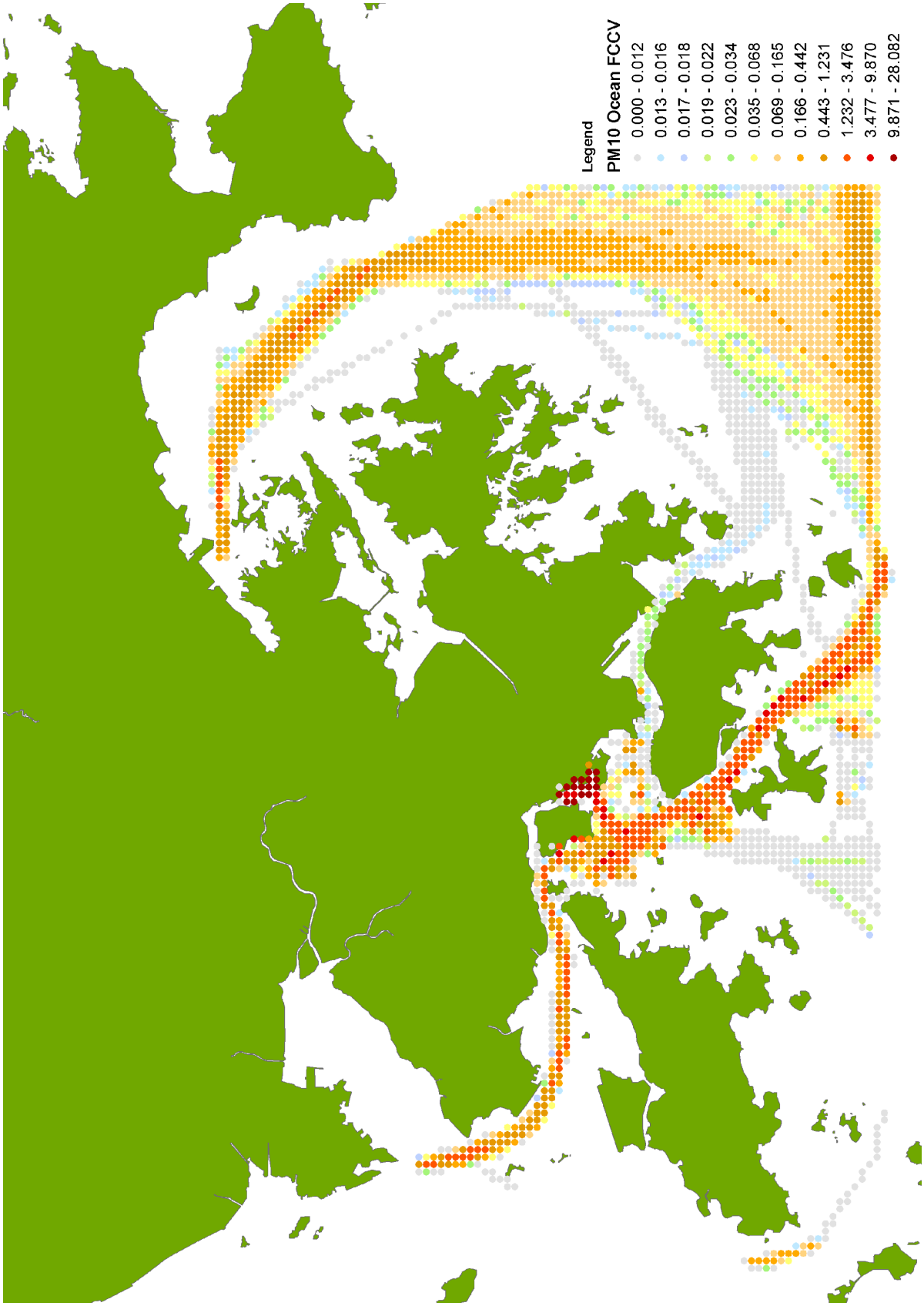


Figure 13-3 Spatial Distribution of PM_{10} Emission (tonne) from FCCV, 2007

Figure 13-4 Spatial Distribution of SO_2 Emission (tonne) from Cruise/Ferry, 2007

13.2.5. For the OGV types other than FCCV and Cruise/Ferry, Figure 13-5 confirms that their emissions were spread out spatially to more locations. For example, emission hot spots (in red) were found along the coast of Tsing Yi (where the oil terminals are located) and Sha Chau (aviation fuel storage), as well as in Castle Peak and Lamma Island (where loading and unloading facilities of power plants can be found). Besides, hot spots of SO_2 emissions were found at mid-stream locations, for examples at the Western Anchorage and South Lamma Anchorage, where vessels were anchored for various purposes such as queuing, documentation clearance, and servicing.

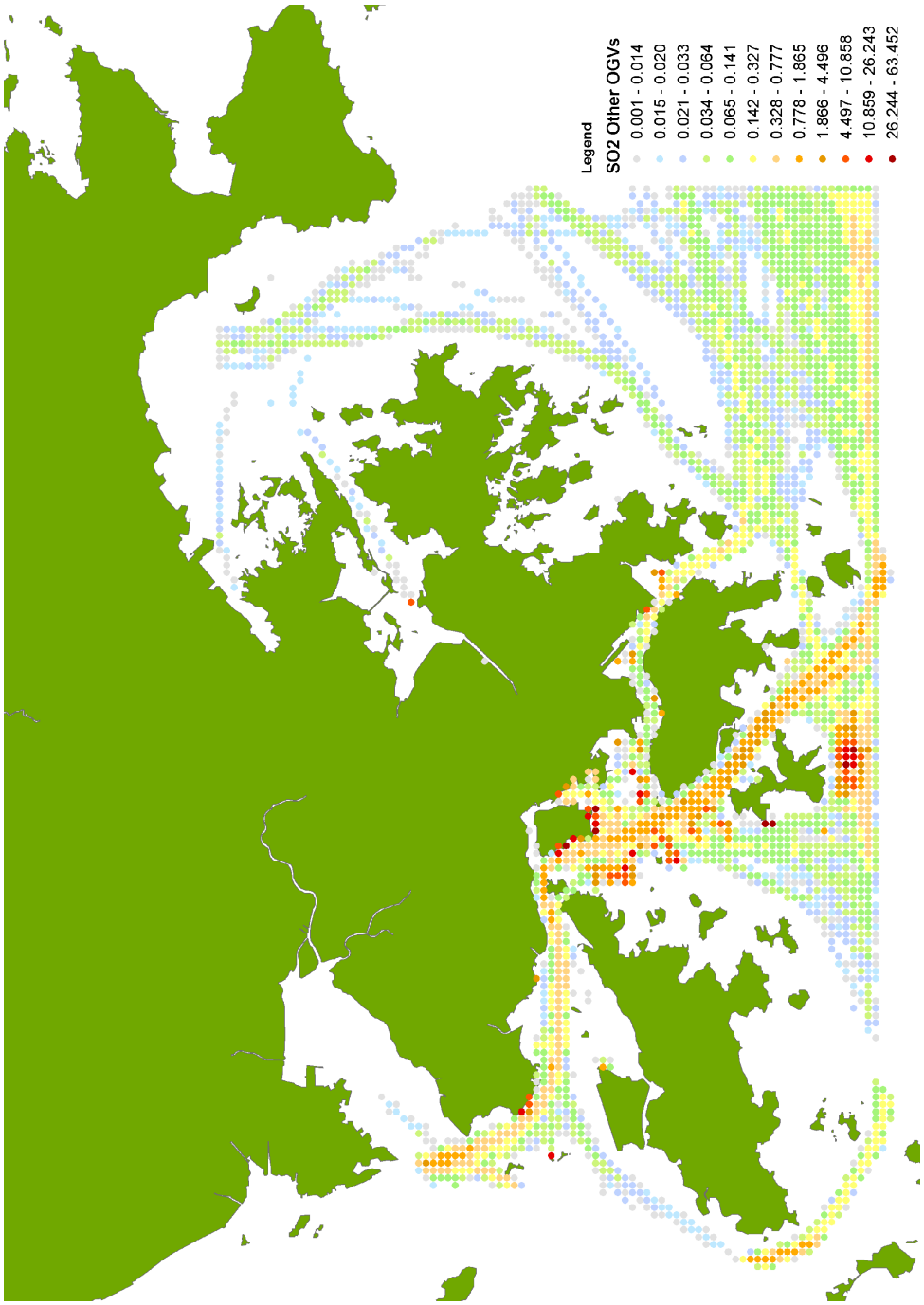


Figure 13-5 Spatial Distribution of SO_2 Emission (tonne) from OGVs other than FCCV and Cruise/Ferry, 2007

River Vessels

13.2.6. Using NO_X emissions as an example, emissions from Macau and PRD Ferry were concentrated at the terminals (in Sheung Wan, Tsim Sha Tsui and at the Airport), as well as along the two major routes starting from Victoria Harbour, either via the south of Lantau Island to the West, or via Ma Wan Fairway and the north of Lantau Island to Pearl River Estuary.

Figure 13-6 Spatial Distribution of NO_X Emission (tonne) from Macau and PRD Ferry, 2007

13.2.7. Contrary to river passenger ferry, RTV operates with both regular and non-regular routes, and their movements are not restricted by the fairway system. As such, their emission pattern as shown in Figure 13-7 spread out to cover a larger portion of Hong Kong waters. Nevertheless, a few emission hot spots were identified (a) at the River Trade Terminal in Tuen Mun, (b) the anchorage areas close to KCCT where mid-stream operation involving RTV were common, and (c) PCWAs such as Kwun Tong and Cha Kwo Lang. There were also trails of emission, following popular sailing routes to other PRD river ports, to the southeast and southwest of Hong Kong.

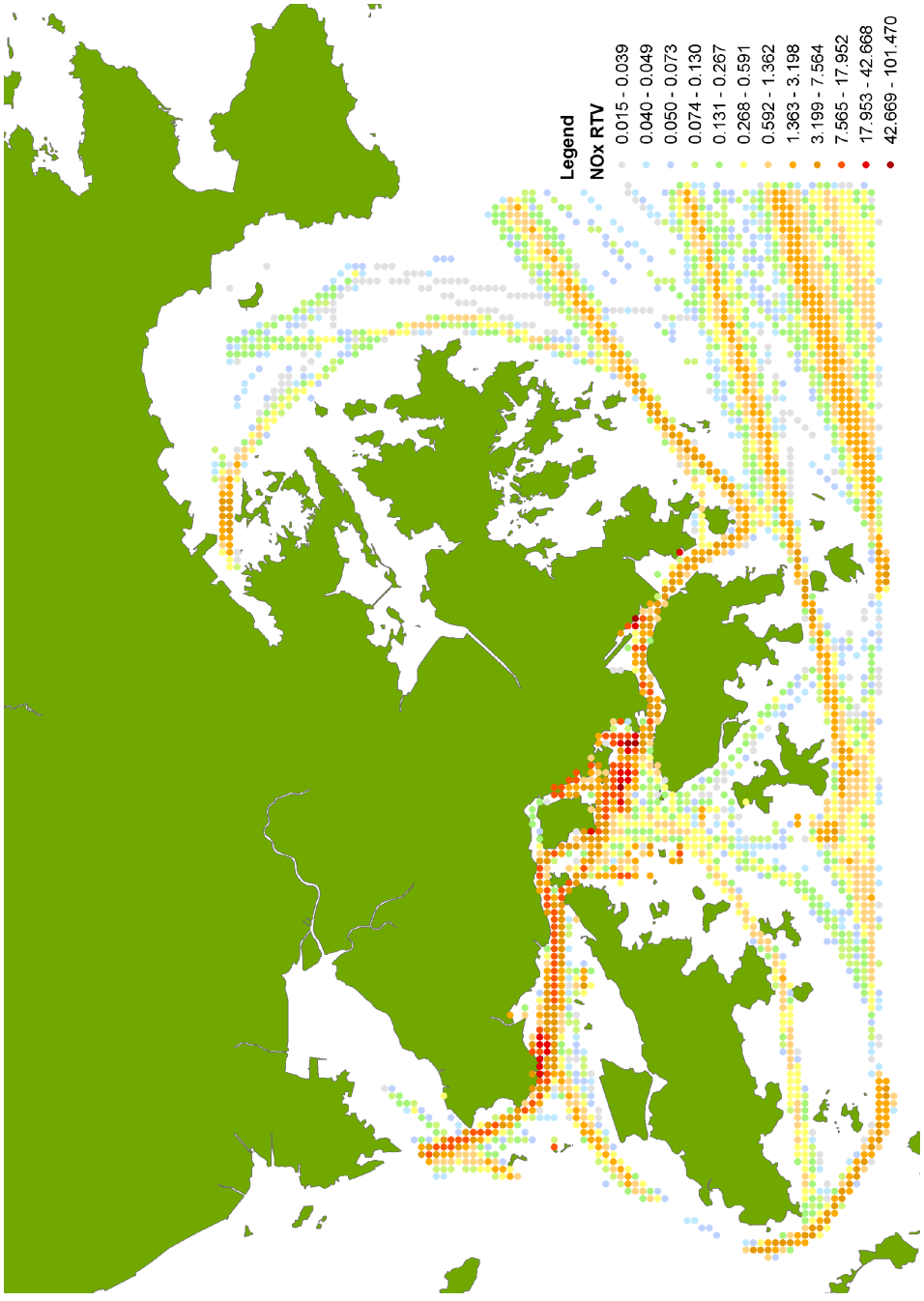


Figure 13-7 Spatial Distribution of NO_X Emission (tonne) from River Trade Vessel, 2007

Local Vessel

13.2.8. Figures 13-8 and 13-9 highlight the spatial pattern of NO_X and VOC emissions from LVs in Hong Kong. As NO_X were emitted mainly from Classes I and II LVs, the distribution patterns mainly reflect location of cargo working areas, ferry piers, and major operating routes of these two LV classes. (Figure 13-8)

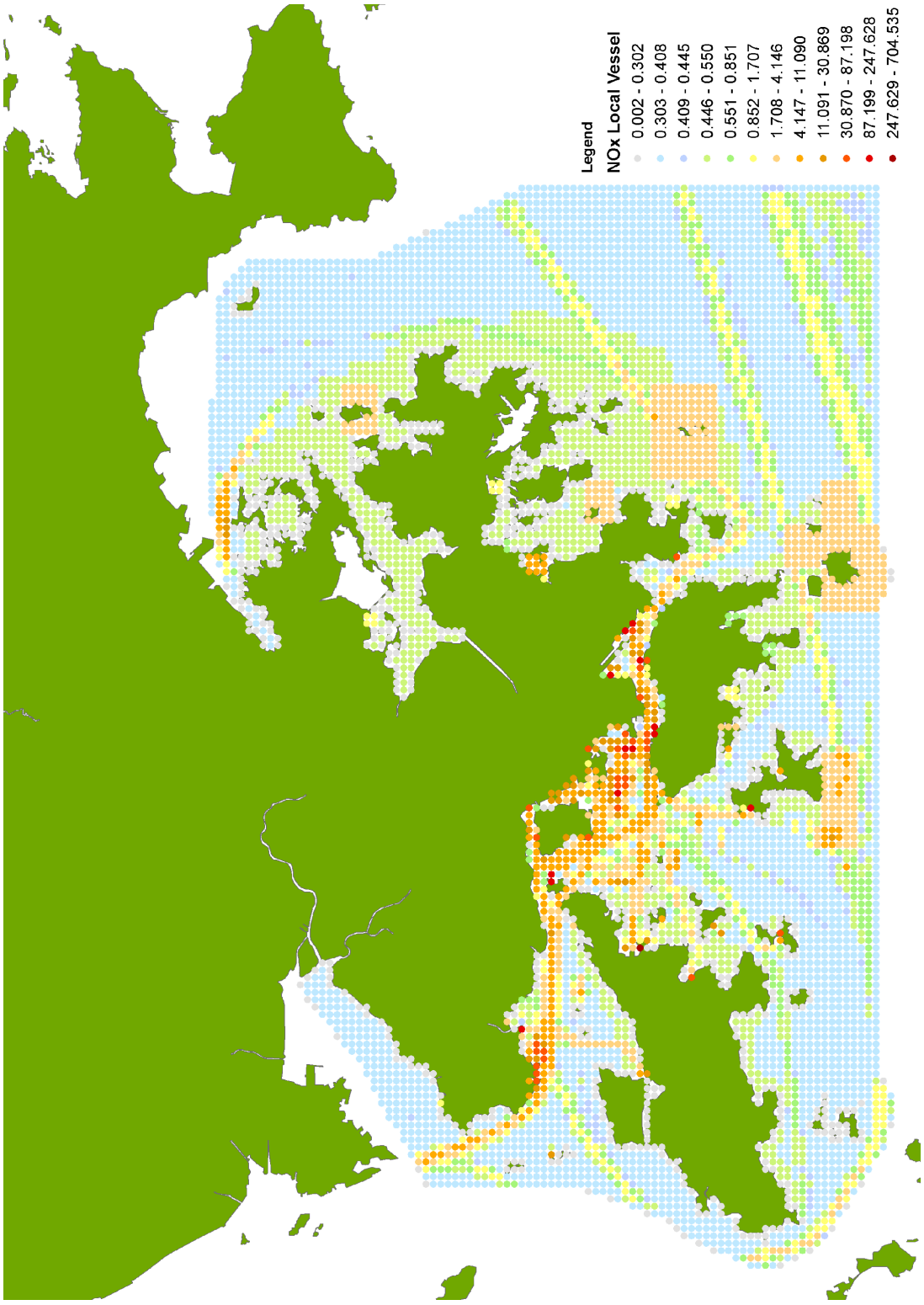


Figure 13-8 Spatial Distribution of NO_X Emission (tonne) from LV, 2007

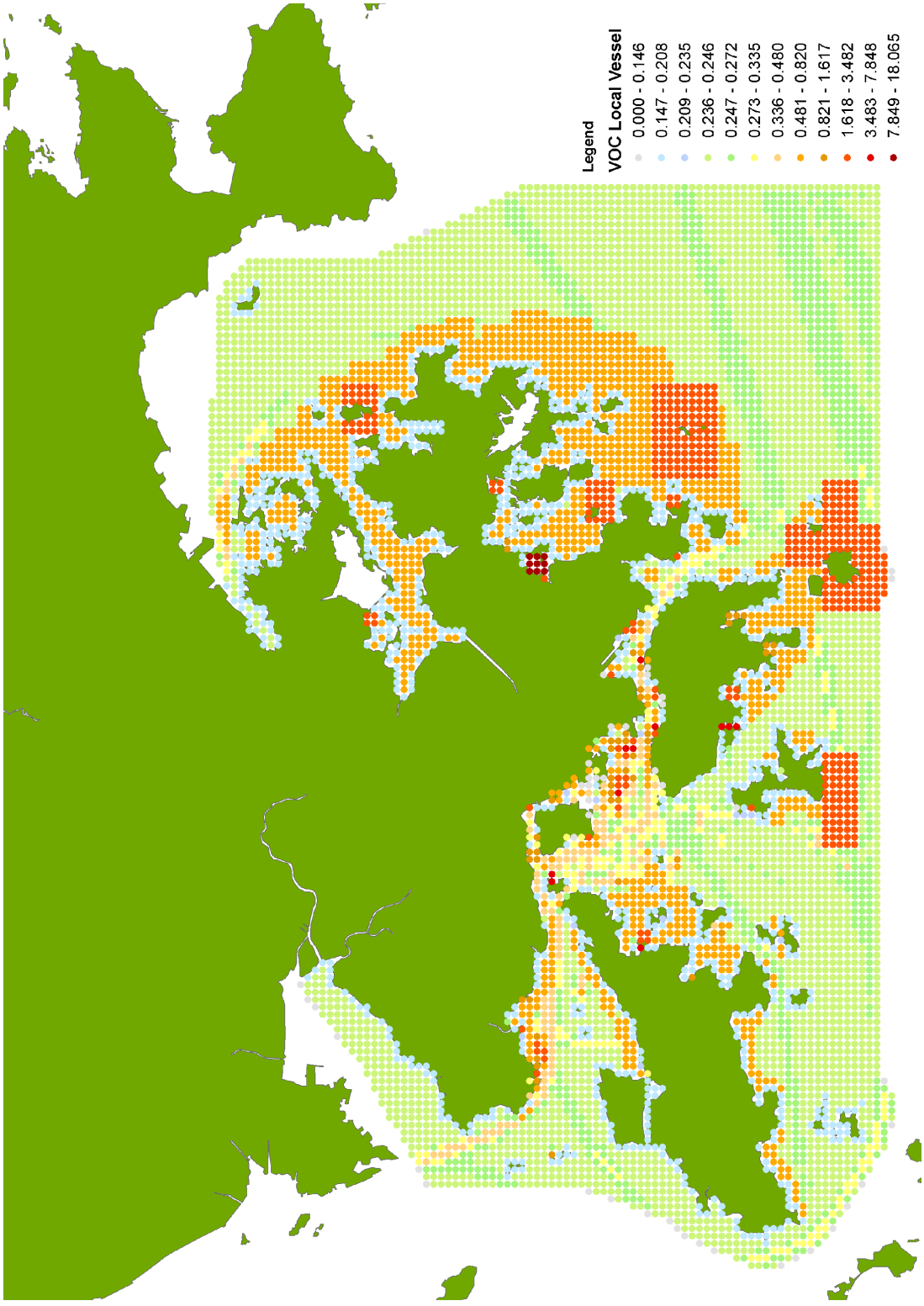


Figure 13-9 Spatial Distribution of VOC Emission (tonne) from LV, 2007

13.2.9. On the other hand, VOC emissions were mainly contributed by fishing vessels (outboard open sampans) and pleasure vessels. The pattern shown in 13-9 hence represented major berthing and operation locations of these two types of local vessel.

Total Emission

13.2.10. Figures 13-10 to 13-14 summarize the spatial distribution of 2007 SO_2, NO_X, PM_{10}, VOC and CO emissions contributed by OGVs, RVs and LVs. SO_2, NO_X, and PM_{10} emission maps show the dominance of OGV, whilst VOC and CO emission maps show the dominance of LVs.

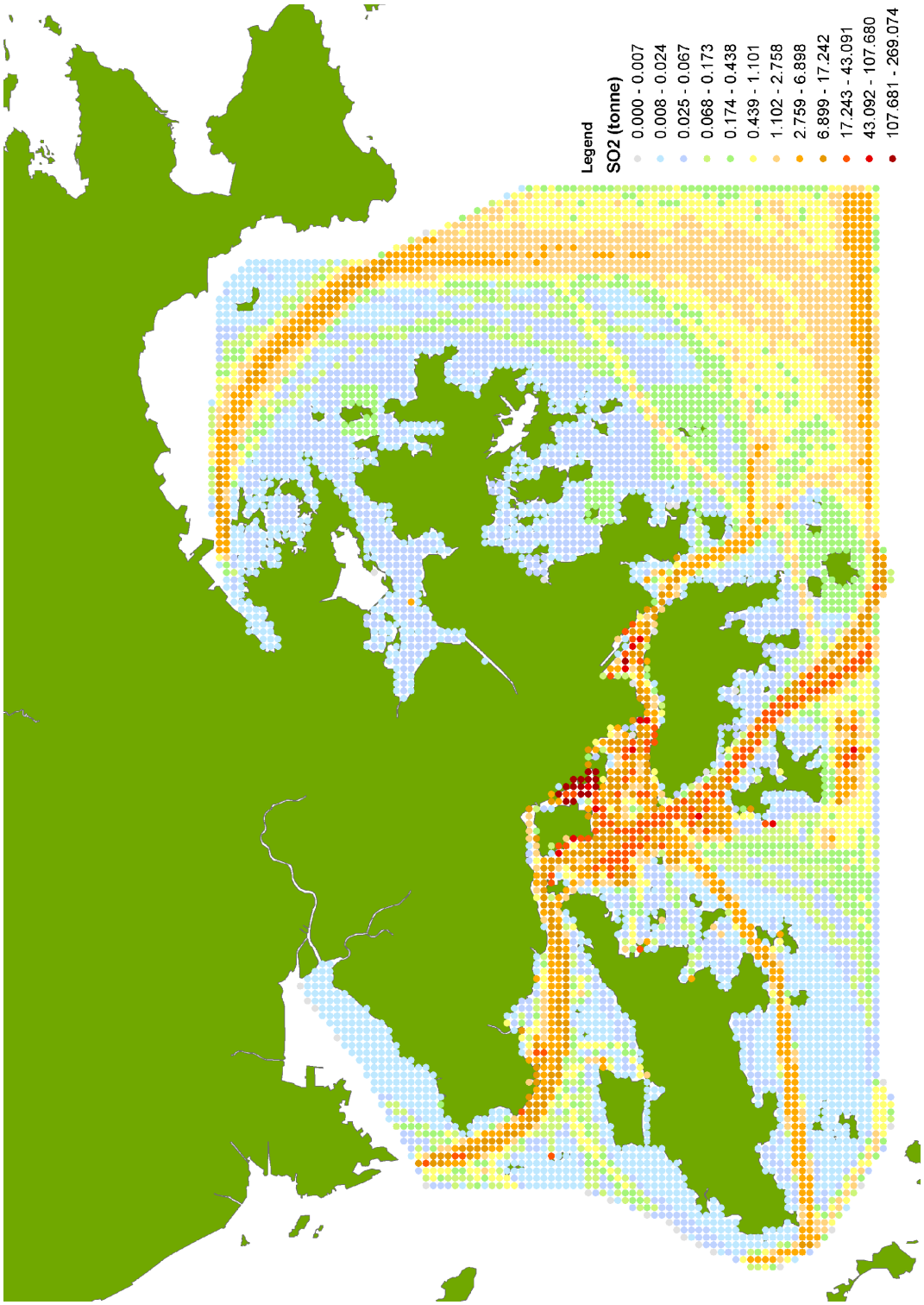


Figure 13-10 Spatial Distribution of SO_2 Emission (tonne) from Marine Sources in Hong Kong, 2007

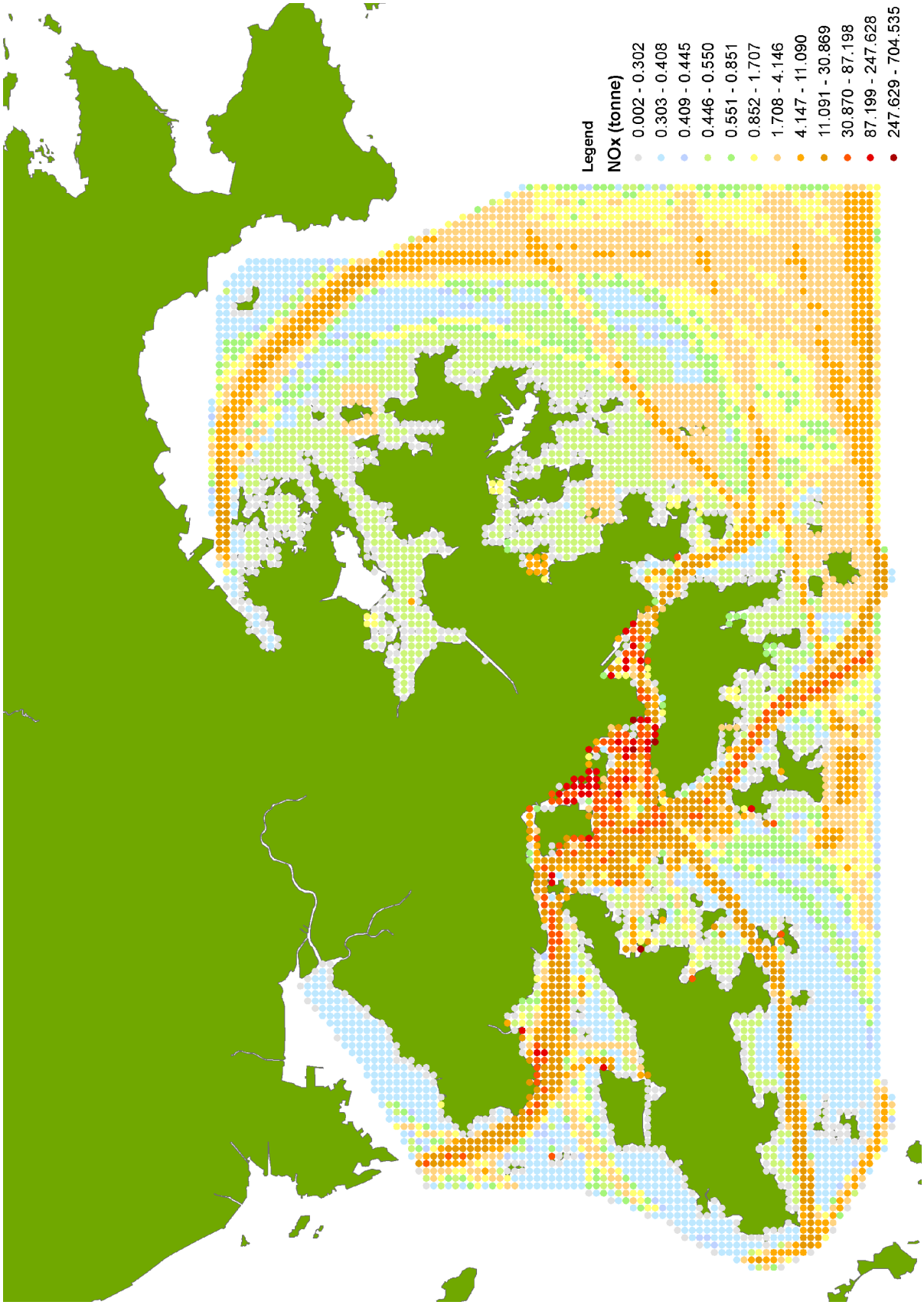


Figure 13-11 Spatial Distribution of NO_X Emission (tonne) from Marine Sources in Hong Kong, 2007

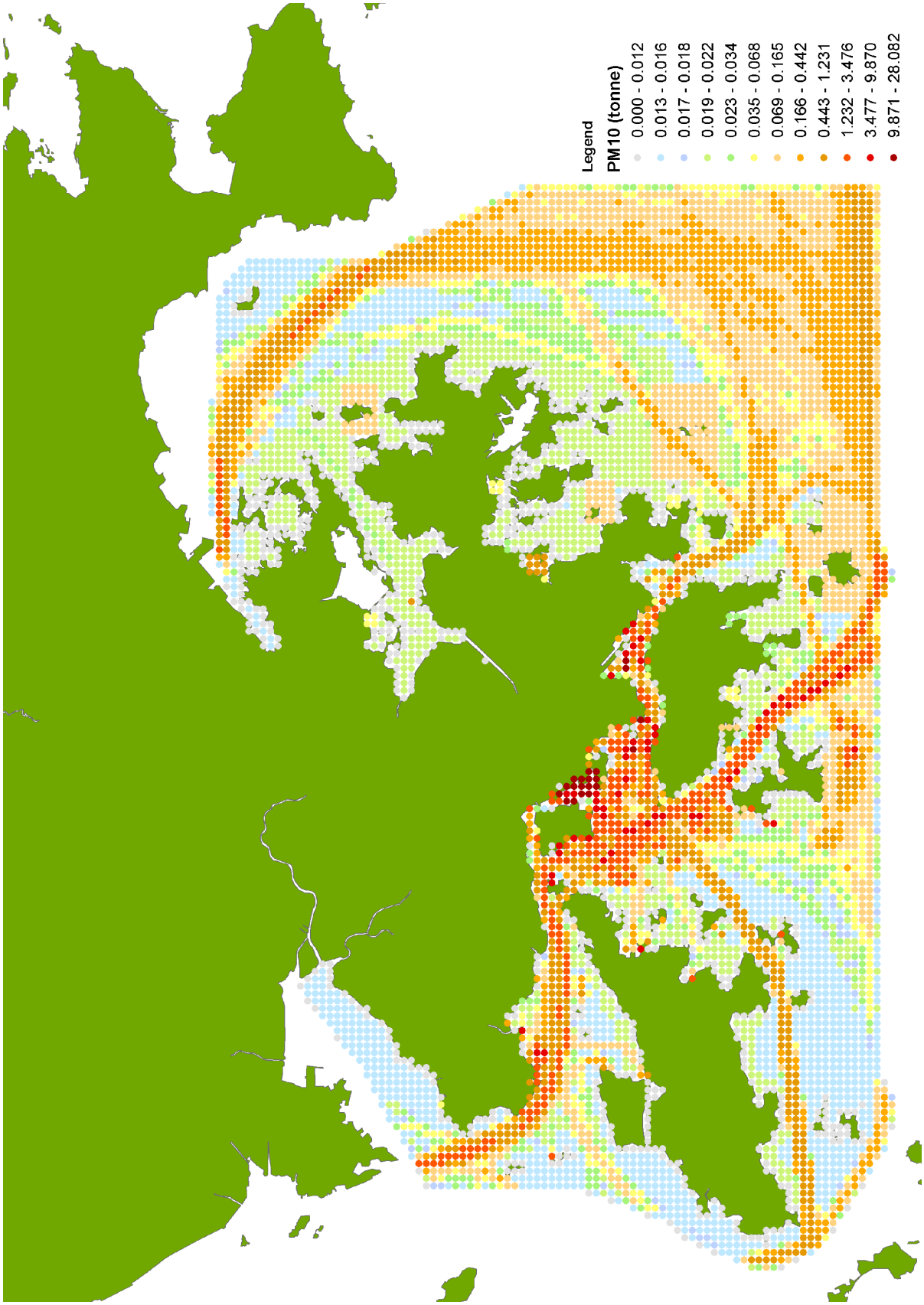


Figure 13-12 Spatial Distribution of PM_{10} Emission (tonne) from Marine Sources in Hong Kong, 2007

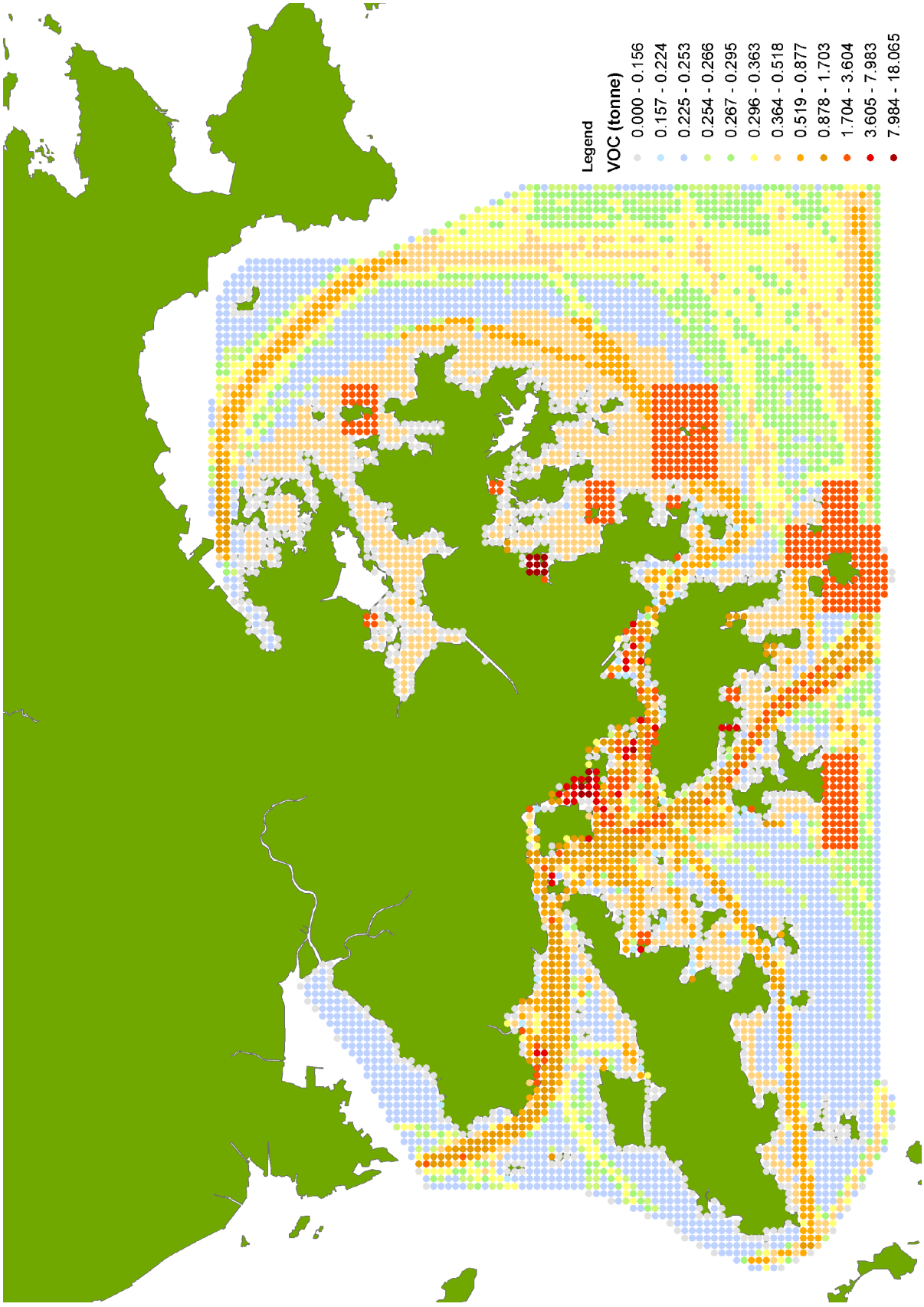


Figure 13-13 Spatial Distribution of VOC Emission (tonne) from Marine Sources in Hong Kong, 2007

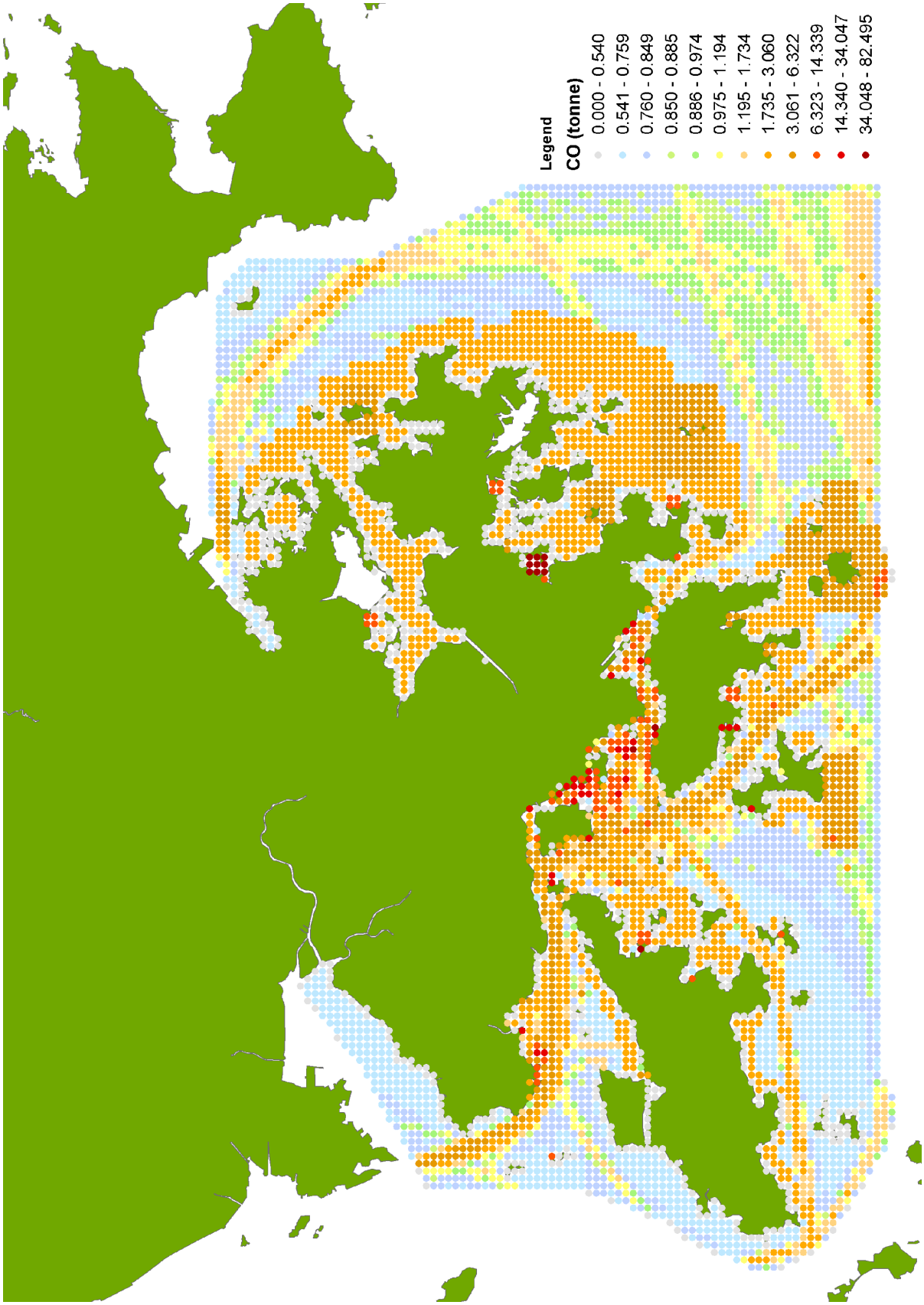


Figure 13-14 Spatial Distribution of CO Emission (tonne) from Marine Sources in Hong Kong, 2007

Discussions

13.2.11. Emission maps are an important tool to complement emission inventory. Firstly, it provides a spatial dimension of marine vessel emissions in Hong Kong, which becomes a valuable input for associated air pollutant dispersion modeling works. Secondly, it helps identify location of emission hot spots and emission corridors, hence also identify localities or communities most likely to be affected by marine vessel emissions. With information as such, effective emission reduction and control measures can be tailor-made.

13.2.12. However, it is explained that the emission maps were produced based on two weeks of radar track data. While the patterns shown on the resultant maps are consistent with common knowledge, some important vessel activities may still be overlooked if they were not covered in the two weeks' period. In other words, there are rooms for improvement if more radar track data can be analyzed. See Chapter 17 for more discussion.

14. TEMPORAL PROFILE OF EMISSION ESTIMATES 2007

14.1. Methodology

14.1.1. In this Chapter, marine emission estimates of 2007 contributed by OGVs, RVs and LVs were disaggregated into hourly, weekly and monthly emission in percentages, where information was available.

Hourly Profile

14.1.2. Hourly profile of marine vessel emissions was developed based on the two weeks' radar track data. Time information was embedded in each data point, and so it was used to classify data points into hours. As each data point also carried information such as vessel type, DWT class, and time-in-mode, hourly profile could be developed for specific vessel type or time-in-mode.

14.1.3. However, the same method was not used to develop hourly profile for Classes III and IV of LVs and government vessels, as their movements were not tracked by MD's radar system. Instead, hourly profile for these vessel types were assumed based on disaggregation of emissions as listed in Table 13-1 of EMEP/CORINAIR Emission Inventory Guidebook 2007, which were discussed further in the following paragraphs.

Weekly and Monthly Profile

14.1.4. As only two weeks' of radar track data were used for the analysis, there was insufficient information from this source to develop weekly and monthly profile of marine vessel emissions. Instead, vessel arrival information provided by different sources was used as a surrogate to develop weekly and monthly profile of vessel emissions.

14.1.5. Vessel arrival data of OGVs were provided by MD, and the data was classified by vessel type and day of the week or month of the year. Vessel arrival numbers by day (Monday to Sunday) or by month (January to December) were then used as a surrogate to reflect quantity of emissions.

14.1.6. For RVs, vessel arrival data of RTV, Macau Ferry and PRD Ferry by month were gathered from the *Hong Kong Monthly Digest of Statistics.* In order to develop a weekly profile for RTV, the weekly schedule of a major river trade operator was used as a reference. However, it was assumed the number of service each day of the week for Macau and PRD Ferry was uniform, as suggested by their sailing schedules.

14.1.7. Information for LVs was difficult to obtain, except for Class I vessels which operated mostly according to fixed schedules. Hence, local ferry schedules were used as the basis to develop weekly and monthly profile for Class I local vessels. For the other local vessel classes, the following surrogates were used:

- Class II – monthly profile of RTV was used as a surrogate, due to their similarities in operation; for weekly profile, temporal disaggregation of emissions as listed in Table 13-1 of *EMEP/CORINAIR Emission Inventory Guidebook 2007* were adopted;

- Class III – monthly profile of Class III vessels was developed with the assumption that there was no activity during the fishing moratorium in June and July 2007, as well as less activity during winter months from October to February; for weekly profile, temporal disaggregation of emissions of *EMEP/CORINAIR Emission Inventory Guidebook 2007* were adopted;

- Class IV – monthly and weekly profile adopted from *EMEP/CORINAIR Emission Inventory Guidebook 2007*, making reference to vessel type "all but 04"; and

- Government vessel – monthly and weekly profile adopted from *EMEP/CORINAIR Emission Inventory Guidebook 2007*, making reference to vessel type "04, Inland Goods Carrying Vessels"

14.2. Results and Discussions

Hourly Profile of Emissions

14.2.1. Hourly profiles of combined emission (by OGVs, RVs and LVs) of SO_2, NO_X, PM_{10}, VOC and CO are presented in Figure 14-1. Hourly profiles of the five pollutants follow a similar pattern. On average, emission during night time was lower (3% to 4%). It picked up in the early morning hours and remained high in the afternoon (4% to 5%). It dropped again in late hours.

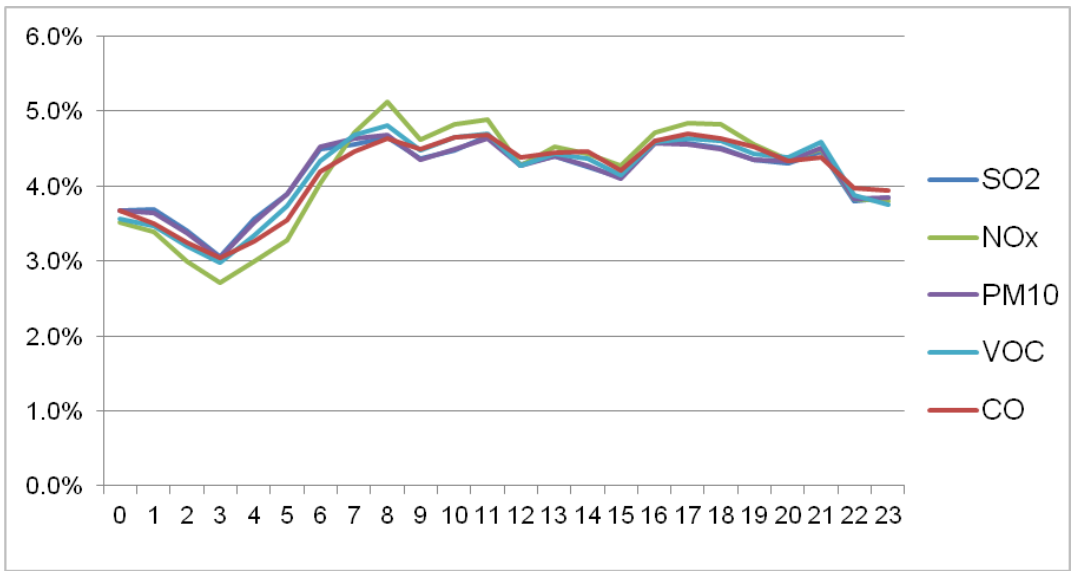


Figure 14-1 Hourly Profile of Marine Vessel Emissions in Hong Kong, 2007

14.2.2. When the hourly profile was disaggregated by OGV, RV and LV, different patterns emerged. To illustrate the point, hourly profile of SO_2 emission was plotted in Figure 14-2. It is apparent that the hourly pattern of OGV was dominant, as it followed closely the pattern in Figure 14-1. Hourly profile of RV fluctuated with higher peaks and lower troughs, whereas the profile of LV was smooth, reflecting in general more activity during daytime.

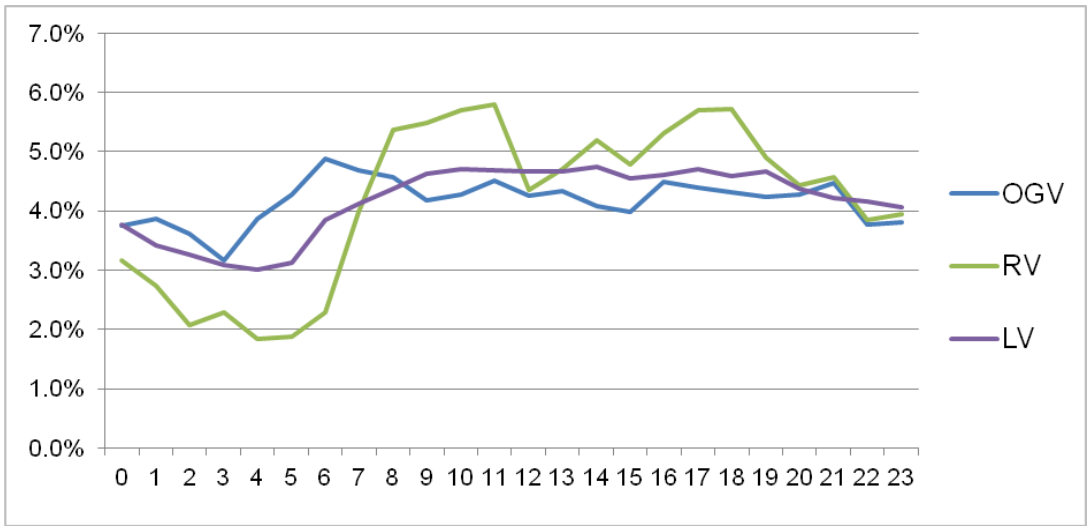


Figure 14-2 Hourly Profile of SO_2 Emissions by Vessel Class, 2007

14.2.3. Figure 14-3 further breaks down the hourly profile of OGV by showing the pattern of FCCV and Cruise/Ferry, the top two OGV emitters. It is interesting to note that the hourly profile of FCCV was very flat, with each hour constantly contributing about 4% of emissions, probably reflecting the round-the-clock operation of the container terminals. On the other hand, emission of cruise/ferry fluctuated during a day, from almost no emission during the early hours (when most cruise ships were in open sea), to 8% in the morning peak (when the ships returned and berthed), to 10% in the evening peak (when the ships started their voyage and sailed towards Tathong Channel).

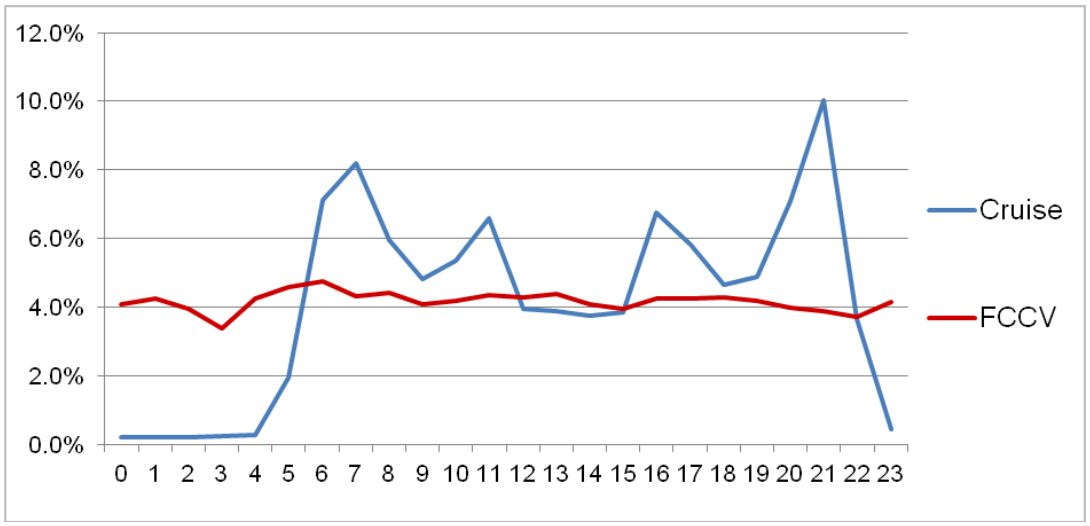


Figure 14-3 Hourly Profile of SO_2 Emissions by FCCV and Cruise, 2007

14.2.4. Similarly, different hourly patterns emerged when RV emissions were disaggregated in Figure 14-4. Firstly, the hourly profile of RTV was fairly flat, ranging from 3.4% to 4.8% throughout the day. Secondly, the hourly profile of Macau Ferry and PRD Ferry mainly reflected their respective operating hours and level of services.

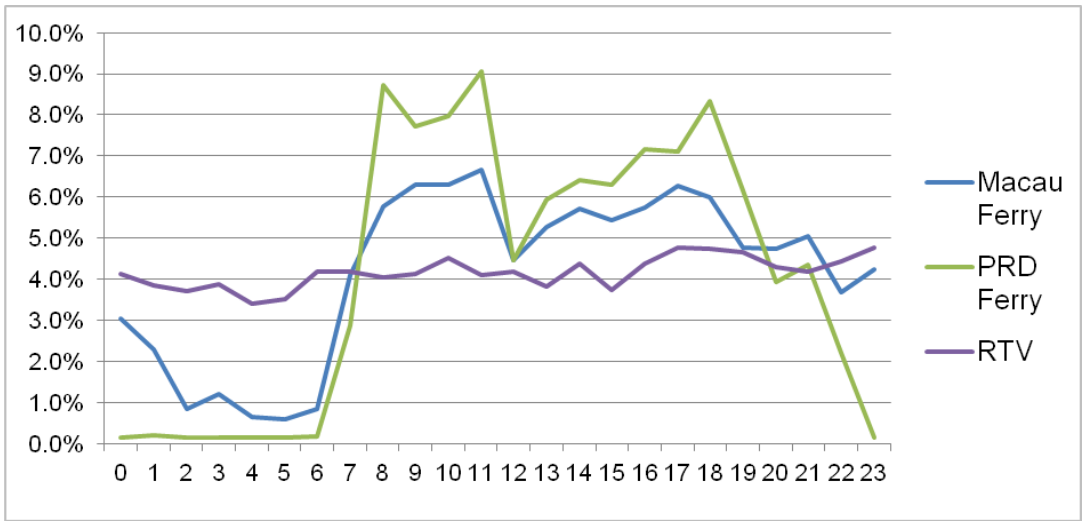


Figure 14-4 Hourly Profile of SO_2 RV Emissions by Vessel Class, 2007

14.2.5. As for LVs, hourly profiles were produced from vessel track data only for Class I (ferry) and Class II (cargo vessel). In Figure 14-5, the hourly profile of cargo vessel was similar to that of RTV (Figure 14-4), given their similar function and operation characteristics. The hourly profile of local ferry was closely related to the working hours of passengers. It ranged from 2.2% in the early hours to 5.2% in late morning.

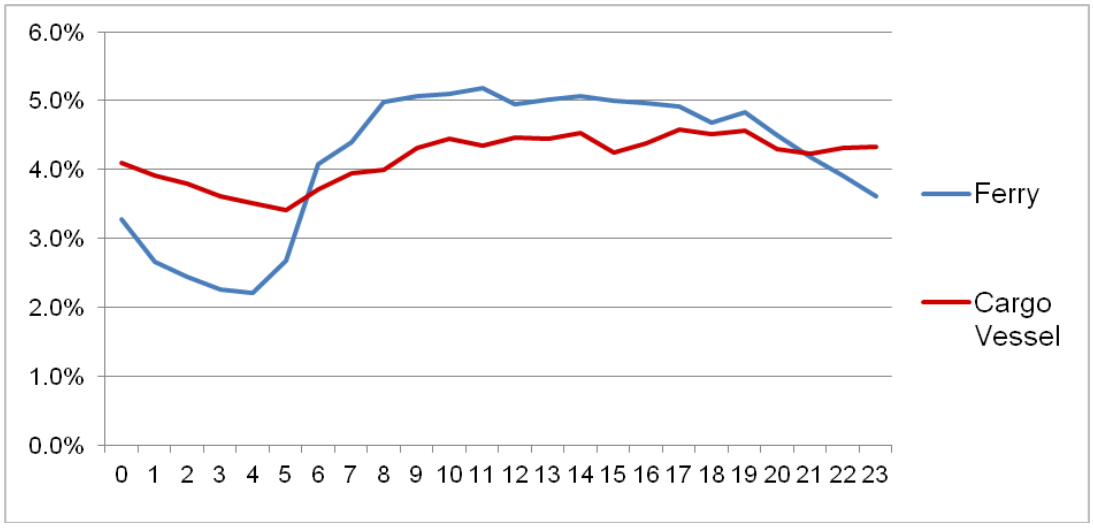


Figure 14-5 Hourly Profile of Local Ferry and Cargo Vessel SO_2 Emissions, 2007

14.2.6. For local vessel Class III, Class IV and government vessel, temporal disaggregation of emissions of *EMEP/CORINAIR Emission Inventory Guidebook 2007* were adopted as the hourly profile. (Table 14-1)

Table 14-1 Hourly Profile of Selected Local Vessels, 2007

	Hours			
	0 – 5	**6 – 11**	**12 – 17**	**18 – 23**
Class III	1%	50%	45%	4%
Class IV	1%	50%	45%	4%
Government Vessel	1%	50%	45%	4%

Weekly Profile of Emissions

14.2.7. Figure 14-6 plots the weekly profile of OGV emissions. In general, emission was higher over the weekend, due to higher vessel arrivals. Figure 14-6 also shows a sharp drop of FCCV emissions on Friday (13.2%), which was offset by higher Cruise/Ferry emission (15.2%) on the same day of the week.

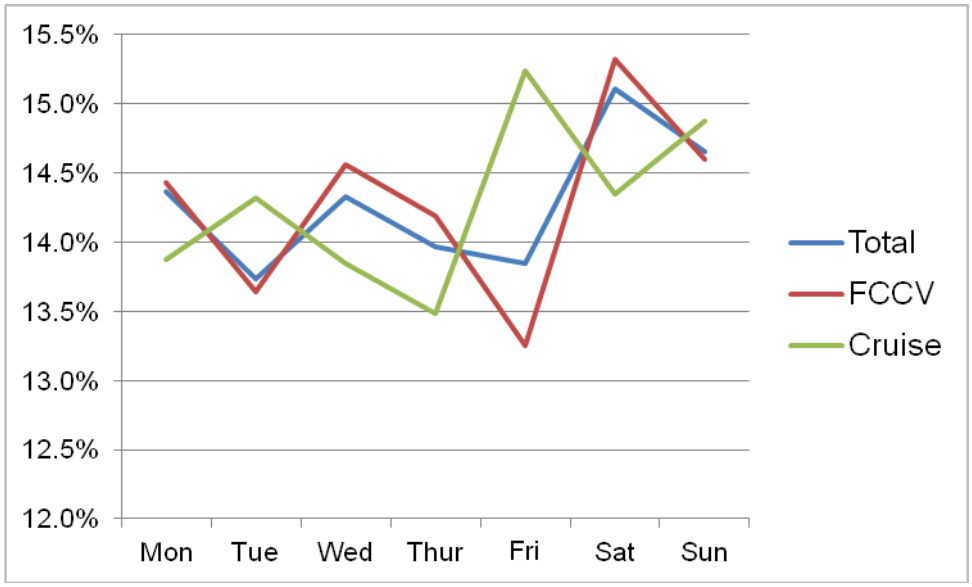


Figure 14-6 Weekly Profile of OGV Emissions, 2007

14.2.8. Table 14-2 shows that the weekly profile of Macau Ferry and PRD Ferry was uniform, according to the sailing schedules. The weekly profile of RTV reflected fewer services on Sundays, whereas emissions during weekdays ranged from 13.2% to 16.6%.

Table 14-2 Weekly Profile of River Vessels, 2007

	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
RTV	16.6%	13.2%	16.6%	13.2%	16.6%	13.2%	10.6%
Macau Ferry	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%
PRD Ferry	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%

14.2.9. For LVs, local ferry schedules showed that number of services each day of the week was fairly uniform for Class I vessels. (Table 14-3) While service frequency of the inner harbour routes was reduced on Sundays, it was compensated by the increase of the outlying island and recreational routes. For the other vessel classes, *EMEP/CORINAIR Emission Inventory Guidebook 2007*'s temporal profile was adopted. In general, work-related vessel classes had a dip in emission during weekends and Sundays, whereas leisure-related vessel class depicted an opposite pattern.

Table 14-3 Weekly Profile of Local Vessels, 2007

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Class I	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%	14.3%
Class II	18.0%	18.0%	18.0%	18.0%	18.0%	5.0%	5.0%
Class III	18.0%	18.0%	18.0%	18.0%	18.0%	5.0%	5.0%
Class IV	5.0%	5.0%	5.0%	5.0%	10.0%	35.0%	35.0%
Government Vessel	18.0%	18.0%	18.0%	18.0%	18.0%	5.0%	5.0%

Monthly Profile of Emissions

14.2.10. On average, the monthly profile of OGV emissions was fairly flat, except modest fluctuation before and after Christmas and Chinese New Year. (Figure 14-7) For FCCV, the drop in February (Chinese New Year) was more obvious, but emission over a year was quite consistent. For Cruise/Ferry, changes in the monthly profile probably reflected the seasonal change within the Cruise business.

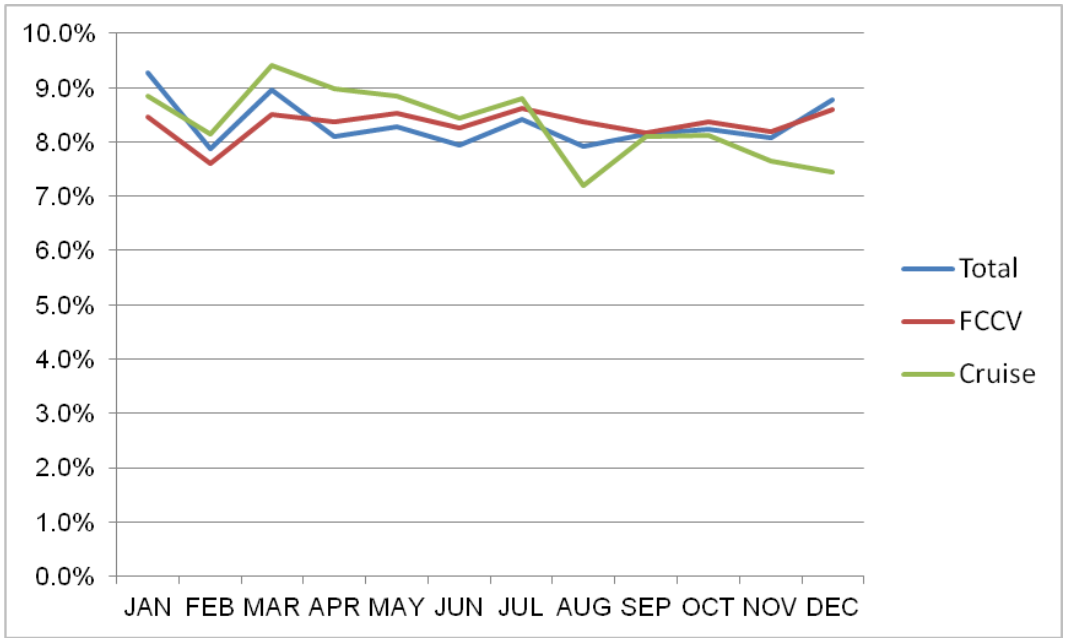


Figure 14-7 Monthly Profile of OGV Emissions, 2007

14.2.11. The monthly profile of RV emissions was also quite flat, ranging from 7.6% to 8.8% in most months. (Figure 14-8) The first exception was a sharp drop for RTV during February to 6.5%, probably due to a reduction of trade activities during Chinese New Year. The second exception was a marked increase of emission from Macau Ferry in December 2007, due to additional services provided by a new operator.

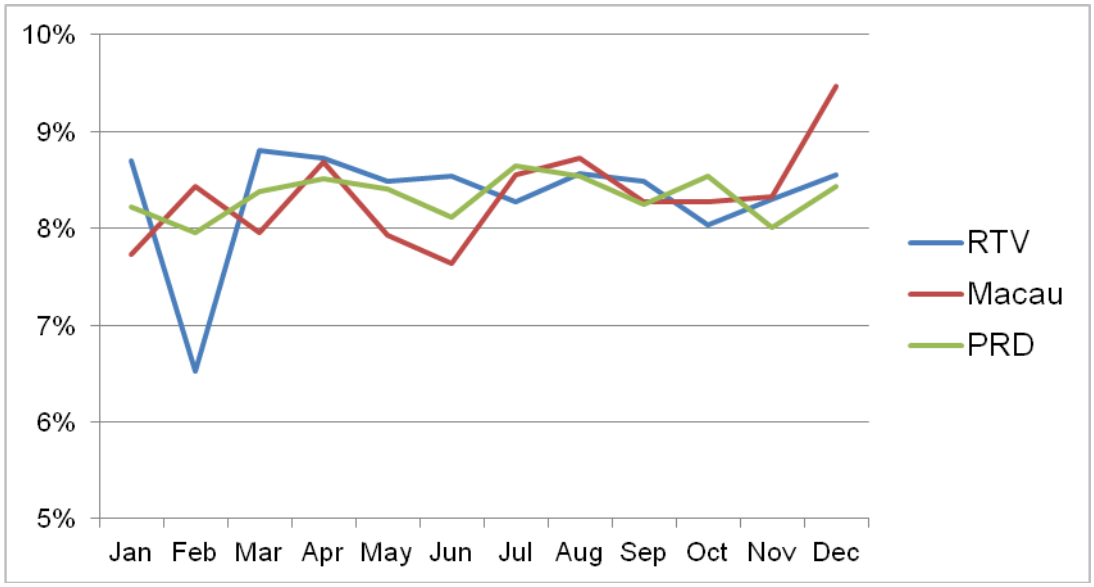


Figure 14-8 Monthly Profile of RV Emissions, 2007

14.2.12. Figure 14-9 demonstrates the monthly profile of LV emissions. The monthly emission patterns of Classes I and II local vessel, as well as government vessel were quite consistent. The monthly profile of Class III (fishing vessel) reflected zero activity during the months of fishing moratorium, and less activity from October to February. The hike of emission during summer months for Class IV reflected the assumption that yachting is more active in summer.

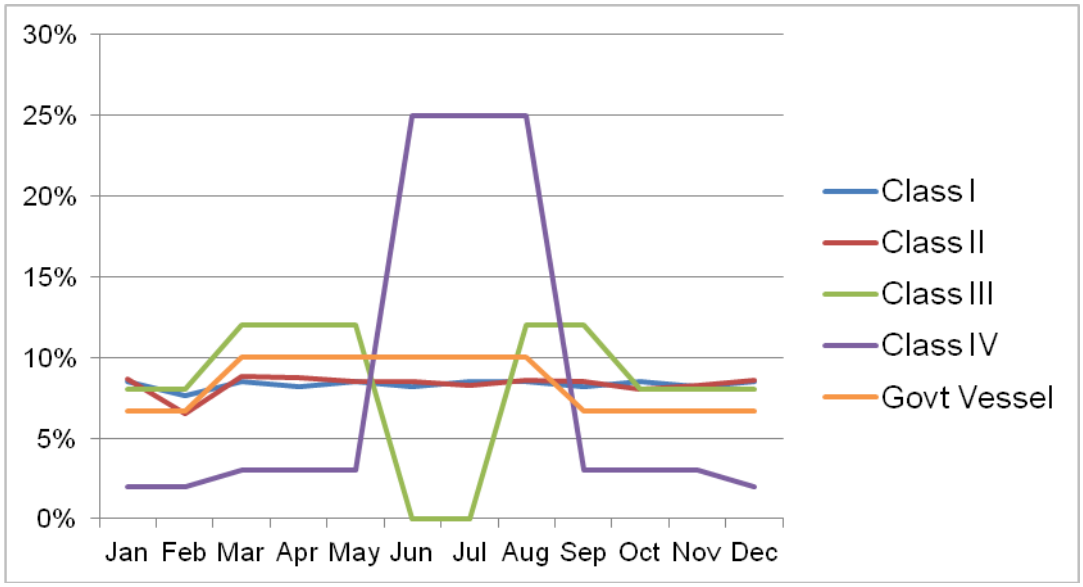


Figure 14-9 Monthly Profile of LV Emissions, 2007

Discussions

14.2.13. Temporal profile of marine vessel emissions is an important input for air pollutant dispersion models, to account for the variation of emissions over a period of time. In this exercise, hourly, weekly and monthly profiles of emission were created for a better understanding of the temporal variation of marine vessel emissions.

14.2.14. However, due to the lack of data, only hourly profiles were meaningfully produced for different vessel types. Weekly and monthly profiles were developed based on surrogates, not emission numbers, and hence they at best only served as a demonstration.

14.2.15. In order to prepare better weekly and monthly profiles of marine vessel emissions, a full year of radar track data would have to be analyzed.

PART VII SULPHUR DIOXIDE DISPERSION MODELLING OF 2007

15. SULPHUR DIOXIDE DISPERSION MODEL

15.1. Methodology

15.1.1. In this section, an air dispersion model run was used to demonstrate the contribution of marine source to air quality in the vicinity of the port area, in particular KCCT and the built-up areas adjacent to Victoria Harbour.

15.1.2. SO_2 was selected as the focus of analysis in this demonstration for a couple of reasons. First, marine vessel is a major source of SO_2 emission after power plant. The situation is less complicated when compared with NO_X and PM_{10}, whose emission sources include power plant, road transport, other fuel combustion sources, and regional sources. Second, SO_2 is a primary pollutant and it is easy to model. On the other hand, the formation of NO_X and PM_{10} may involves complex chemical reactions. It is more complicated to differentiate between the contribution of marine source and other sources to NO_X and PM_{10} emissions. Overseas study also uses SO_2 as an indicator to analyse shipping emissions[52].

The PATH Model

15.1.3. The PATH modeling system (PATH), which was developed and currently used by EPD, was selected in this exercise. In general, PATH consists of a meteorological model, that is, the Fifth-generation NCAR/Penn State Mesoscale Model (MM5) or the Weather Research and Forecasting modeling system (WRF) and an air quality model called CAMx (Comprehensive Air Quality Model with extensions).

15.1.4. In PATH, there are four nested horizontal domains, Domains 1 to 4 (D1 to D4), with grid resolution of 27km, 9km, 3km and 1km, respectively. The corresponding number of horizontal grid (column × row) for each domain in MM5/WRF are 282×183 (D1), 222×162 (D2), 171×129 (D3), and 213×162 (D4), and those in CAMx are 182×138 (D1), 98×74 (D2), 152×110 (D3), and 179×125 (D4), respectively. (Figure 15-1)

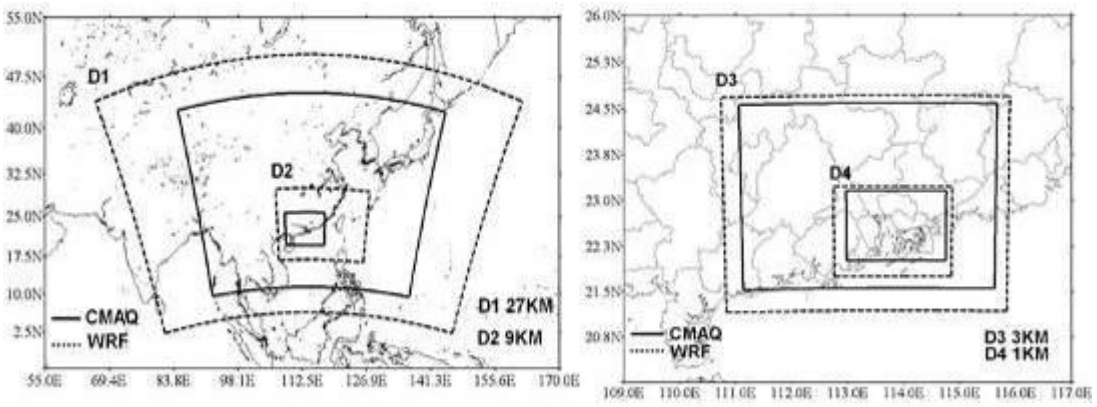


Figure 15-1 MM5/WRF (dotted line) and CAMx (solid line) Modeling Domains

[52] For example, Elshout, S. van den and de Gier, C. (2010).

15.1.5. In terms of geographic coverage, D1 covers most of China, Japan, and a large part of Southeast Asia. D2 covers southeastern China, including Guangdong, Hong Kong and Macau. D3 covers most of Guangdong, Hong Kong and Macau. D4, the smallest, focuses on the PRD region, as well as Hong Kong. D4 was used for this task.

15.1.6. For the vertical structure, MM5 uses 38 sigma layers in total which extends from the ground to 50 millibar (mb) pressure level (about 20km above ground). Subsequently, 26 layers, not all 38 layers, were selected from MM5 for CAMx, including the more important 20 layers within 2km distance from the ground, for computational efficiency without sacrificing the quality of modeled results. (Table 15-1)

Table 15-1 Vertical Layers of MM5

Layer	Sigma Value	Pressure (mb)	Height (m)	Chosen for CAMx (Yes/No)
38	0.0000	50	20,576	Yes
37	0.0241	73	18,185	No
36	0.0542	101	16,086	No
35	0.0903	136	14,240	Yes
34	0.1324	176	12,603	No
33	0.1801	221	11,148	No
32	0.2316	270	9,775	No
31	0.2850	321	8,624	Yes
30	0.3393	372	7,597	No
29	0.3934	424	6,682	No
28	0.4467	474	5,864	No
27	0.4958	524	5,135	Yes
26	0.5484	571	4,483	No
25	0.5690	616	3,901	No
24	0.6410	659	3,382	Yes
23	0.6883	699	2,918	No
22	0.7229	737	2,503	Yes
21	0.7597	772	2,133	No
20	0.7937	804	1,802	Yes
19	0.8251	834	1,506	Yes
18	0.8521	859	1,259	Yes
17	0.8753	882	1,051	Yes
16	0.8951	900	877	Yes
15	0.9120	916	730	Yes
14	0.9263	930	608	Yes
13	0.9385	942	505	Yes
12	0.9488	951	419	Yes
11	0.9575	960	346	Yes
10	0.9649	967	285	Yes
9	0.9711	973	234	Yes
8	0.9763	977	192	Yes
7	0.9807	982	156	Yes
6	0.9844	985	126	Yes
5	0.9875	988	101	Yes

4	0.9904	991	77	Yes
3	0.9931	993	55	Yes
2	0.9956	996	35	Yes
1	0.9979	998	17	Yes
0	1.0000	1,000	0	Yes

Meteorological Mode

15.1.7. Meteorological inputs for CAMx include cloud parameter, rain information, vertical diffusivity, water vapour concentration, temperature, wind and pressure. Input parameters are generated from MM5, based on data provided by the Hong Kong Observatory (HKO). MM5 was designed to simulate or predict mesoscale atmospheric circulation. As the MM5 outputs are not recognized by CAMx, a Meteorology-Chemistry Interface Processor (metcamx) was used to link MM5 with the CAMx model, providing both meteorological data and geographic data (land use type) for the CAMx system.

Model-ready Emissions

15.1.8. To demonstrate the impact of marine emission in Hong Kong on air quality, only marine sources were included in the D4 emission inventory. Emission estimates produced in this Study, covering the entire Hong Kong waters, were used as the base emission numbers (see Chapter 5, Table 5-2).

15.1.9. Two adjustments were made to prepare the emission numbers for model runs. First, as the emission numbers only covered OGV, RV and LV, emissions produced by transit vessel within Hong Kong waters, which was beyond the scope of this Report, were estimated and added to become total emissions inside Hong Kong waters. Second, since D4 covers an area larger than the land and waters of Hong Kong, the total emission numbers were scaled up to fit the size of D4 with spatial distribution following the vessel tracks outside Hong Kong waters.

15.1.10. Besides, the model run did not differentiate between stack height for OGV and other vessels. It was considered acceptable in this demonstration, especially when OGV emissions dominated marine SO_2 sources. The PATH model also does not require detailed stack parameters for air dispersion as those used for localized assessment for grid resolution down to 500 m square.

15.1.11. The spatial and temporal profiles of marine vessels emissions in Hong Kong, developed in this Study and documented in Chapters 13 and 14, respectively, were also used as inputs for the CAMx model. For spatial distribution, emission estimates of each pollutant were allocated to the vessel track pattern by vessel type, DWT class and operation mode. For temporal distribution, an average hourly temporal profile was derived based on the two-week vessel track data, and this average profile was used for all vessel types[53].

[53] Notwithstanding the discussion of hourly temporal profile for LVs in Chapter 14, OGVs and RVs average hourly profile was used instead. Given that SO_2 of LVs represents only 9% of total marine sources (Table 5-3), the error introduced in such manner is minimal.

Model Simulation

15.1.12. A period from 6th July to 21st July 2007 was chosen for model simulation. The chosen simulation period represents a typical summer time meteorological condition in Hong Kong, with hot and humid air. Wind directions were predominantly southwesterly or southerly. (Figure 15-2) Aided by southwesterly and southerly wind, the distinct impact of marine vessels emission produced over KCCT will be readily captured by the nearby Kwai Chung and Tsuen Wan air quality monitoring stations at downwind locations. (Figure 15-3)

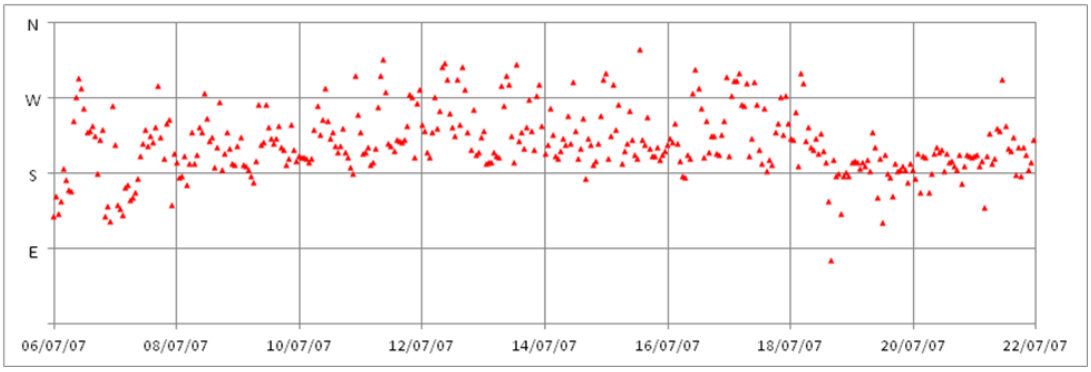


Figure 15-2 Hourly Wind Directions, 6th July to 21st July 2007

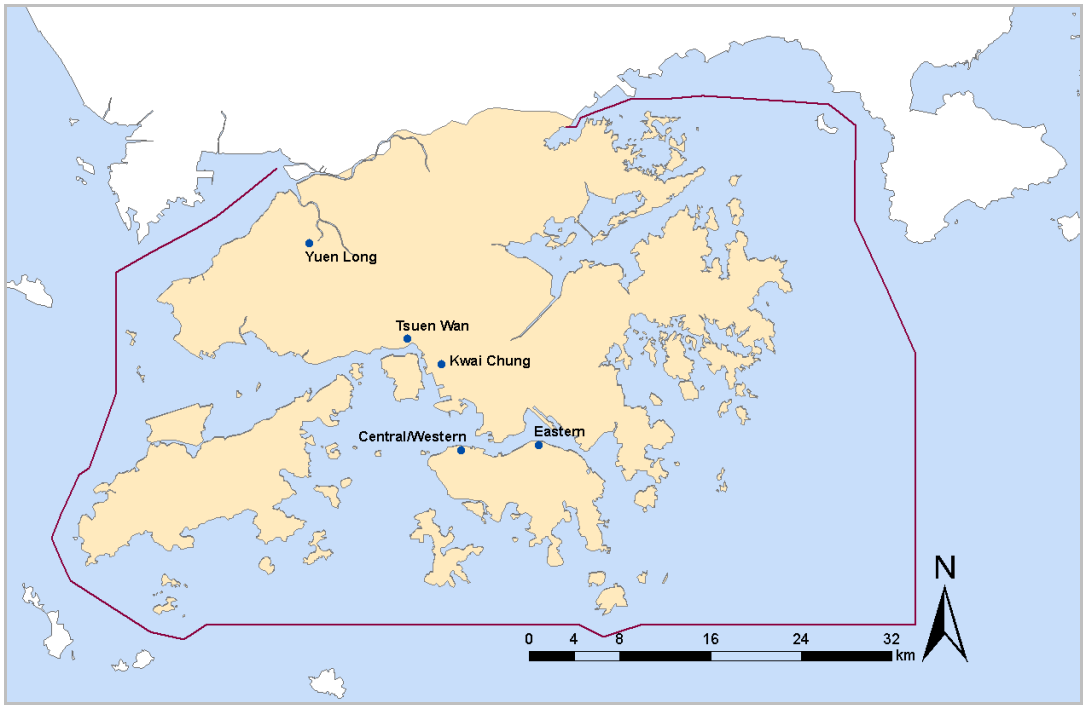


Figure 15-3 Location Map of Selected Monitoring Stations in Hong Kong

15.1.13. As the first four days (i.e. 6th to 9th July 2007) are regarded as the spin up time, they are excluded in the model run.

15.2. Results and Discussions

15.2.1. Figure 15-4 displays observed SO_2 concentration during model simulation period recorded at air quality monitoring stations located around Victoria Harbour. It is apparent that between 10th and 15th of July 2007, high SO_2 concentrations were recorded at the monitoring stations in Central/Western monitoring station, around 60 ppb. Judging by the magnitude of SO_2 concentration and wind direction at that time, it was likely that such a period of high SO_2 concentration was associated with emissions from power plant and other regional sources. With such dominant sources, it is difficult to study the impact of marine source in isolation during that period.

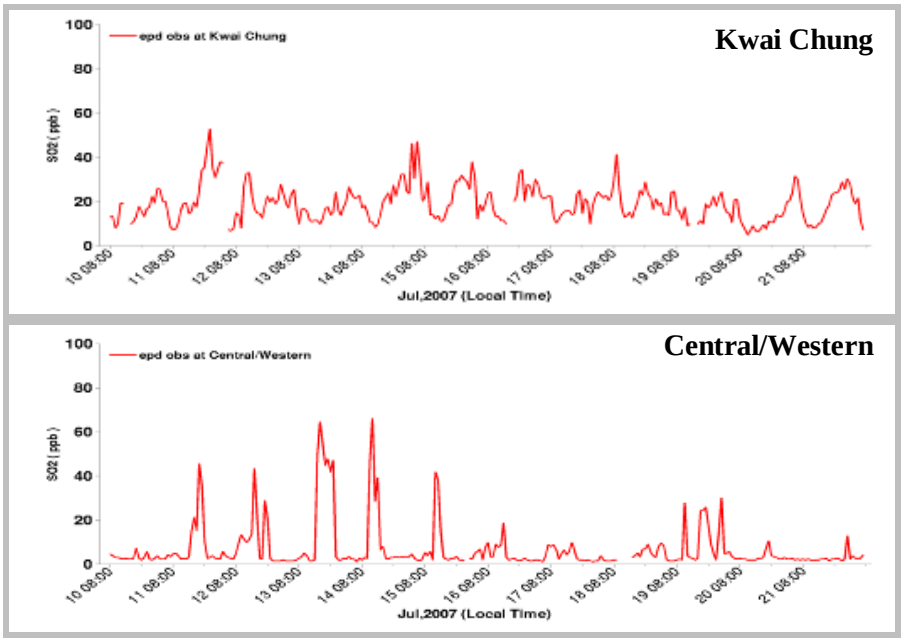


Figure 15-4 Observed SO_2 Concentration at Various Monitoring Stations, 10th July to 21st July 2007

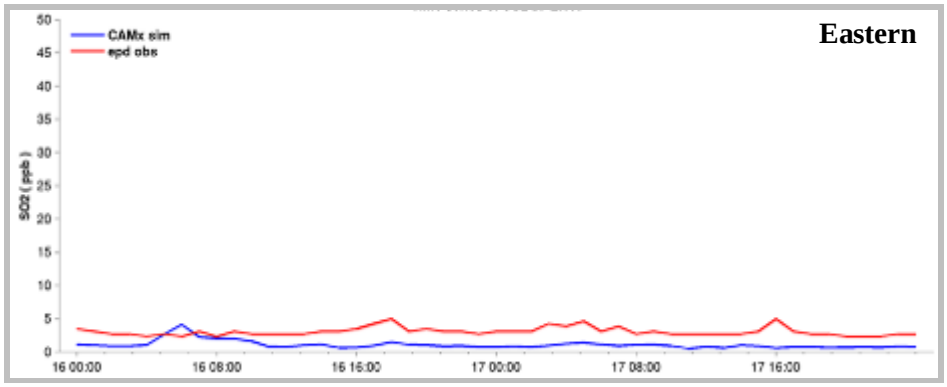
15.2.2. Hence, attention was focused on the period between 16th and 21st of July. After much consideration, the two-day period of 16th and 17th July 2007 was selected for scrutiny because southerly wind was dominant during this period whilst wind direction during the period from 19th to 21st July varied and pattern for 18th July is similar to 16th and 17th July. With southerly wind, regional influence on air quality can be ignored, and marine sources were established as the key contributor of SO_2 in the ambient air around Kwai Chung area.

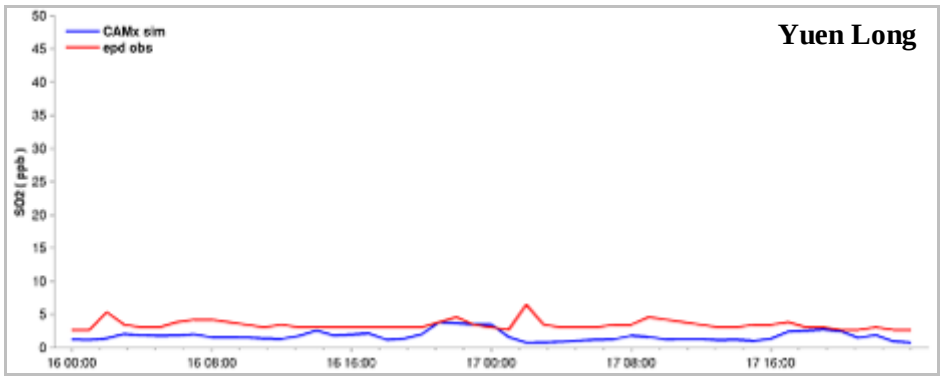
15.2.3. Simulated results at selected monitoring stations on 16th and 17th of July were shown and compared to observed readings in Figure 15-5. From the graphs, it is apparent that:

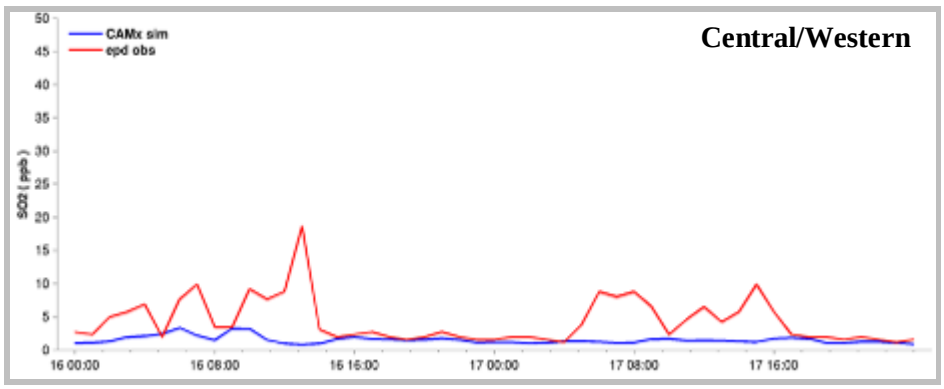
- Eastern in the east and Yuen Long in the west (can be treated as "background" stations) had very low SO_2 concentration contributed from marine source. This is expected since these two stations are far away from major marine sources; marine emission is likely to have minimal impact;
- Central/Western, which is to the south of major marine sources, was not affected by marine emission on both days since the wind was southerly. Occasional high

observed readings did not match with the simulation, which may be due to power plant emissions from Lamma Island at upwind location; and

- Kwai Chung to the north and Tsuen Wan to the north-west of major marine emission sources saw SO_2 concentrations more than 10 ppb (about 26 ug/m^3) higher than that of the background stations (Eastern and Yuen Long), which shows that marine emission sources had made a large impact to the ambient SO_2 concentration in Kwai Chung and Tsuen Wan.







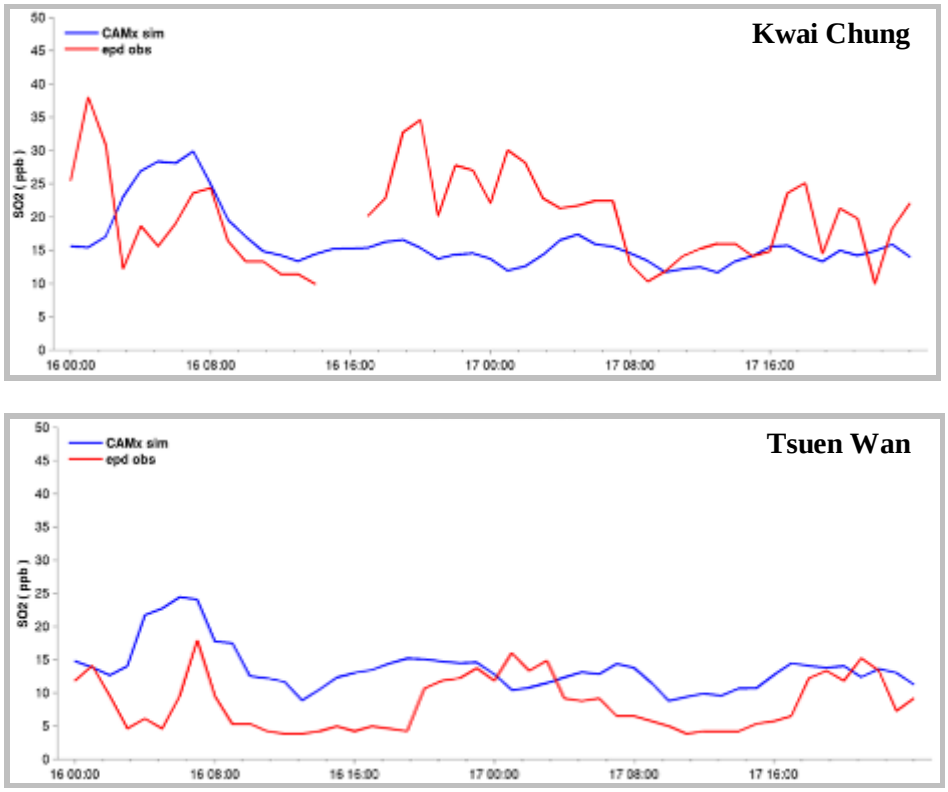


Figure 15-5 Hourly Time Series SO_2 Concentration at Selected Monitoring Stations, 16th to 17th July 2007

15.2.4. From this simple model simulation, it is demonstrated that marine emissions did have an impact on ambient air of Kwai Chung and Tsuen Wan.

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PART VIII POLICY ANALYSIS

16. POLICY OPTIONS FOR MARINE VESSELS EMISSION CONTROL

16.1. Overview

16.1.1. The purpose of this chapter is to provide a simple analysis of policy options that would help reduce marine vessels emission in Hong Kong in the short and medium term. As this Study relates basically to emission inventory, the following discussion only serves as a first attempt on policy discussion for both OGVs and harbour crafts[54]. Overseas experience and best practices were reviewed and studied, to determine the merits and demerits of individual measures, as well as their applicability in Hong Kong.

16.1.2. Marine emissions are drawing more attention in recent years. People's concern over the negative impact of ship emissions on public health is a major driver of change. The impact of global shipping on climate change is another important consideration.

16.1.3. From international organizations, regional bodies, local governments, port authorities to individual companies, policy and control meaures have been put in place to reduce ship emissions within their jurisdictions. Some ports even put aside local rivalry and work together for the common good of a better environment. Some examples to control marine vessels emission by regulations and other initiatives are summarized in the following paragraphs.

Regulations on Ocean-going Vessels

16.1.4. The IMO, a United Nations (UN) agency, adopted Annex VI to the International Convention for the Prevention of Marine Pollution from Ships (MARPOL VI) in 2005. There are measures to regulate SO_2 and NO_X emissions. As far as SO_2 is concerned, MARPOL VI stipulates that the sulphur content of fuel used in ships cannot exceed 4.5%. MARPOL VI also allows a signatory country to apply to the IMO the designation of a Sulphur Emission Control Area (SECA) where the sulphur content of fuel was capped at 1.5%. Subsequently, amendments to MARPOL VI were approved and adopted in 2008, under which global sulphur cap was tightened to 3.5% in 2012 and will become 0.5% in 2020, subject to a review in 2018 on the availability of fuel oil to comply with the standard. SECA was renamed as Emission Control Area (ECA). The fuel cap for ECA has been tightened to 1% since July 2010 and will be further reduced to 0.1% in January 2015. IMO allows for the use of suitable abatement equipment as an alternative to the above fuel requirements. For NO_X, IMO has defined Tier I, II and III NO_X emission standards, with the former two applicable globally whilst Tier III only within ECA (see Table 16-1). The Tier II and III standards represent a 20% and 80% NO_X reduction below Tier I respectively. Hong Kong, which ratified MARPOL VI in June 2008, is now bound by any future modification of the Convention.

[54] The term 'harbour craft' is used overseas to refer to small vessels, which is equivalent to river and local vessels in Hong Kong's context.

Table 16-1 NO_X Limits for Marine Engines (g/kWh)

Tier	Effective Year	n < 130	130 ≤ n < 2,000	n ≥ 2,000
I*	2000	17.0	$45 \times n^{-0.2}$	9.8
II	2011	14.4	$44 \times n^{-0.23}$	7.7
III	2016	3.4	$9 \times n^{-0.2}$	2.0

Notes: n = engine maximum operating speed in RPM; * some existing ships built between 1990 and 2000 would be subject to retrofit requirements of Tier I.

16.1.5. In March 2010, IMO officially designated the North American ECA, covering waters adjacent to the Pacific coast, the Atlantic/Gulf coast and the eight main Hawaiian Islands. The North American ECA, which is the world's third ECA alongside ECAs in the Baltic Sea area and the North Sea area in Europe, will become enforceable in August 2012. The world's fourth ECA, covering waters within 50 nm off the coast of Commonwealth of Puerto Rico and the US Virgin Island, is expected to become enforceable in January 2014.

16.1.6. As from 1st January 2010, a 0.1% sulphur limit on fuel used by OGVs at berth in EU ports was imposed according to Directive 2005/33/EC. Ships which switch off all engines and use shore-side electricity (often referred to as cold ironing or shore power) are permitted as an alternative. Vessels due to be berthed for less than 2 hours according to published timetables are exempted. The regulation also allows an approved emission abatement technology.

16.1.7. Effective from 1st July 2009, all OGVs that operate within 24 nm off the California coastline are mandatorily required to switch from burning high sulphur bunker fuel to low sulphur marine fuel (either MGO at 1.5% sulphur or MDO at or below 0.5% sulphur). Shoreside electricity has been considered as an alternative to diesel auxiliary engines when a vessel is at berth. Similarly, a regulation approved by CARB in December 2007 also required container ships, refrigerated-cargo ships, and passenger ships to reduce emissions when docked at specific California ports, either by the use of alternative power source such as shore power, or by the use of alternative control techniques that achieve equivalent emission reductions. Ultimately, a fleet operator is required to reduce emissions at berth from his vessels' auxiliary engines by 80% by 2020.

Regulations on Harbour Crafts

16.1.8. For harbour craft, low sulphur fuel is being used in most developed countries. California has been mandating diesel of 15 ppm sulphur limit since mid-2006 for harbour crafts. The US and Canada have been using 500 ppm (0.05%) sulphur diesel since mid-2007 and will tighten the limit to 15 ppm by June 2012. According to Directive 2009/30/EC, Member States of the EU shall ensure that, no later than from 1st January 2008, gas oils intended for use by inland waterway vessels and recreational craft may be placed on the market within their territory only if the sulphur content of those gas oils does not exceed 1,000 mg/kg. The latter was tightened to 10 ppm. Member States shall ensure that such liquid fuels be used in inland waterway vessels and recreational craft.

16.1.9. In March 2008, the US finalized the regulation establishing new emission standards

for new Category 1 and Category 2 diesel engines rated over 50 horsepower (hp) used for propulsion in most harbour craft. The new Tier 3 engine standards began phasing in starting in 2009. The more stringent Tier 4 engine standards (based on the application of high-efficiency catalytic after treatment technologies) will phase in beginning in 2014 and will apply only to new and re-manufactured commercial marine diesel engines greater than 800 hp.

16.1.10. In November 2007, CARB adopted a regulation for new and in-use commercial harbour craft operating within 24 nm of the California coastline. All auxiliary and propulsion engines installed in commercial harbour craft must meet the most stringent emission standards of USEPA per a compliance schedule. Newly acquired engines shall meet Tier 2 or Tier 3 standards of the USEPA and engines on new ferries must either be the best available control technology (BACT) or meet Tier 4 standards. The compliance schedule for in-use engine replacement began in 2009.

Other Initiatives

16.1.11. Apart from setting regulations as listed above, various overseas ports have also been adopting voluntary programmes, such as the Northwest Ports Clean Air Strategy in December 2007 to reduce air emissions in the Pacific Northwest for Ports of Metro Vancouver, Seattle and Tacoma, and the voluntary vessel speed reduction (VSR) programme for the Ports of Los Angeles and Long Beach since 2001. Among these programmes initiated by port authorities, the San Pedro Bay Ports Clean Air Action Plan (CAAP) in US is the most notable example. The following paragraphs briefly discuss various voluntary measures under CAAP, as well as in other European and Asian countries and individual liners.

San Pedro Bay Ports Clean Air Action Plan

16.1.12. CAAP is a joint five-year action plan approved by the Ports of Los Angeles and Long Beach in 2006 to reduce emissions related to port operations. It has been widely considered as a benchmark in port and ship emissions reduction and control because of its comprehensiveness (covering OGV, harbour craft, cargo handling equipment, heavy duty vehicle and railroad locomotives) and its ground-breaking, joint-port collaborative framework. Control measures were backed up by the setting of standards and goals, implementation strategies, as well as technological and financial support. For examples, differential tariffs were put in place or financial incentives were provided to encourage participation. New standards were also written in as lease requirements.

16.1.13. The primary objective of CAAP with respect to OGV was to reduce both transit emissions and at-berth emissions. A combination of measures and initiatives were used, including VSR, cleaner fuel, and at-berth emissions reduction through shore-power or other alternative technologies.

16.1.14. For harbour crafts operating in the San Pedro Bay, they have already been using 15 ppm sulphur diesel since mid-2006 as in mentioned in paragraph 16.1.8. As discussed in paragraphs 16.1.9 and 16.1.10, harbour crafts are required to comply with the CARB's in-use harbour craft regulation and the USEPA's recently adopted Tiers 3 and 4 standards. The ports are working towards a goal of repowering all harbour craft home-based in the San Pedro Bay to Tier 3 levels, within five years

after the Tier 3 engines became available, as well as the use of shore power at their home port location. Ports plan to accelerate harbour craft emission reductions through emerging technologies such as hybrid tug, new and more-efficient engine configurations, alternative fuels, and shore power for tugs at berth and at the staging areas, through incentives or voluntary measures.

16.1.15. Another merit of CAAP was its annual review mechanism, which was successful in bringing in new measures since the adoption of the original CAAP. For example, an original measure to improve ME and AE emissions was re-classified to focus on reducing diesel particulate matter (DPM) and NO_X emissions, and a health risk reduction standard was implemented to complement the emission reduction plan.

16.1.16. In summary, there were some significant achievements related to marine vessels:

- VSR started off within 20 nm from the two ports. Compliance rates were 90% for the Port of Los Angeles and 95% for the Port of Long Beach. In 2009, VSR was extended to 40 nm;
- The Vessel Main Engine Fuel Incentive Program was approved in March 2008 to provide financial incentive to vessels using low sulphur fuel in their ME. Subsequently, the CARB vessel fuel regulation was put in place in July 2009, requiring the use of low sulphur fuel in ME, AE and AB;
- The construction of shore power infrastructure was ongoing in both ports. Facilities are now in operation in several terminals, and works will be completed in the remaining terminals by 2014; and
- Compared to 2005 levels, emissions of SO_X, NO_X and DPM from OGV and harbour craft in 2010 were reduced by 74%/91%, 27%/28% and 68%/28% respectively[55].

European Experience

16.1.17. In addition to the EU Sulphur Directive (paragraph 16.1.6), a study submitted to the European Commission recommended packages of measures that include seawater sulphur scrubbing, low sulphur residual oil, humid air engines for new ships, slide valves retrofitting for existing ship engines, and the use of selective catalytic reduction (SCR) technology[56].

16.1.18. For individual port cities, efforts were made to cut port and ship emissions. For examples, shore power was introduced in the port of Goteborg as early as in 2000. Studies were carried out and many are in progress to study the feasibility or construction of shore power in ports like Le Harve, Barcelona, Rotterdam, Amsterdam and Hamburg. Differential tariffs were enforced in Goteborg to penalise ships using high sulphur fuel. Staggered discount on port dues related to a vessel's emission performance has also been introduced in the Port of Hamburg since July 2011. Similar award schemes with port due reduction incentive were in practice in Rotterdam and Amsterdam.

[55] See Tables 9.9 and 9.15 of *Port of Los Angeles Inventory of Air Emissions 2010*, July 2011 in http://www.portoflosangeles.org/pdf/2010_Air_Emissions_Inventory.pdf.
[56] http://ec.europa.eu/environment/air/pdf/06107_final.pdf

Asian Examples

16.1.19. In Asia, where marine vessels emission control regulation is not yet in place, several major shipping lines have taken voluntary actions to reduce their emissions. Since 1st January 2011 in Hong Kong, 17 shipping companies signed on to the FWC for 2 years, under which vessels will switch to fuel with sulphur content of 0.5% or less while at berth. Subsequent to this green initiative in Hong Kong, Taiwan and Singapore have also introduced clean fuel programmes for marine vessels as described in the following paragraphs.

16.1.20. Taiwan is perhaps the only place in Asia at the moment which has devised a comprehensive management strategy to reduce port and ship emissions in the short, medium and long term. It was a collaborative effort between the Environmental Protection Administration Taiwan (EPAT) and USEPA for partnership and exchange. Under the strategy, emission reduction measures were included to tackle OGVs, harbour crafts, cargo handling equipment, trucks, railroads and other fugitive sources. With respect to OGV, speed reduction, fuel change and the use of shore power are the key recommendations. Fuel change to 10 ppm sulphur diesel and use of shore power were recommended for harbour crafts.

16.1.21. In Singapore, the Maritime Singapore Green Initiative was announced in April 2011. The Maritime and Port Authority of Singapore (MPA) will provide incentives to (a) all OGVs that use type-approved abatements technology or low sulphur fuel in the form of port dues reduction, (b) Singapore-flagged ships that adopt energy efficient ship designs in the forms of reduction in ship initial registration fee and a rebate on annual tonnage tax, and (c) local maritime companies that develop and adopt green technologies in the form of costs rebate.

16.1.22. In the Shenzhen ports of Yantian and Shekou, trial schemes on shore power are ongoing, with the twin aims of improving energy efficiency and reducing emissions, which are in line with the principles of China's Twelfth Five-Year Plan.

Individual Liners

16.1.23. The practice of operating at slower vessel speed, also known as slow steaming, will significantly reduce fuel consumption and hence emissions. In recent years, a number of ocean carriers have turned their attention to slow steaming, even without regulatory requirements, as a corporate strategy to combat adverse economic environment, over-capacity, and hiking fuel price.

Emission Control Measures

16.1.24. Table 16-2 below summarizes a series of OGV emission control measures implemented or under consideration in different ports around the world. It gives an impression about the major policy directions in terms of ship emissions reduction. However, it is important to note that there are other measures not listed in Table 16-2, not because they are not being considered or they are ineffective, but because these measures are usually considered at the corporate level, rather than recommended by port authorities. The adoption of appropriate emission reduction technology on ships is one example. Even though the government or port authority may provide incentive, the final decision rested with ship owners or operators. By

the same token, ECA is not included in Table 16-2 as it will require a country member of IMO to apply for the establishment of an ECA.

Table 16-2 Common OGV Emission Control Measures Considered by Port Authorities

	Fuel switching in transit	Fuel switching at berth	Vessel speed reduction	Shore power	Differential tariffs
Los Angeles / Long Beach	√	√	√	√	
Goteborg		√		√	√
Hamburg		√		√	√
Le Havre		√		√	
Barcelona		√		√	√
Antwerp		√		√	
Rotterdam		√		√	√
Amsterdam		√		√	√
Taiwan ports	√	√	√	√	
Singapore		√			√
Yantian / Shekou				√	

16.1.25. Emission control measures for harbour craft are similar. Key measures that are commonly adopted overseas include: (a) use of low sulphur fuel, comparable to OGV fuel switching in transit and at berth; (b) shore power; (c) higher engine emission standard, comparable to IMO's NO_X standard. It is important to note that while vessels at slower speed will emit less air pollutant, effect of vessel speed reduction on harbour craft is less prominent.

16.2. Policy Evaluation

16.2.1. In this section, a number of common OGV emission control strategies were evaluated, based on the following criteria: (a) technical feasibility, (b) institutional support, (c) emission reduction benefits, (d) financial costs, and (e) operational viability. The strategies to be covered include fuel switching, shore power, speed reduction, and ECA. Thereafter, a brief discussion on harbour craft emission control strategies is provided.

Technical Feasibility

16.2.2. In general, it is proven that low sulphur distillate fuels can be used in ME and AE without much difficulty. Some AB may need some modifications to use the distillate fuel. CARB conducted a survey in 2009 to understand the operational experience of OGV performing fuel switching. Findings show that while there were equipment problems and issues in maneuvering operations, 85% of the operators had reported either excellent or good experience with fuel switching.

16.2.3. Vessel speed reduction may require adjustment of propellor and engine for optimal

performance at sustained slow speed operation.

16.2.4. For many years, the technology to provide ships with electrical connections from shore is already in place. However, the promotion of shore power at berthing locations still faces a number of barriers. For example, the variation in power demand for different types of vessels is huge. Shore-side power supply facility may not be able to support all vessel types without careful planning. There is also the issue of different system voltage and system frequency. At the moment, frequency converter is often required to facilitate the use of shore power.

Institutional Support

16.2.5. One of the most effective ways to manage air quality is by standards and regulation. Experience in the world showed that while voluntary measures such as fuel switching and speed reduction proved to be a useful first step to engage the industry and to introduce new measures, regulation is much preferred as it creates a level playing field for all competitors. As illustrated by CAAP, control strategies complemented by standards and targets could be a very powerful tool to drive change and improvement.

16.2.6. In a different context where shore power is to be promoted, government support can be valuable in two aspects. First, it can come as a contractual requirement. For example, tenants at the Ports of Los Angeles and Long Beach are to provide shore power to vessels as a lease requirement. Similarly, provision of shore power supply facility can be written into the contract of new terminals. Second, government may provide incentives for key players, such as electricity companies and terminal operators, to invest in shore power supply.

16.2.7. To make shore power a more attractive proposition, shore power supply must be standardized. In 2009, an IEC/ISO publicly available specification (PAS) was published, followed by working group meetings involving important stakeholders like ship owners, terminal operators, utility companies and equipment manufacturers. At the time of writing, the full international standard to be endorsed by IEC/ ISO/ IEEE is close to completion and its publication should not be later than April 2012, i.e. within three years of PAS.

Emission Reduction Benefits

16.2.8. In terms of emission reduction benefits, it is well documented that fuel switching at berth from HFO to low sulphur distillate fuel (0.5% sulphur at most) will reduce SO_2 and PM_{10} emissions by about 80%. Its contribution to total emission will of course depend on the share of at-berth emissions, fuel sulphur content and fuel switching participation rate. For example, switching to 0.1% sulphur fuel will push SO_2 and PM_{10} reduction to 90%. However, a low participation rate may reduce the level of improvement.

16.2.9. If fuel switching is also performed when the vessel is underway, its emission reduction potential will be further enhanced, because part of the transit emissions will also be eliminated. By the same token, if the use of clean fuel is extended to a larger area like an ECA, emission reduction benefits will be extremely significant. It is especially true as under an ECA, there will be additional control over engine

standards (paragraph 16.1.4), contributing to the reduction of NO_X.

16.2.10. The use of shore power will also bring along emission reduction benefits. Imagine a vessel plugging into shore power instead of burning bunker fuel at berth to keep the generators and boilers on. The size of benefits should be comparable to fuel switching at berth. However, the greatest benefits will be realized only if electricity is generated by clean energy. Otherwise, it will be seen as merely a transfer of air pollution from the port to the power plants. As power plant control is tightened continually by imposing emission cap, thus leading to increasing portion of electricity generated by natural gas or coal mitigated with control technologies, shoreside electricity is cleaner than that generated by generators using low sulphur diesel.

16.2.11. Engine power is related to vessel speed by a third power function according to the Propeller Law. In other words, reduction in vessel speed will bring an even larger reduction in engine power requirements. Less fuel will be burned, and emission will be reduced. However, sailing time will be increased due to lower speed over the same distance, which will offset some of the emission reduction benefits. Nevertheless, it is reckoned that emission reduction benefits are much greater than the extra emissions caused by longer sailing time.

Financial Costs

16.2.12. All the control measures discussed in this section will incur additional costs, including vessel speed reduction in the form of higher logistic costs of moving goods (though fuel cost will be less). For example, fuel switching will involve paying high fuel costs by the operators, mainly to cover the cost difference between HFO and distillate fuel. It was quoted that a company who joined the Fair Winds Charter in Hong Kong would have to pay over US$1 million extra each year to cover the higher low sulphur fuel costs. Similarly, shore power will require significant investment in both shore-side and ship-side facilities.

Operational Viability

16.2.13. Whilst all measures are being implemented overseas, there may be different level of operational issues arising from their experiences that shed light on their operational viability. The latter may also indicate the level of readiness by the trade in accepting the control measures and crews training required to implement such measures.

Harbour Craft Policy Evaluation

16.2.14. The three measures for harbour crafts mentioned in paragraph 16.1.25 were evaluated in the following paragraphs. In general, each of them will produce less emission reduction benefits from harbour crafts than from OGVs, because (a) the initial fuel used by OGVs is residual oil, which is much higher in sulphur content than the diesel currently used by harbour craft, thus leading to less benefits in SO_2 and PM reduction; and (b) the engine power rating is much lower per engine, thus leading to less NO_X reduction benefits per engine.

16.2.15. Use of low sulphur fuel – in-depth technical and financial assessment was conducted by CARB staff prior to CARB's adoption of 15 ppm sulphur diesel for harbour craft

effective from mid-2006. EU has also been using 0.1% and 10 ppm sulphur diesel for harbour craft since 1st January 2008 and 2011, respectively. HKSAR government conducted a trial of local ferries using ULSD in 2009-10 and confirmed technical feasibility, Thus, both overseas and local experiences have demonstrated the technical and operational feasibility. Financial costs depend on logistic cost, mostly affected by the delivery cost of fuel from oil terminal to end-use harbour craft by oil carriers. Specifically, this is related to whether tank flushing is necessary, which in turn depends on whether territory-wide requirement of institutional support is available.

16.2.16. Use of shore power – various places have low voltage shore power installations including Taiwan ports and some local spots in Hong Kong, thus demonstrating the technical and operational feasibility. Financial costs are favourable as set-up cost for low voltage system is relatively small and the payback period is short in view of the higher diesel cost over onshore electricity charge. Institutional support may be in form of its adoption by government infrastructure projects but unlikely mandatory requirement, given that there is no legislative precedent overseas.

16.2.17. Higher engine emission standard – IMO has NO_X whilst the US has NO_X, PM, HC and CO emission limits for marine engines, under different tier systems. IMO, the US and California have mandatory time-table to phase in their implementation. Engine manufacturers have been launching products to meet the requirements, assuring the technical and operational feasibility. Emission reduction benefits depend on which tier is used, with greatest for tier 4 of USEPA. Financial costs will depend on the engine replacement schedule: the least for business-as-usual on natural retirement of engines. Institutional support in form of government subsidy for early engine replacement will be needed for speedier introduction.

16.3. Discussions

16.3.1. In Hong Kong, at the time of writing, voluntary fuel switching at berth is up and running. The administration is also exploring the scope of providing shore power at the first berth of the new Kai Tak Cruise Terminal. In the following paragraphs, the feasibility of implementing the above control measures will be briefly discussed.

16.3.2. As far as technical feasibility is concerned, fuel switching appears to be the most favourable, followed by vessel speed reduction and shore power. In view of the inadequate supply of 0.1% sulphur fuel in the market, the prospect of establishing an ECA remains to be long-term.

16.3.3. In terms of institutional support, works remain to be done to improve the situation. However, amongst the measures, perhaps regulation related to fuel switching at berth in Hong Kong will be more straightforward, as forerunners within the shipping industry have already committed to a voluntary scheme. In comparison, the other measures will require a lot of support, involving different stakeholders, and even different levels of government agencies.

16.3.4. For emission reduction benefits, Table 16-3 below summarized preliminary emission reduction potential estimation of various control strategies in 2020. Figures shown in the table are only rough estimate as they are based on various assumptions and subject to review upon detailed policy analyses to be conducted in the future.

Both vessel speed reduction and shore power have two scenarios: higher and lower values for with and without fuel switching in transit respectively. The higher values are chosen in the following discussions. It was also assumed that all strategies are independent with each other. Comparing emission reduction potential on such basis, fuel switching within Hong Kong waters, with or without ECA, will bring most SO_2 and PM reduction benefits, followed by fuel switching at berth and then vessel speed reduction programme. ECA will bring additional benefits to SO_2 and PM reduction in adjacent waters, as well as NO_X reduction benefits. Emission reduction potential by shore power seems modest, but the benefits will rise if all OGVs turn to shore-side electricity supply while at berth.

Table 16-3 Emission Reduction Potential of Different Control Strategies

	Fuel switching in transit	Fuel switching at berth	Vessel speed reduction	Shore power	ECA
SO_2	80%	29%	8%	4%	80%
NO_X	3%	1%	7%	2%	12%
PM_{10}	64%	18%	7%	4%	64%
VOC	0%	0%	1%	1%	0%
CO	0%	0%	1%	1%	0%

Notes: Fuel switch to 0.1% sulphur fuel at berth or in transit; vessel speed reduction at 12 knots limit; 100% ocean cruise using shore power at Kai Tak Cruise Terminal and 20% of FCCV at KCCT; 0.1% sulphur fuel and NO_X tier 3 regulation for ECA; reduction within Hong Kong waters only.

16.3.5. The investment costs of shore power will be quite high, relative to the fuel switching costs. At the other end of the scale, vessel speed reduction may even help shipping lines to cut fuel costs.

16.3.6. Lastly, the operational viability is the highest for fuel switching at berth as illustrated with the FWC being operational in 2011 to 2012. Similarly, shore power as an approved alternative to EU's Directive for fuel switching at berth should also be at a similar level. Notwithstanding that most vessel operators are successfully complying with the CARB regulation for fuel switch in transit without incident, some operators have reported operational difficulties. Similarly, most ships had already slowed down to save on costs, it is difficult to impose mandatory limit for vessel speed reduction as operators need flexibility to respond to changing market conditions. Thus, both fuel switching at transit and vessel speed reduction are less feasible operationally. ECA should be the least, given the additional NO_X control over fuel switching at berth.

16.3.7. Based on the discussions above, a simple scorecard was created to compare the merits and demerits of the various OGV measures. (Table 16-4) It is apparent that fuel switching is a prime candidate to be promoted in the short term. In the medium term, efforts should be made to study vessel speed reduction and shore power thoroughly, and to engage the trade on these two policy directions. In the long run, the establishment of an ECA in the PRD region is extremely important, which is supported by the emission reduction potential and associated health benefits.

Table 16-4 Emission Reduction Strategy Scorecard of OGV Measures for Hong Kong

	Fuel switching in transit	Fuel switching at berth	Vessel speed reduction	Shore power	ECA
Technical Feasibility	*****	*****	****	****	***
Institutional Support	**	***	**	**	*
Emission Reduction Benefits	****	***	**	**	*****
Financial Costs	**	***	****	*	*
Operational Viability	**	***	**	***	*

Keys: ***** most favourable *** average * least favourable

16.3.8. Based on paragraphs 16.2.14 to 16.2.17, a similar emission reduction strategy scorecard was prepared for measures suitable to harbour craft. (Table 16-5) Use of low sulphur fuel is the most favourable option, followed by use of shore power. The higher engine emission standard is least favourable at this moment.

Table 16-5 Emission Reduction Strategy Scorecard of Harbour Craft Measures for Hong Kong

	Use of low sulphur fuel	Use of shore power	Higher engine emission standard
Technical Feasibility	*****	*****	****
Institutional Support	**	**	**
Emission Reduction Benefits	***	**	****
Financial Costs	***	***	**
Operational Viability	****	****	**

Keys: ***** most favourable *** average * least favourable

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PART IX CONCLUSION

17. CONCLUSION AND RECOMMENDATION

17.1. Improvements to Past Emission Inventories

17.1.1. This Study has contributed to a number of improvements to past emission inventories. These were achieved partly due to the availability of new data, such as MD's vessel track data, and partly due to advancement in the international practice of marine vessel emission inventory compilation.

17.1.2. Notably, there was a better understanding of marine fuel used by different types of vessels visiting Hong Kong through the Marine Vessel Survey. With such information, estimation of marine emission as a function of the quality of marine fuel was greatly enhanced.

17.1.3. The inclusion of boiler emissions in this Study was another significant step towards a more comprehensive marine vessel emission inventory for Hong Kong. This was made possible by the boiler information collected from local survey and overseas publications.

17.1.4. Time-in-mode information was greatly improved, as more information was gathered from MD's vessel activity reports (hotelling time) and vessel track data (slow cruise / maneuvering time).

17.1.5. Main engine load factor for vessels sailing in Hong Kong waters was estimated by the vessel speed information embedded in the vessel track data. It allowed the use of local data, rather than adopting load factors developed in other parts of the world, which again was an improvement.

17.1.6. Main engine power data was extracted from LRS, rather than being estimated by GRT as in the past, which vastly reduced the uncertainty factor related to past assumption and estimation of main engine power.

17.1.7. With the above improved data, quantitative analysis for uncertainties of marine vessel emissions was conducted for OGVs and RVs of 2007.

17.1.8. Last, but not least, a new temporal and spatial dimension was added to the marine emission inventory. It facilitates the identification of emission hot spots and greatly enhances air quality modeling, and in turn helps the formulation of effective emission control strategies.

17.2. Areas for Further Improvement

Data Quality and Data Gaps

17.2.1. Broadly speaking, the quality of data collected for OGV was very good. The situation was helped by the fact that information related to OGV was often available from more than one source, allowing cross-checking and verification and consequently the weeding out of errors. Whilst RVs do not have the same level of OGVs data quality, much improvement over the past has also been achieved. The much enhanced data quality of both OGVs and RVs has led to the low and

comparable uncertainties of their emission inventories. (see Chapter 6)

17.2.2. However, there are data gaps in auxiliary engine and boiler information. Similarly, there is a general lack of comprehensive RV information, such as time-in-mode, fuel quality and consumption. Acquisition of these information through additional local surveys or vessel boarding programme similar to California will largely reduce uncertainties and greatly enhance emission estimation.

17.2.3. Quality of fuel used by RTVs should be reviewed since distillate fuel with 0.5% sulphur content was assumed in this study. It is also useful to find out if boilers are installed onboard of tankers operated as RVs, and their emissions should be included in future emission estimates if applicable.

17.2.4. Uncertainty characterization for AE LFs or power demand were based on overseas PoLA studies (2006-2009). Similarly, AB energy defaults were adopted from PoLA reports. Local data should be collected in future to become more representative and to reduce uncertainty. Furthers work for AE and AB should first focus on top emitters such as FCCV, cruise/ferry and oil tanker.

17.2.5. While the development of local emission factors is important in reducing uncertainty, it is acknowledged that the measurement of emission factors of marine sources is time-consuming and very costly. A more effective way to approach this issue is to cooperate with port authorities and research institutes in other parts of the world, particularly those in China. Similarly, tracking the penetration of emission reduction technologies like MAN slide fuel valve should continue for inclusion of adjustment factor after base year 2007. That would require continual contact with stakeholders like engine manufacturers.

17.2.6. Detailed information related to multiple berthing is lacking. As explained in paragraph 2.2.11, shifting time between different berthing locations was ignored in this Study. In reality, multiple berthing is in practice in Hong Kong, especially among RTVs, and this is clearly an area that warrants further investigation.

17.2.7. Spatial distribution was based on 2 weeks' radar data. Radar data is also not available for small vessels that do not equip with Automatic Identification System. Such data gaps may be filled by analyzing a full year's radar data and surveying spatial distribution for river and local vessel activities. Similarly, there are data gaps related to temporal distribution. A full year of radar data showing seasonal variations will substantially improve data quality and reduce uncertainty.

Air Quality and Health Study

17.2.8. An air dispersion model was developed using PATH and SO_2 to demonstrate the contribution of marine source to air quality in the vicinity of KCCT and the built-up areas adjacent to Victoria Harbour. Noting the proximity of marine source to the public, health impact arising from the modeled results should be studied as the next step. Such study may also be conducted on a micro level and at different areas (e.g. the northeastern part of Hong Kong which is affected by the growing marine traffic to and from the Port of Yantian in Shenzhen), and other air dispersion models like

ADMS or AERMOD[57] may serve the purpose better.

Joint Study for Pearl River Delta Waters

17.2.9. While the main task of this Study is to compile marine vessels emission inventories for Hong Kong, it must be acknowledged that the operation of the neighbouring Guangdong ports, in particular the Shenzhen ports of Yantian, Shekou, Mawan, Chiwan and Da Chan Bay, are making an impact on air quality in Hong Kong.

17.2.10. First, the rapid growth and expansion of Shenzhen ports over the last decade has led to an increase in the number of vessels transiting Hong Kong. Vessels calling Shekou might choose to sail through Hong Kong because of the deeper channels (hence avoiding delays due to unfavourable tidal conditions) and better pilotage service. To the East, marine traffic has increased tremendously due to the continuous expansion of Yantian port.

17.2.11. Second, air pollution has no boundary. Even if vessels calling Yantian or Shekou or other Guangzhou ports do not pass through Hong Kong but instead sail via Tonggu and Lingding Channels and hence not emitting within the boundary of Hong Kong waters, they are operating close enough to Hong Kong that any emissions would disperse into Hong Kong's air shed and impact on Hong Kong people. Study for all marine vessels plying within the PRD Region should thus be worthy of future exploration. Such study was mentioned under the public consultation on initial proposals for the Regional Cooperation Plan on Building a Quality Living Area by the Hong Kong, Guangdong and Macao governments on 1st September 2011[58].

17.2.12. Third, even though some of the container facilities in Shenzhen ports are owned/co-owned and managed by Hong Kong's container terminal operators, competition remains fierce among the ports in the PRD area. Port rivalry could alter logistics of import and export which then affect distribution of marine vessel activity among the ports of Hong Kong, Shenzhen and Guangzhou. A joint study of marine vessel emissions embracing all ports within PRD Region will be extremely useful, regardless of future changes in cargo distribution among the PRD ports.

17.2.13. Such a joint study will contribute significantly in enhancing the quality of the existing and future marine vessel emission inventories. Consequently, the governments concerned will be able to make informed decisions on policy, control measures and air quality management plans related to the marine sources. The joint study will also benefit port authorities in the Pearl River Delta region, who are facing astronomical growth in port throughput and the associated public health risk. When combined, the ports of Hong Kong, Shenzhen and Guangzhou in 2010 handled about 59 million TEUs of the world's container throughput, and the figure is still growing. Therefore, there is a pressing need for Hong Kong, Shenzhen and Guangzhou to devise together a green port strategy for the region, and the basis for an effective strategy would be an accurate regional emission inventory for marine vessels and other port-related sources.

[57] ADMS and AERMOD are atmospheric dispersion models developed in the UK and US, respectively.

[58] See http://www.gprd-qla.com/. Prior to the consultation document, there were three policy documents referring to vessel emission reduction, that is, the Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020), Study on the Action Plan for the Bay Area of the Pearl River Estuary (2009-11); and Framework Agreement on Hong Kong/Guangdong Cooperation (2010).

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APPENDIX A

MARINE VESSEL SURVEY (OGV) SURVEY FORM (IN ENGLISH AND CHINESE)

Confidential

Survey Form

for

Ocean-going / River Vessels
Calling at Hong Kong

Survey Period: 1 February – 30 April 2009

Prepared by

Institute for the Environment
Hong Kong University of Science and Technology

on behalf of

Environmental Protection Department
HKSAR Government

Please "X" the appropriate box ☐

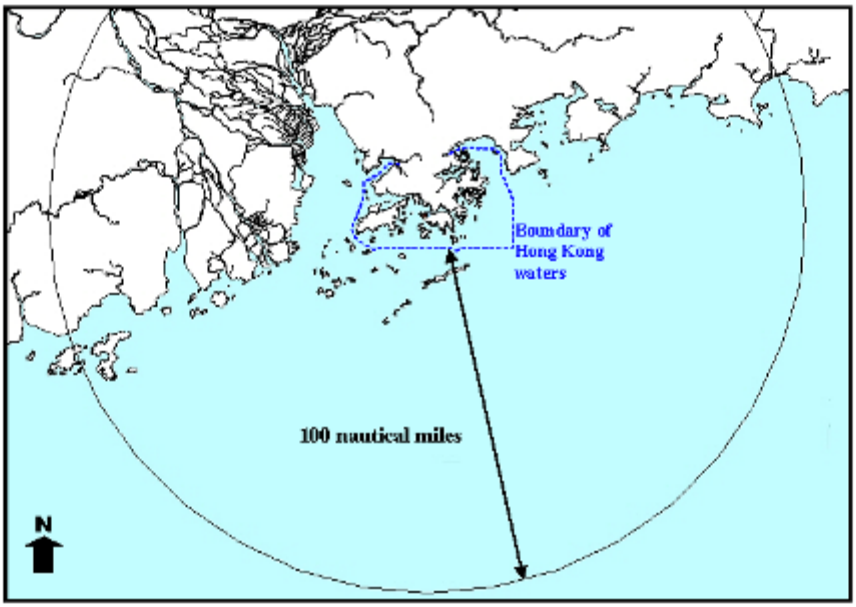
Completed form to be returned within one week of departing Hong Kong.

Information Notes for Marine Vessel Survey Form

Units, Abbreviations and Terms used in the Survey Form

DWT: Dead Weight Tonnage
HFO: Heavy Fuel Oil, also known as Marine Residual Oil (MRO)
HK: Hong Kong
hp: horse-power
kg/h: kilogram/hour
kg: kilogram
kW: kilowatt
liter/h: liter/hour
LOA: Length Overall
MCR: Maximum Continuous Rating
MDO: Marine Diesel Oil, also known as distillated oil
MGO: Marine Gas Oil, distillated oil with higher quality
MRO: Marine Residual Oil
RPM: Revolution per Minute
S%: Sulphur content

Map showing HK waters and within 100 nautical miles of the HK coastline



Survey on Ocean-going / River Vessels Calling at Hong Kong, 1 February – 30 April 2009 HKUST

1 Vessel Information

Vessel Name: _____	**IMO Number:** _____	☐ **Ocean-going Vessel** ☐ **River Vessel**
Ship Owner: _____	**Operating Agent:** _____	

Vessel Type: ☐A. Chemical Carrier/Tanker; ☐B. Conventional Cargo Vessel; ☐C. Cruise/Ferry; ☐D. Dry Bulk Carrier;
☐E. Fishing/Fish Processing Vessel; ☐F. Fully Cellular Container Vessel; ☐G. Gas Carrier/Tanker; ☐H. Lighter/Barge/Cargo Junk;
☐I. Oil Tanker; ☐J. Pleasure Vessel; ☐K. Roll On/Roll Off; ☐L. Semi-container Vessel;
☐M. Tug; ☐N. Others (please fill in) _____

Maximum Vessel Speed:____ ☐knot(nm/h) ☐km/h	**Vessel LOA:** _____ meters	**DWT:** _____ Metric tons	**Gross Tonnage :** _____

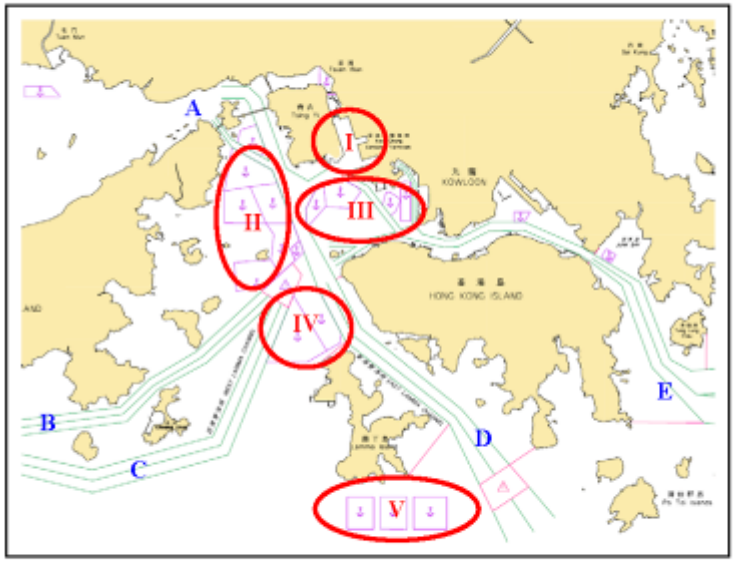
2 Call Information

Arrival: ____/____/ 2009 (dd/mm/yyyy)
Departure: ____/____/ 2009 (dd/mm/yyyy)

Last Port: _____ **Next Port:** _____

Berthing Locations: (you may tick more than one)
☐I ☐II ☐III ☐IV ☐V ☐Tuen Mun River Trade Terminal
☐PCWA: (please fill in)_____
☐Others: (please fill in)_____

Routing:
You enter Hong Kong waters through: ☐A ☐B ☐C ☐D ☐E
You depart Hong Kong waters through: ☐A ☐B ☐C ☐D ☐E



Berthing Site:
I: Kwai Chung Terminals
II: Western Anchorage
III: Western Dangerous Anchorage and Yau Ma Tei Anchorage
IV: North Lamma Anchorage
V: South Lamma Anchorage

Shipping Route:
A: Ma Wan Fairway
B: Adamasta Chanel
C: West Lamma Channel
D: East Lamma Channel
E: Tathong Channel

1

3 Engine Information

3.1 Main (Propulsion) Engine (For diesel-electric/ generator-set engine on cruise ships, please list them under "3.2 Auxiliary engine/generator" on Page 3)

Number of Main Engines: _____	**Engine Type:** ☐Gas turbine ☐Steam turbine ☐2-Stroke diesel engine ☐4-Stroke diesel engine	
Total MCR Power: _____ ☐kW ☐hp	**RPM at MCR:** _____	**Engine Speed Type:** ☐High ☐Medium ☐Slow
Fuel Used #1: ☐HFO ☐MDO ☐MGO, S% _____		**Fuel Used #2:** ☐HFO ☐MDO ☐MGO, S% _____
Average Fuel Consumption per Hour: 1) Average outside HK waters (within 100 nautical miles from HK coastline): _____ ☐kg ☐liter 2) Average within HK waters _____ ☐kg ☐liter		
Main Engine Operating Hours (from entering to leaving Hong Kong waters) : **1) Underway outside** Hong Kong waters (within 100 nautical miles from HK coastline) _____hours; **2) Underway within** Hong Kong waters _____ hours; **3) Maneuvering*** _____ hours; **4) Loading/Unloading** _____ hours; **5) Berthing**** _____ hours		
Operating Power and Vessel Speed: Power used when **underway outside** Hong Kong waters: _____ ☐kW ☐hp, **Vessel Speed:** _____ knot Power used when **underway within** Hong Kong waters: _____ ☐kW ☐hp, **Vessel Speed:** _____ knot Power used when **maneuvering*** within Hong Kong waters: _____ ☐kW ☐hp, **Vessel Speed:** _____ knot Power used when **loading/unloading** within Hong Kong waters: _____ ☐kW ☐hp, **Vessel Speed:** 0 knot Power used when **berthing**** within Hong Kong waters: _____ ☐kW ☐hp, **Vessel Speed:** 0 knot		
Do you switch fuel in your main engine(s)? **Outside Hong Kong Waters:** ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **S% from** _____ **To** _____ **(ii) Time** _____hours before entering and _____ hours after leaving HK Waters		**Within Hong Kong Waters:** ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **S% from** _____ **To** _____ **(ii) During** ☐Underway ☐Maneuvering* ☐Loading/Unloading ☐Berthing**

* Maneuvering is when vessel moves at very slow speed executing a turn or other maneuver just before/after mooring at buoy/anchorage or berthing.
Berthing mode **does not include loading/unloading.

3.2 Auxiliary Engine/Generator and all Diesel-Electric Engines (excluding emergency and standby engines)

Engine	Engine #1	Engine #2	Engine #3	Engine #4	Engine #5	Engine #6
MCR Power	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Engine Type	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke	☐Gas Turbine ☐Diesel Engine ☐2-Stroke ☐4-Stroke
Fuel Type used within Hong Kong Waters	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____	☐HFO: S%____ ☐MDO: S%____ ☐MGO: S%____
Average Fuel Consumption per hour	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter
Auxiliary engine operating hours:						
1) Underway						
outside HK waters	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No
within HK waters	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No
2) Maneuvering*	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No
3) Loading/Unloading	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No
4) Berthing**	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No	☐Yes___hrs ☐No
Combined power generated from the above auxiliary engine(s) when:						
1) Underway: _____ ☐kW ☐hp; **2) Maneuvering*** _____ ☐kW ☐hp; **3) Loading/Unloading** _____ ☐kW ☐hp; **4) Berthing**** _____ ☐kW ☐hp						
Do you switch fuel in your auxiliary engine(s)?						
Outside Hong Kong Waters: ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **(ii)Time** _____ hours before entering and _____ hours after leaving HK Waters			**Within Hong Kong Waters:** ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **(ii) During** ☐Underway ☐Maneuvering* ☐Loading/Unloading ☐Berthing**			

3.3 Onboard Boiler (excluding standby boilers)

Boiler	Boiler #1	Boiler #2	Boiler #3	Boiler #4
Capacity	_____ ton Steam/hour	_____ ton Steam/hour	_____ ton Steam/hour	_____ ton Steam/hour
Purpose	☐Providing hot water ☐Heating residual oil ☐Producing steam for pumps ☐Others: _____	☐Providing hot water ☐Heating residual oil ☐Producing steam for pumps ☐Others: _____	☐Providing hot water ☐Heating residual oil ☐Producing steam for pumps ☐Others: _____	☐Providing hot water ☐Heating residual oil ☐Producing steam for pumps ☐Others: _____
Fuel Type used within Hong Kong Waters	☐HFO: S%_____ ☐MDO: S%_____ ☐MGO: S%_____	☐HFO: S%_____ ☐MDO: S%_____ ☐MGO: S%_____	☐HFO: S%_____ ☐MDO: S%_____ ☐MGO: S%_____	☐HFO: S%_____ ☐MDO: S%_____ ☐MGO: S%_____
Average Fuel Consumption per Hour	_____ ☐kg/hour ☐liter/hour	_____ ☐kg/hour ☐liter/hour	_____ ☐kg/hour ☐liter/hour	_____ ☐kg/hour ☐liter/hour
Boiler Operating Hours				
1) Underway outside HK	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours
2) Underway within HK	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours
3) Maneuvering*	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours
4) Loading/Unloading	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours
5) Berthing**	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours	Duration: _____ hours
Do you switch fuel in your boiler(s)				
Outside Hong Kong Waters: ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **(ii)Time** _____ hours before entering and _____ hours after leaving HK Waters			**Within Hong Kong Waters:** ☐Yes ☐No; If Yes, please continue **(i) From** ☐HFO ☐MDO ☐MGO **To** ☐HFO ☐MDO ☐MGO; **(ii) During** ☐Underway ☐Maneuvering* ☐Loading/Unloading ☐Berthing**	

^ Is your vessel a regular visitor to the port of Hong Kong? ☐Yes ☐No; If Yes, **how often?** _____ calls in 2008

 # Survey form completed by: **Name:** _____ **Date:** _____/_____/ 09 (dd/mm) **Email address:** _____

- End of Survey. Thank You -

機密文件

抵港（香港）
遠洋船隻 / 內河船隻
調查表

調查時間：2009 年 2 月 1 日至 4 月 30 日

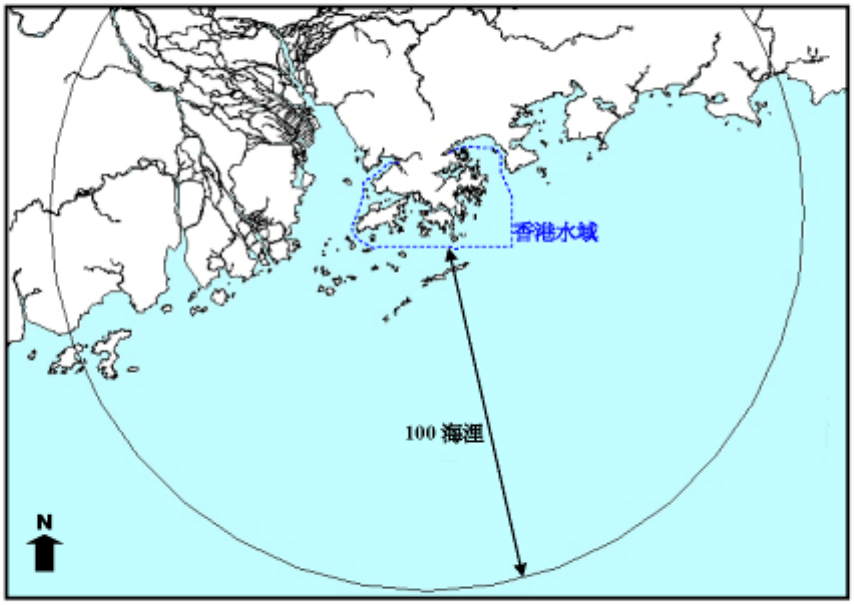
由香港科技大學環境研究所
代表香港特區政府環境保護署擬定

請在方格□內標示 "X"

請在船隻離港 1 周內交付此調查表

調查表補充資料

地圖：香港水域及香港海岸線 100 海浬範圍



1 船隻資料

船隻英文名稱：____	**船隻中文名稱（如適用）：**____	**IMO 號碼：**____	☐ **遠洋船** ☐ **內河船**
船東：____		**運營代理商：**____	
船隻類型: ☐**A**. 化學品運載船； ☐**E**. 漁船/魚類加工船； ☐**I**. 油輪； ☐**M**. 拖船；	☐**B**. 普通貨船； ☐**F**. 全槽格式貨櫃船； ☐**J**. 遊樂船舶； ☐**N**. 其他類型船（請補充）____	☐**C**. 郵船/渡輪； ☐**G**. 液化氣體運載船； ☐**K**. 滾裝船；	☐**D**. 散裝乾貨船； ☐**H**. 駁船/躉船/貨艇； ☐**L**. 半貨櫃船；
船隻最高航速：____ ☐節（海浬/小時）☐公里/小時	**船長：**____ 米	**載重噸位（DWT）：**____ 噸	**總噸位（GT）：**____ 噸

2 航次資料

抵港日期：2009 /　　/　　/(年/月/日)
離港日期：2009 /　　/　　/(年/月/日)

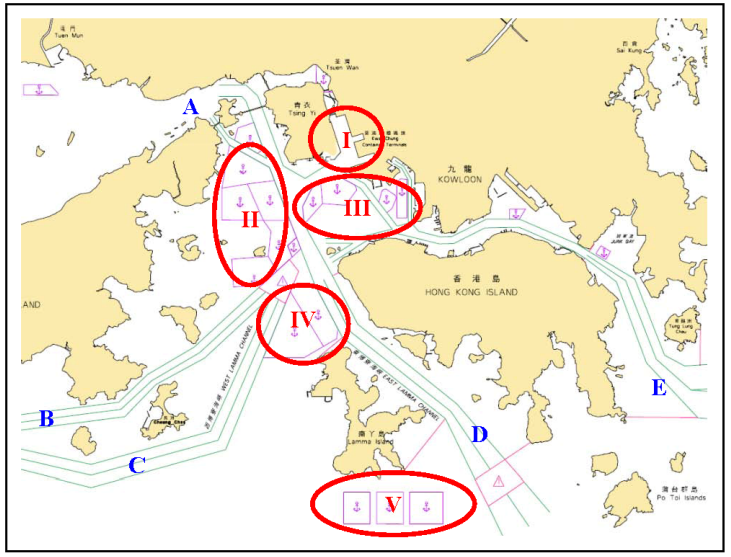
上一個停靠港：____　　**下一個停靠港：**____

停泊位置： (可選多項)
☐I ☐II ☐III ☐IV ☐V ☐屯門內河船碼頭
☐公衆貨物裝卸區：(請補充位置)____
☐其它泊位：(請補充位置)____

航行路線 ：
船隻*進入*香港港口是通過：☐A ☐B ☐C ☐D ☐E
船隻*離開*香港港口是通過：☐A ☐B ☐C ☐D ☐E

停泊區:
I： 葵涌貨櫃碼頭
II： 西面錨地
III：西面危險品錨地和油麻地錨地
IV：南丫島北錨地
V： 南丫島南錨地

航線出入口:
A: 馬灣航道
B: 北長洲海峽
C: 西博寮海峽
D: 東博寮海峽
E: 藍塘海峽



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3 引擎資料

3.1 主引擎(發動機)資料 (請將郵船上裝設的柴油發電機牘列於下頁 3.2 輔助發電機/發動機部分)

主引擎數量: _____	**引擎類型:** ☐燃氣發動機 ☐蒸汽發動機 ☐二衝程柴油發動機 ☐四衝程柴油發動機	
總最大功率: _____ ☐千瓦 ☐馬力	**最大功率時轉速:** _____	**轉速類型:** ☐高速 ☐中速 ☐低速
使用燃料類別（1）: ☐重油 ☐柴油 ☐輕質柴油, 含硫率 _____**%**		**使用燃料類別（2）:** ☐重油 ☐柴油 ☐輕質柴油, 含硫率 _____**%**
一般航行情況下，平均每小時耗油量： 1) 在香港水域*以外*（但進入香港海岸線 100 海浬範圍內）: _____ ☐千克 ☐公升 2) 在香港水域*以內* _____ ☐千克 ☐公升		
主引擎運作時間（以每次進出香港水域計算）: 1) 在香港水域*以外*正常航行（但進入香港海岸線 100 海浬範圍內）_____小時 2) 在香港水域*以內*正常航行_____ 小時；**3)** 錨泊/離泊操縱***** _____ 小時; **4)** 裝卸貨物 _____小時; **5)** 停泊****** _____ 小時		
主引擎運作功率和航速： 在香港水域以外正常航行時，引擎功率爲： _____ ☐千瓦 ☐馬力， **航速：** _____ 節 在香港水域以內正常航行時，引擎功率爲： _____ ☐千瓦 ☐馬力， **航速：** _____ 節 在香港水域以內錨泊/離泊操縱時，引擎功率爲： _____ ☐千瓦 ☐馬力， **航速：** _____ 節 在香港水域以內裝卸貨物時，引擎功率爲： _____ ☐千瓦 ☐馬力， **航速：** **0** 節 在香港水域以內停泊時，引擎功率爲： _____ ☐千瓦 ☐馬力， **航速：** **0** 節		
是否有轉換主引擎燃料？ **A** **在香港水域以外：**☐是 ☐否; 如若是，請繼續以下問題 **A1 由** ☐重油 ☐柴油 ☐輕質柴油 **轉為** ☐重油 ☐柴油 ☐輕質柴油； **含硫率由**_____**%** **轉爲** _____% **A2 轉換時間為**，在進入香港水域前_____小時和離開香港水域後_____小時		**B** **在香港水域以內：**☐是 ☐否; 如若是，請繼續以下問題 **B1 由** ☐重油 ☐柴油 ☐輕質柴油 轉為 ☐重油 ☐柴油 ☐輕質柴油； 含硫率由_____**%** **轉爲** _____% **B2 轉換時間為** ☐正常航行時 ☐錨泊/離泊操縱時* ☐裝卸貨物時 ☐停泊時**

* 錨泊/離泊操縱是指船舶在港區內以低速靠近或離開浮泡/碇泊處/碼頭泊位的操作模式。
** 停泊模式<u>不包括</u>裝卸貨物的時間。

3.2 輔助發電機/發動機，或其他非航行引擎（不包括應急和備用機）

發電機/發動機	發電機（一）	發電機（二）	發電機（三）	發電機（四）	發電機（五）	發電機（六）
最大功率	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力
發電機/發動機類型	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程	☐燃氣發動機 ☐柴油發動機 ☐二衝程 ☐四衝程
在香港水域以內使用的燃料	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%
平均每小時耗油量	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升
輔助發電機/發動機運作時間：						
1) 正常航行						
香港水域以外	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否
香港水域以內	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否
2) 錨泊/離泊操縱*	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否
3) 裝卸貨物	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否
4) 停泊**	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否	☐是___小時 ☐否
上列使用中發電機/發動機產生的總功率： 1) 正常航行時 ____ ☐千瓦 ☐馬力；2) 錨泊/離泊操縱時* ☐千瓦 ☐馬力；3) 裝卸貨物時 ☐千瓦 ☐馬力；4) 停泊時** ☐千瓦 ☐馬力						
是否有轉換輔助引擎燃料？						
A 在香港水域以外：☐是 ☐否；　如若是，請繼續以下問題 A1 由 ☐重油 ☐柴油 ☐輕質柴油 轉爲 ☐重油 ☐柴油 ☐輕質柴油； 含硫率由____% 轉爲 ____% A2 轉換時間爲，在進入香港水域前____小時和離開香港水域後____小時			B 在香港水域以內：☐是 ☐否；　如若是，請繼續以下問題 B1 由 ☐重油 ☐柴油 ☐輕質柴油 轉爲 ☐重油 ☐柴油 ☐輕質柴油； 含硫率由____% 轉爲 ____% B2 轉換時間爲 ☐正常航行時 ☐錨泊/離泊操縱時* ☐裝卸貨物時 ☐停泊時**			

3.3 船用鍋爐（不包括備用鍋爐）

鍋爐	鍋爐（一）	鍋爐（二）	鍋爐（三）	鍋爐（四）
功率	____ 噸蒸汽/小時	____ 噸蒸汽/小時	____ 噸蒸汽/小時	____ 噸蒸汽/小時
用途	☐供應熱水用 ☐加熱重油 ☐爲泵提供動力 ☐其他用途：____	☐供應熱水用 ☐加熱重油 ☐爲泵提供動力 ☐其他用途：____	☐供應熱水用 ☐加熱重油 ☐爲泵提供動力 ☐其他用途：____	☐供應熱水用 ☐加熱重油 ☐爲泵提供動力 ☐其他用途：____
在香港水域以內使用的燃料	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%	☐重油：含硫率____% ☐柴油：含硫率____% ☐輕質柴油：____%
平均每小時耗油量	____ ☐千克 ☐公升	____ ☐千克 ☐公升	____ ☐千克 ☐公升	____ ☐千克 ☐公升
鍋爐運作時間				
1) 在香港水域以外	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時
2) 在香港水域以內	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時
3) 錨泊/離泊操縱*	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時
4) 裝卸貨物	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時
5) 停泊**	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時	持續時間：____ 小時

是否有轉換鍋爐燃料？

A 在香港水域以外：☐是 ☐否；　如若是，請繼續以下問題

A1 由 ☐重油 ☐柴油 ☐輕質柴油 **轉爲** ☐重油 ☐柴油 ☐輕質柴油；
含硫率由____% **轉爲** ____%

A2 **轉換時間爲**，在進入香港水域前____小時和離開香港水域後____小時

B 在香港水域以內：☐是 ☐否；　如若是，請繼續以下問題

B1 由 ☐重油 ☐柴油 ☐輕質柴油 轉爲 ☐重油 ☐柴油 ☐輕質柴油；
含硫率由____% **轉爲** ____%

B2 **轉換時間爲** ☐正常航行時 ☐錨泊/離泊操縱時* ☐裝卸貨物時 ☐停泊時**

^ **此船隻是否經常停靠香港港口？**☐是 ☐否；　如若是，那麼在 2008 年，此船隻抵達香港共多少次？ ____ 船次。

 # 調查表填寫人員資料：　姓名 ____　**日期：**2009/____/____（月/日）　**電子郵件：**____

— 調查結束，謝謝提供資料！—

APPENDIX B

MARINE VESSEL SURVEY (RTV) SURVEY FORM (IN CHINESE)

致：香港科技大學環境研究所（傳真：2358 1582）

機密文件

內河船舶（中轉服務）調查表
船舶基本資料部分

調查時間：2009 年 2 月 1 日至 4 月 30 日

由香港科技大學環境研究所
代表香港特區政府環境保護署擬定

填表需知:
1.請將填妥的調查表以傳真方式交回香港科技大學環境研究所（傳真：2358 1582）。

資料保密聲明：香港科技大學於調查過程中蒐集的資料將絕對保密，而且只會用於本研究項目。在未得到受訪者同意的情況下，香港科技大學將不會向第三方透露任何資料，亦不會在報告內容中，披露個別人士或公司的身份和資料。

船公司/代理公司名稱：_____

聯絡人名稱：_____ 聯絡電話：_____ 電郵：_____

香港科技大學環境研究所
內河船舶（中轉服務）調查表 – 船舶基本資料部分　　頁____

船隻中文名稱			
船隻英文名稱			
建成年份			
船籍港			
非作業時停靠港			
香港海事處參考編號			
船總長	_____ 米	_____ 米	_____ 米
船寬	_____ 米	_____ 米	_____ 米
船總噸位（GT）	_____ 噸	_____ 噸	_____ 噸
載重噸位（DWT）	_____ 噸	_____ 噸	_____ 噸
最高航速	_____ 節（海浬/小時）	_____ 節（海浬/小時）	_____ 節（海浬/小時）

	航班 1	航班 2	航班 1	航班 2	航班 1	航班 2
主要航班	_____ ⇆ 香港	_____ ⇆ 香港	_____ ⇆ 香港	_____ ⇆ 香港	_____ ⇆ 香港	_____ ⇆ 香港
班次	每周 _____ 班	每周 _____ 班	每周 _____ 班	每周 _____ 班	每周 _____ 班	每周 _____ 班
香港主要靠泊位置						

	主機 1	主機 2	主機 1	主機 2	主機 1	主機 2
主機類型	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____
額定功率（kW）						
額定轉速（r/min）						
	發電機 1	發電機 2	發電機 1	發電機 2	發電機 1	發電機 2
發電機類型	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____	柴油機/_____
額定功率（kW）						
額定轉速（r/min）						

致：香港科技大學環境研究所（傳真：2358 1582）

機密文件

內河船舶（中轉服務）調查表
船舶航行資料部分

調查時間：2009 年 2 月 1 日至 4 月 30 日

由香港科技大學環境研究所
代表香港特區政府環境保護署擬定

填表需知:
1. 請為每艘船每一航程填寫一份調查表。每一航程包括船舶自珠三角港口啓航、抵港、裝卸貨物、離港及回航。
2. 請將填妥的調查表以傳真方式交回香港科技大學環境研究所（傳真：2358 1582）。

資料保密聲明：香港科技大學於調查過程中蒐集的資料將絕對保密，而且只會用於本研究項目。在未得到受訪者同意的情況下，香港科技大學將不會向第三方透露任何資料，亦不會在報告內容中，披露個別人士或公司的身份和資料。

船公司/代理公司名稱：____

聯絡人名稱：____　　聯絡電話：____　　電郵：____

香港科技大學環境研究所
內河船舶（中轉服務）調查表 – 船舶航行資料部分

1 船隻資料

船隻中文名稱：____		船隻英文名稱：____	
香港海事處參考編號：____		船隻類型: ☐集裝箱船 ☐其他（請補充）____	
船隻最高航速：____節（海浬/小時）	船總長：____米	載重噸位（DWT）：____噸	總噸位（GT）：____噸

2 航線資料

航線：____ ⇆ 香港

班次： ☐ 每星期____班 ☐ 每月____班

香港停泊位置(可選多項)：

☐ 葵涌貨櫃碼頭

☐ 屯門內河船碼頭

☐ 公眾貨物裝卸區：（請補充位置）____

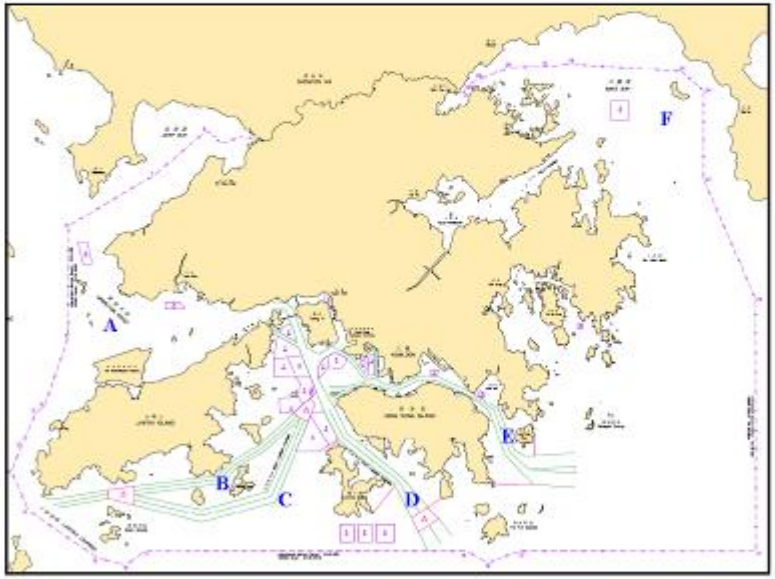
☐ 海港錨地：（請補充位置）____

☐ 其他碇泊處：（請補充位置）____

航行路線：

進入香港水域時通過： ☐A ☐B ☐C ☐D ☐E ☐F

離開香港水域時通過： ☐A ☐B ☐C ☐D ☐E ☐F



航行路線:
A: 鏡鼓水道
B: 北長洲海峽
C: 西博寮海峽
D: 東博寮海峽
E: 藍塘海峽
F: 大鵬灣

1

香港科技大學環境研究所
內河船舶（中轉服務）調查表 – 船舶航行資料部分

3 主發動機資料

	主發動機（一）	主發動機（二）	主發動機（三）	主發動機（四）
發動機類型:	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率（kW）	____ 千瓦（kW）	____ 千瓦（kW）	____ 千瓦（kW）	____ 千瓦（kW）
額定轉速（r/min）	____	____	____	____
使用燃料類別：	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %
每小時平均耗油量：	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升

航行模式	主發動機總功率	航速	主發動機運作時間
在香港水域以外正常航行時：	____ 千瓦（kW）	____ 節（海浬/小時）	____ 小時
在香港水域以內正常航行時：	____ 千瓦（kW）	____ 節（海浬/小時）	____ 小時
在香港水域以內錨泊/離泊操縱時*：	____ 千瓦（kW）	____ 節（海浬/小時）	____ 小時
在香港水域以內裝卸貨物時：	____ 千瓦（kW）	**0** 節（海浬/小時）	____ 小時
在香港水域以內停泊時：**	____ 千瓦（kW）	**0** 節（海浬/小時）	____ 小時

* 錨泊/離泊操縱是指船舶在港區內以低速靠近或離開浮泡/碇泊處/碼頭泊位的操作模式。
** 停泊模式不包括裝卸貨物的時間。

香港科技大學環境研究所
內河船舶（中轉服務）調查表 – 船舶航行資料部分

4 發電機資料

	發電機（一）	發電機（二）	發電機（三）	發電機（四）
發電機類型:	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率（kW）	____ 千瓦（kW）	____ 千瓦（kW）	____ 千瓦（kW）	____ 千瓦（kW）
額定轉速（r/min）	____	____	____	____
使用燃料類別：	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫率 ____ %
每小時平均耗油量：	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升	____ ☐ 千克 ☐ 公升

發電機操作情況	發電機（一）		發電機（二）		發電機（三）		發電機（四）	
在香港水域以外正常航行時：	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關
在香港水域以內正常航行時：	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關
在香港水域以內錨泊/離泊操縱時*：	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關
在香港水域以內裝卸貨物時：	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關
在香港水域以內停泊時：**	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關	☐ 開 ____ 千瓦 ____ 小時	☐ 關

— 調查結束，謝謝提供資料！—

APPENDIX C

MARINE VESSEL SURVEY (MACAU FERRY) SURVEY FORM (IN ENGLISH AND CHINESE)

HKUST Study on Marine Vessels Emission Inventory

CONFIDENTIAL

Local / Macau / PRD Ferry Information Sheet

1. Vessel Information

Vessel Name:			**Chinese Vessel Name:**			**Vessel Type:**	
IMO Number:	**MD Ownership/Reference Number:**			**Flag:**		**Port of Registry:**	
Vessel Owner:			**Operator:**				
Year of Built:	**LOA:** meters	**Breadth:** meters		**Depth:** meters		**Max. Passenger:**	
Maximum Vessel Speed:	☐knot(nm/h) ☐km/h	**GT:** metric tons		**NT:** metric tons		**DWT:** metric tons	

2. Main (Propulsion) Engine Information

Engine	**Engine #1**	**Engine #2**	**Engine #3**	**Engine #4**
Rated Power at MCR	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
RPM at MCR	**r/minute**	**r/minute**	**r/minute**	**r/minute**
Engine Type	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine
Fuel Used: ☐ Marine Residual Oil ☐ Marine Diesel Oil ☐ Marine Gas Oil % sulphur content				

3. Auxiliary Engine/Generator and all Diesel-Electric Engines (excluding emergency and standby engines)

Engine	**Aux. Engine #1**	**Aux. Engine #2**	**Aux. Engine #3**	**Aux. Engine #4**
Rated Power at MCR	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
RPM at MCR	**r/minute**	**r/minute**	**r/minute**	**r/minute**
Engine Type	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel Engine ☐ 4-Stroke Diesel Engine
Fuel Used: ☐ Marine Residual Oil ☐ Marine Diesel Oil ☐ Marine Gas Oil % sulphur content				

4. Fuel Use Information

Annual Fuel Consumption: ☐ kg ☐ liter	**Average Daily Fuel Consumption:** ☐ kg ☐ liter		
Re-fuelling: ☐ everyday ☐ every two days ☐ three times a week ☐ twice a week ☐ once a week			
Re-fuelling Location(s): 1. **2.**	**Typical Amount Re-fuelled per Visit:** ☐ kg ☐ liter		

– End –

香港科技大學環境研究所 船舶排放清單研究 **資料絕對保密**

本港渡輪 / 港澳客輪 / 珠三角客輪 船舶資料調查表

1. 船隻資料

船隻英文名稱：		**船隻中文名稱（如適用）：**		**船隻類別:**
IMO 號碼：	**海事處擁有權證明書/牌照號碼：**		**船旗：**	**船隻登記港口：**
船東：		**營辦商：**		
建成年份：	**船總長：** 米	**船寬：** 米	**型深：** 米	**最高載客人數：** 人
最高航速： ☐ 節（海浬/小時） ☐ 公里/小時		**船總噸位(GT)：** 噸	**淨噸位(NT)：** 噸	**載重噸位(DWT)：** 噸

2. 主引擎(發動機)資料

主引擎	**主機 1**	**主機 2**	**主機 3**	**主機 4**
額定功率	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
引擎類別	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
使用燃料類別： ☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %				

3. 輔助發電機或發動機（不包括應急和備用機）

輔助發電機	**發電機 1**	**發電機 2**	**發電機 3**	**發電機 4**
額定功率	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力	☐千瓦 ☐馬力
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
引擎類別	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
使用燃料類別： ☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %				

4. 燃料使用資料

全年總耗油量： ☐千克 ☐公升	**每日平均耗油量：** ☐千克 ☐公升
加添燃料次數： ☐ 每日一次 ☐ 每兩日一次 ☐ 每星期三次 ☐ 每星期兩次 ☐ 每星期一次	
加油位置： 1. 2.	**每次平均加油量：** ☐千克 ☐公升

– 完 –

Confidential

HKUST Study on Marine Vessels Emission Inventory

Survey Form for Passenger Vessels Operating Between Hong Kong and Macau 2009

Prepared by

Institute for the Environment
Hong Kong University of Science and Technology

on behalf of

Environmental Protection Department
HKSAR Government

Please "X" the appropriate box ☐

HKUST Study on Marine Vessels Emission Inventory
Survey Forms for Passenger Vessels Operating between Hong Kong and Macau 2009

1. Vessel Information

Vessel Name:		**Chinese Vessel Name:**		**Vessel Type:**
IMO Number:	**MD Ownership/Reference Number:**		**Flag:**	**Port of Registry:**
Vessel Owner:		**Operator:**		
Year of Built:	**LOA:** meters	**Breadth:** meters	**Depth:** meters	**Max. Passenger:**
Maximum Vessel Speed:	☐knot(nm/h) ☐km/h	**GT:** metric tons	**NT:** metric tons	**DWT:** metric tons

2. Service Information

Route: Hong Kong ⇆ Macau

Frequency: sailings (one way) per ☐ day ☐ week

Berthing Location (Hong Kong):

- ☐ Hong Kong-Macau Ferry Terminal (Shun Tak)
- ☐ China Ferry Terminal (Tsim Sha Tsui)
- ☐ Hong Kong International Airport
- ☐ Others (please specify):

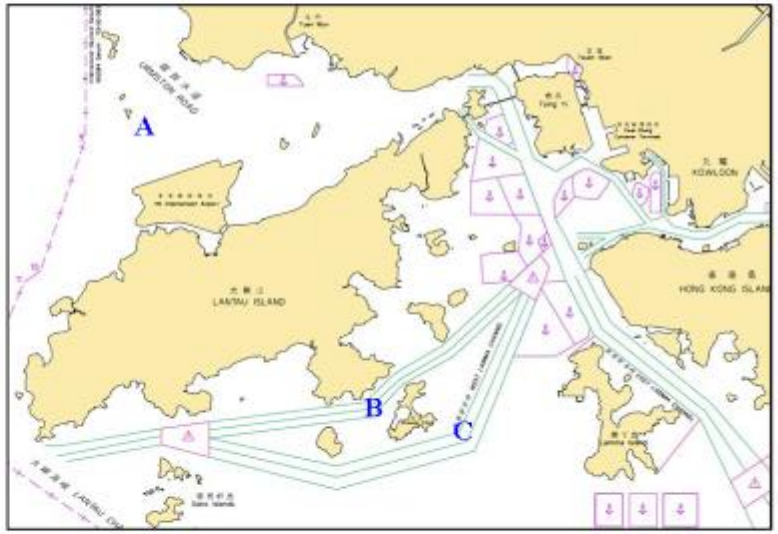
Berthing Location (Macau):

- ☐ Macau Ferry Terminal
- ☐ Taipa Ferry Terminal
- ☐ Others (please specify):

Routing:

You enter Hong Kong waters through ☐A ☐B ☐C

You depart Hong Kong waters through ☐A ☐B ☐C



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HKUST Study on Marine Vessels Emission Inventory
Survey Forms for Passenger Vessels Operating between Hong Kong and Macau 2009

3. Main (Propulsion) Engine Activities

		Engine #1	Engine #2	Engine #3	Engine #4
Engine Type		☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel
Rated Power at MCR		☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
RPM at MCR		**r/minute**	**r/minute**	**r/minute**	**r/minute**
Fuel Used		☐ Marine Residual Oil ☐ Marine Diesel Oil ☐ Marine Gas Oil			% sulphur
Average Daily Fuel Consumption		☐kg ☐liter	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter
Operation Mode (Round Trip)	**Time-in-mode / Speed**	**Power Output**	**Power Output**	**Power Output**	**Power Output**
Berthing in Hong Kong	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Outward maneuvering from terminal	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise in Victoria Harbour	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Cruising after Victoria Harbour	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise approaching Macau	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Inward maneuvering (Macau)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Berthing in Macau	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Outward maneuvering from terminal	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise in Macau breakwater	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Cruising after breakwater	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise approaching Hong Kong	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Inward maneuvering (Hong Kong)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Other Operations	**Time-in-mode / Speed**	**Power Output**	**Power Output**	**Power Output**	**Power Output**
Re-fuelling	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Sailing to re-fuelling point (if any)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Idling during lunch / dinner break	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Idling after service hour	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp

HKUST Study on Marine Vessels Emission Inventory
Survey Forms for Passenger Vessels Operating between Hong Kong and Macau 2009

4. Auxiliary Engine Activities (Including generator and all diesel-electric engines, but excluding emergency and standby engines)

		Aux. Engine #1	Aux. Engine #2	Aux. Engine #3	Aux. Engine #4
Auxiliary Engine Type		☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel	☐ Gas Turbine ☐ Steam Turbine ☐ 2-Stroke Diesel ☐ 4-Stroke Diesel
Rated Power at MCR		☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
RPM at MCR		**r/minute**	**r/minute**	**r/minute**	**r/minute**
Fuel Used		☐ Marine Residual Oil ☐ Marine Diesel Oil ☐ Marine Gas Oil			% sulphur
Average Daily Fuel Consumption		☐kg ☐liter	☐kg ☐liter	☐kg ☐liter	☐kg ☐liter
Operation Mode (Round Trip)	**Time-in-mode / Speed**	**Power Output**	**Power Output**	**Power Output**	**Power Output**
Berthing in Hong Kong	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Outward maneuvering from terminal	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise in Victoria Harbour	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Cruising after Victoria Harbour	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise approaching Macau	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Inward maneuvering (Macau)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Berthing in Macau	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Outward maneuvering from terminal	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise in Macau breakwater	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Cruising after breakwater	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Slow cruise approaching Hong Kong	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Inward maneuvering (Hong Kong)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Other Operations	**Time-in-mode / Speed**	**Power Output**	**Power Output**	**Power Output**	**Power Output**
Re-fuelling	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Sailing to re-fuelling point (if any)	min / knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Idling during lunch / dinner break	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp
Idling after service hour	min / **0** knot	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp	☐kW ☐hp

– End of Survey. Thank You. –

資料絕對保密

香港科技大學環境研究所
船舶排放清單研究

來往香港及澳門客輪（航行情況）調查表
2009 年

由香港科技大學環境研究所
代表香港特區政府環境保護署擬定

請在方格☐內標示“X”

香港科技大學環境研究所 船舶排放清單研究　　資料絕對保密

1. 船隻資料

船隻英文名稱：		船隻中文名稱（如適用）：	船隻類別:	
IMO 號碼：	海事處擁有權證明書/牌照號碼：		船旗：	船隻登記港口：
船東：		營辦商：		
建成年份：	船總長： 米	船寬： 米	型深： 米	最高載客人數： 人
最高航速： ☐ 節（海浬/小時） ☐ 公里/小時		船總噸位(GT)： 噸	淨噸位(NT)： 噸	載重噸位(DWT)： 噸

2. 航線資料

航線： 香港 <-> 澳門

班次：☐ 每日　　班（單程）

香港靠泊位置：

☐ 港澳客運碼頭（信德中心）

☐ 中國客運碼頭（尖沙咀）

☐ 香港國際機場海天碼頭

☐ 其他：(請 列明)

澳門靠泊位置：

☐ 澳門客運碼頭

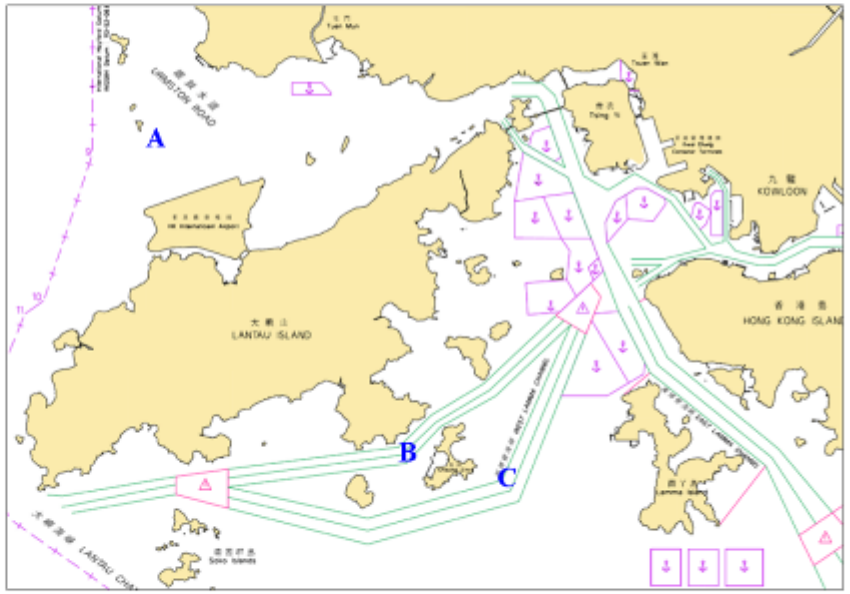
☐ 氹仔客運碼頭

☐ 其他：(請 列明) _

航行路線 ：

進入香港水域時通過： ☐A ☐B ☐C

離開香港水域時通過： ☐A ☐B ☐C



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3. 主引擎(發動機)使用情況

	主發動機（一）	主發動機（二）	主發動機（三）	主發動機（四）
發動機類型	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率	☐千瓦	☐千瓦	☐千瓦	☐千瓦
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
使用燃料類別	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %			
每日平均耗油量	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升

航行模式 (來回兩程)	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在港方碼頭靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在維港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開維港後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近澳門港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭停泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開澳門後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近港方碼頭低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

其他運作模式	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在加油期間船舶靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
往來加油站時 (如適用)	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在午膳或晚膳期間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在晚間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

4. 輔助發電機或發動機使用情況（不包括應急和備用機）

	發電機（一）	發電機（二）	發電機（三）	發電機（四）
發電機類型	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率	☐千瓦	☐千瓦	☐千瓦	☐千瓦
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
使用燃料類別	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %			
每日平均耗油量	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升

航行模式 (來回兩程)	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在港方碼頭靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在維港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開維港後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近澳門港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭停泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在澳門港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開澳門後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近港方碼頭低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

其他運作模式	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在加油期間船舶靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
往來加油站時 (如適用)	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在午膳或晚膳期間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在晚間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

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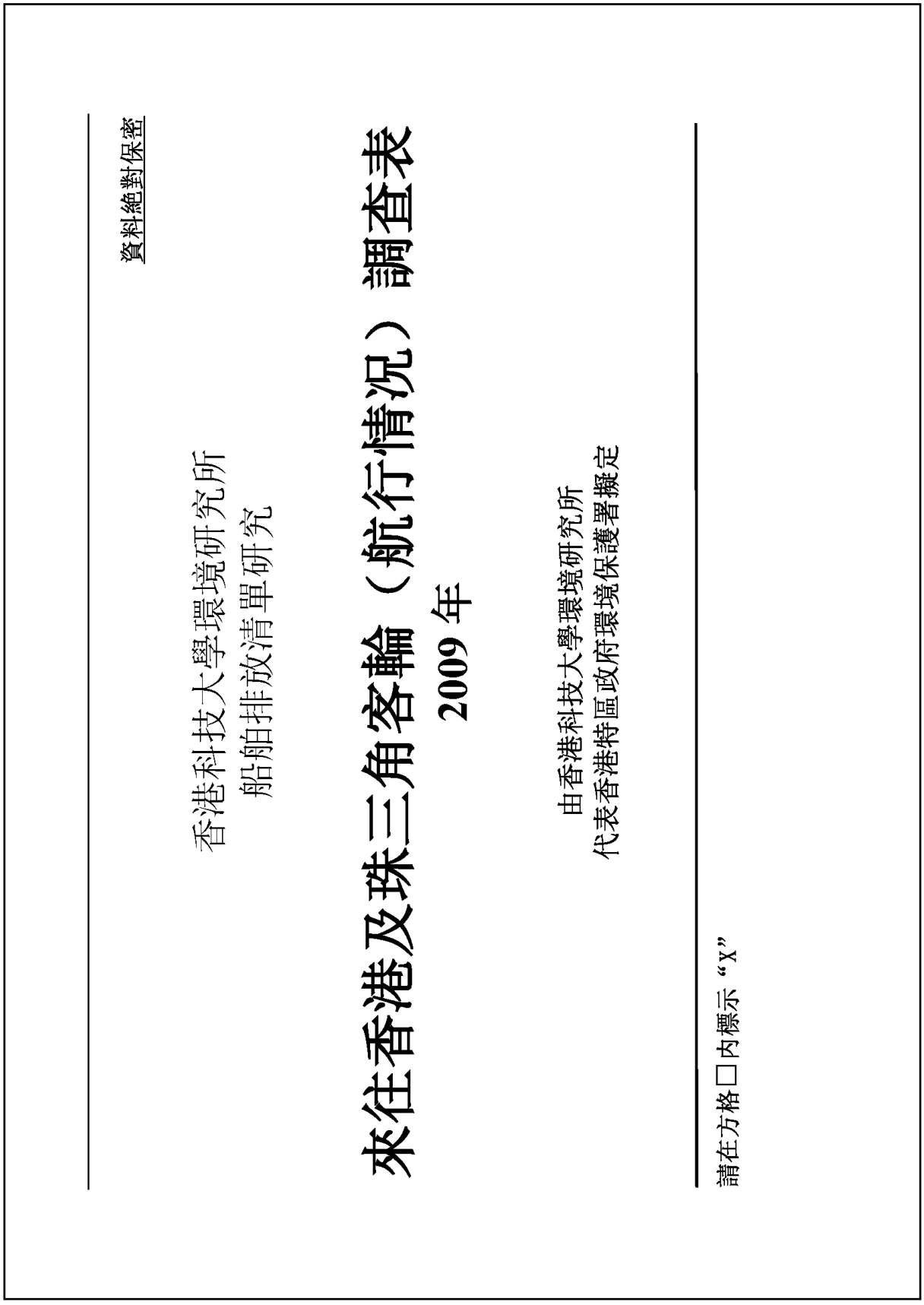
APPENDIX D

MARINE VESSEL SURVEY (PRD FERRY) SURVEY FORM (IN CHINESE)



資料絕對保密

香港科技大學環境研究所
船舶排放清單研究

來往香港及珠三角客輪（航行情況）調查表
2009 年

由香港科技大學環境研究所
代表香港特區政府環境保護署擬定

請在方格□內標示"X"

香港科技大學環境研究所 船舶排放清單研究 **資料絕對保密**

1. 船隻資料

船隻英文名稱：		**船隻中文名稱（如適用）：**	**船隻類別:**	
IMO 號碼：	**海事處擁有權證明書/牌照號碼：**		**船旗：**	**船隻登記港口：**
船東：		**營辦商：**		
建成年份：	**船總長：** 米	**船寬：** 米	**型深：** 米	**最高載客人數：** 人
最高航速： ☐ 節（海浬/小時） ☐ 公里/小時		**船總噸位(GT)：** 噸	**淨噸位(NT)：** 噸	**載重噸位(DWT)：** 噸

2. 航線資料

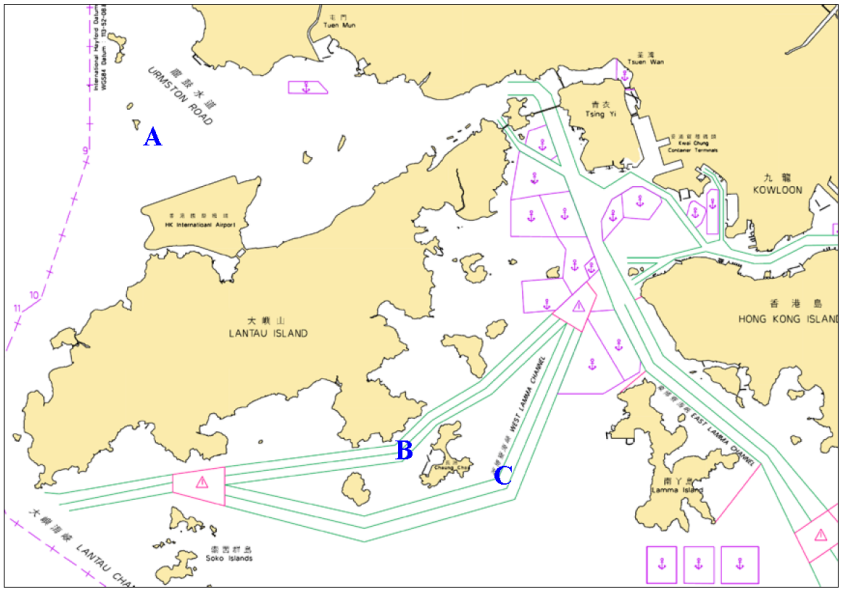
航線： 香港 <-> ☐ 斗門 ☐ 高明 ☐ 鶴山
☐ 虎門 ☐ 江門 ☐ 蓮花山
☐ 南沙 ☐ 平州 ☐ 三埠
☐ 蛇口 ☐ 深圳 ☐ 順德
☐ 肇慶 ☐ 中山 ☐ 珠海
☐ 其他：(請 列明)

班次： ☐ **每日** **班（單程）**

香港靠泊位置：

☐ 中國客運碼頭（尖沙咀）
☐ 屯門碼頭
☐ 香港國際機場海天碼頭
☐ 其他：(請 列明)

航行路線 ：
進入香港水域時通過： ☐**A** ☐**B** ☐**C**
離開香港水域時通過： ☐**A** ☐**B** ☐**C**



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3. 主引擎(發動機)使用情況

	主發動機（一）	主發動機（二）	主發動機（三）	主發動機（四）
發動機類型	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率	☐千瓦	☐千瓦	☐千瓦	☐千瓦
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
使用燃料類別	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %			
每日平均耗油量	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升

航行模式 (來回兩程)	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在港方碼頭靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在香港水域內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開香港水域後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近內河港口低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口停泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開內河港口後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近港方碼頭低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

其他運作模式	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在加油期間船舶靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
往來加油站時 (如適用)	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在午膳或晚膳期間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在晚間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

4. 輔助發電機或發動機使用情況（不包括應急和備用機）

	發電機（一）	發電機（二）	發電機（三）	發電機（四）
發電機類型	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機	☐ 燃氣發動機 ☐ 蒸汽發動機 ☐ 二衝程柴油發動機 ☐ 四衝程柴油發動機
額定功率	☐千瓦	☐千瓦	☐千瓦	☐千瓦
最大功率時轉速	每分鐘 轉	每分鐘 轉	每分鐘 轉	每分鐘 轉
使用燃料類別	☐ 重油 ☐ 柴油 ☐ 輕質柴油 含硫量 %			
每日平均耗油量	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升	☐千克 ☐公升
航行模式 (來回兩程)	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在港方碼頭靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在香港水域內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開香港水域後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近內河港口低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口停泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港口離泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在內河港內低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在離開內河港口後高速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在靠近港方碼頭低速航行時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在港方碼頭靠泊操縱時	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
其他運作模式	**運作時間 / 航速**	**輸出功率**	**輸出功率**	**輸出功率**	**輸出功率**
在加油期間船舶靠泊時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
往來加油站時 (如適用)	分鐘 / 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在午膳或晚膳期間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦
在晚間船舶停航時	分鐘 / **0** 節	☐千瓦	☐千瓦	☐千瓦	☐千瓦

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