APPENDIX 13.1 HAZARD TO LIFE ASSESSMENT FOR PROPOSED EFFLUENT POLISHING PLANT (EPP)

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1. INTRODUCTION

1.1 Background

1.1.1.1 This section identifies the hazardous scenarios associated with the generation, storage, utilization, processing and transmission (if applicable) of biogas during operation of the Project, and presents the analysis and findings of the Quantitative Risk Assessment (QRA) undertaken.

1.1.1.2 An organic waste co-digestion facility that processes off-site pre-treated organic wastes (approximately 100 wet tonnes / day) together with sewage sludge and handles the associated wastewater and biogas will be installed at the proposed Effluent Polishing Plant (EPP). The preliminary site layout of the proposed EPP and the location of its biogas related facilities are shown in **Annex A**.

1.1.1.3 In accordance with Section 3.4.14 of the EIA Study Brief (ESB-340/2021), a hazard assessment should be conducted to evaluate the biogas risk to existing, committed and planned off-site population due to operation of the organic waste co-digestion facility.

1.2 Hazard to Life Assessment Objectives and Risk Criteria

1.2.1 Objectives

1.2.1.1 The Hazard to Life Assessment requirements for the proposed EPP, as detailed in Appendix H of the EIA Study Brief, are shown below:

(a) Identify hazardous scenarios associated with the generation, storage, use and on-site transport of biogas at the proposed sewage treatment works and then determine a set of relevant scenarios to be included in a QRA;

(b) Execute a QRA of the set of hazardous scenarios determined in (a), expressing population risks in both individual and societal terms;

(c) Compare individual and societal risks with the criteria for evaluating hazard to life as stipulated in Annex 4 of the TM; and

(d) Identify and assess practicable and cost-effective risk mitigation measures.

1.2.2 EIAO-TM Risk Criteria

1.2.2.1 Annex 4 of the EIAO-TM specifies the Individual and Societal Risk Guidelines. The Hong Kong Risk Guidelines (HKRG) per the EIAO-TM Annex 4 states that the individual risk is the predicted increase in the chance of fatality per year to an individual due to a potential hazard. The individual risk guidelines require that the maximum level of individual risk should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year. Societal risk expresses the risks to the whole population. It is expressed in terms of lines plotting the cumulative frequency (F) of N or more deaths in the population from incidents at the installation. Two F-N risk lines are used in the HKRG that demark "Acceptable" or "Unacceptable" societal risks. To avoid major disasters, there is a vertical cut-off line at the 1000 fatality level extending down to a frequency of 1 in a billion years. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is "as low as reasonably practicable" (ALARP). It seeks to ensure that all practicable and cost-effective measures that can reduce risk are considered. The HKRG is presented graphically in **Plate 1.1**.

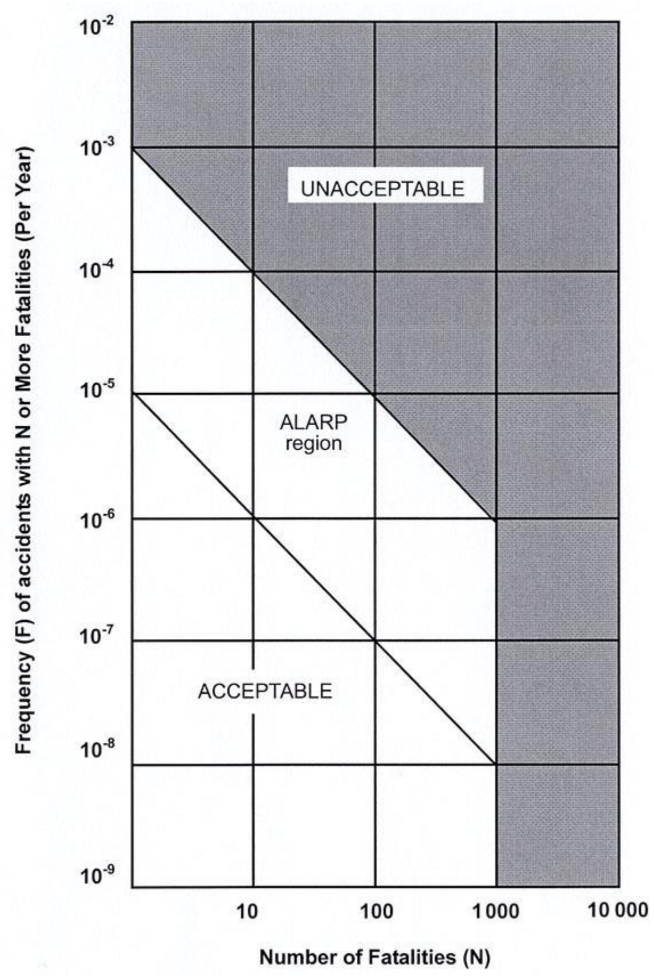

Plate 1.1 Societal Risk Guidelines

1.3 Study Approach

1.3.1.1 This assessment consists of the following six main tasks:

(a) **Data / Information Collection and Update**: Relevant data / information necessary for the hazard assessment, including project design and surroundings of the Project were collected;

(b) **Hazard Identification**: A set of relevant hazardous scenarios associated with the operations of the organic waste co-digestion facility were identified by reviewing relevant literature and studies with similar installations as well as historical accident database, such as Major Hazard Incident Data Service (MHIDAS);

(c) **Frequency Estimation**: Frequencies of each hazardous event leading to fatalities with full justification were estimated by reviewing historical accident data, previous similar projects and using Fault Tree Analysis (FTA) of the identified hazardous scenarios;

(d) **Consequence Analysis**: The consequences of the identified hazardous scenarios were analysed by conducting source term modelling and effect modelling;

(e) **Risk Assessment and Evaluation**: The risks associated with the identified hazardous scenarios were evaluated. The evaluated risks were compared with the HKRG in EIAO-TM to determine their acceptability; and

(f) **Identification of Mitigation Measures**: Where necessary, practicable and cost-effective risk mitigation measures were identified and assessed to ensure compliance with the ALARP principle in the HKRG. Risks of the mitigated case were re-assessed to determine the level of risk reduction as required.

1.3.1.2 The main tasks of the QRA are shown schematically in **Plate 1.2**.

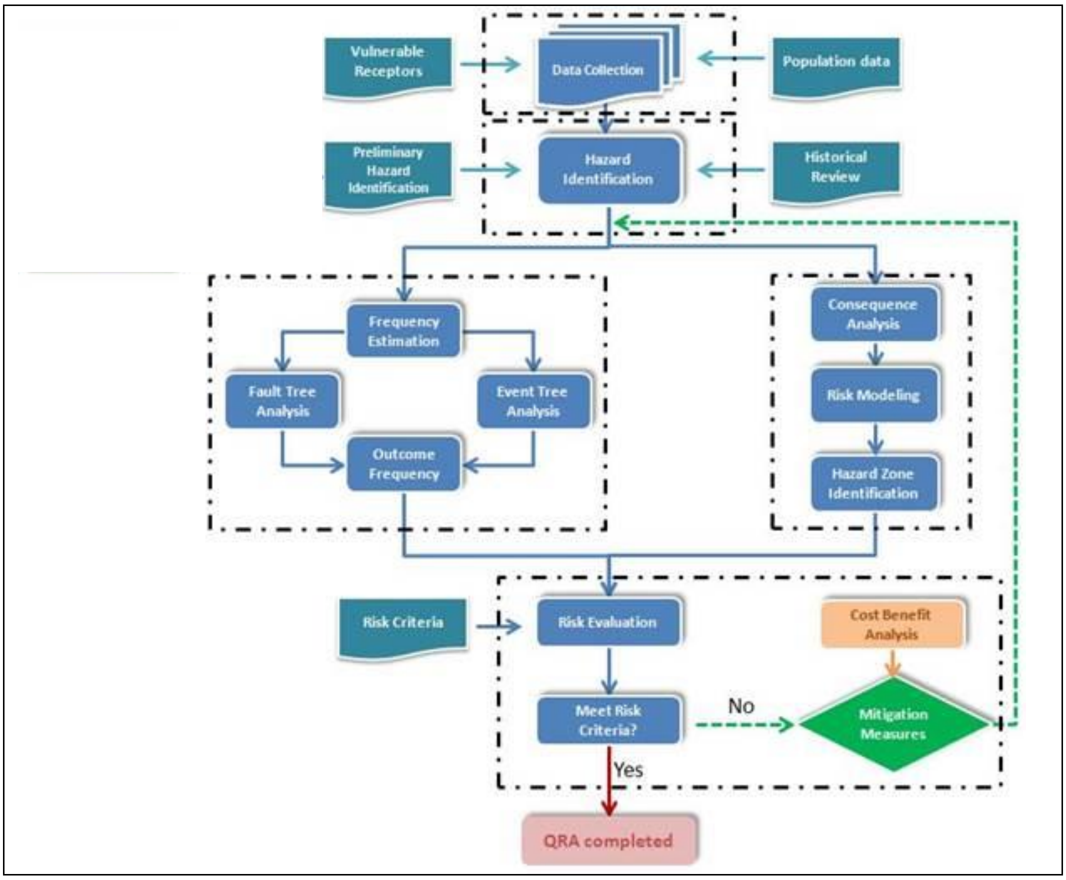

Plate 1.2 Schematic Diagram of QRA Process

1.4 Assessment Scenario

1.4.1.1 Based on the currently envisaged construction programme, the proposed EPP will be commenced in 2031. The hazard assessment covers the following two scenarios:

(a) Year 2032 (Construction phase) – The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFS, and the HP Gas Pipeline to the existing, committed and planned population in 2032. This scenario accounted for the commencement of the EPP and the two GFSs, and also the presence of the construction workers for areas of the proposed development located along the San Tam Road.

(b) Year 2039 (Operation phase) – The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFSs, and the HP Gas Pipeline to the existing, committed and planned population in 2039. This scenario accounted for the ultimate situation with all the planned land users of the proposed development being considered.

2. SITE DESCRIPTION

2.1 Description of Surroundings

2.1.1.1 Societal risk is a measure of the consequence magnitude and the frequency of the hazardous events. To establish the impact of any release (the number of people likely to be affected) in the future, it is necessary to know the future surrounding population levels. These would include residential population, government and institutional population and transport population but exclude staff of the EPP since they are considered as voluntary risk takers.

2.2 On-site Populations

2.2.1.1 The following population is anticipated in the EPP during operation phase of the plant:

(a) Staff: the number of staff of EPP would be around 200, and they are considered as voluntary risk takers and would not be considered in this assessment.

2.3 Surrounding Populations

2.3.1.1 The site of the proposed EPP is located at the western part of STLMC development. The proposed organic waste co-digestion facility is located in the middle portion of the proposed EPP. All population groups included in this assessment are detailed in **Annex B**.

2.3.2 Land and Building Population

2.3.2.1 Population covered in the QRA included residents and workers in the residentials, institutions, government facilities and amenity. Estimation of land and building populations was based on the latest information provided by Civil Engineering and Development Department (CEDD) and are summarized in **Table 2.1**.

2.3.2.2 Residential population of the existing buildings was estimated based on the average household size obtained from the Territory Population and Employment Data Matrix (TPEDM) data, together with the building information (e.g. no. of units and floors) obtained from Centamap.

2.3.2.3 The TPEDM population projections for Planning Data Zones (PDZs) (i.e. PDZ 183 and PDZ332) was obtained from the Planning Department (PlanD) to forecast the population of the existing residential developments in the assessment years. The average domestic household sizes for the respective PDZs in 2031 were adopted to estimate the residential population in 2031. The 2030+ TPEDM data showed negative growth of average domestic household size in all the concerned PDZs from 2031 to 2041. To be conservative, the population of the existing residential developments (i.e. E02 and E05) in 2032 and 2039 were assumed to remain the same as those in 2031.

2.3.2.4 The population groups considered in this QRA are shown in **Plate 2.1** and the numbers of population in each area are listed in **Table 2.1**, while details of the population at different time modes and information sources are provided in **Annex A**. The numbers of population were estimated based on the following assumptions:

(a) According to the 2030+ TPEDM data, the average domestic household size in PDZ 183 and PDZ 332 in 2031 are 3.12 and 3.20 respectively. Since a negative growth of average domestic household size from 2031 to 2041 was observed in all the concerned PDZs, the residential population in existing residential developments in 2032 and 2039 was assumed to remain the same as those in 2031;

(b) The amenity areas were assumed to be unmanned, while population in open areas were estimated based on a density of 100m^2/ person; and

(c) An average of 5% population was considered to be outdoor for residential, institution and industrial population, while 100% population was assumed to be outdoor for construction workers, users in open spaces and open storages area.

Table 2.1 Land and Building Population Data

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
E02	Scenic Heights	106	106
E05	Mai Po San Tsuen	3164	3164
P01	A.5.1 - Amenity	0	0
P02	OU(ESS).5.12 - Reserve	0	0
P03	G.5.3 - Existing Mai Po ESS	125	84
P04	G.5.1 - Sport Centre	125	1018
P05	RSc.2.1 - Public Housing	9899	9899
P06	RSc.2.2 - Public Housing	7603	7603
P07a	OU(EPP).5.3 - Food Waste Pretreatment Facilities	100	100
P08	OU(GFS).5.1 - Green Fuel Station	10	10
P09	G.5.2 - Reserve	0	0
P10	GB.5.3 - Green Belt	0	0
P11	OU(ESS).5.6 - 132kV ESS	0	0
P12	G.5.5 - Reserve	0	0
P13	E.5.3 - Potential Education Facilities	125	1680
P14	GB.5.4 - Green Belt	0	0
P15	OU(SPS).5.7 - Sewage Pumping Station	30	30
P53	OU(LSW).1.2 - Logistics, Storage and Warehouse	220	220
P54	OU(DSC).1.11 - District Cooling System	25	25
P55	O.1.3 - Open space	410	410
P56	OU(I&T)3.1.9 - Information and Technology - Zone 3	80	5228
P57	OU(WRP).5.2 - Water Reclamation Plant	100	100
P58	E.2.1 - 2 Primary School	129	1678
P59	OU(RCP).5.5 - RCP	0	0
P60	GB.5.1 - Green Belt	0	0
P61	GB.5.2 - Green Belt	0	0
P63	A.1.17 - Amenity	0	0

Plate 2.1 Population Groups Considered

2.3.3 Traffic Population

2.3.3.1 The traffic data was based on the latest Annual Traffic Census (ATC) published by Transport Department (TD) [6] and the Traffic Impact Assessment (TIA) report prepared for this Assignment. The traffic population was predicted based on the following equation:

$$Traffic\ Population = \frac{No.of\ Person\ per\ vehicle \times No.of\ Vehicle\ per\ hour \times Road\ Length}{Speed}$$

2.3.3.2 Based on the latest ATC [6], the occupancies for each vehicle type and vehicle mix were taken at the core station no. 5016 (San Tin Highway, Castle Peak Road and San Tam Road (from Kam Tin Road to Fairview Park Boulevard) were selected to represent the road traffic for this assessment.

2.3.3.3 The traffic population considered in this assessment, which was assumed to be 100% outdoor, is summarized in **Table 2.2** and detailed in **Annex B**. The locations of roads considered for construction and operation phases are presented in **Plate 2.2**.

Table 2.2 Estimated Road Population

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R1	50	18	12	24	14
R2	50	14	10	17	12
R3	50	9	7	20	11
R4	50	16	12	43	22
R5	50	22	13	24	13
R6	100	158	71	191	85
R7	100	148	66	166	73
R8	100	210	93	252	110
R9	100	115	53	129	60
R10	100	260	116	293	133
R11	50	49	26	58	30
R12	50	113	54	98	47
R13	50	20	13	27	15
R14	50	16	11	25	15
R15	50	13	9	20	12
R16	50	17	11	25	15
R17	50	16	11	13	9
R18	50	8	8	13	10
R19	50	35	21	39	22
R20	50	46	26	54	28
R21	50	40	23	47	25
R22	50	42	24	44	24
R23	50	66	35	67	35
R24	50	153	74	168	80
R25	50	176	85	170	81
R26	50	22	14	74	36
R27	50	21	14	77	38
R28	50	0	0	22	13
R29	50	0	0	21	13
R30	50	43	19	88	42
R31	50	45	21	64	29
R32	50	33	20	36	20
R33	50	36	21	51	26
R34	50	34	18	39	19
R35	50	24	15	27	16
R36	50	89	44	83	41
R37	50	7	7	7	7
R38	50	60	31	58	31
R39	50	119	58	149	71
R40	50	7	7	7	7

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R41	50	7	7	7	7
R42	50	10	10	12	12
R43	50	20	20	24	24
R44	50	10	10	13	13
R45	50	9	9	10	10
R46	50	10	10	12	12

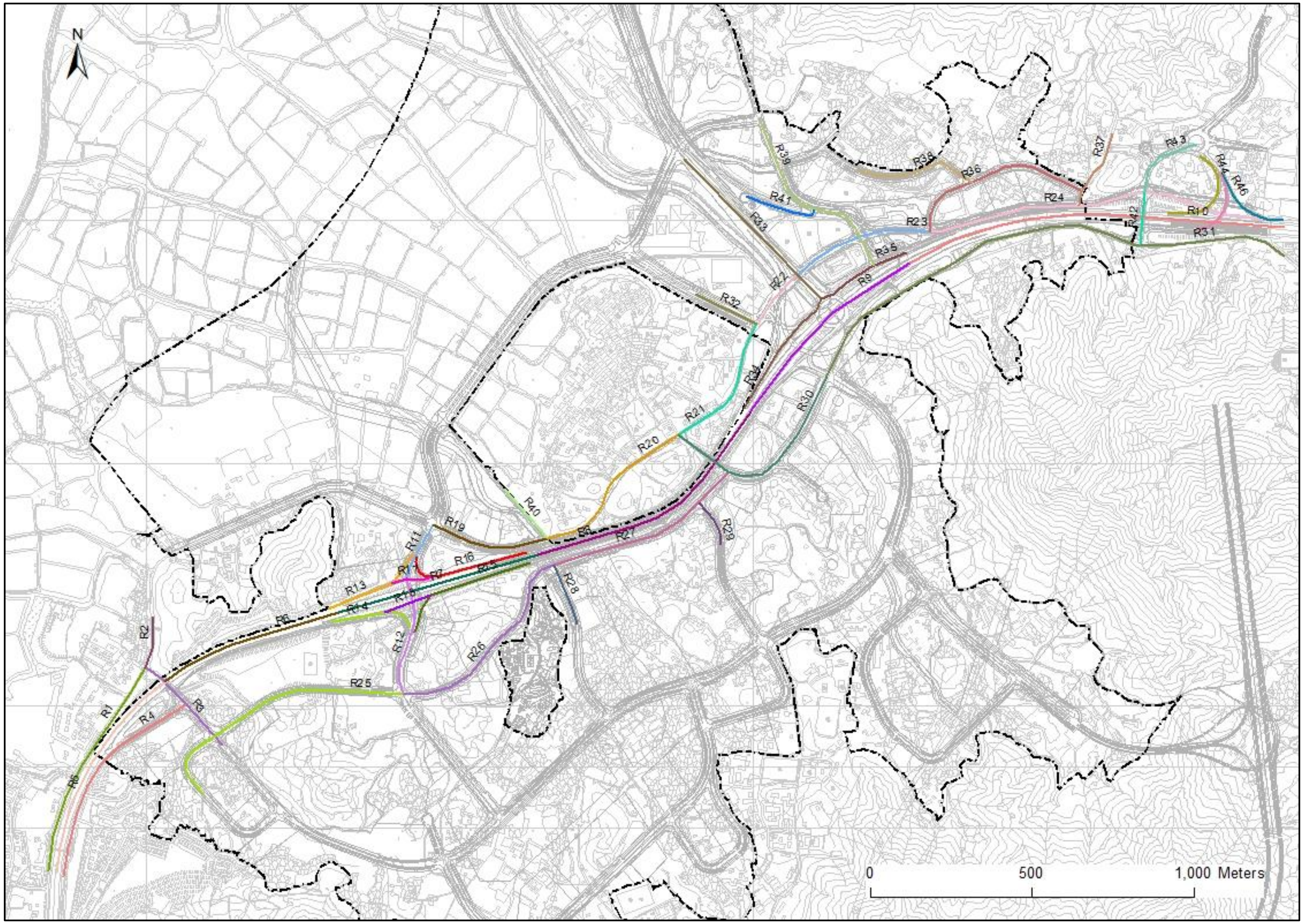

Plate 2.2 **Locations of Road Population Groups**

2.3.4 Time Modes and Occupancies of Population Groups

2.3.4.1 With reference to previous similar studies [1][2][4][5], four time modes as detailed in **Table 2.3** were applied in this hazard assessment to reflect the temporal distribution of population and to address the variation in levels of activities that could lead to a release and the variation in population in the assessment area with time.

Table 2.3 Definitions of Time Modes

Day Category	Time Period		Time Mode
Weekday	Daytime	(07:00 to 19:00)	35.71%
	Night	(19:00 to 07:00)	35.71%
Weekend	Daytime	(07:00 to 19:00)	14.29%
	Night	(19:00 to 07:00)	14.29%

2.4 Meteorology

2.4.1.1 Meteorological data is required for consequence modelling and risk calculation. Consequence modelling (dispersion modelling) requires wind speed and stability class to determine the degree of turbulent mixing potential whereas risk calculation requires wind-rose frequencies for each combination of wind speed and stability class.

2.4.1.2 Meteorological data was obtained from Wetland Park Weather Station (2021) where wind speed, stability class, weather class and wind direction are available. This data represented the weather conditions for the whole year in 2021 and has already taken into account seasonal variations and was therefore considered applicable for the assessment. **Table 2.4** shows the wind speed-stability frequencies.

Table 2.4 Stability Category-Wind Speed Frequencies at Wetland Park Weather Station

Daytime							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
0.0-1.9	25.55	7.91	0.00	13.77	0.00	14.46	61.69
2.0-3.9	7.62	14.30	6.36	6.34	1.76	0.36	36.74
4.0-5.9	0.00	1.05	0.27	0.18	0.00	0.00	1.50
6.0-7.9	0.00	0.00	0.00	0.05	0.00	0.00	0.05
Over 8.0	0.00	0.00	0.00	0.02	0.00	0.00	0.02
All (%)	33.17	23.26	6.63	20.36	1.76	14.82	100.00
Night-time							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
0.0-1.9	0.00	0.00	0.00	3.76	0.00	82.06	85.82
2.0-3.9	0.00	0.00	0.00	2.25	8.83	2.44	13.52
4.0-5.9	0.00	0.00	0.00	0.52	0.07	0.00	0.59
6.0-7.9	0.00	0.00	0.00	0.07	0.00	0.00	0.07
Over 8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All (%)	0.00	0.00	0.00	6.60	8.90	84.50	100.00

2.4.1.3 According to **Table 2.4**, six combinations (2B, 1D, 3D, 6D, 2E and 1F) and five combinations (1D, 3D, 7D, 2E and 1F) of wind speed and stability class were chosen for daytime and night-time meteorological conditions respectively. These combinations were considered adequate to reflect the full range of observed variations in these quantities. It is not necessary and efficient to consider every combination observed. The principle is to group these combinations into representative weather classes that together cover all conditions observed.

2.4.1.4 Once the weather classes have been selected, frequencies for each wind direction for each weather class can then be determined. The frequency distributions for the daytime and night-time meteorological conditions are summarised in **Table 2.5**.

Table 2.5 Weather Class-Wind Direction Frequencies at Wetland Park Weather Station

Daytime							
Direction	**2B**	**1D**	**3D**	**6D**	**2E**	**1F**	**Total (%)**
0 – 30	4.53	1.99	0.82	0.00	0.55	3.21	11.10
30 – 60	6.01	1.30	1.89	0.10	0.60	1.10	11.00
60 – 90	12.03	2.02	3.96	0.02	1.00	1.02	20.05
90 – 120	3.59	1.47	2.69	0.00	0.65	1.49	9.89
120 – 150	2.47	0.50	1.30	0.00	0.42	0.67	5.36
150 – 180	5.58	0.82	2.96	0.00	0.72	1.02	11.10
180 – 210	6.19	0.42	2.59	0.00	0.57	0.62	10.39
210 – 240	3.64	0.12	0.52	0.00	0.07	0.15	4.50
240 – 270	2.07	0.20	0.15	0.00	0.00	0.15	2.57
270 – 300	2.67	0.45	0.17	0.00	0.05	0.20	3.54
300 – 330	4.04	0.32	0.12	0.00	0.00	0.22	4.70
330 – 360	4.11	0.57	0.37	0.00	0.00	0.75	5.80
All (%)	56.93	10.18	17.54	0.12	4.63	10.60	100.00

Night-time						
Direction	**1D**	**3D**	**7D**	**2E**	**1F**	**Total (%)**
0 – 30	0.83	0.32	0.00	1.52	20.93	23.60
30 – 60	0.48	1.47	0.11	2.96	4.32	9.34
60 – 90	0.48	0.37	0.00	2.06	4.46	7.37
90 – 120	0.32	1.15	0.00	4.46	7.98	13.91
120 – 150	0.08	0.27	0.00	1.23	5.37	6.95
150 – 180	0.16	0.03	0.00	7.29	12.01	19.49
180 – 210	0.13	0.21	0.00	6.41	5.47	12.22
210 – 240	0.05	0.05	0.00	0.35	0.43	0.88
240 – 270	0.03	0.00	0.00	0.03	0.27	0.33
270 – 300	0.00	0.00	0.00	0.03	0.29	0.32
300 – 330	0.08	0.03	0.00	0.03	0.72	0.86
330 – 360	0.51	0.19	0.00	0.27	3.76	4.73
All (%)	3.15	4.09	0.11	26.64	66.01	100.00

3. HAZARD IDENIFICATION AND ANALYSIS

3.1 Introduction

3.1.1.1 A hazard is described as the property of a material or activity with the potential to do harm. Potential hazards associated with generation, transfer, storage and use of biogas in the organic waste co-digestion facility within the proposed EPP were identified. All the operation information and parameters have been confirmed with the engineers. This section outlines the hazards preliminarily identified for the facility.

3.1.1.2 Historical incidents and relevant studies of similar facilities were reviewed to identify the possible hazardous scenarios and to ensure that all the relevant hazardous scenarios were incorporated into this assessment.

3.2 Facility Description

3.2.1.1 The organic waste co-digestion facility at the proposed EPP will receive approximately 100 wet tonnes / day of pre-treated organic wastes through pipelines or tankers for co-digestion with sewage sludge and handle the associated wastewater and biogas. Proven biological treatment technologies will be adopted to recover reusable energy, i.e. biogas, from source-separated organic wastes and sewage sludge. Biogas generated will be used onsite heat and power production. The location plan of the facility and the treatment process are illustrated in **Annex A**.

3.2.2 Digesters

3.2.2.1 Five duty and one standby cylindrical anaerobic sludge digesters, each of which is 22m (Dia.) × 28m (H) (internal dimension) in size, will be provided to handle the pre-treated organic waste and sludge. The biogas volume of each digester is 380m^3. The working temperature and pressure of the digesters will be maintained at 35ºC and 1.03 bar.

3.2.2.2 The digesters consist of concrete, steel or glass enamel holding tanks, with either gas or top mounted mixing systems. Approximately 100 wet tonnes / day of pre-treated organic waste and 70 wet tonnes / day of sewage sludge will enter the digestion tanks along with additional water to reduce the Dissolved Solid (DS) content from an estimated 15% to 5%. The estimated average residence time of the organic waste / sludge within the digesters is assumed to be 20 days. Digested sludge / organic waste will be dewatered for disposal and the wastewater from the dewatered compost will be transferred to the side-stream treatment facilities / inlet works of EPP for treatment.

3.2.2.3 Heating is required for biomass feeding of the digesters and for heat loss compensation from the digesters. The required heating will be provided via heat recovered from the combined heat and power (CHP) unit, or from a boiler.

3.2.2.4 Pressure relief valves will be installed on the digesters to protect against overpressure (50 mbarg). Overflow pipes will be provided on the digesters for protection against overfilling.

3.2.3 Biogas Holders

3.2.3.1 The biogas generated will be stored in the biogas holders. There will be three cylindrical biogas holders, each of which is 19m (Dia.) × 13.7m (H) in size with a maximum biogas storage of 2,300m^3 per tank. The total storage amount of the biogas will be around 8,860 kg. The quantity does not exceed the lower threshold quantity, i.e. 15 tonnes, for Potentially Hazardous Installations (PHIs) for flammable gas and town gas installations in Hong Kong. Therefore, the proposed waste treatment facilities are not classified as a PHI. The biogas storage would be maintained at a temperature 35 ºC and a pressure of 1.03 bar.

3.2.3.2 Dry seal (Wiggins) type biogas holders with steel containment will be used in the proposed facility for evening out variations in biogas production from the digesters. This type of gas holder typically consists of a cylindrical steel shell and a displacement piston, which is allowed to go up and down with the change of volume of gas. The gas tightness is maintained by a seal between the piston and the inside of the shell. There are pressure relief valves on the biogas holder for protection against the exceedance of designed gas storage pressure and overflow pipes for protection against overfilling.

3.2.3.3 A non-return valve will be installed at the inlet pipe to prevent gas from back-flow. Gas is discharged through the outlet pipe by suction blower. There will be emergency shut-off valves at the inlet and outlet pipes of the gas holder. In case of gas holder failure, the emergency shut-off valves can close the inlet and outlet pipes and the release of biogas to the atmosphere can be minimised.

3.2.4 Sulphur Absorption Vessels

3.2.4.1 The stored biogas will go through the sulphur absorption vessels to remove the hydrogen sulphide (H_2S) before passing to the CHP generator to produce electricity and heat for use onsite.

3.2.4.2 Two duty and one standby sulphur absorption vessels, each of which is 3.5m (Dia.) x 3.7m (H) in size, will be provided downstream of the gasholders for the absorption of H_2S in the biogas. The working temperature and pressure of the sulphur absorption vessels will be maintained at 35 ºC and 1.03 bar. The absorption vessels are made of steel and filled with zinc oxide or iron oxide as absorbents. An explosion proof blower will be used to extract the biogas from gasholder to the sulphur absorption vessels at 400 mbarg.

3.2.5 Inlet / Outlet Piping

3.2.5.1 A total of 140m of aboveground inlet / outlet pipe (150mm Dia.) will be provided to the facility. All other piping will be underground or provided at the basement of concrete buildings. The working temperature and pressure of the inlet and outlet piping will be maintained at 35 ºC and 1.03 bar.

3.3 Biogas Properties

3.3.1.1 Biogas is a colourless flammable a combustible mixture of gases at atmospheric conditions that comprises mainly methane (CH_4) and CO_2. Generally, biogas from anaerobic digestion process has a methane content of 55% to 70% by volume. The exact composition of biogas depends on the substance that is being decomposed. If the material consists of mainly carbohydrates, such as glucose and other simple sugars and high-molecular compounds (polymers) such as cellulose and hemicellulose, the methane production is low. However, if the fat content is high, the methane production is likewise high [3]. In general, the physical properties of biogas are also very similar to those of natural gas. While it is non-toxic, in high concentrations it could lead to asphyxiation. A loss of containment can lead to jet fire (if stored/ transferred under sufficient pressure) or to an explosion if the gas accumulates in a confined space. The properties of biogas from Anaerobic Digestion (AD) process are summarized in **Table 3.1** [1][2].

Table 3.1 Composition and Properties of Biogas from Anaerobic Digestion Process

Property	Biogas from Anaerobic Digestion
Methane Content	55% – 70%
Carbon Dioxide Content	30% – 45%
Density	1.2 Kg/Nm^3
Lower Caloric Value	23 MJ/Nm^3
Flammability#	Extremely Flammable
Auto-Ignition Temperature#	580°C
Flash Points#	-188°C

Property	Biogas from Anaerobic Digestion
Melting Point#	-182.5°C
Boiling Point#	-161.4°C
Flammable Limits#	5% (Lower) – 15% (Upper)
Vapour Density#	0.59-0.72 (air = 1)

Remark:
Physical properties of biogas that are similar to natural gas.

3.3.1.2 Given that flammability increases with increase of methane content, and the exact composition of biogas varies with the substance that is being decomposed, it is conservatively assumed that the biogas is 100% methane in the risk model.

3.4 Review of Historic Incident Database and Relevant Studies

3.4.1.1 Relevant biogas or methane release scenarios from OWTF and YLSEPP (which are facilities of similar nature as the proposed facility at EPP) identified in historical incident databases, such as MHIDAS database, eMARS, FACTS and ARIA, were examined. The recorded hazardous scenarios were mainly associated with leakages from piping, valves and storage vessels and operator error. A total of 11 incidents records related to biogas and methane were identified and these are summarized in **Table 3.2** and detailed in **Annex C**.

Table 3.2 Summary of Biogas or Methane Incidents

Hazardous Scenario	No. of Cases	Country
Methane Storage Tank Failure	3	Turkey, India, Australia
Methane Pipeline Failure	2	UK, USA
Anaerobic Digestion Plant Failure	6	Italy, France, Germany, India

3.4.1.2 The hazardous scenarios of biogas identified in the relevant studies were reviewed and adopted in this hazard assessment where applicable. Failure events and the respective hazardous scenarios associated with the biogas facilities were identified and assessed in the approved EIA studies for OWTF, Phase 2 (AEIAR-180/2013) [1] and YLEPP (AEIAR-220/2019) [2]. The identified hazardous scenarios were mainly associated with leakages from piping, valves and storage vessels due to undetected material defect.

3.5 Spontaneous Failures

3.5.1 Digester Failure

3.5.1.1 Failure of the digesters could be caused by undetected corrosion, fatigue, material or construction defect. Release of biogas could be from various parts of the digesters as well as the associated piping and devices. Possible hazardous outcomes include fireball, jet fire, flash fire and Vapour Cloud Explosion (VCE).

3.5.2 Gasholder Failure

3.5.2.1 Dry seal (Wiggins) type biogas holders will be used for the proposed facility. A dry seal (Wiggins) type gas holder is different from column guided water-sealed gas holder that do not have a gas holder crown. A seal is installed between the piston and the inside of the shell to maintain gas tightness inside the holder and prevent rotation or side movement of the piston. A levelling system consists of wire ropes and balance weights is equipped to prevent tilting of the piston. The seal and the levelling system will be inspected regularly.

3.5.2.2 Failure of the gas holders could be caused by undetected corrosion, fatigue, material or construction defect. Release of biogas could be from various parts of the gas holders or associated piping and devices. Possible hazardous outcomes include fireball, jet fire, flash fire and VCE.

3.5.3 Sulphur Absorption Vessel Failure

3.5.3.1 The absorbents used for removal of H_2S in the sulphur absorption vessels are neither flammable nor explosive that the major hazard will be from the release of biogas. Failure of sulphur absorption vessels could be caused by undetected corrosion, fatigue, material or construction defect. Release of biogas could be from various parts of the process vessels as well as associated piping and devices. Possible hazardous outcomes include fireball, jet fire, flash fire and VCE.

3.5.4 Aboveground Inlet or Outlet Piping Failure

3.5.4.1 Piping will be used to connect process vessels to the gasholder, compressor, and further purification unit and CHP. Failure along the on-site piping may be caused by undetected corrosion, fatigue, material or construction defect, or associated with flange gasket / valve leakage resulting in continuous gas release to the atmosphere. The biogas facilities including the piping are operating with low pressure (~1.03bar), it is considered that any failure of the underground pipelines operating at such low pressure will not cause significant impact to the surrounding as the pipelines are buried under concrete pavement, and thus the underground pipelines was not further considered in the assessment. Failures of gaskets and valve leak only tend to give relatively small-scale leakage and will not contribute to any off-site risk. Nonetheless, gasket and valve leak failure were considered and included into pipework failure in this hazard assessment with reference to previous similar studies [1][2]. Possible hazardous outcomes from the aboveground piping include jet fire, flash fire and VCE.

3.6 External Hazards

3.6.1.1 External hazards that are outside the control of the operating personnel could still pose a threat to the organic waste co-digestion facility at the proposed YLSEPP. Such hazards are termed as ‘external hazards’ because they are independent of the operations on-site but can lead to major hazard scenarios. This section discusses the credibility of loss of containment due to the external hazards with respect to Hong Kong’s geographical location

3.6.2 Aircraft Crash

3.6.2.1 The Project is located around 25 km northeast from the Hong Kong International Airport. The frequency of aircraft crash was estimated using the methodology of the HSE [9] and detailed in **Section 4**.

3.6.3 Earthquake

3.6.3.1 In Hong Kong, buildings and infrastructures are designed to withstand earthquakes up to Modified Mercali Intensity (MMI) VII. It was estimated that MMI VIII is required to provide sufficient intensity to result in damage to specially designed structure. It was assumed that failure in earthquake is possible for storage tank rupture, leakage, pipeline rupture and leakage. Details of frequency analysis are given in **Section 4**.

3.6.4 Vehicle Impact

3.6.4.1 Only authorised vehicles will be permitted to enter the proposed EPP, and speed will be restricted for vehicle movements within the site. Safety markings and marked crash barriers will be provided to the above ground piping, digesters and gasholders near the internal road. Vehicle impact could cause only leak failure to digesters and gas holders as well as both rupture failure and leak failure to aboveground piping [1][2]. The accident rate was estimated based on statistical data for Vehicle/ Object Crash accident involving medium and heavy goods vehicles in recent years and detailed in **Section 4**.

3.6.5 Lightning

3.6.5.1 Lightning sparks could ignite combustible gas in air. The proposed EPP will be equipped with a lightning protection system that can effectively protect the equipment, include the organic waste co-digestion facility, from lightning. Lightning protection installations should be installed following IEC 62305, BS EN 62305, AS/NZS 1768, NFPA 780 or equivalent standards [14]. The installations will be protected with lightning conductors to safely earth direct lightning strikes. The double grounding system will be inspected regularly. Therefore, failures due to lightning strikes are to be covered by generic failure frequencies [1][2].

3.6.6 External Fire

3.6.6.1 External fire means the occurrence of fire event which leads to the failure of the equipment inside the organic waste co-digestion facility. In the proposed EPP, the facilities will be equipped with fire alarm and fire suppression system. In addition, stringent procedures will be implemented to prohibit smoking or naked flames to be used on-site to further lower the probability of initiation due to external fire. Therefore, failures due to external fire was not considered further in this assessment.

3.6.7 Typhoon / Tsunami

3.6.7.1 Loss of containment due to severe environmental event such as typhoon or tsunami (large scale tidal wave) is not possible as the proposed EPP is designed to withstand wind load for local typhoon while Hong Kong is not threatened by tsunami. Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Thus, typhoon or tsunami causing a release of biogas was not considered further in this assessment.

3.7 Possible Hazardous Scenarios Considered

3.7.1.1 The organic waste co-digestion facility at the proposed EPP will be using organic waste treatment technology, similar to that in the operation of the OWTF Phase 2 and YLEPP, i.e. anaerobic digestion of the organic waste. The sulphur absorption vessels would be structurally similar to anaerobic digestion vessels. Possible hazardous scenarios of the facility are listed in **Table 3.3**.

Table 3.3 Possible Hazardous Scenarios and Hazardous Outcomes of the Organic Waste Co-digestion Facility at the Proposed EPP

Potential Sources	Release Type	Hazardous Outcome
Gasholder	Rupture	Fireball; VCE; and Flash fire
	Leak	Jet fire; VCE; and Flash fire
Digester	Rupture	Fireball; VCE; and Flash fire
	Leak	Jet fire; VCE; and Flash fire
Sulphur Absorption Vessel	Rupture	Fireball; VCE; and Flash fire

Potential Sources	Release Type	Hazardous Outcome
	Leak	Jet fire; VCE; and Flash fire
Aboveground inlet or outlet piping / pump / non-return valve / flange	Rupture / Leak	Jet fire; VCE; and Flash fire

3.7.1.2 Hazardous outcomes were assessed using PhastRisk 6.7, to determine the risk impact, where the potential risk associated with the operation, layout and facilities threat posed to life and neighbouring property in a hazardous outcome at the Project.

4. FREQUENCY ANALYSIS

4.1 General

4.1.1.1 Frequencies for each of the identified hazardous scenarios were estimated using the best available failure data or historical accident data in the process and gas industry or failure frequencies of similar installations or events. The frequencies documented in the relevant sources were reviewed and justified as necessary to reflect the specific operation and risk reduction practices evident at the organic waste co-digestion facility.

4.2 Spontaneous Failures Frequencies

4.2.1 Digester / Gasholder / Sulphur Absorption Vessel Failure

4.2.1.1 According to Guidelines for Quantitative Risk Assessment: Purple Book, the catastrophic rupture and leak failure frequencies of digester tank / gasholder / sulphur absorption vessel are 1×10^{-5} per year and 1×10^{-4} per year respectively [7].

4.2.2 Aboveground Piping Failure

4.2.2.1 According to Guidelines for Quantitative Risk Assessment: Purple Book, catastrophic rupture and leak failure frequencies of aboveground piping are 3×10^{-7} per metre per year (150 mm dia.) and 2×10^{-6} per metre per year (150 mm dia.) respectively [7].

4.2.2.2 A summary of the base event frequencies is shown in **Table 4.1**.

Table 4.1 Summary of Spontaneous Failures Frequencies

Events	Frequency of Occurrence	
	Rupture / Catastrophic Failure	Leak / Partial Failure
Digester	1.00×10^{-5} per year	1.00×10^{-4} per year
Gasholder	1.00×10^{-5} per year	1.00×10^{-4} per year
Sulphur Absorption Vessel	1.00×10^{-5} per year	1.00×10^{-4} per year
Aboveground Inlet or Outlet Piping	3.00×10^{-7} per metre per year	2.00×10^{-6} per metre per year

4.3 External Event Frequencies

4.3.1 Aircraft Crash

4.3.1.1 The model takes into account specific factors such as the target area of the proposed hazard site and its longitudinal (x) and perpendicular (y) distances from the runway threshold (**Plate 4.1** refers).

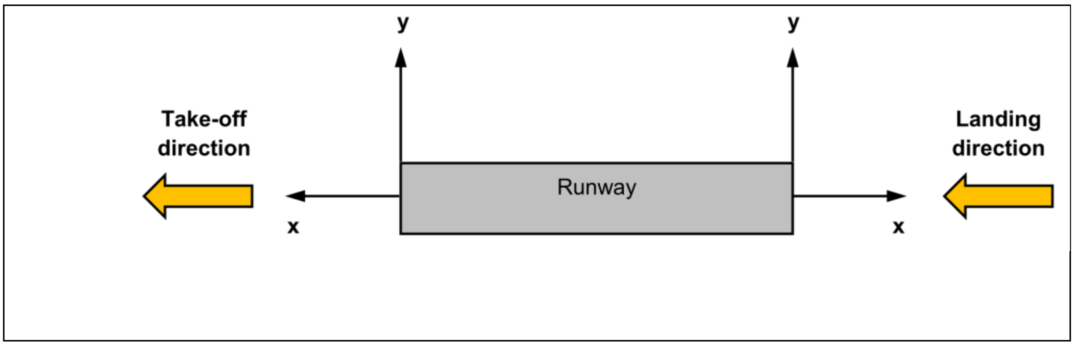

Plate 4.1 Aircraft Crash Coordinate System

4.3.1.2 The crash frequency per unit ground area (per km²) is calculated as:

$$g(x,y) = NRF(x,y) \qquad (1)$$

where *N* is the number of runway movements per year and *R* is the probability of an accident per movement (landing or take-off). *F*(*x*,*y*) gives the spatial distribution of crashes and is given by:

Landings

$$F_L(x,y) = \frac{(x+3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}} \right] \qquad (2)$$

for $x > -3.275\ km$.

Take-off

$$F_T(x,y) = \frac{(x+0.6)}{1.44} e^{\frac{-(x+0.65)}{12}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635 e^{-4.1|y|} + 0.08 e^{-|y|} \right] \qquad (3)$$

for $x > -0.6\ km$.

4.3.1.3 Equations (2) and (3) are valid only for the specified range of x values. If x lies outside this range, the impact probability is zero. This case applies for 07L and 07R runways for arrival and 25L and 25R runways for departure flight path.

4.3.1.4 The probability of an accident per movement R is interpreted from NTSB data for fatal accidents in the U.S. involving scheduled airline flights during the period 1986 – 2010. The 10-year moving average suggested a downward trend with recent years showing a rate of about 2×10^{-7} per flight. There were only 13.5% of accidents associated with the approach to landing, 15.8% associated with take-off and 4.2% were related to the climb phase of the flight [15]. The frequency for the approach of landings was therefore taken as 2.7×10^{-8} per flight and for take-off was 4.0×10^{-8} per flight.

4.3.1.5 The number of runway movement of aircraft N was provided by yearly statistics of the Hong Kong International Airport (HKIA), and the figures from 2009 are presented in **Table 4.2** [16]. Due to the social unrest since mid-2019 and the outbreak of COVID-19, the number of runway movement in 2019 to 2021 was considered to be not representative, as such, the numbers of movements at 2032 and 2039 were estimated by linear regression of the data from 2009 to 2018.

4.3.1.6 The movement numbers for both landing and take-off adopted in the calculation were divided by 4 to take into account that only a quarter of landing or take-off use a specific runway.

Table 4.2 Hong Kong International Airport Civil International Air Transport Movements of Aircraft

Year	Landing	Take-off	Total
2009	139,715	139,686	279,401
2010	153,279	153,260	306,539
2011	166,919	166,887	333,806
2012	175,861	175,823	351,684
2013	186,048	186,032	372,080
2014	195,520	195,488	391,008
2015	203,043	203,005	406,048
2016	205,793	205,773	411,566
2017	210,339	210,320	420,659
2018	213,899	213,867	427,766
2019 Note 1	209,904	209,891	419,795
2020 Note 1	80,330	80,336	160,666
2032	**414,890#**	**414,866#**	**829,756#**
2039	**577,824#**	**577,816#**	**1,155,639#**

Note:
1 The data between 2019 and 2021 were not used to calculate the annual growth rate for linear regression due to the social unrest since mid-2019 and the outbreak of COVID-19.
#: based on an annual growth rate of +4.85% between 2009 and 2018 estimated by linear regression.

4.3.1.7 Only the aircraft arriving from north-east using either 25R or 25L arrival flight path as well as the aircraft departing towards northeast using either 07C or 07R departure flight path would have potential impact to the proposed EPP.

4.3.1.8 For the aircraft arriving from south-west using either 07R or 07L arrival flight path, the longitudinal distance from the runway is more than -17km, which is much smaller than -3.275km and thus the potential impact is considered to be zero. Likewise, for the aircraft departing towards south-west using either 25L or 25C departure flight path, the longitudinal distance from the runway is more than -17km, which is much smaller than -0.6km and thus the potential impact is considered to be zero.

4.3.1.9 The aircraft crash frequency was obtained by multiplying g(x,y) to the target area which was estimated to be 2.36×10^{-2} km^2 as tabulated in **Table 4.3**. The total crash frequency was calculated to be 4.72×10^{-12} per year and 6.57×10^{-12} per year for 2032 and 2039, respectively. The total crash frequencies are much less than 1.0×10^{-9} per year. The risk of aircraft crash at the proposed EPP was therefore not considered further in the analysis.

Table 4.3 Calculation for Aircraft Crash Frequency

Year	Runway	x (km)	y (km)	F(x,y)	N (per year)	R (per flight)	Crash frequency (per unit area)	Target area (km^2)	Crash Frequency (per year)
2031	25R Landing	15.2	17.5	3.0E-08	103723	2.7E-08	6.8E-11	2.36E-02	2.0E-12
2031	25L Landing	13.4	20.3	4.2E-08	103723	2.7E-08	9.5E-11	2.36E-02	2.8E-12
2031	07R Landing	x > -3.275km							0.0E+00
2031	07L Landing	x > -3.275km							0.0E+00
2031	07C Landing	No landings at 07C							0.0E+00
2031	25C Landing	No landings at 25C							0.0E+00
2031	07C Take-off	16.1	18.3	9.1E-15	103716	4.0E-08	3.1E-17	2.36E-02	4.0E-18
2031	07R Take-off	14.2	20.6	3.9E-15	103716	4.0E-08	1.3E-17	2.36E-02	9.7E-19
2031	25L Take-off	x > -0.6km							0.0E+00
2031	25C Take-off	x > -0.6km							0.0E+00
2031	07L Take-off	No take-off at 07L							0.0E+00
2031	25R take-off	No take-off at 25R							0.0E+00
2046	25R Landing	15.2	17.5	3.0E-08	144456	2.7E-08	1.2E-10	2.36E-02	2.7E-12
2046	25L Landing	13.4	20.3	4.2E-08	144456	2.7E-08	1.6E-10	2.36E-02	3.8E-12
2046	07R Landing	x > -3.275km							0.0E+00
2046	07L Landing	x > -3.275km							0.0E+00
2046	07C Landing	No landings at 07C							0.0E+00
2046	25C Landing	No landings at 25C							0.0E+00
2046	07C Take-off	16.1	18.3	9.1E-15	144454	4.0E-08	5.2E-17	2.36E-02	5.5E-18
2046	07R Take-off	14.2	20.6	3.9E-15	144454	4.0E-08	2.3E-17	2.36E-02	1.4E-18
2046	25L Take-off	x > -0.6km							0.0E+00
2046	25C Take-off	x > -0.6km							0.0E+00
2046	07L Take-off	No take-off at 07L							0.0E+00
2046	25R take-off	No take-off at 25R							0.0E+00

4.3.2 Earthquake

4.3.2.1 As Hong Kong is situated in a region of low seismicity [11][12] and located rather far away from Circum-Pacific Seismic Belt that runs through Japan, Taiwan and the Philippines [13], the probability of earthquake occurrence at MMI VIII and higher is very low comparing with other places and is estimated to be 1.0×10^{-5} per year [1]. It was assumed that failure in earthquake was possible for storage tank rupture, leakage, pipeline rupture and leakage and the probability of failure in earthquake was assumed to be 0.01 [1][10].

4.3.3 Vehicle Impact

4.3.3.1 The overall numbers of accident involvements of Medium/ Heavy Goods Vehicles (M/HGVs) [17] in Hong Kong are tabulated in **Table 4.4**. The overall accident involvement rate of M/HGVs have been quite steady in recent years. The statistics indicate the overall high and medium impact accident involvement rate per million vehicle kilometre for MGV/HGVs is 0.15. The vehicle crash frequency was therefore estimated to be 1.5×10^{-7} per vehicle kilometre per year.

Table 4.4 Accident Involvements of Medium / Heavy Goods Vehicles in Hong Kong

Serious and Fatal Vehicle involvements of M/HGVs	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Invol rate: per million veh-km	0.89	0.87	0.93	0.86	0.96	0.94	0.90	0.95	0.91	1.02	0.92
Total involvements	1 105	1 085	1 125	1 063	1 167	1 162	1 083	1 093	1 008	1 204	1110
Fatal involvements	17	25	23	23	18	26	19	22	17	21	21
Serious injury involvements	175	193	170	250	171	146	134	137	120	109	161
Fatal vehicle involvements ratio	1.5%	2.3%	2.0%	2.2%	1.5%	2.2%	1.8%	2.0%	1.7%	1.7%	1.9%
Serious injury involvements ratio	15.8%	17.8%	15.1%	23.5%	14.7%	12.6%	12.4%	12.5%	11.9%	9.1%	14.5%
High impact accident involvement rate per million vehicle km	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	**0.02**
Medium impact accident involvement rate per million vehicle km	0.14	0.15	0.14	0.20	0.14	0.12	0.11	0.12	0.11	0.09	**0.13**

4.3.3.2 A summary of the base event frequencies is presented in **Table 4.5**.

Table 4.5 Summary of Base Event Frequencies

Events	Frequency of Occurrence
Aircraft Crash	6.6×10^{-12} per year#
Earthquake	1.0×10^{-5} per year
Vehicle Impact	1.5×10^{-7} per vehicle-km per year

4.4 Fault Tree Analysis

4.4.1.1 Fault Tree Analysis (FTA) was conducted to evaluate the frequencies of the identified biogas release scenarios. FTA is the use of a combination of simple logic gates, "AND" and "OR" gates, to synthesise a failure model of the biogas facilities. Fault Tree Analyses are shown in **Annex D**. The assumptions used in FTA are summarised in the following **Table 4.6**.

Table 4.6 Assumptions used in Fault Tree Analysis

Items	Assumed Value	Justification
Probability of rupture failure in aircraft crash	1	On conservative approach
Length of internal road close to biogas facilities	0.63 km	Measured from the site plan (**Annex A** refers).
No. vehicle movements per day	95	Included tankers, sludge collectors and staff vehicles
Probability of vehicle running into gasholder / digesters / absorption vessels / pipelines	0.5	With reference to approved EIA report of the OWTF Phase 2 [1], and based on the fact that concerned process vessels are only at one side of the road.
Probability of vehicle causing damage to gasholder / digesters / absorption vessels / pipelines	0.5	With reference to approved EIA report of the OWTF Phase 2 [1].
Probability pipeline rupture failure in car crash	0.1	With reference to approved EIA report of the OWTF Phase 2 [1].
Probability pipeline leak failure in car crash	0.9	With reference to approved EIA report of the OWTF Phase 2 [1].

4.5 Ignition and Explosion Probability

4.5.1.1 In general, the probability of immediate or delayed ignitions depends on the scale of release, the presence and location of ignition sources, and the weather conditions.

4.5.1.2 Possible ignition sources include hot surfaces, static electricity, flame and hot particles from external fire etc. [18]. The ignition probabilities are further split between immediate ignition and delayed ignition in equal proportions [1]. Immediate ignition of biogas could lead to a fireball or jet fire, whereas delayed ignition could cause a flash fire or vapour cloud explosion. **Table 4.7** shows the total ignition probabilities and explosion probabilities according to gas release size [18].

Table 4.7 Ignition and Explosion Probabilities for Gas Releases

Release Size	Ignition Probability	Explosion Probability
Minor (< 1 kg/s)	0.01	0.04
Major (1 – 50 kg/s)	0.07	0.12
Massive (> 50 kg/s)	0.3	0.3

4.5.1.3 Event Tree Analysis (ETA) was developed to determine the possible hazard event outcomes from the identified hazardous events and to estimate the hazard event frequencies from the initiating release frequency. Event Tree Analyses are shown in **Annex E**.

4.6 Estimating Generic Frequencies

4.6.1.1 Generic frequency was estimated based on the historical incidents review identified the accidents involving generation, transfer, storage and use of biogas or methane, anaerobic digesters or facilities of similar nature. The generic accident frequency can be estimated through the information of the number of biogas plants works involved, the operating period and the total number of accidents occurred within the operating period. The objective of the generic frequency estimation is to confirm the appropriateness of adopting generic failure frequencies for this hazard assessment.

4.6.1.2 The generic frequencies estimated based on European experience were 1.73×10^{-4} incident per plant-year [1], whilst the overall failure frequency for organic waste co-digestion facility was 3.97×10^{-3} per year (according to FTA shown in **Annex D**), which was greater than the estimated value from the European historical incidents. The failure frequencies adopted for the facility in this hazard assessment were therefore considered reasonably conservative.

5. CONSEQUENCE AND IMPACT ANALYSIS

5.1 Introduction

5.1.1.1 Consequence and impact analysis were conducted to provide a quantitative estimate of the likelihood and number of deaths associated with the range of possible outcomes (i.e. fireball, jet fire, flash fire etc.) which were resulted from failure cases identified. The consequence assessment consists of two major parts, including:

- Source term modelling – to determine the appropriate discharge models to be used for calculation of the release rate, duration and quantity of the release; and
- Effect modelling – to determine dispersion modelling, fire modelling and explosion modelling from the input of source term modelling.

5.1.1.2 Releases from hazardous sources and their consequences were modelled using PhastRisk 6.7.

5.2 Source Term

5.2.1.1 For instantaneous failure, the whole content release of a tank is modelled. In case of continuous release, release parameters such as release rate and exit velocity are calculated by a discharge model according to storage conditions. Release duration is based on capacity of the storage tank [1]. For piping connecting to the storage tank, release duration is based on the time to empty the whole tank gas content for anaerobic digesters and the response time to completely isolate the gasholder. Release parameters together with release duration are then fed into the dispersion model to calculate the effect. Process vessel, piping and storage vessel would be the major release sources.

5.3 Potential Hazardous Outcomes and Effect Modelling

5.3.1.1 This section gives a brief description of the physical effects models used in the study to assess the effects zones for the following hazardous outcomes in case of loss of containment at the co-digestion facility.

5.3.2 Fireball

5.3.2.1 The release rate following a rupture, if ignition was immediate, would be too high to give a stable flame, and the initial ‘quasi instantaneous’ release is characterised as a fireball. The fireball is limited to a maximum duration of 30 seconds. The combustion would develop into a stable jet fire once the instantaneous release has been burnt and the release rate has become sufficiently steady for a flame to stabilise as stated by Bilo and Kinsman [19]. A release from a hole, if ignited, gives a stable flame close to the hole and produces a jet fire.

5.3.2.2 Due to the large size and intensity of a fireball, its effects are not significantly influenced by weather or wind direction. The principal hazard of fireball arises from thermal radiation. The thermal radiation from a fireball at given distances from the fireball centre are estimated using the PhastRisk’s built-in fireball modelling suite in which TNO model and HSE model are adopted. The modelling suite is set such that it decides the most appropriate one in the effect modelling. Sizes, height, shape, duration, heat flux and radiation are determined in the consequence analysis. A 100% fatality is assumed for anyone within the fireball radius.

5.3.3 Jet Fire

5.3.3.1 A jet fire occurs following the ignition and combustion of a pressurised flammable gas, which burns close to the release source. The jet fire which follows the fire ball is assumed to be directed vertically upwards out of the crater. The jet fire shape is the frustum of a cone and the location and orientation of the frustum are dependent on a number of factors such as release rate and wind speed.

5.3.3.2 Combustion in a jet fire occurs in the form of a strong turbulent diffusion flame that is strongly influenced by the initial momentum of the release. The principal hazards from a jet fire are thermal radiation and the potential for knock-on effects. Jet fires also dissipate thermal radiation and causes casualty and damage to the population and property nearby. The thermal effect to adjacent population is quantified in the consequence model.

5.3.4 Gas Dispersion and Flash Fire

5.3.4.1 Since biogas is lighter than air, its releases will tend to rise rapidly due to the buoyancy nature of the gas under atmospheric conditions. They will propagate and be diluted as a result of air entrainment with the influence of wind. The Unified Dispersion Model (UDM) model is used for the dispersion calculation of biogas for non-immediate ignition scenarios. The model takes into account various transition phases, from dense cloud dispersion to buoyant passive gas dispersion, in both instantaneous and continuous releases.

5.3.4.2 The principal hazard arising from a cloud of dispersing biogas is the delayed ignition of the flammable cloud that cause a flame to flash back to the release location and develop into a stable jet or crater fire. Large scale experiments on the dispersion and ignition of flammable gas clouds show that ignition is unlikely when the average concentration is below the Lower Flammable Limit (LFL) or above the Upper Flammable Limit (UFL).

5.3.4.3 Major hazards from flash fire are thermal radiation and direct flame contact. It is considered that there is no scope for escape within the LFL of a flammable cloud in a flash fire. Therefore, a fatality probability of 100% of persons present within the flammable cloud is assumed for flash fires.

5.3.5 Vapour Cloud Explosion

5.3.5.1 A vapour cloud explosion can occur when a flammable vapour is ignited in a confined or partially confined situation. When there is a large amount of pressurised gas rapidly releasing to the atmosphere from a pressurised tank, a vapour cloud could be formed, dispersed and mixed with the surrounding air. If the vapour cloud is passing through a confined / semi-confined environment and gets ignited, the confinement could limit the degree of expansion of the burning cloud and create an overpressure and explosion.

5.3.5.2 The risk model will be accounted for the VCE hazard according to probabilities for delayed ignition in consequence modelling. The program models the delayed ignition effect by considering the flammable cloud area and location of ignition sources at each time step. Potential damage from a VCE is caused by overpressure.

5.4 Impact Assessment

5.4.1 Thermal Radiation

5.4.1.1 Hazardous consequences, such as jet fire, flash fire, etc. were assessed using PHAST's consequence models. Fatality probabilities of various hazardous event outcomes were evaluated at a number of end-point criteria in each type of hazard outcome. The estimation of the fatality/ injury caused by a physical effect such as thermal radiation or overpressure requires the use of probit equations, which describe the probability of fatality as a function of some physical effect. The probit is an alternative way of expressing the probability of fatality and is derived from a statistical transformation of the probability of fatality.

5.4.1.2 The probability of fatality, Pr, due to exposure to heat radiation, i.e. jet fire and fireball is given by the following probit relationship by Eisenberg et al. which provides one of the more conservative estimates [20]:

$$Pr = -14.9 + 2.56\ ln\left(Q^{\frac{4}{3}} \times t\right)$$

Where,
Pr is the probit associated with the probability of fatality;
Q is the heat radiation intensity (kW/m^2);

t is the exposure time (s).

5.4.2 Overpressure

5.4.2.1 The probability of fatality due to overpressure is taken from CIA guidelines [21] as shown in **Table 5.1**. The indoors fatality probability is higher taken into account the increased risk from flying debris such as breaking windows [8].

Table 5.1 End Point Criteria for Vapour Cloud Explosions

Overpressure (psi)	Fatality Probability (Outdoors)	Fatality Probability (Indoors)
5	0.09	0.55
3	0.02	0.15
1	0.00	0.01

6. RISK EVALUATION

6.1 Introduction

6.1.1.1 By combining the population data, meteorological data, results of frequency estimation and consequence analysis, risk levels due to the operation of the organic waste co-digestion facility at the proposed EPP are assessed and evaluated in terms of both individual and societal risks.

6.1.1.2 Individual risk is a measure of the risk to a chosen individual at a particular location. As such, this is evaluated by summing the contributions to that risk across a spectrum of incidents which could occur at a particular location.

6.1.1.3 Societal risk is a measure of the overall impact of an activity upon the surrounding community. As such, the likelihoods and consequences of the range of incidents postulated for that particular activity are combined to create a cumulative picture of the spectrum of the possible consequences and their frequencies. This is usually presented as an F-N curve and the acceptability of the results can be judged against the societal risk criterion under the risk guidelines.

6.2 Individual Risk

Risk Level

6.2.1.1 The individual risk (IR) contours associated with the organic waste co-digestion facility at the proposed EPP are shown in **Plate 6.1**. The risk levels were estimated based on 100% occupancy with no allowance made for shelter or escape, which can be referred from the user manual of PhastRisk.

6.2.1.2 The HKRG criterion for individual risk is that no person off-site should be subject to an additional risk of 1×10^{-5} per year.

Acceptability

6.2.1.3 Individual risk contours down to the level 1×10^{-9} per year are shown in the diagram. The level 1×10^{-5} per year individual risk contour is confined entirely within the boundary of the proposed EPP. The maximum individual risk remains below 1×10^{-5} per year at the site boundary and meets the HKRG requirements.

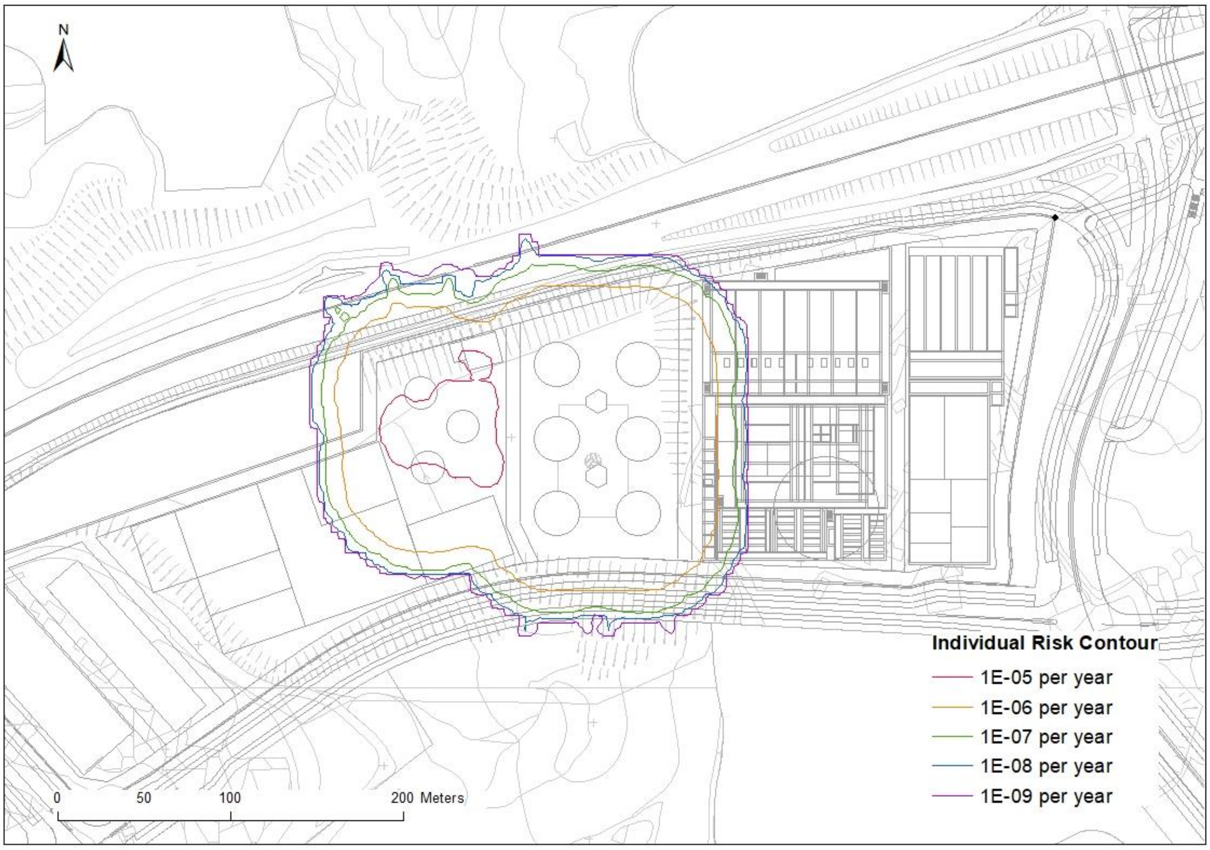

Plate 6.1 Individual Risk Contours for the Proposed EPP

6.3 Societal Risk

6.3.1.1 The societal risk results for the proposed EPP are presented in **Plate 6.2** in form of F-N curves for comparison with the HKRG.

Acceptability

6.3.1.2 The societal risk associated with operation of the biogas facilities in the proposed EPP falls within the "Acceptable" region. The potential loss of life (PLL) for the facility was estimated to be 3.09×10^{-6} per year and 3.57×10^{-6} per year for construction and operation phases respectively.

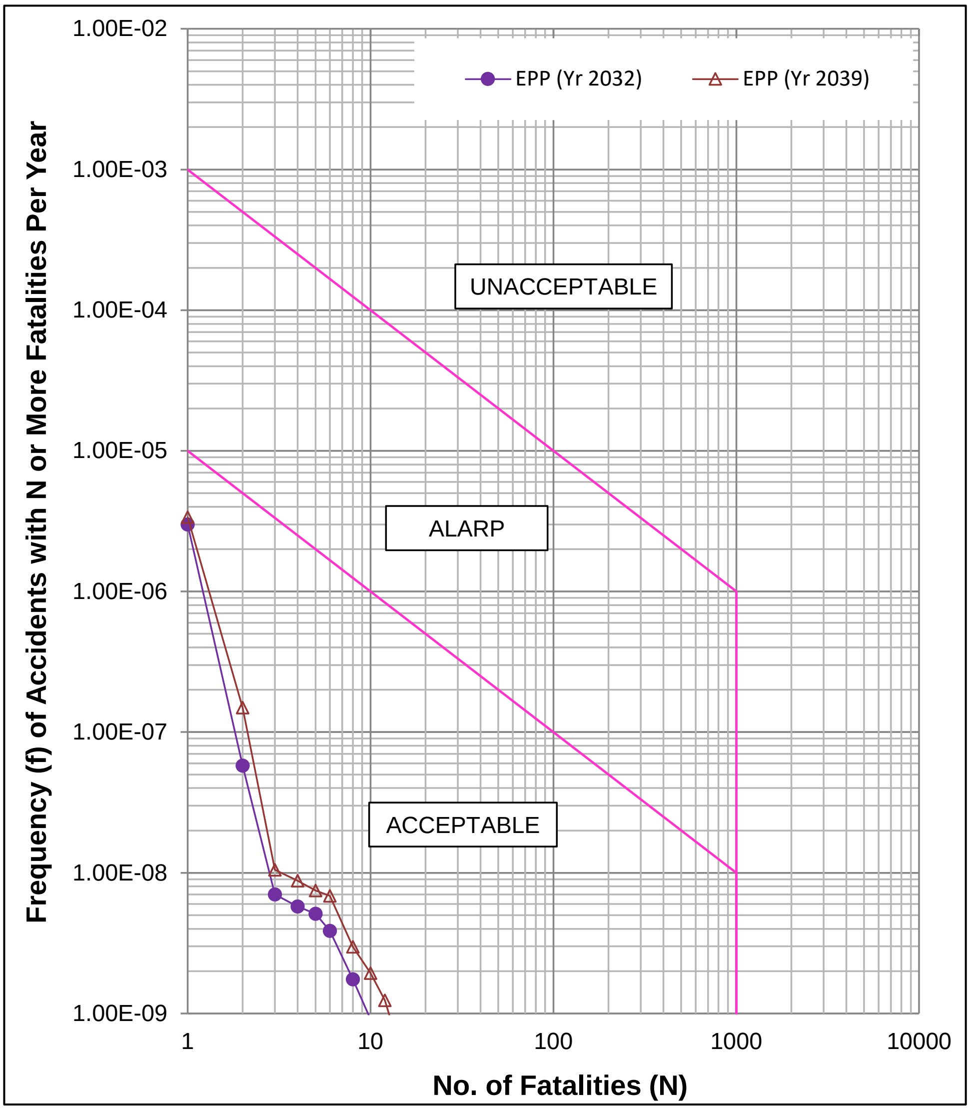

Plate 6.2 Societal Risk Curve in Comparison with HKRG

7. RECOMMENDATIONS

7.1.1.1 While the risks associated with organic waste co-digestion facility are within the acceptable region and no mitigation measures are required, it is still advisable for the following good safety practices and recommended design measures to be followed for the design and operation of the facility as far as practicable:

- the process plant building should be provided with adequate number of gas detectors distributed over various areas of potential leak sources to provide adequate coverage;
- all electrical equipment inside the building should be classified in accordance with the electrical area classification requirements. No unclassified electrical equipment should be used during operations or maintenance;
- all safety valves should be designed to discharge the released fluid to a safe location and stop misdirection of fluid flows in order to avoid hazardous outcome;
- safety markings and crash barriers should be provided to the aboveground piping, digesters and gas holders near the entrance;
- fixed crash barriers should be provided in areas where process equipment is adjacent to the internal roadway to protect against vehicle collision. Adequate warning signage and lighting should also be provided and maximum speed limit should also be in place; and
- lightning protection installations should be installed following *IEC 62305, BS EN 62305, AS/NZS 1768, NFPA 780* or equivalent standards;
- suitable fire extinguishers should be provided within the site. An External Water Spray System (EWSS) should be installed in appropriate areas, such as around the gasholders, digester and sulphur removal vessels. The facilities should also be equipped with fire and gas detection system and fire suppression system; and
- stringent procedures should be implemented to prohibit smoking or naked flames to be used on-site.

8. ENVIRONMENTAL MONITORING AND AUDIT REQUIREMENT

8.1.1.1 The EIA study concluded that no unacceptable risk is anticipated during the operation phase of the Project, no mitigation measures would be required. Good safety practices and recommended design measures are recommended to further manage and minimize the potential risks during operation phase of the Project. No environmental monitoring and audit requirements would be required.

9. CONCLUSION

9.1.1.1 A quantitative hazard assessment was conducted to evaluate the biogas risk to existing, committed and planned off-site population due to operation of the organic waste co-digestion facility at the proposed EPP in accordance with Section 3.4.14 and Appendix H of the EIA Study Brief (ESB-340/2021).

9.1.1.2 Both the individual and societal risk levels were found to meet relevant requirements stipulated in the HKRG, i.e. the off-site individual risk level is far below 1×10^{-5} per year and the societal risk falls into the “Acceptable” region, no mitigation measure is required.

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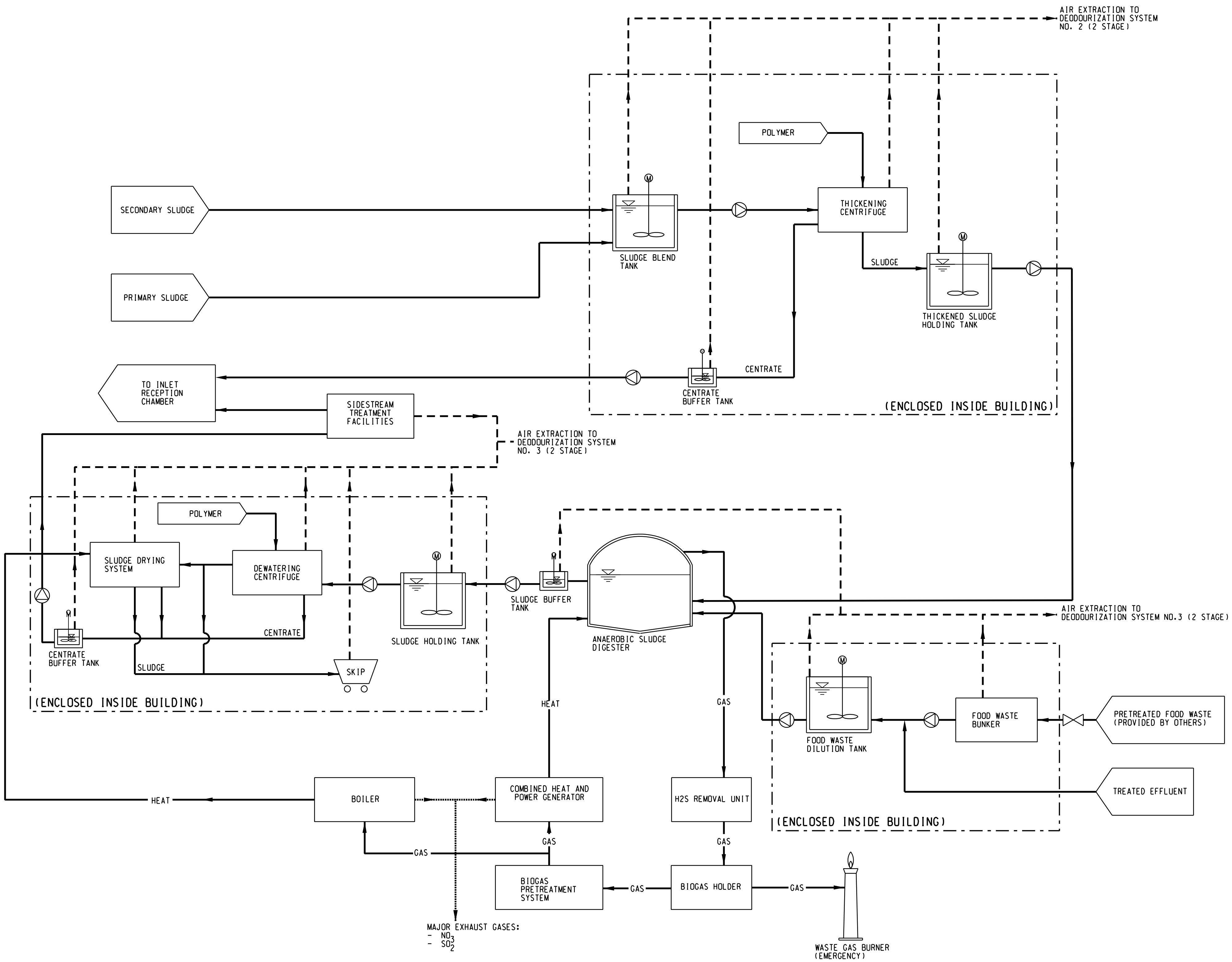
Annex A

Process Flow Description



AECOM

PROJECT 項目

FIRST PHASE DEVELOPMENT OF THE NEW TERRITORIES NORTH – SAN TIN / LOK MA CHAU DEVELOPMENT NODE – INVESTIGATION

CLIENT 業主

土木工程拓展署
Civil Engineering and Development Department

規劃署
Planning Department

CONSULTANT 工程顧問公司

AECOM Asia Company Ltd.
www.aecom.com

SUB-CONSULTANTS 分判工程顧問公司

ISSUE/REVISION 修訂

I/R 修訂	DATE 日期	DESCRIPTION 內容摘要	CHK. 複核

STATUS 階段

SCALE 比例: N.T.S.

DIMENSION UNIT 尺寸單位: METRES

KEY PLAN 索引圖

PROJECT NO. 項目編號: 60670882

AGREEMENT NO. 協議編號: CE 20/2021

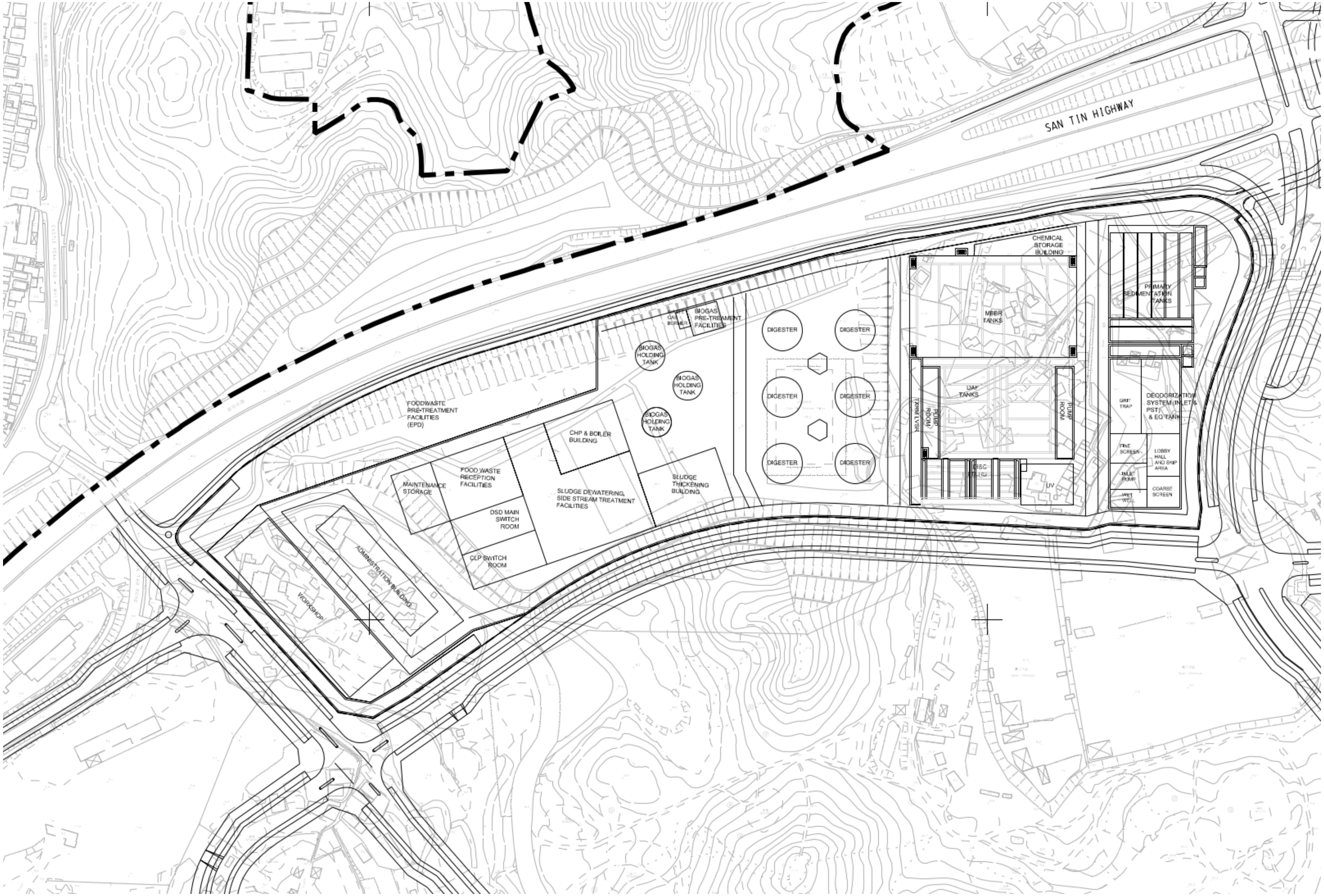
SHEET TITLE 圖紙名稱

SLUDEGE DIAGRAM

SHEET NUMBER 圖紙編號

60670882/A19/431

ISO A1 594mm x 841mm
Approved: Checked: Designer: Project Management Initials:
Plot File by: PENGW 2022/10/12
PATH P:\PROJECTS\60670882\DRAWING\REPORT\A19\A19_431.dgn



Proposed Layout of EPP

Annex B

Population Data

Popu_ID	Land_ID	Description	Maximum Population in 2032	Maximum Population in 2039	Indoor Ratio in 2032	**% Occupancy in 2032**				Population in 2032				Shielding Factor [FB]	Shielded Population in 2032				Indoor Ratio in 2039	**% Occupancy in 2039**				Population in 2039				Shielding Factor [FB]	Shielded Population in 2039			
						Weekday		Weekend		Weekday		Weekend			Weekday		Weekend			Weekday		Weekend		Weekday		Weekend			Weekday		Weekend	
						Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night		Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night
E02	-	Scenic Heights	106	106	0.95	0.5	1	0.7	1	53	106	74	106	0.5	27	53	37	53	0.95	0.5	1	0.7	1	53	106	74	106	0.5	27	53	37	53
E05	-	Mai Po San Tsuen	3164	3164	0.95	0.5	1	0.7	1	1582	3164	2215	3164	0.5	791	1582	1108	1582	0.95	0.5	1	0.7	1	1582	3164	2215	3164	0.5	791	1582	1108	1582
P01	A.5.1	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P02	OU(ESS).5.12	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P03	G.5.3	Existing Mai Po ESS	125	84	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	84	8	42	8	0.5	42	4	21	4
P04	G.5.1	Sport Centre	125	1018	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	1018	102	509	102	0.5	509	51	255	51
P05	RSc.2.1	Public Housing	9899	9899	0.95	0.5	1	0.7	1	4950	9899	6929	9899	0.5	2475	4950	3465	4950	0.95	0.5	1	0.7	1	4950	9899	6929	9899	0.5	2475	4950	3465	4950
P06	RSc.2.2	Public Housing	7603	7603	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802
P07a	OU(EPP).5.3	Food Waste Pretreatment Facilities	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P08	OU(GFS).5.1	Green Fuel Station	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10
P09	G.5.2	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P10	GB.5.3	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P11	OU(ESS).5.6	132kV ESS	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P12	G.5.5	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P13	E.5.3	Reserve (Potential Education Facilities)	125	1680	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0	0.5	0	1680	0	840	0	0.5	840	0	420	0
P14	GB.5.4	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P15	OU(SPS).5.7	Sewage Pumping Station	30	30	0.95	1	0.1	0.5	0.1	30	3	15	3	0.5	15	2	8	2	0.95	1	0.1	0.5	0.1	30	3	15	3	0.5	15	2	8	2
P53	OU(LSW).1.2	Logistics, Storage and Warehouse	220	220	0.95	1	0.1	0.5	0.1	220	22	110	22	0.5	110	11	55	11	0.95	1	0.1	0.5	0.1	220	22	110	22	0.5	110	11	55	11
P54	OU(DSC).1.11	District Cooling System	25	25	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2
P55	O.1.3	Open space	410	410	0	1	1	1	1	410	410	410	410	0	410	410	410	410	0	1	1	1	1	410	410	410	410	0	410	410	410	410
P56	OU(I&T)3.1.9	Information and Technology - Zone 3	80	5228	0	1	0.1	0.5	0.1	80	8	40	8	0	80	8	40	8	0.95	1	0.1	0.5	0.1	5228	523	2614	523	0.5	2614	262	1307	262
P57	OU(WRP).5.2	Water Reclamation Plant	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P58	E.2.1	2 Primary School	129	1678	0	1	0.1	0.5	0.1	129	13	65	13	0	129	13	65	13	0.95	1	0	0.5	0	1678	0	839	0	0.5	839	0	420	0
P59	OU(RCP).5.5	RCP	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P60	GB.5.1	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P61	GB.5.2	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P63	A.1.17	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2032)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	2	73	12	1	26	34	30	4	0	3	186
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	3	18
Road R2													
Total Vehicle per hour	0.16	50	9	299	50	5	49	115	100	16	0	7	652
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R3													
Total Vehicle per hour	0.34	50	5	160	27	3	0	25	21	9	0	0	250
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road R4													
Total Vehicle per hour	0.69	50	6	183	30	3	3	45	39	11	0	4	323
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	1	1	1	3	0	3	16
Road R5													
Total Vehicle per hour	0.7	50	7	232	39	4	21	73	63	13	0	0	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	5	2	2	4	0	0	22
Road R6													
Total Vehicle per hour	0.58	100	106	3416	568	62	134	1266	1081	189	6	224	7051
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	28	7	2	13	10	8	23	0	66	158
Road R7													
Total Vehicle per hour	0.64	100	99	3197	532	58	131	1166	996	176	4	164	6524
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	7	2	14	10	8	23	0	54	148
Road R8													
Total Vehicle per hour	0.83	100	106	3440	572	62	131	1244	1064	189	5	192	7007
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	10	3	18	14	11	32	0	81	210
Road R9													
Total Vehicle per hour	0.68	100	77	2474	412	45	108	816	698	136	3	105	4872
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	24	6	2	12	8	6	19	0	37	115
Road R10													
Total Vehicle per hour	1.18	100	109	3518	586	64	108	903	772	192	4	147	6402
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	59	14	4	21	14	11	46	0	89	260
Road R11													
Total Vehicle per hour	0.19	50	7	238	39	4	3	142	121	14	5	201	774
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	39	49
Road R12													
Total Vehicle per hour	0.37	50	7	217	36	4	0	34	29	12	7	273	619
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	103	113
Road R13													
Total Vehicle per hour	0.32	50	3	101	17	2	0	29	25	5	1	38	222
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20
Road R14													
Total Vehicle per hour	0.27	50	4	115	18	2	3	70	59	7	1	26	305
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	8	16
Road R15													
Total Vehicle per hour	0.45	50	4	133	22	2	0	37	32	7	0	7	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R16													
Total Vehicle per hour	0.39	50	3	110	18	2	0	41	36	6	1	20	238
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	9	17

Road R17													
Total Vehicle per hour	0.13	50	2	74	12	1	0	11	10	4	2	62	179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	9	16

Road R18													
Total Vehicle per hour	0.15	50	3	103	17	2	3	83	70	6	0	0	286
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8

Road R19													
Total Vehicle per hour	0.37	50	2	56	9	1	52	36	30	3	1	53	244
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	7	1	1	1	0	21	35

Road R20													
Total Vehicle per hour	0.54	50	1	43	7	1	52	28	24	3	1	53	213
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	9	1	1	1	0	30	46

Road R21													
Total Vehicle per hour	0.44	50	2	65	11	1	67	13	11	4	1	51	227
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	10	1	1	1	0	23	40

Road R22													
Total Vehicle per hour	0.2	50	3	110	18	2	89	78	66	6	4	139	516
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	6	1	1	1	0	29	42

Road R23													
Total Vehicle per hour	0.45	50	9	281	47	5	17	86	73	16	3	109	645
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	3	0	50	66

Road R24													
Total Vehicle per hour	1.11	50	7	226	38	4	17	55	47	12	3	109	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	6	0	124	153

Road R25													
Total Vehicle per hour	0.86	50	5	161	27	3	0	31	27	9	5	185	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	163	176

Road R26													
Total Vehicle per hour	0.67	50	1	27	4	0	0	4	3	2	1	21	61
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	15	22

Road R27													
Total Vehicle per hour	0.63	50	0	7	1	0	0	4	3	0	1	21	36
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	14	21

Road R28													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R29													
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R30													
Total Vehicle per hour	0.67	50	1	22	4	0	0	8	6	1	1	52	95
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	36	43

Road R31													
Total Vehicle per hour	1.62	50	7	219	36	4	5	125	107	12	0	4	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	10	3	1	3	6	5	9	0	7	45

Road R32													
Total Vehicle per hour	0.21	50	4	130	21	2	0	56	49	7	3	121	394
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	26	33

Road R33													
Total Vehicle per hour	0.6	50	28	918	154	17	0	38	32	49	0	0	1237
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	16	4	1	0	1	1	12	0	0	36

Road R34													
Total Vehicle per hour	0.42	50	7	238	39	4	12	127	108	14	1	42	593
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	2	2	2	3	0	19	34

Road R35													
Total Vehicle per hour	0.31	50	23	730	123	13	0	73	63	38	0	19	1082
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	1	1	5	0	6	24

Road R36													
Total Vehicle per hour	0.59	50	4	125	21	2	0	37	32	7	3	131	362
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	79	89

Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	4	139	23	3	0	41	35	8	3	131	388
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	51	60

Road R39													
Total Vehicle per hour	0.6	50	19	603	101	11	45	182	155	32	3	130	1281
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	11	3	1	9	3	3	8	0	80	119

Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20

Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9

Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2032)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	1	32	6	0	13	7	6	2	0	1	69
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	2	12
Road R2													
Total Vehicle per hour	0.16	50	5	149	29	1	24	23	21	6	0	3	261
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	2	1	1	1	0	1	10
Road R3													
Total Vehicle per hour	0.34	50	2	76	15	0	0	5	4	3	0	0	106
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R4													
Total Vehicle per hour	0.69	50	3	83	16	1	1	9	8	4	0	2	126
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	2	12
Road R5													
Total Vehicle per hour	0.7	50	4	115	22	1	10	14	13	5	0	0	184
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	52	1673	322	8	66	242	216	73	4	102	2758
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	14	4	1	7	2	2	9	0	31	71
Road R7													
Total Vehicle per hour	0.64	100	49	1583	304	7	64	224	200	69	3	75	2579
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	7	2	2	9	0	25	66
Road R8													
Total Vehicle per hour	0.83	100	53	1704	328	8	64	239	214	74	3	88	2776
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	9	3	3	13	0	37	93
Road R9													
Total Vehicle per hour	0.68	100	38	1239	238	5	53	158	142	54	2	48	1977
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	4	1	6	2	2	8	0	17	53
Road R10													
Total Vehicle per hour	1.18	100	55	1778	341	8	53	175	157	77	3	67	2713
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	8	1	10	3	3	19	0	41	116
Road R11													
Total Vehicle per hour	0.19	50	4	112	22	1	1	27	24	5	4	93	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	18	26
Road R12													
Total Vehicle per hour	0.37	50	3	98	19	1	0	6	5	4	5	121	262
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	46	54
Road R13													
Total Vehicle per hour	0.32	50	2	52	10	0	0	5	5	2	1	17	94
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	6	13
Road R14													
Total Vehicle per hour	0.27	50	2	38	8	0	1	13	10	2	0	10	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	3	11
Road R15													
Total Vehicle per hour	0.45	50	2	65	12	0	0	7	7	3	0	3	100
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R16												
Total Vehicle per hour	0.39	50	2	56	11	0	0	8	8	2	0	10	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R17													
Total Vehicle per hour	0.13	50	1	38	7	0	0	2	2	2	1	26	79
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R18													
Total Vehicle per hour	0.15	50	2	41	8	0	1	16	13	2	0	0	83
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8

Road R19													
Total Vehicle per hour	0.37	50	1	25	5	0	26	7	6	1	1	25	96
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	4	1	1	1	0	10	21

Road R20													
Total Vehicle per hour	0.54	50	1	19	4	0	26	5	5	1	1	25	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	14	26

Road R21													
Total Vehicle per hour	0.44	50	1	27	5	0	33	3	2	1	1	24	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	11	23

Road R22													
Total Vehicle per hour	0.2	50	2	54	10	0	44	15	13	2	3	64	208
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23													
Total Vehicle per hour	0.45	50	4	134	26	1	9	17	15	6	2	51	264
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24													
Total Vehicle per hour	1.11	50	4	113	22	0	9	11	10	5	2	51	226
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	58	74

Road R25													
Total Vehicle per hour	0.86	50	2	80	15	0	0	6	5	3	3	86	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	76	85

Road R26													
Total Vehicle per hour	0.67	50	0	12	2	0	0	1	1	1	0	10	27
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R27													
Total Vehicle per hour	0.63	50	0	3	1	0	0	1	1	0	0	10	14
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R28													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R29													
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R30													
Total Vehicle per hour	0.67	50	0	8	2	0	0	1	1	0	1	17	29
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	12	19

Road R31													
Total Vehicle per hour	1.62	50	3	108	21	1	3	24	21	5	0	2	187
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	2	2	1	4	0	3	21

Road R32													
Total Vehicle per hour	0.21	50	2	62	12	0	0	11	10	3	2	56	159
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	14	480	92	2	0	7	6	20	0	0	622
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	1	1	5	0	0	21
Road R34													
Total Vehicle per hour	0.42	50	4	102	20	1	6	24	21	5	1	19	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	9	18
Road R35													
Total Vehicle per hour	0.31	50	12	394	75	1	0	14	13	16	0	9	534
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	3	15
Road R36													
Total Vehicle per hour	0.59	50	2	60	12	0	0	7	6	3	2	61	153
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	37	44
Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R38													
Total Vehicle per hour	0.38	50	2	69	13	0	0	8	7	3	2	61	166
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31
Road R39													
Total Vehicle per hour	0.6	50	9	320	61	1	22	35	31	13	2	60	556
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	1	1	4	0	37	58
Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	32	28	2	0	0	114
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20
Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Note:
[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2039)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	6	185	30	3	26	86	74	11	0	3	425
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	6	2	2	4	0	3	24
Road R2													
Total Vehicle per hour	0.16	50	22	725	120	13	49	238	203	40	0	7	1419
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	1	1	3	0	2	17
Road R3													
Total Vehicle per hour	0.34	50	20	661	110	12	0	124	107	37	0	0	1071
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	6	0	0	20
Road R4													
Total Vehicle per hour	0.69	50	23	733	122	13	3	148	126	40	0	4	1212
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	1	3	3	12	0	3	43
Road R5													
Total Vehicle per hour	0.7	50	9	287	48	5	21	106	91	15	0	0	582
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	2	2	5	0	0	24
Road R6													
Total Vehicle per hour	0.58	100	152	4909	816	89	133	1785	1522	270	6	228	9910
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	9	3	13	14	11	32	0	68	191
Road R7													
Total Vehicle per hour	0.64	100	124	4007	667	73	131	1416	1210	220	4	159	8011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	36	9	3	14	12	10	29	0	52	166
Road R8													
Total Vehicle per hour	0.83	100	154	4969	827	90	131	1557	1330	272	5	185	9520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	58	14	4	18	17	14	46	0	79	252
Road R9													
Total Vehicle per hour	0.68	100	94	3046	508	55	108	748	640	166	3	116	5485
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	7	2	12	7	6	23	0	41	129
Road R10													
Total Vehicle per hour	1.18	100	136	4409	736	80	108	853	730	238	4	153	7448
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	73	17	5	21	14	11	58	0	92	293
Road R11													
Total Vehicle per hour	0.19	50	17	560	93	10	3	269	229	32	6	225	1443
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	2	2	3	0	44	58
Road R12													
Total Vehicle per hour	0.37	50	43	1389	231	25	0	262	223	77	4	157	2410
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	0	3	2	12	0	60	98
Road R13													
Total Vehicle per hour	0.32	50	10	336	55	6	0	136	116	20	1	41	721
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	14	27
Road R14													
Total Vehicle per hour	0.27	50	18	566	94	10	3	232	197	31	1	28	1179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	1	2	2	4	0	8	25
Road R15													
Total Vehicle per hour	0.45	50	17	561	93	10	0	66	56	31	0	0	835
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	6	0	0	20

Road R16													
Total Vehicle per hour	0.39	50	12	401	67	7	0	75	64	22	1	25	674
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	0	1	1	4	0	11	25

Road R17													
Total Vehicle per hour	0.13	50	13	424	70	8	0	88	75	24	1	26	729
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R18													
Total Vehicle per hour	0.15	50	6	204	34	4	3	136	115	11	1	28	540
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	5	13

Road R19													
Total Vehicle per hour	0.37	50	9	275	45	5	52	84	71	16	1	53	612
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	7	1	1	3	0	21	39

Road R20													
Total Vehicle per hour	0.54	50	8	266	44	5	52	87	74	15	1	53	607
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	9	2	1	4	0	30	54

Road R21													
Total Vehicle per hour	0.44	50	10	315	52	6	67	95	82	17	1	51	696
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	10	2	1	4	0	23	47

Road R22													
Total Vehicle per hour	0.2	50	10	329	54	6	89	149	127	19	4	139	925
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	29	44

Road R23													
Total Vehicle per hour	0.45	50	9	295	49	5	17	97	83	16	3	109	684
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	4	0	50	67

Road R24													
Total Vehicle per hour	1.11	50	8	244	41	4	17	62	53	13	3	121	567
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	7	0	138	168

Road R25													
Total Vehicle per hour	0.86	50	14	459	76	8	0	72	62	25	4	159	880
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	2	2	9	0	140	170

Road R26													
Total Vehicle per hour	0.67	50	15	478	80	9	0	121	103	26	2	68	901
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	3	2	8	0	47	74

Road R27													
Total Vehicle per hour	0.63	50	11	346	58	6	0	75	64	19	2	89	671
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	5	0	58	77

Road R28													
Total Vehicle per hour	0.2	50	15	491	81	9	0	127	108	28	1	52	913
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	11	22

Road R29													
Total Vehicle per hour	0.15	50	17	542	90	10	0	136	116	30	2	68	1011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	11	21

Road R30													
Total Vehicle per hour	0.67	50	11	340	56	6	0	78	66	19	3	98	676
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	2	6	0	67	88

Road R31													
Total Vehicle per hour	1.62	50	12	376	62	7	5	182	156	21	0	4	826
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	4	1	3	8	7	15	0	7	64

Road R32													
Total Vehicle per hour	0.21	50	9	297	49	5	0	211	181	17	3	121	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	2	1	2	0	26	36

Road R33													
Total Vehicle per hour	0.6	50	39	1265	212	23	0	118	100	67	0	0	1825
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	22	5	2	0	2	2	17	0	0	51

Road R34													
Total Vehicle per hour	0.42	50	15	481	78	9	12	251	215	29	1	36	1127
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	2	3	3	5	0	16	39

Road R35													
Total Vehicle per hour	0.31	50	30	965	163	17	0	71	61	49	0	13	1370
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	2	1	0	1	1	7	0	5	27

Road R36													
Total Vehicle per hour	0.59	50	5	164	27	3	0	50	42	9	3	118	422
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	72	83

Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	2	69	11	1	0	33	28	4	3	131	282
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	51	58

Road R39													
Total Vehicle per hour	0.6	50	31	991	166	18	45	268	229	52	4	154	1958
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	17	4	1	9	5	4	13	0	95	149

Road R40													
Total Vehicle per hour	0.2	50	4	129	21	2	0	23	19	7	0	0	206
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2039) Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	3	76	15	1	13	17	16	4	0	1	145
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R2													
Total Vehicle per hour	0.16	50	11	358	69	2	24	46	41	16	0	3	570
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	1	12
Road R3													
Total Vehicle per hour	0.34	50	10	327	63	2	0	24	22	14	0	0	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	0	11
Road R4													
Total Vehicle per hour	0.69	50	11	364	70	2	1	28	25	16	0	2	520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	1	1	1	5	0	2	22
Road R5													
Total Vehicle per hour	0.7	50	5	151	29	1	10	21	19	6	0	0	241
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	76	2439	469	11	66	343	304	107	4	105	3923
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	7	3	3	13	0	31	85
Road R7													
Total Vehicle per hour	0.64	100	62	2005	385	9	64	273	243	87	3	73	3205
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	5	1	7	3	2	12	0	24	73
Road R8													
Total Vehicle per hour	0.83	100	77	2489	478	11	64	300	268	108	3	85	3884
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	8	1	9	4	3	19	0	36	110
Road R9													
Total Vehicle per hour	0.68	100	47	1548	297	6	53	145	131	67	2	53	2350
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	6	2	2	10	0	19	60
Road R10													
Total Vehicle per hour	1.18	100	69	2263	434	9	53	165	149	97	3	70	3312
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	38	10	1	10	3	3	24	0	43	133
Road R11													
Total Vehicle per hour	0.19	50	9	265	51	1	1	51	45	12	4	104	545
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	21	30
Road R12													
Total Vehicle per hour	0.37	50	21	690	133	3	0	50	44	30	3	73	1048
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	5	0	28	47
Road R13													
Total Vehicle per hour	0.32	50	5	146	28	1	0	26	23	7	1	19	256
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	7	15
Road R14													
Total Vehicle per hour	0.27	50	9	288	55	1	1	44	38	12	1	13	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	4	15
Road R15													
Total Vehicle per hour	0.45	50	9	278	54	1	0	13	12	12	0	0	378
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road R16													
Total Vehicle per hour	0.39	50	6	206	39	1	0	15	13	9	0	12	301
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	5	15

Road R17													
Total Vehicle per hour	0.13	50	7	208	40	1	0	17	15	9	1	13	309
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R18													
Total Vehicle per hour	0.15	50	3	102	20	0	1	26	22	4	1	13	192
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	2	10

Road R19													
Total Vehicle per hour	0.37	50	4	130	25	1	26	16	14	6	1	25	247
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	4	1	1	1	0	10	22

Road R20													
Total Vehicle per hour	0.54	50	4	123	24	1	26	17	15	6	1	25	240
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	14	28

Road R21													
Total Vehicle per hour	0.44	50	5	157	30	1	33	18	17	7	1	24	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	11	25

Road R22													
Total Vehicle per hour	0.2	50	5	150	29	1	44	29	26	7	3	64	357
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23													
Total Vehicle per hour	0.45	50	5	144	28	1	9	19	17	6	2	51	280
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24													
Total Vehicle per hour	1.11	50	4	123	24	1	9	12	11	5	2	56	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	64	80

Road R25													
Total Vehicle per hour	0.86	50	7	226	44	1	0	14	13	10	3	74	392
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	0	1	1	4	0	65	81

Road R26													
Total Vehicle per hour	0.67	50	7	239	46	1	0	23	21	10	1	31	381
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	22	36

Road R27													
Total Vehicle per hour	0.63	50	5	171	33	1	0	15	13	8	2	41	289
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	27	38

Road R28													
Total Vehicle per hour	0.2	50	8	231	45	1	0	24	22	11	1	24	366
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R29													
Total Vehicle per hour	0.15	50	8	274	53	1	0	26	23	12	1	31	430
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R30													
Total Vehicle per hour	0.67	50	5	164	32	1	0	15	13	7	2	45	285
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	31	42

Road R31													
Total Vehicle per hour	1.62	50	6	178	34	1	3	35	32	8	0	2	299
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	2	2	2	6	0	3	29

Road R32													
Total Vehicle per hour	0.21	50	5	139	27	1	0	41	37	6	2	56	313
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	20	673	129	2	0	23	20	28	0	0	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	1	1	7	0	0	26

Road R34													
Total Vehicle per hour	0.42	50	7	198	39	2	6	49	44	10	1	17	371
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	8	19

Road R35													
Total Vehicle per hour	0.31	50	15	540	103	1	0	14	13	22	0	6	715
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	2	16

Road R36													
Total Vehicle per hour	0.59	50	3	84	16	0	0	10	8	4	2	55	181
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	33	41

Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	1	32	6	0	0	6	6	1	2	61	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31

Road R39													
Total Vehicle per hour	0.6	50	16	526	101	2	22	52	46	22	3	71	860
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	5	1	1	6	0	44	71

Road R40													
Total Vehicle per hour	0.2	50	2	61	12	0	0	4	4	3	0	0	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	33	28	2	0	0	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Note:
[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Annex C

Review of Historic Incidents Database

Annex C Review of Historical Incidents Database

Year	Location	Injury	Death	Description	Reference	Source of Accident
1988	US	0	0	2 underground pipelines, one carrying methane and the other propane, ruptured causing an explosion leaving 25ft deep, 30ft diameter crater. Flames were sent 300ft into the air. Firefighter could not apprach the fire because of the heat.	MHIDAS	Methane Transportation Pipeline
1989	UK	2	0	Pipework being cooled down prior to export of gas. Gas drained into burner and flashed back igniting gas in the vicinity.	MHIDAS	Methane Transportation Pipeline
1992	Turkey	64	32	Explosion in 1000m3 storage tank under factory canteen. Suspected methane being pumped in with water. 32 killed due to blast and drowning. 64 injured.	MHIDAS	Methane Storage Tank
1996	India		3	Tank of methane gas exploded at effluent treatment plant while welding work was being complete on tank's roofs. Three workers killed and 1 seriously injured. Workers were trying to prevent gas leaks upon orders of state pollution control officers.	MHIDAS	Methane Storage Tank
1997	Italy	1	2	In a municipal sewage plant (wastewater), an explosion occurred during repair work in a concrete silo of a biogas plant. Residue gas and welding operations are the cause of the accident. Two workers were thrown out and killed, and a third one falls to the bottom of the building and was seriously injured. The roof of the silo has been blown.	(i), (ii), (iii)	Biogas in Anaerobic Digestion Plant
1999	France	0	0	In a recycling unit of biogas from the anaerobic treatment plant of a paper mill, an explosion (5kg of TNT) buffer destoryed a ballon of flexible material 10m and their associated piping supplying a boiler or stream flare safety. The ballon exploded, the railings are bent in a radius of 3m, the tiles are destoryed within a radius of 20m, claddding and windows on the unit up to 130m fly into pieces away. There has been no victim. The balloon will be blocked and downhill into depression. Air would be entered by Telfon joints rubbing on the central axis. The biogas has come back and then has formed the explosive mixture which has been ignited by the pilot flame of the flare. An accidental production of hydrogen in the digester and an act of malice were also discussed. Expertise was made. Safety devices were then installed (analyzers, valves, etc.	(i), (ii), (iii)	Biogas in Anaerobic Digestion Plant
2002	Australia	0	0	Gas started leaking from gasometer after tank top tilted. Situation worsened as gas was still being pumped into tank. 2km safety zone imposed.	MHIDAS	Methane Storage Tank
2006	Germany	0	0	At a biogas plant for the treatment of household waste in the vicinity of Göttingen, two fermentation tanks burst, causing around seven million litres of fermentation sludge and rainwater to spread over adjacent fields. A third 20-m-high tank was at risk of collapsing. The mixture ran down from the plateau on which the plant had been built and polluted not only the site but also two bodies of water. There was no risk to the population. However, the bursting force of the standing fermenters caused damage to an adjacent building and a fuel oil tank, from which about 1,000 litres of fuel oil leaked. The amount of the loss was approximately €10m. To date, it has not been possible to clearly ascertain the cause of the loss – it was probably due to a tank failure.	(iv)	Biogas in Anaerobic Digestion Plant
2007	Germany	0	0	An accident also occurred at a biogas plant in Daugendorf, near Riedlingen in Southern Germany. The cause of the accident, in which the plant's 20-m-high and 17-m-wide fermenter ruptured, leaving behind a scene of devastation, is still unknown. The biomass in the fermenter spread up to 200 m around the plant. Several items of construction equipment were badly damaged, while the	(iv)	Biogas in Anaerobic Digestion Plant

Year	Location	Injury	Death	Description	Reference	Source of Accident
				buildings in the immediate vicinity were partially destroyed. Several hundred litres of fuel oil poured out of an overturned tank. The plant had only begun operating two days before. The property damage came to around €1.5m and the business interruption loss to around €1m.		
2009	Germany	2	1	An explosion occurred at a biogas plant and killed a worker and injured two others.	(v)	Biogas in Anaerobic Digestion Plant
2009	India	3	4	A large biogas reactor built in masonry and RCC in Edathala Panchayat Ernakulam District exploded during the commissioning stage, killing four persons and injuring three. The tragedy occurred at 11.30 Hrs on 19th August 2009. The explosion happened when some outlet steel pipe was getting welded or heated by a welder. During the week before the accident, the reactor was partially charged for trial operations with animal dung and other wastes. Gas was getting accumulated and an explosive mixture was naturally building up in the upper spaces of the reactor which could measure a several hundreds of cubic meters. The spark or naked flame from the welding equipment could instantly trigger the explosion of such a large mass of gas-air mix and explosion was severely felt and heard even thousands of feet away. More than a dozen of people were standing on the roof of the reactor or working nearby, when the roof structures caved in as the result of the explosion. Three workers fell into the thick slurry, and one of them was extricated safe with great difficulty and two died, whose dead bodies were recovered later. Workers, standing nearby including the welder, were thrown away by the explosion and two of them died instantly. It was clear that the rule book was violated on several counts. The plant was built unlawfully by the Arabic College Trust.	(vi), (vii)	Biogas in Anaerobic Digestion Plant

Note:

(i) FACTS, http://www.factsonline.nl/

(ii) ARIA, http://www.aria.developpement-durable.gouv.fr/

(iii) Biogas Production - Safety & Regulation, Discussion document for the workshop organized on 24 November 2010 in Paris, Version 09, compiled by Samuel Delsinne, November 2010

(iv) Renewable Energies, German Insurance Association, Berlin: 2008

(v) Industrial Fire World, http://www.fireworld.com/incident_logs/incident_log.php

(vi) Gas Plant Tragedy at Edathala, Visit Report By Er K Vijayachandran FIE And Dr. TV Jacob FIE, Cochin Centre For Policy Initiatives

(vii) “Four killed in explosion at Aluva biogas plant”, The Hindu, 27 August, 2009

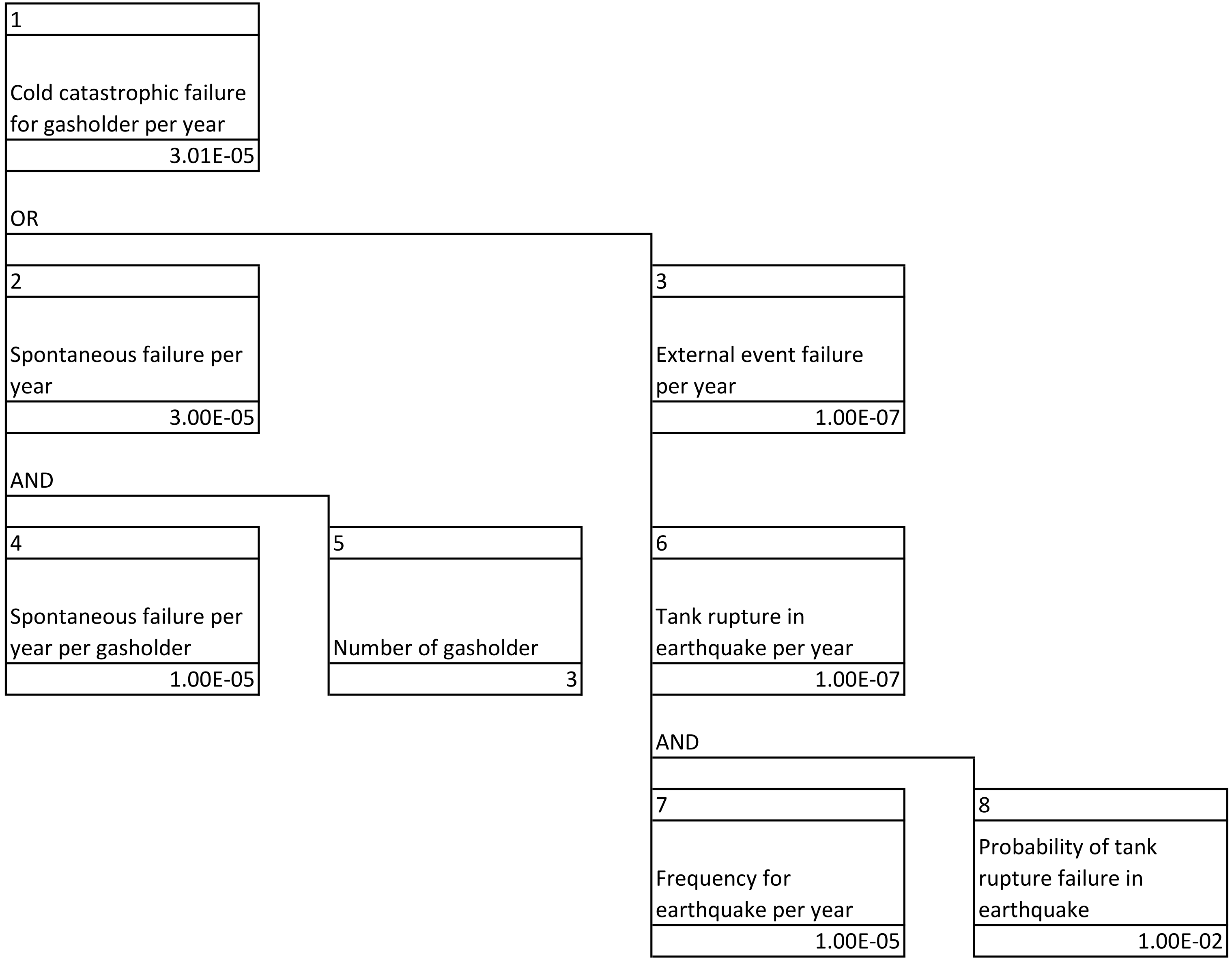
(viii) No record related to biogas accident was found in eMARS database.

Annex D

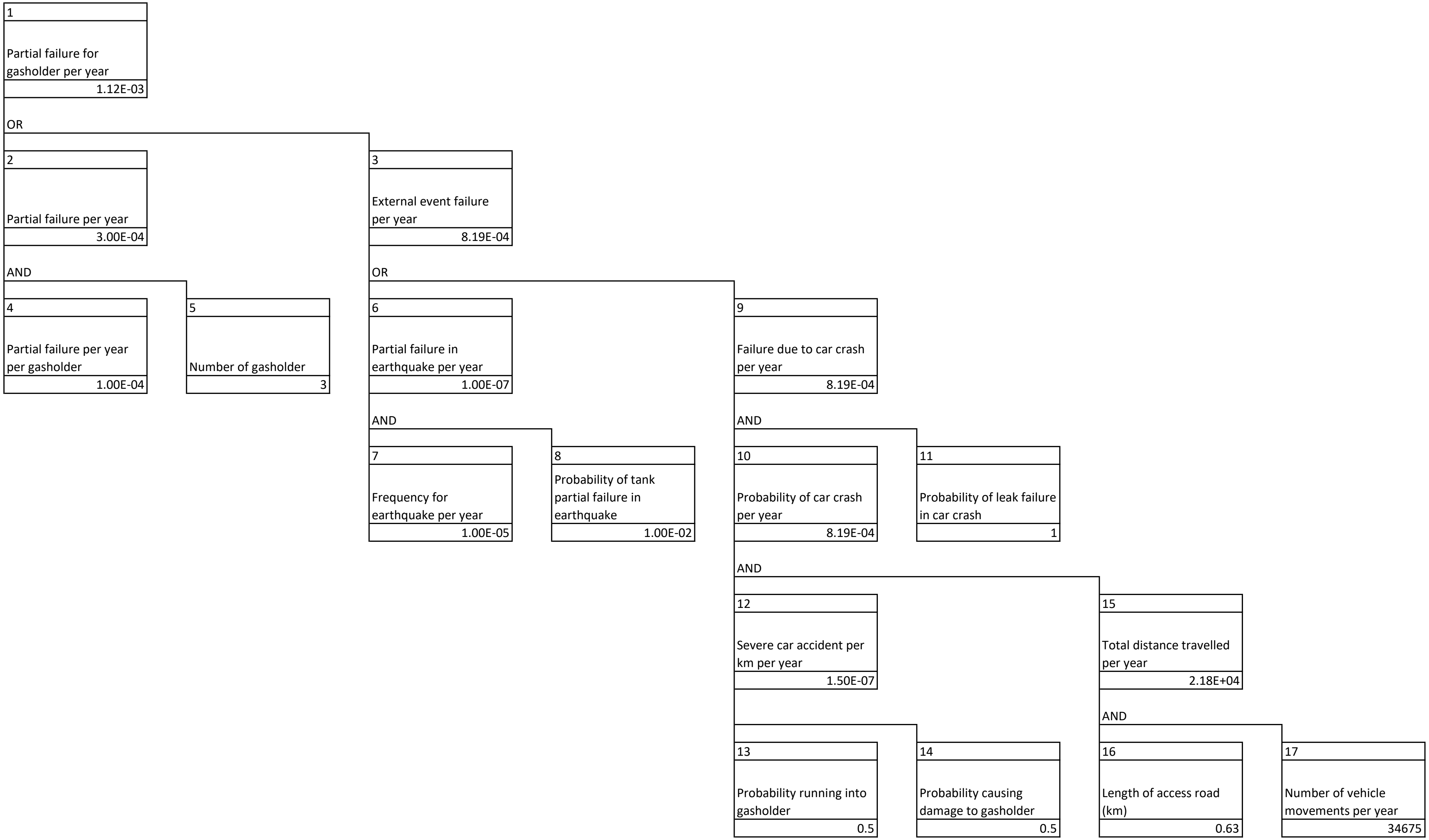
Fault Tree Analysis

Annex D - Fault Tree Analysis

F01 **Catastrophic Failure of Gasholder**

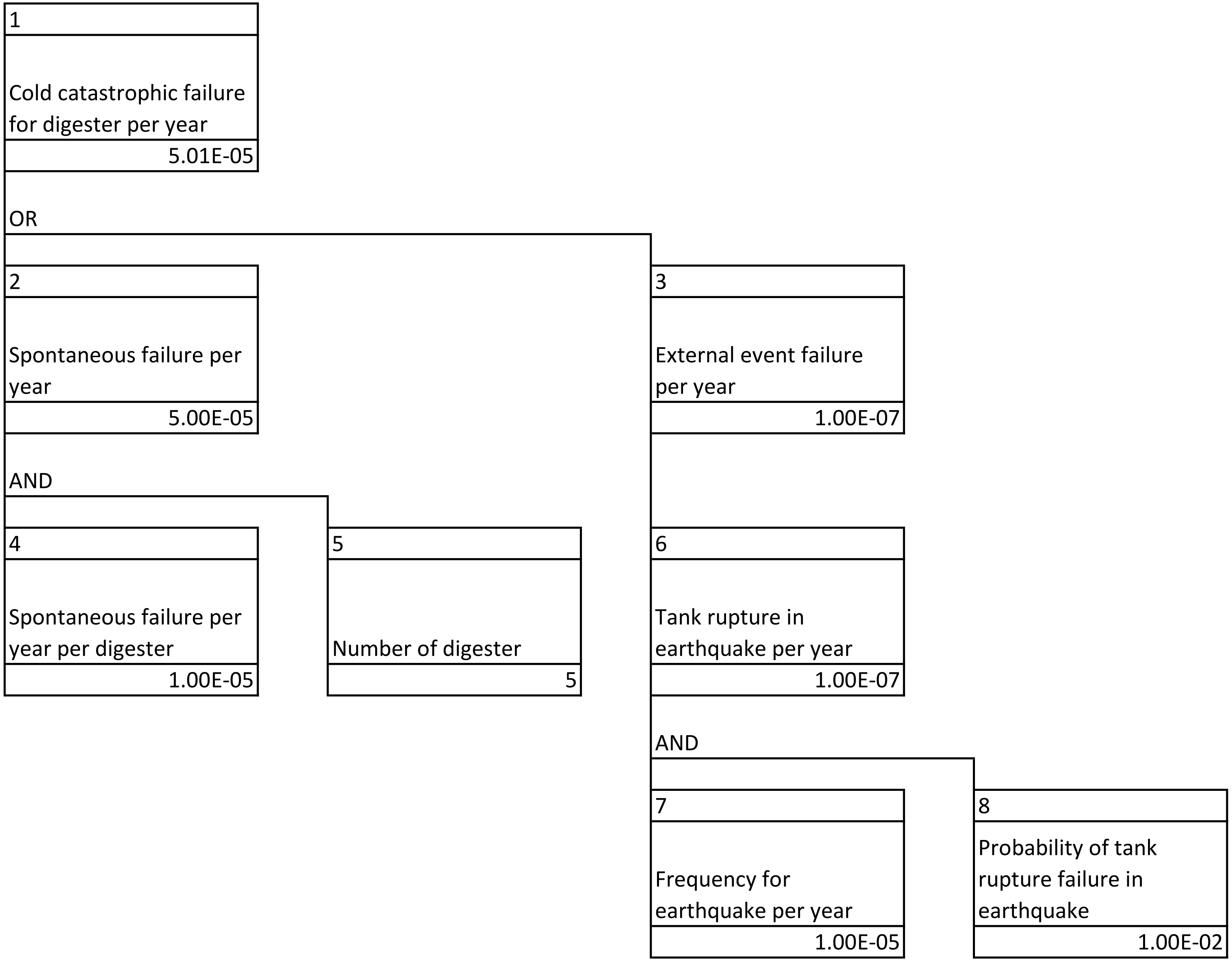


F02 **Partial Failure of Gasholder**

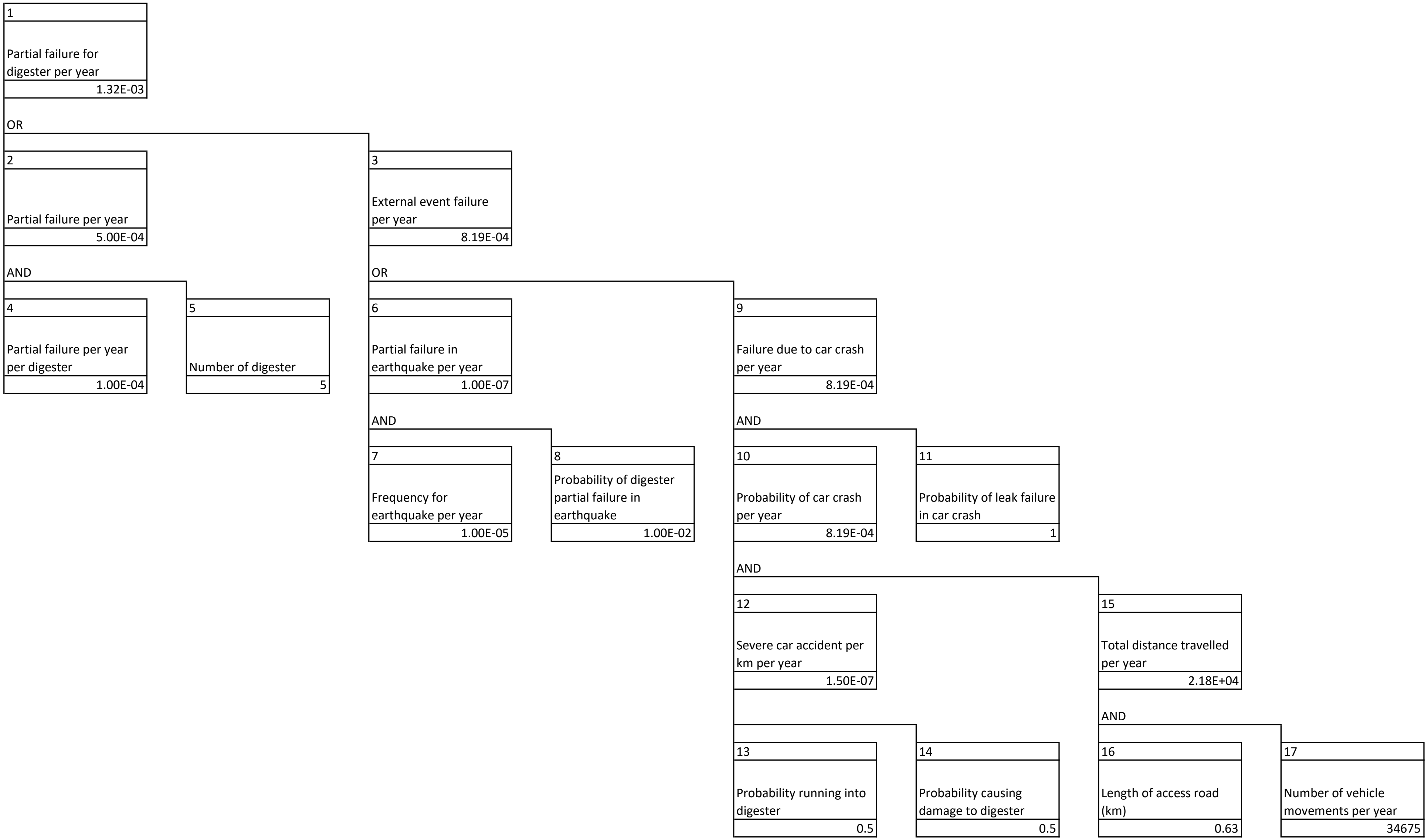


Annex D - Fault Tree Analysis

F03 **Catastrophic Failure of Digesters**

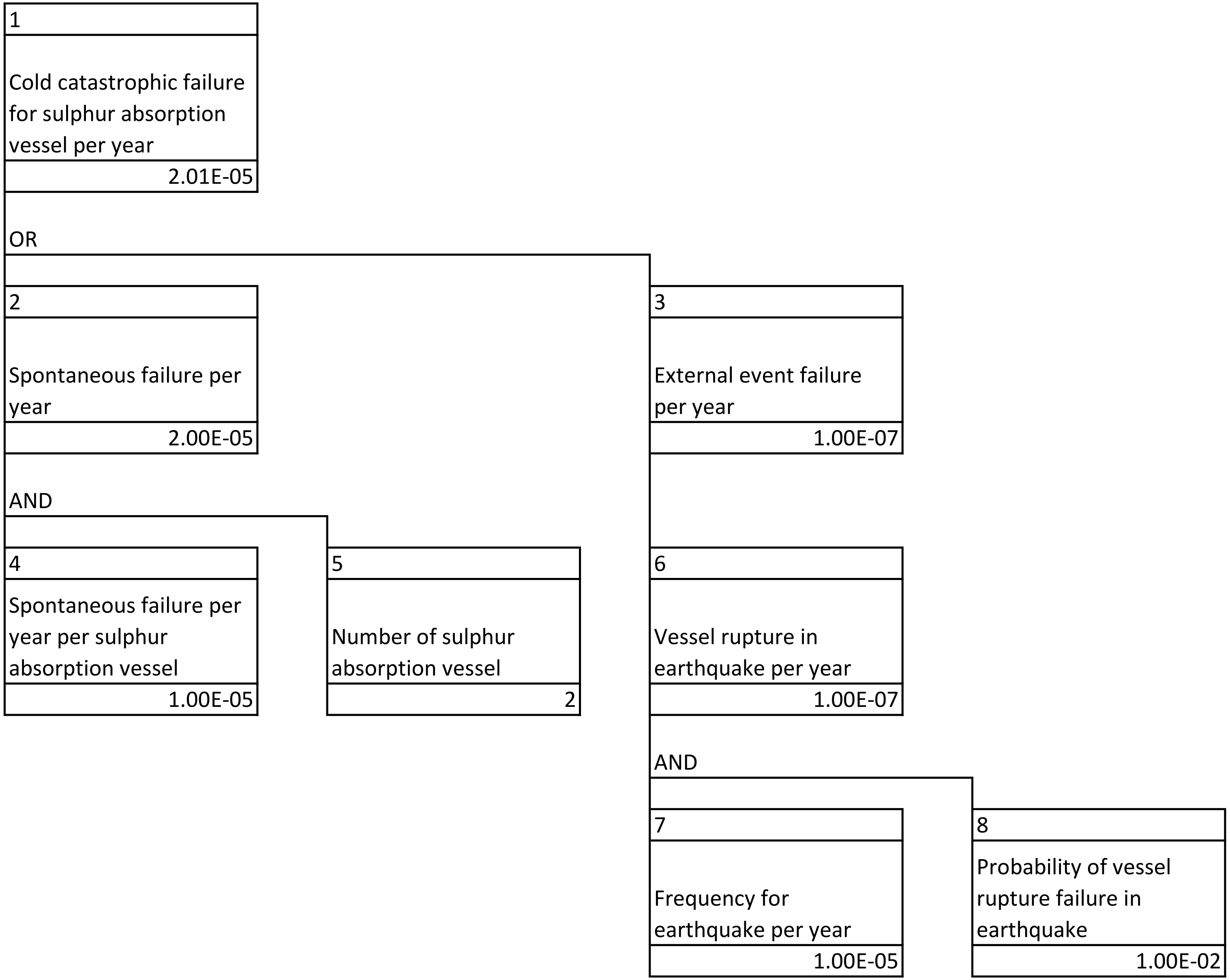


F04 **Partial Failure of Digesters**

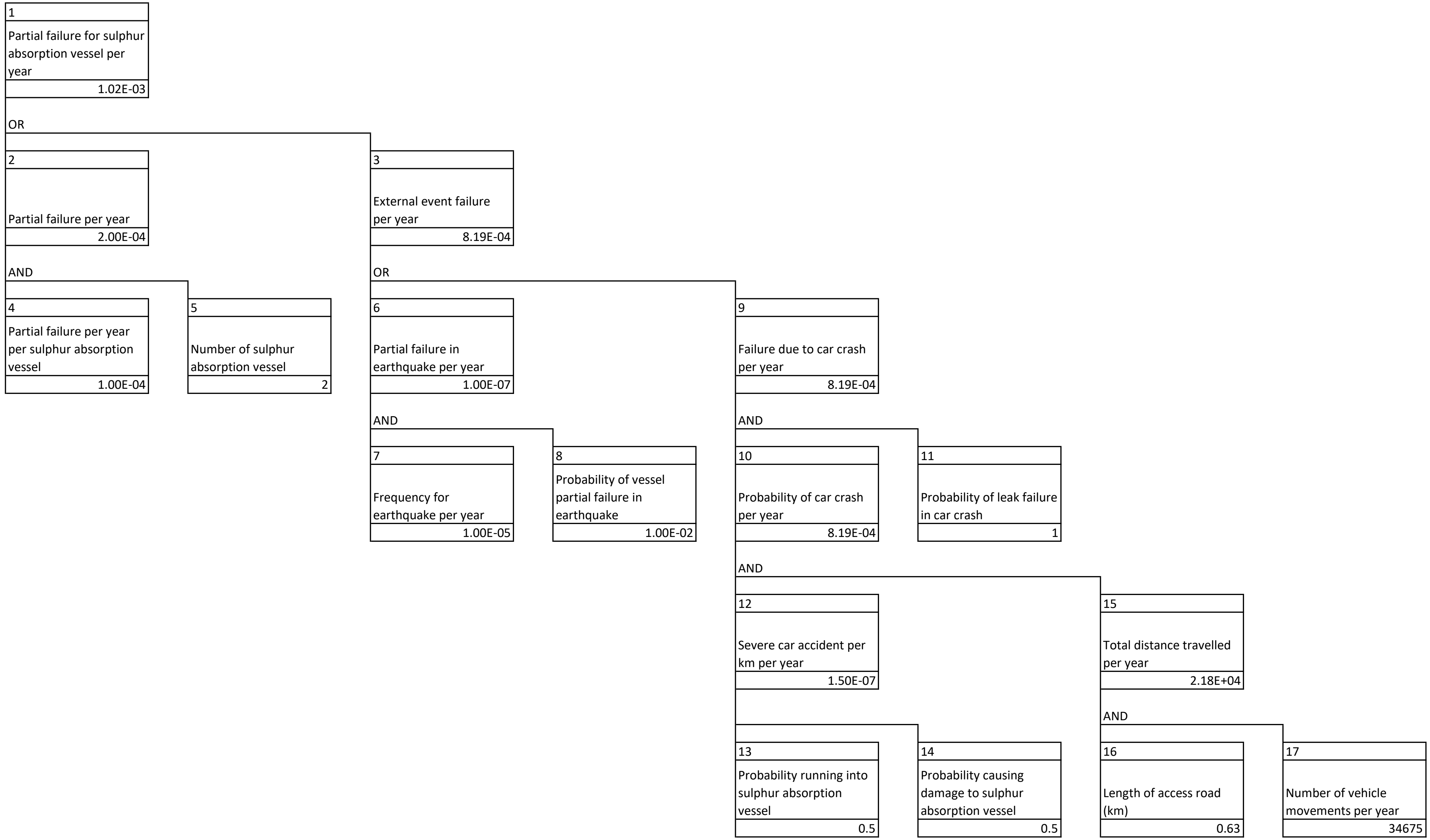


Annex D - Fault Tree Analysis

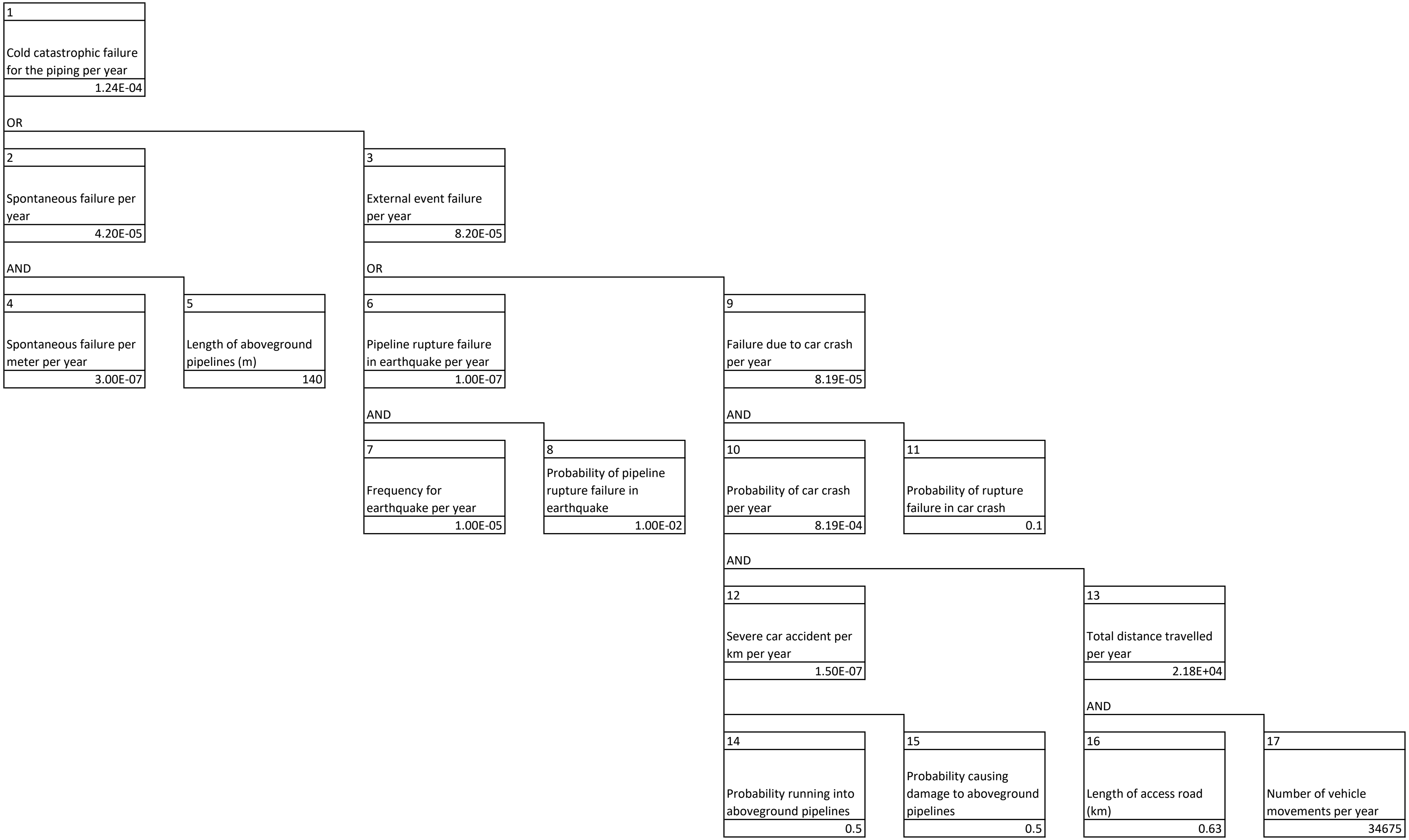
F05 **Catastrophic Failure of Sulphur Absorption Vessels**



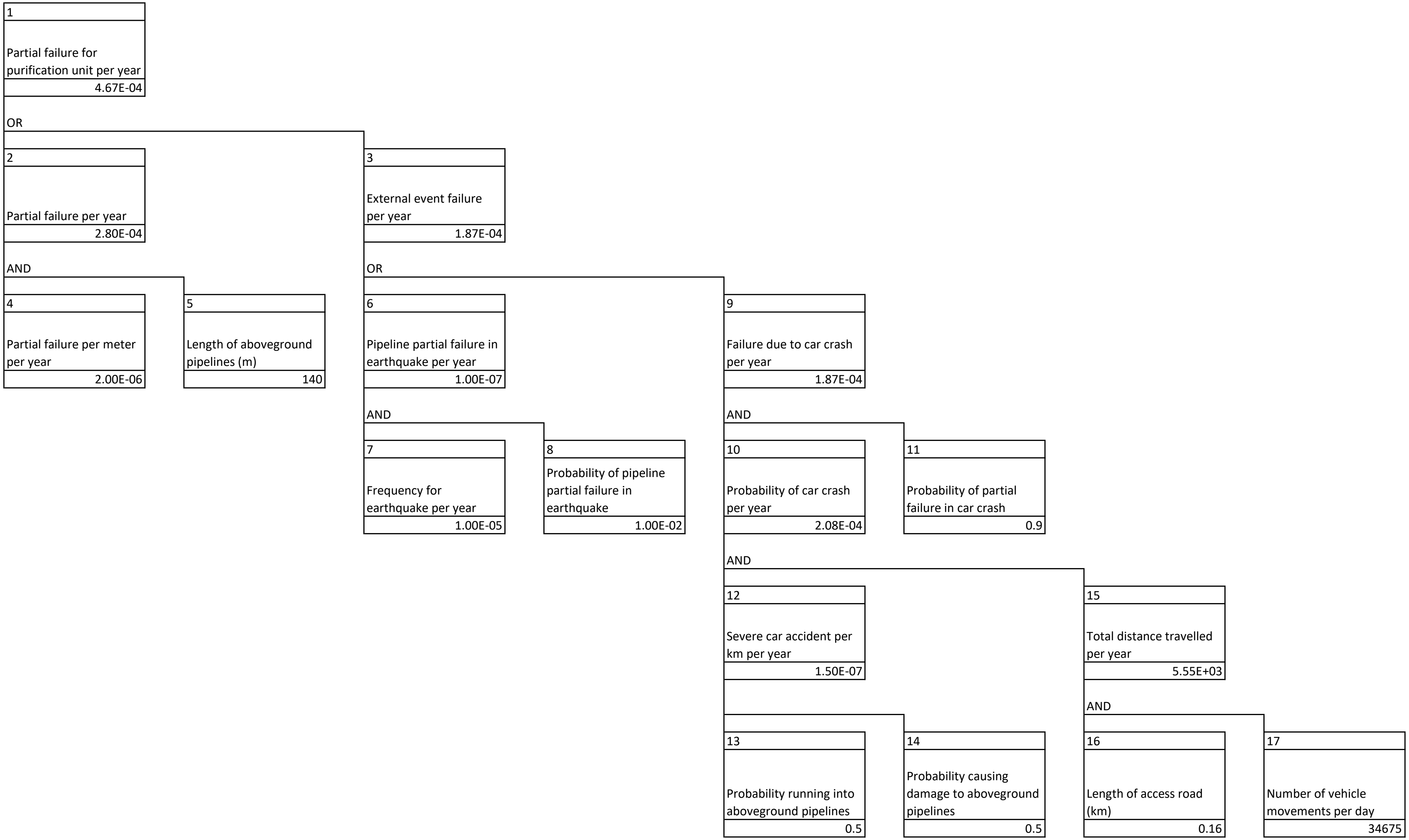
F06 Partial Failure of Sulphur Absorption Vessels



F07 **Catastrophic Failure of Aboveground Pipelines**



F08 **Partial Failure of Aboveground Pipelines**



Annex E

Event Tree Analysis

E01 Gasholder Release

	Leak Size	Ignition	Explosion	Outcome	Frequency (per year)
Gasholder Release (size = 1,600m^3)	Leak, 300mm hole (~ 18.4kg/s) 1.12E-03	Immediate 0.035		Jet Fire	3.92E-05
		Delay 0.035	Yes 0.12	VCE	4.70E-06
			No 0.88	Flash Fire	3.45E-05
		No 0.93		No Consequence	1.04E-03
	Rupture (release quantity = 1,600m^3) 3.01E-05	Immediate 0.15		Fire Ball	4.52E-06
		Delay 0.15	Yes 0.3	VCE	1.35E-06
			No 0.7	Flash Fire	3.16E-06
		No 0.7		No Consequence	2.11E-05

Note: There are 2 nos. of gasholders on-duty with 1,600m^3 each.

E02 Digester Release

	Leak Size	Ignition	Explosion	Outcome	Frequency (per year)
Digester Release (biogass volume = 330m^3)	Leak, 300mm hole (~ 18.1kg/s) 1.32E-03	Immediate 0.035		Jet Fire	4.62E-05
		Delay 0.035	Yes 0.12	VCE	5.54E-06
			No 0.88	Flash Fire	4.06E-05
		No 0.93		No Consequence	1.23E-03
	Rupture (release quantity = 330m^3) 5.01E-05	Immediate 0.15		Fire Ball	7.52E-06
		Delay 0.15	Yes 0.3	VCE	2.25E-06
			No 0.7	Flash Fire	5.26E-06
		No 0.7		No Consequence	3.51E-05

Note: There are 3 nos. of digesters on-duty with 330m^3 each.

E03 Sulphur Absorption Vessel Release

	Leak Size	Ignition	Explosion	Outcome	Frequency (per year)
Sulphur Absorption Vessel Release (size = 50m^3 of methane)	Leak, 10mm hole (~ 0.02kg/s) 1.02E-03	Immediate 0.005		Jet Fire	5.10E-06
		Delay 0.005	Yes 0.04	VCE	2.04E-07
			No 0.96	Flash Fire	4.89E-06
		No 0.99		No Consequence	1.01E-03
	Rupture (release quantity = 50m^3) 2.01E-05	Immediate 0.15		Fire Ball	3.02E-06
		Delay 0.15	Yes 0.3	VCE	9.05E-07
			No 0.7	Flash Fire	2.11E-06
		No 0.7		No Consequence	1.41E-05

Note: There are 2 nos. of sulphur absorption vessels on-duty with 50m^3 each.

E04 Aboveground Piping Release

	Leak Size	Ignition	Explosion	Outcome	Frequency (per year)
Aboveground Piping Release	Leak, 15mm hole (~ 0.05kg/s) 4.67E-04	Immediate 0.005		Jet Fire	2.34E-06
		Delay 0.005	Yes 0.04	VCE	9.35E-08
			No 0.96	Flash Fire	2.24E-06
		No 0.99		No Consequence	4.63E-04
	Rupture, 150mm dia. (~4.6kg/s) 1.24E-04	Immediate 0.035		Jet Fire	4.34E-06
		Delay 0.035	Yes 0.12	VCE	5.21E-07
			No 0.88	Flash Fire	3.82E-06
		No 0.93		No Consequence	1.15E-04

Note: 100m length of DN150 aboveground pipeline is assumed.

APPENDIX 13.2 HAZARD TO LIFE ASSESSMENT FOR HP GAS PIPELINE

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1. INTRODUCTION

1.1 Background

1.1.1.1 An existing 600mm high pressure HP underground town gas transmission pipeline (HP gas pipeline) along the San Tam Road was identified in close vicinity to the proposed development (the Project). According to the information provided by the Hong Kong and China Gas Company (HKCG), the length of HP gas pipeline between the upstream and downstream isolation valves is around 6.2km. Location of the HP gas pipeline is shown in **Plate 1-1**.

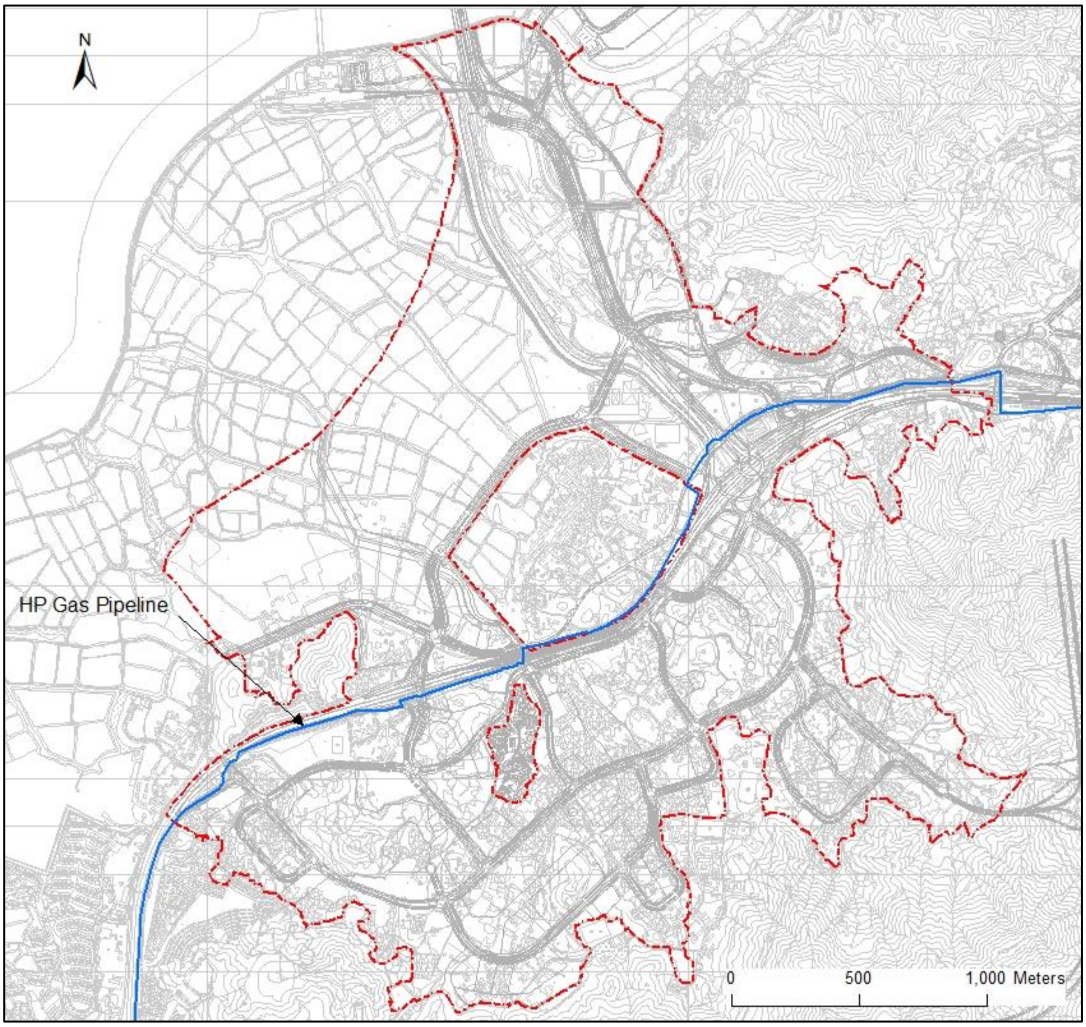

Plate 1-1 Location of the Project Site

1.2 Hazard to Life Assessment Objectives and Risk Criteria

1.2.1 Objectives

1.2.1.1 The Hazard to Life Assessment requirements for the HP gas pipeline are shown below:

(a) Identify hazardous scenarios associated with the operation of the HP gas pipeline and then determine a set of relevant scenarios to be included in a Quantitative Risk Assessment (QRA);

(b) Execute a QRA of the set of hazardous scenarios determined in (a), expressing population risks in both individual and societal terms;

(c) Compare individual and societal risks with the criteria for evaluating hazard to life as stipulated in Annex 4 of the TM; and

(d) Identify and assess practicable and cost-effective risk mitigation measures.

1.2.2 EIAO-TM Risk Criteria

1.2.2.1 Annex 4 of the EIAO-TM specifies the Individual and Societal Risk Guidelines. The Hong Kong Risk Guidelines (HKRG) per the EIAO-TM Annex 4 states that the individual risk is the predicted increase in the chance of fatality per year to an individual due to a potential hazard. The individual risk guidelines require that the maximum level of individual risk should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year. Societal risk expresses the risks to the whole population. It is expressed in terms of lines plotting the cumulative frequency (F) of N or more deaths in the population from incidents at the installation. Two F-N risk lines are used in the HKRG that demark “Acceptable” or “Unacceptable” societal risks. To avoid major disasters, there is a vertical cut-off line at the 1000 fatality level extending down to a frequency of 1 in a billion years. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is “as low as reasonably practicable” (ALARP). It seeks to ensure that all practicable and cost-effective measures that can reduce risk are considered. The HKRG is presented graphically in **Plate 1-2**.

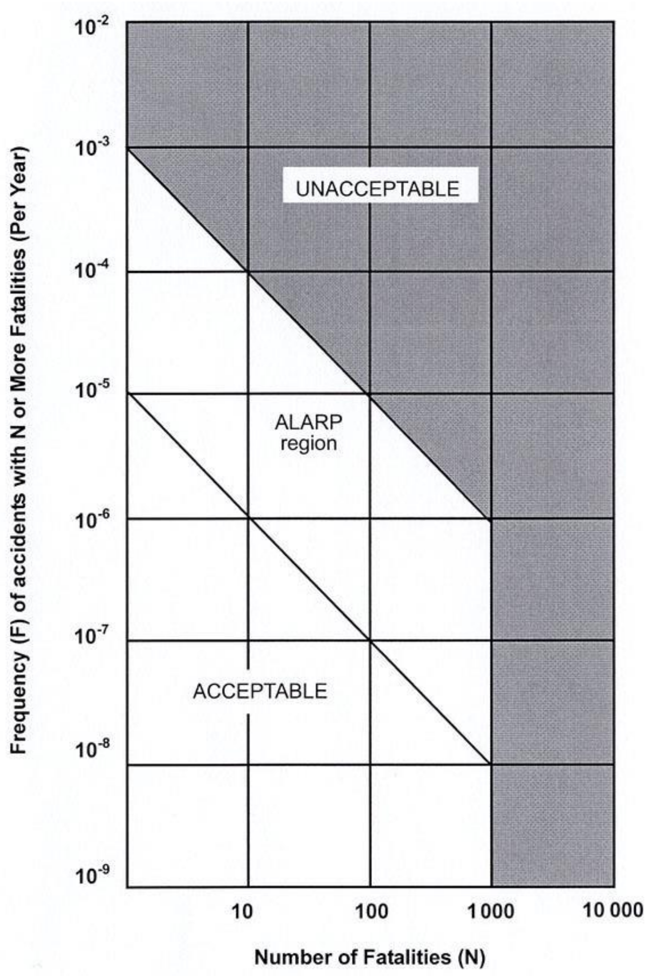

Plate 1-2 Societal Risk Guidelines

1.3 Study Approach

1.3.1.1 This assessment consists of the following six main tasks:

(a) **Data / Information Collection and Update**: Collect relevant data / information necessary for the hazard assessment;

(b) **Hazard Identification**: Identify a credible set of hazardous scenarios associated with operation of the HP gas pipeline;

(c) **Frequency Estimation**: Estimate the frequencies of each hazardous event leading to fatalities based on the collected data with the support of justifications through the review of historical accident data and previous hazard assessments of similar projects;

(d) **Consequence Analysis**: Analyse the consequences of the identified hazardous scenarios;

(e) **Risk Assessment and Evaluation**: Evaluate the risks associated with the identified hazardous scenarios. The evaluated risks will be compared with the HKRG to determine their acceptability; and

(f) **Identification of Mitigation Measures**: Where necessary, risk mitigation measures will be identified and assessed to comply with the "as low as reasonably practicable" (ALARP) principle used in the HKRG. Practicable and cost-effective risk mitigation measures will be identified and assessed as necessary. The risk outcomes of the mitigated case will then be reassessed to determine the level of risk reduction.

1.4 Assessment Scenario

1.4.1.1 The hazard assessment covers the following two scenarios:

(a) Year 2032 (Construction phase) – The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFS, and the HP Gas Pipeline to the existing, committed and planned population in 2032. This scenario accounted for the commencement of the EPP and the two GFSs, and also the presence of the construction workers for areas of the proposed development located along the San Tam Road.

(b) Year 2039 (Operation phase) – The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFSs, and the HP Gas Pipeline to the existing, committed and planned population in 2039. This scenario accounted for the ultimate situation with all the planned land users of the proposed development being considered.

2. SITE DESCRIPTION

2.1 Study Area

2.1.1.1 The Project site is located within a 150 m Consultation Zone (CZ) from the HP gas pipeline. According to the Guidance Note [1], the highest risk 1.6km pipeline segment with a study area of 200 m from the pipeline segment should be assessed. The interacting distance of around 4.6km of HP gas pipeline was determine considering the consequence distance of potential hazards of the HP gas pipeline, separation distance between the end points of the HP gas pipeline section assessed and the proposed development site was kept at least 200m.

2.1.1.2 **Plate 2-1** presents the location and the study area of 200m from the HP gas pipeline.

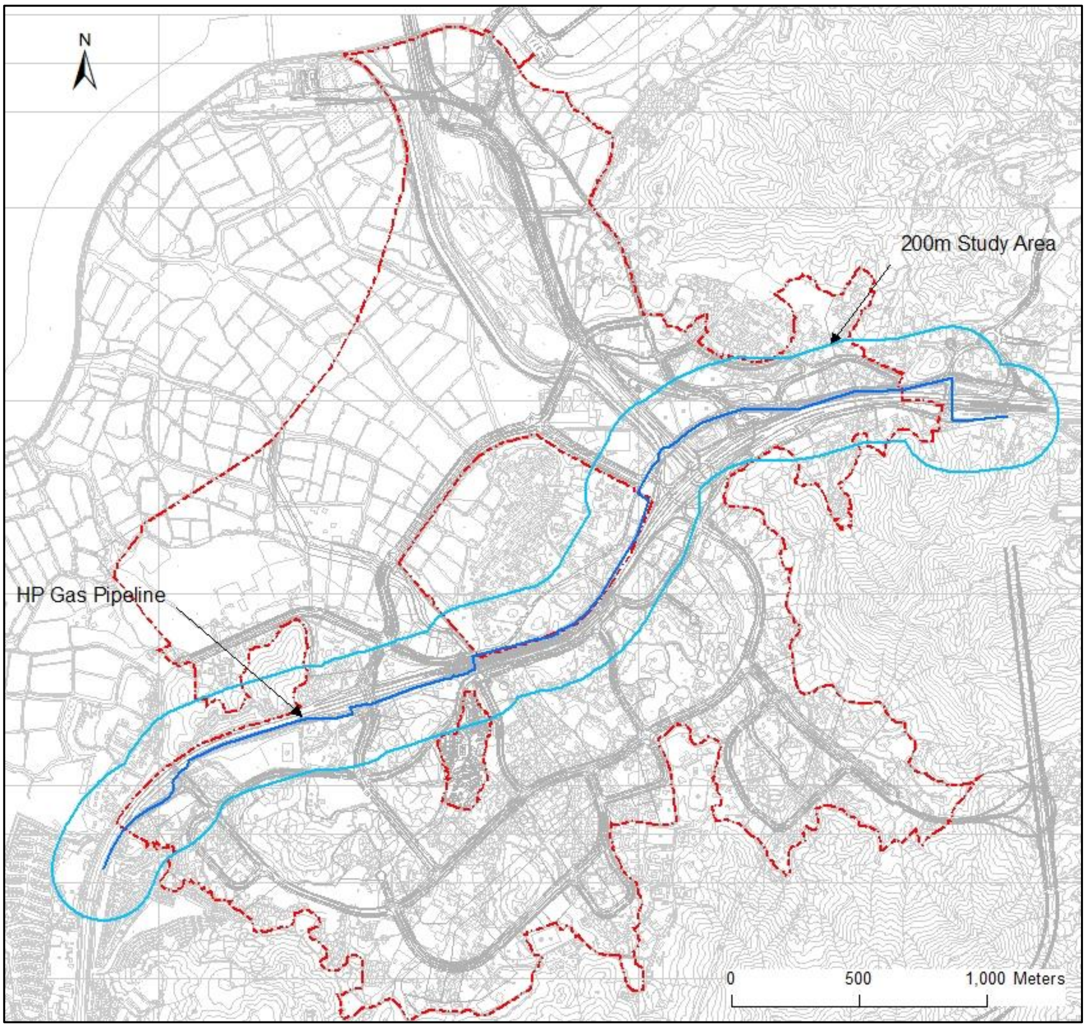

Plate 2-1 Study Area for HP Gas Pipeline

2.2 Proposed Development Site

2.2.1 Construction Phase

2.2.1.1 The number of construction workers for Phase 1b and Phase 2 of the proposed development along the San Tam Road was estimated based on Consultant's past project experience.

2.2.2 Operation Phase

2.2.2.1 The population of STLMC Development within the study area for the HP gas pipeline was estimated based on the latest information provided by Civil Engineering and Development Department (CEDD).

2.3 Surrounding Population

2.3.1 Land and Building Population

2.3.1.1 Residential population of the existing buildings was estimated based on the average household size obtained from the Territory Population and Employment Data Matrix (TPEDM) data, together with the building information (e.g. no. of units and floors) obtained from Centamap.

2.3.1.2 The TPEDM population projections for Planning Data Zones (PDZs) (i.e. PDZ 183, PDZ332, PDZ 378 and PDZ 402) was obtained from the Planning Department (PlanD) to forecast the population of the existing residential developments for the assessment years. The average domestic household sizes for the respective PDZs in 2031 were adopted to estimate the residential population in 2031. The 2030+ TPEDM data showed negative growth of average domestic household size in all the concerned PDZs from 2031 to 2041. To be conservative, the residential population in 2032 and 2039 were assumed to remain the same as those in 2031.

2.3.1.3 The numbers of population in each area are listed in **Table 2.1**, while details of the population at different time modes and information sources are provided in **Annex A**. The numbers of population were estimated based on the following assumptions:

(a) According to the 2030+ TPEDM data, the average domestic household size in PDZ 183, PDZ 332, PDZ 378 and PDZ 402 in 2031 are 3.12, 3.20, 3.18 and 2.59 respectively. Since a negative growth of average domestic household size from 2031 to 2046 was observed in all the concerned PDZs, the residential population in existing residential developments in 2032 and 2039 was assumed to remain the same as those in 2031;

(b) The amenity areas were assumed to be unmanned, while population in open areas were estimated based on a density of $100m^2$/ person; and

(c) An average of 5% population was considered to be outdoor for residential, institution and industrial population, while 100% population was assumed to be outdoor for construction workers, users in open spaces and open storages area.

Table 2.1 Land and Building Population Data

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
E01	Maple Gardens	532	532
E02	Scenic Heights	106	106
E03	Mai Po San Tsuen No. 201-201C	47	47
E04	Open Storage	39	39
E05	Mai Po San Tsuen	3,164	3,164
E06	Tsing Lung Tsuen, Fan Tin Tsuen, Wing Ping Tsuen	1,788	1,788
E07	Pak Shek Au	954	954
P01	A.5.1 - Amenity	0	0

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
P02	OU(ESS).5.12 - Reserve	0	0
P03	G.5.3 - Existing Mai Po ESS	125	84
P04	G.5.1 - Sport Centre	125	1018
P05	RSc.2.1 - Public Housing	9899	9899
P06	RSc.2.2 - Public Housing	7603	7603
P07a	OU(EPP).5.3 - Effluent Polishing Plant and Food Waste Pretreatment Co-Digestion Facilites	100	100
P07b	OU(EPP).5.3 - Effluent Polishing Plant and Food Waste Pretreatment Co-Digestion Facilites	200	200
P08	OU(GFS).5.1 - Green Fuel Station	10	10
P09	G.5.2 - Reserve	0	0
P10	GB.5.3 - Green Belt	0	0
P11	OU(ESS).5.6 - 132kV ESS	0	0
P12	G.5.5 - Reserve	0	0
P13	E.5.3 - Potential Education Facilities	125	1680
P14	GB.5.4 - Green Belt	0	0
P15	OU(SPS).5.7 - Sewage Pumping Station	30	30
P16	A.2.1 - Amenity	0	0
P17	O.2.4 - Open Space	483.971623	484
P18	V - Village Type Development	440	440
P19	G.5.7 - Cultural & Recreational Complex	32.46667654	1502
P20	O.5.1 - Open Space	534.47	534
P21	G.5.7 - Cultural & Recreational Complex	92.53332346	4280
P22	V.3.1 - Village Resite	78	78
P23	GB.5.5 - Green Belt	0	0
P24	G.5.13 - Reserve	125	30
P25	OU(RAF).5.2 - Vent Shaft	0	0
P26	G.5.14 - Sport Centre	125	1018
P27	A.1.13 - Amenity	0	0
P28	A.1.15 - Amenity	0	0
P29	A.1.16 - Amenity	0	0
P30	OU(RAF).1.2 - Vent Shaft	0	0
P31	OU(LSW).1.1 - Logistics, Storage and Warehouse	2833	2833
P32	OU(RTS/RRF).1.9 - Refuse Transfer Station cum Resource Recovery Facilities	50	50
P33	OU(DSC).1.6 - District Cooling System	25	25
P34	OU(ESS).1.7 - 400kV ESS	0	0
P35	OU(RCP).1.8 - RCP	10	10
P36	A.1.9 - Amenity	0	0

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
P37	A.1.7 - Amenity	0	0
P38	A.1.8 - Amenity	0	0
P39	OU(VB) - Chau Tau Ventilation Building	0	0
P40	A.1.6 - Amenity	0	0
P41	OU(I&T)3.1.7 - Information and Technology - Zone 3	3536	3536
P42	OU(I&T)3.1.8 - Information and Technology - Zone 3	7442	7442
P43	OU(I&T)2.1.2 - Information and Technology - Zone 2	80	1194
P44	A.1.10 - Amenity	0	0
P45	OU(I&T)2.1.1 - Information and Technology - Zone 2	2788	2788
P46	OU(ESS).1.4 - 132kV ESS	0	0
P47	A.1.4 - Amenity	0	0
P48	OU(MU)2.1.1 - Mixed use (Chau Tau Station)	80	17826
P49	G.1.4 - HyD Depot	1	1
P50	O.1.2 - Open space	342.69	343
P51	G.1.5 - Divisional Police Station cum Operational Base, Petrol Station and Dangerous Goods Storage	125	515
P52	OU(ESS).1.10 - 132kV ESS	0	0
P53	OU(LSW).1.2 - Logistics, Storage and Warehouse	220	220
P54	OU(DSC).1.11 - District Cooling System	25	25
P55	O.1.3 - Open space	410.39	410
P56	OU(I&T)3.1.9 - Information and Technology - Zone 3	80	5228
P57	OU(WRP).5.2 - Water Reclamation Plant	100	100
P58	E.2.1 - 2 Primary School	129	1678
P59	OU(RCP).5.5 - RCP	0	0
P60	GB.5.1 - Green Belt	0	0
P61	GB.5.2 - Green Belt	0	0
P62	E.3.3 - Secondary School	129	1329
P63	A.1.17 - Amenity	0	0
P64	O.5.2 - Open Space	28	28
P65	OU(GFS).1.1 - Green Fuel Station	10	10
P66	A.1.5 - Amenity	0	0
P67	OU(I&T)3.1.5 - Information and Technology - Zone 3	1135	1135
P68	OU(I&T)3.1.4 - Information and Technology - Zone 3	1580	1580

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
P69	A.1.3 - Amenity	0	0
P70	OU(I&T)3.1.6 - Information and Technology - Zone 3 (Government Data Centre)	240	240

2.3.2 Road Population

2.3.2.1 The traffic data was based on the latest Annual Traffic Census (ATC) published by Transport Department (TD) [2] and the Traffic Impact Assessment (TIA) report prepared for this Assignment. The traffic population was predicted based on the following equation:

$$Traffic\ Population = \frac{No.of\ Person\ per\ vehicle \times No.of\ Vehicle\ per\ hour \times Road\ Length}{Speed}$$

2.3.2.2 Based on the latest ATC [2], the occupancies for each vehicle type and vehicle mix were taken at the core station no. 5016 (San Tin Highway, Castle Peak Road and San Tam Road (from Kam Tin Road to Fairview Park Boulevard) were selected to represent the road traffic for this assessment.

2.3.2.3 The traffic population considered in this assessment, which was assumed to be 100% outdoor, is summarized in **Table 2.2** and detailed in **Annex A**.

Table 2.2 Estimated Road Population

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R1	50	18	12	24	14
R2	50	14	10	17	12
R3	50	9	7	20	11
R4	50	16	12	43	22
R5	50	22	13	24	13
R6	100	158	71	191	85
R7	100	148	66	166	73
R8	100	210	93	252	110
R9	100	115	53	129	60
R10	100	260	116	293	133
R11	50	49	26	58	30
R12	50	113	54	98	47
R13	50	20	13	27	15
R14	50	16	11	25	15
R15	50	13	9	20	12
R16	50	17	11	25	15
R17	50	16	11	13	9
R18	50	8	8	13	10
R19	50	35	21	39	22

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R20	50	46	26	54	28
R21	50	40	23	47	25
R22	50	42	24	44	24
R23	50	66	35	67	35
R24	50	153	74	168	80
R25	50	176	85	170	81
R26	50	22	14	74	36
R27	50	21	14	77	38
R28	50	0	0	22	13
R29	50	0	0	21	13
R30	50	43	19	88	42
R31	50	45	21	64	29
R32	50	33	20	36	20
R33	50	36	21	51	26
R34	50	34	18	39	19
R35	50	24	15	27	16
R36	50	89	44	83	41
R37	50	7	7	7	7
R38	50	60	31	58	31
R39	50	119	58	149	71
R40	50	7	7	7	7
R41	50	7	7	7	7
R42	50	10	10	12	12
R43	50	20	20	24	24
R44	50	10	10	13	13
R45	50	9	9	10	10
R46	50	10	10	12	12

2.3.2.4 The locations of population groups and roads considered for construction and operation phases are presented in **Plate 2-2** and **Plate 2-3** respectively. Details on the estimated population for each population group are provided in **Annex A**.

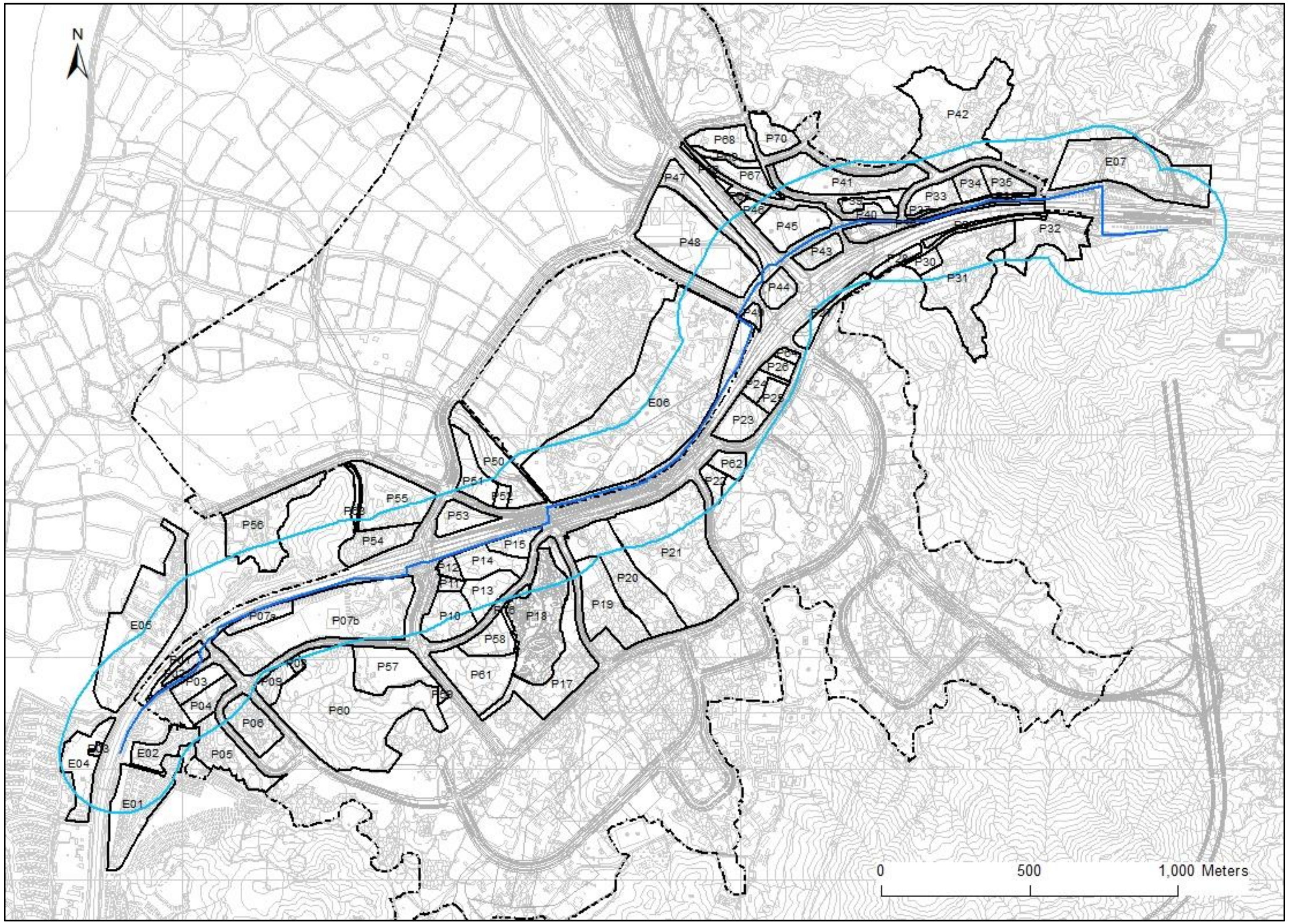

Plate 2-2 Locations of Land and Population Groups

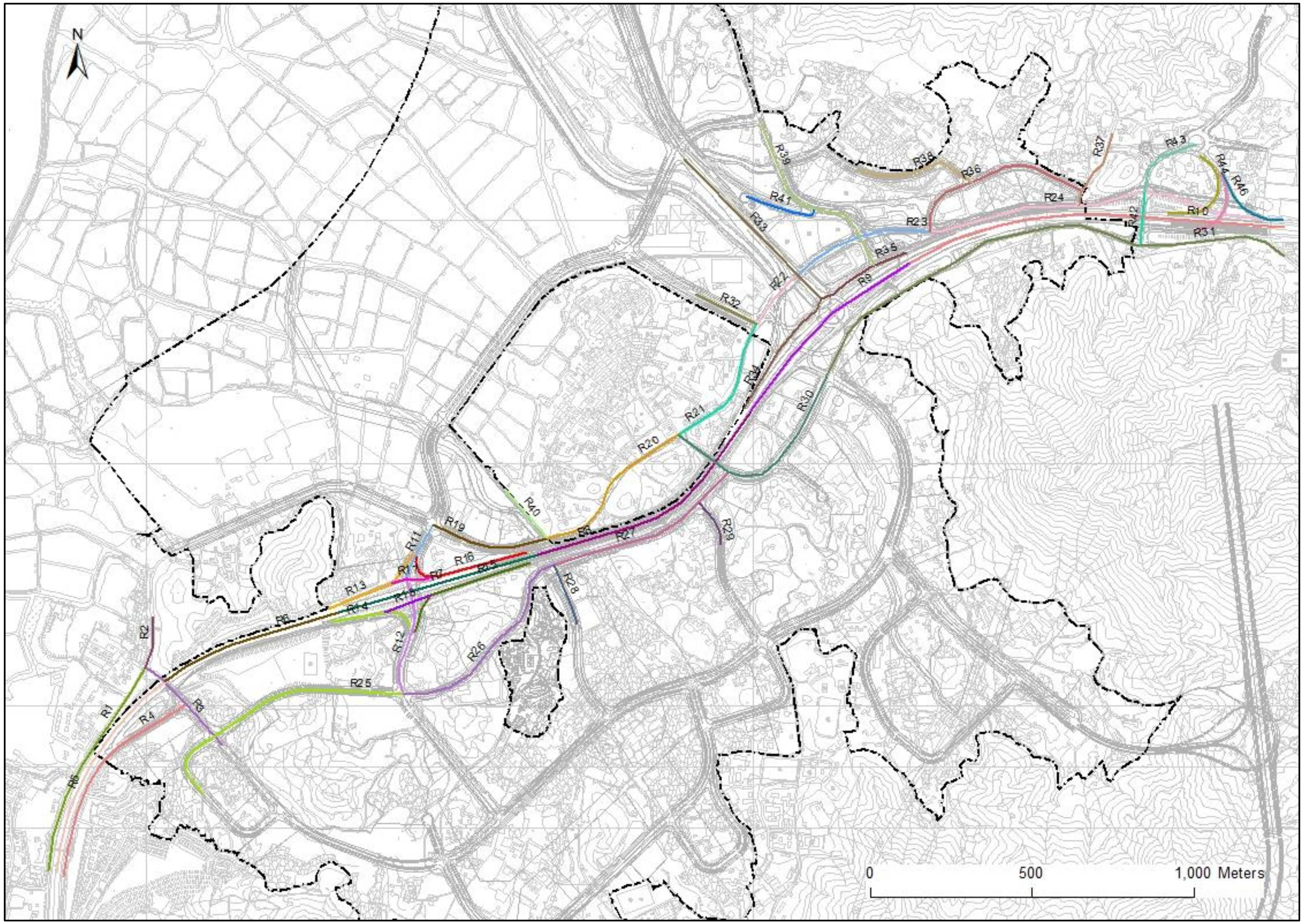

Plate 2-3 Locations of Road Population Groups

2.3.3 Time Modes and Occupancies of Population Groups

2.3.3.1 Four representative time modes were identified to address the variation in levels of activities that could lead to a release and the variation in population in the study area with time. **Table 2.3** shows the time periods adopted in this assessment. Furthermore, the assumptions of the occupancy rate for various time modes including the indoor ratio considered for the population groups are summarized in **Table 2.4**.

Table 2.3 Definitions of Time Modes

Time Period	Definition	Proportion of Time
Weekday Day	Mon-Fri, 7am-7pm	35.71%
Weekday Night	Mon-Fri, 7pm – 7am	35.71%
Weekend Day	Sat-Sun, 7am-7pm	14.29%
Weekend Night	Sat-Sun, 7pm – 7am	14.29%

Table 2.4 Occupancies of Population Groups at Different Time Modes

Population Group	Percentage of Occupancy at Different Time Modes				Indoor Ratio
	Weekday (Day)	Weekday (Night)	Weekend (Day)	Weekend (Night)	
Residential	50%	100%	70%	100%	5%
Educational	100%	0%	50%	0%	5%
Open Area	100%	100%	100%	100%	100%
Construction Site	100%	10%	50%	10%	100%
G/IC	100%	10%	50%	10%	5%
Ventilation Building / ESS	100%	100%	100%	100%	100%
Industrial	100%	10%	50%	10%	5%
Open Storage	100%	10%	100%	10%	100%
Amenity	100%	100%	100%	100%	100%

2.4 Meteorology

2.4.1.1 Meteorological data is required for consequence modelling and risk calculation. Consequence modelling (dispersion modelling) requires wind speed and stability class to determine the degree of turbulent mixing potential whereas risk calculation requires wind-rose frequencies for each combination of wind speed and stability class.

2.4.1.2 Meteorological data was obtained from Wetland Park Weather Station (2021) where wind speed, stability class, weather class and wind direction are available. This data represented the weather conditions for the whole year in 2021 and has already taken into account seasonal variations and was therefore considered applicable for the assessment. **Table 2.5** shows the wind speed-stability frequencies.

Table 2.5 Stability Category-Wind Speed Frequencies at Wetland Park Weather Station

Daytime							
Wind Speed (m/s)	A	B	C	D	E	F	Total (%)
0.0-1.9	25.55	7.91	0.00	13.77	0.00	14.46	61.69
2.0-3.9	7.62	14.30	6.36	6.34	1.76	0.36	36.74

Daytime							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
4.0-5.9	0.00	1.05	0.27	0.18	0.00	0.00	1.50
6.0-7.9	0.00	0.00	0.00	0.05	0.00	0.00	0.05
Over 8.0	0.00	0.00	0.00	0.02	0.00	0.00	0.02
All (%)	33.17	23.26	6.63	20.36	1.76	14.82	100.00
Night-time							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
0.0-1.9	0.00	0.00	0.00	3.76	0.00	82.06	85.82
2.0-3.9	0.00	0.00	0.00	2.25	8.83	2.44	13.52
4.0-5.9	0.00	0.00	0.00	0.52	0.07	0.00	0.59
6.0-7.9	0.00	0.00	0.00	0.07	0.00	0.00	0.07
Over 8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All (%)	0.00	0.00	0.00	6.60	8.90	84.50	100.00

2.4.1.3 According to **Table 2.5**, six combinations (2B, 1D, 3D, 6D, 2E and 1F) and five combinations (1D, 3D, 7D, 2E and 1F) of wind speed and stability class were chosen for daytime and night-time meteorological conditions respectively. These combinations were considered adequate to reflect the full range of observed variations in these quantities. It is not necessary and efficient to consider every combination observed. The principle is to group these combinations into representative weather classes that together cover all conditions observed.

2.4.1.4 Once the weather classes have been selected, frequencies for each wind direction for each weather class can then be determined. The frequency distributions for the daytime and night-time meteorological conditions are summarised in **Table 2.6**.

Table 2.6 Weather Class-Wind Direction Frequencies at Wetland Park Weather Station

Daytime							
Direction	**2B**	**1D**	**3D**	**6D**	**2E**	**1F**	**Total (%)**
0 – 30	4.53	1.99	0.82	0.00	0.55	3.21	11.10
30 – 60	6.01	1.30	1.89	0.10	0.60	1.10	11.00
60 – 90	12.03	2.02	3.96	0.02	1.00	1.02	20.05
90 – 120	3.59	1.47	2.69	0.00	0.65	1.49	9.89
120 – 150	2.47	0.50	1.30	0.00	0.42	0.67	5.36
150 – 180	5.58	0.82	2.96	0.00	0.72	1.02	11.10
180 – 210	6.19	0.42	2.59	0.00	0.57	0.62	10.39
210 – 240	3.64	0.12	0.52	0.00	0.07	0.15	4.50
240 – 270	2.07	0.20	0.15	0.00	0.00	0.15	2.57
270 – 300	2.67	0.45	0.17	0.00	0.05	0.20	3.54
300 – 330	4.04	0.32	0.12	0.00	0.00	0.22	4.70
330 – 360	4.11	0.57	0.37	0.00	0.00	0.75	5.80
All (%)	56.93	10.18	17.54	0.12	4.63	10.60	100.00

Night-time						
Direction	**1D**	**3D**	**7D**	**2E**	**1F**	**Total (%)**
0 – 30	0.83	0.32	0.00	1.52	20.93	23.60
30 – 60	0.48	1.47	0.11	2.96	4.32	9.34
60 – 90	0.48	0.37	0.00	2.06	4.46	7.37
90 – 120	0.32	1.15	0.00	4.46	7.98	13.91
120 – 150	0.08	0.27	0.00	1.23	5.37	6.95
150 – 180	0.16	0.03	0.00	7.29	12.01	19.49
180 – 210	0.13	0.21	0.00	6.41	5.47	12.22
210 – 240	0.05	0.05	0.00	0.35	0.43	0.88
240 – 270	0.03	0.00	0.00	0.03	0.27	0.33
270 – 300	0.00	0.00	0.00	0.03	0.29	0.32
300 – 330	0.08	0.03	0.00	0.03	0.72	0.86
330 – 360	0.51	0.19	0.00	0.27	3.76	4.73
All (%)	3.15	4.09	0.11	26.64	66.01	100.00

3. HAZARD IDENIFICATION AND ANALYSIS

3.1 Introduction

3.1.1.1 A hazard is an undesired event which may cause harm to people or to the environment or damage to property.

3.1.1.2 Potential hazards related to transmission of town gas and process gas were identified and discussed. The Hong Kong and China Gas Company Limited (HKCG) was consulted for the operation information and parameters. This section outlined the hazard identification for the operation of the HP gas pipeline including a review of historical accident database (i.e. Major Hazard Incident Data Services (MHIDAS)).

3.2 The HP Gas Pipeline

3.2.1.1 The 600mm HP gas pipeline is constructed of steel to the specification API 5L X 42 with a nominal wall thickness of 12.7 mm. The maximum operating pressure of this pipeline is 35 barg and is buried underground with a minimum earth cover of 1.1 m. The pipeline is provided with an external 400 micro of fusion bonded epoxy coating, and a sacrificial anode cathodic protection system. The upstream isolation valve is located at Castle Peak Road – Chau Tau, while the downstream isolation valve is located at Fairview Park Boulevard Round About. The pipe length between these two isolation valves is around 6.2 km.

3.2.1.2 The initiating events resulting in a release of town gas could occur due to various reasons, including spontaneous failure and leakage of pipeline. The main hazard from the HP gas pipeline is a loss of containment leading to a gas leak, fire, explosion and toxic release. Town gas is both flammable and explosive due to the presence of methane, hydrogen and carbon dioxide. It is also considered toxic due to the presence of carbon dioxide and carbon monoxide.

3.2.1.3 The highest risk 1.6km pipeline segment was determined based on the population within the study area as determined in Section 2.1 above, and is presented in **Plate 3-1**.

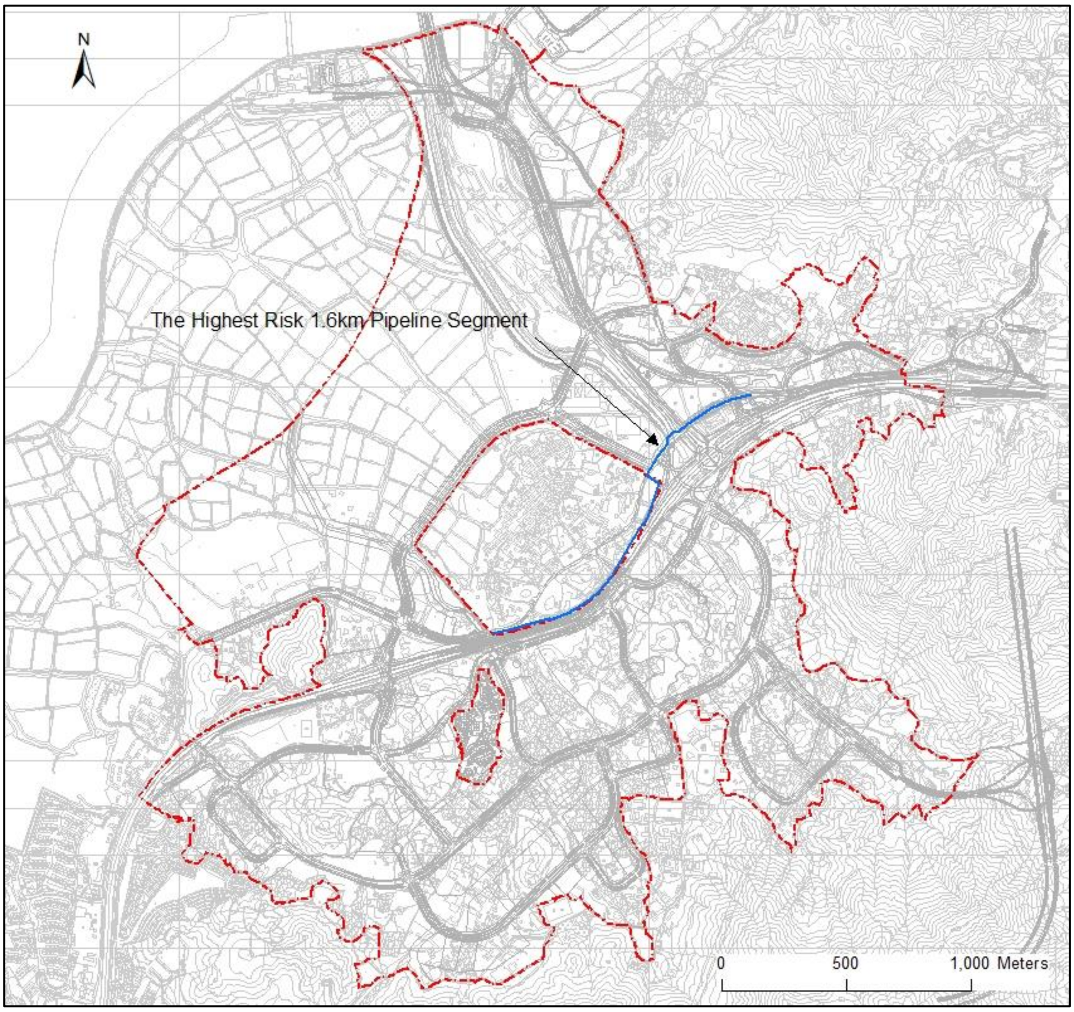

Plate 3-1 The Highest Risk 1.6km Pipeline Segment

3.3 Behaviour of Town Gas

3.3.1.1 Town gas, which is produced mainly from naphtha and natural gas, is the final product of the gas works. It is a clean, safe and reliable gaseous fuel. With about half the density of air, it will rise and dissipate in the air if leakages occur. Since it is both colourless and odourless, a special odour has been added to the gas such that it can easily be detected.

3.3.1.2 Town gas is a mixture of hydrogen, methane, carbon dioxide and carbon monoxide. It is both flammable and toxic while carbon monoxide, one of the components of the town gas, is a chemical asphyxiant. The composition and physical properties of town gas are summarised in **Table 3.1**.

Table 3.1 Compositions and Properties of Town Gas

Composition	% (By Volume)	Physical Properties	Values
Hydrogen	49%	Calorific Value	17.27 MJ/m^3
Methane	28.5%	Specific Gravity	0.52
Carbon Dioxide	19.5%	Wobbe Index	24
Carbon Monoxide	3.0%	Weaver Flame Speed	35

3.3.1.3 Release in large quantity, if ignited immediately, will produce a fireball. Initially the gas concentration in the mixture will be above the Upper Flammability Limit (UFL). As burning occurs around the edges of the release, this will entrain more air into the mixture and more combustion will take place. The process accelerates until the mixture rises above the ground as a ball of fire.

3.3.1.4 If not ignited immediately, the gas will disperse and dilute. If ignition occurs when the gas concentration is between the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL), a flame front will propagate to produce a flash fire. In case of a continuous release, fire is flashed back to the release source and leads to a jet fire.

3.3.1.5 For continuous releases, immediate ignition will produce a long vigorous jet flame from the point of release.

3.3.1.6 For all sizes of release, town gas and process gas will have a toxic effect on nearby population sites if there is no source of ignition and allowed to disperse.

3.4 Hazard Analysis

3.4.1 General

3.4.1.1 The hazards in associated with pipeline transport of gas are well understood based on historical experience world-wide relating to pipeline transportation of oil and gas. From the incident review by HSE (1995) [3], some common causes of failure gas pipelines are identified below:

(a) External events;

(b) Pipeline corrosion;

(c) Defective pipe and welds;

(d) Equipment malfunction and improper operations; and

(e) Spontaneous & partial failure.

3.4.2 External Events

3.4.2.1 A town gas release event could occur due to external events and the consequences could be catastrophic. The related external events are listed as follows:

(a) Earthquake

(b) Aircraft crash

(c) Landslide

(d) Severe environmental event such as typhoon or tsunami

(e) Subsidence

(f) Lightning

(g) Third Party Damage

<u>Earthquake</u>

3.4.2.2 An earthquake has the potential to cause damage to the HP gas pipeline. The damage could occur due to ground movement or vibration leading to spontaneous failure of pipelines. Hong Kong is located in a region of low seismicity where an earthquake is an unlikely event.

The generic failure frequencies adopted in this assessment are based on historical incidents that include earthquakes in their cause of failure. Since Hong Kong is not at disproportionate risk from earthquakes compared to other similar facilities worldwide, it is deemed appropriate to use these generic frequencies without adjustment. As such, earthquake was not considered separately in this assessment.

Aircraft Crash

3.4.2.3 Aircrafts crashing into the HP gas pipeline due to take-off and landing as well as airway accidents along the arrival and departure flight paths were accounted for in this assessment. The method given in HSE (1997) [4] for the calculation of aircraft crash frequency was adopted and detailed in **Annex B**. The calculated aircraft frequency was found to be 2.4×10^{-13} per year and 3.4×10^{-13} per year in Year 2032 and Year 2039 respectively. Since the calculated failure rate is much lower than the order of 10^{-9}, failure caused by aircraft crash was not further considered in the assessment.

Landslide

3.4.2.4 The HP gas pipeline is buried at 1.1m underground along San Tam Road, and loss of containment due to landslide was considered not possible. Therefore, the probability of landslide is negligible and this external event was not further considered in this assessment.

Severe Environmental Events

3.4.2.5 Loss of containment due to severe environmental events such as typhoon or tsunami (i.e. a tidal wave following an earthquake) was considered to be insignificant as the HP gas pipeline is installed underground and situated away from seashore. Therefore, the probabilities of failure due to severe environmental events were very small or negligible and thus not further considered in this assessment.

Subsidence

3.4.2.6 Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Therefore, the probability of subsidence is very small or negligible and such external event was not further considered in this assessment.

Lightning

3.4.2.7 The HP gas pipeline is buried at 1.1m underground along San Tam Road, the road surface provides shielding to prevent the pipeline from being struck by lightning. With sufficient protection system, no further consideration was given for the effect of lightning strike in this assessment.

Third Party Damage

3.4.2.8 Third party damage includes activities causing incidents such as work on other underground utilities, drilling for ground sampling, construction work on adjoining areas, etc. Any excavation works are well controlled in Hong Kong, and there are guidelines issued by Electrical and Mechanical Services Department (EMSD) as well as those issued by the gas company for construction in the vicinity of gas pipelines. Accurate alignment records of the HP gas pipeline will be provided by HKCG for works in the vicinity of the pipelines. Nevertheless, failures may still occur due to inadequate site control and supervision, and the adopted failure rates as detailed in **Section 4** were included to account for this cause of gas pipeline failure.

3.4.3 Pipeline Corrosion

3.4.3.1 The gas pipelines are protected by protective internal and external coatings and sacrificial anode cathodic protection system. In addition, the gas transported by the pipeline consists of mainly dry hydrogen and methane. There are no other components which could cause internal corrosion. Failures due to corrosion were considered well covered by the failure rates adopted in **Section 0** and thus not considered in the fault tree analysis separately.

3.4.4 Defective Pipe and Welds

3.4.4.1 HKCG has not experienced any loss of containment failure in their high pressure transmission network (35bar) due to material or construction defect since commencement of operation in 1983. In addition, HKCG adopts 100% non-destructive testing as per IGEM/TD/1, which is more stringent than ANSI B31.8 that requires only a minimum of 75% of the welds to be inspected for pipeline operating at 20% Specified Minimum Yield Strength (SMYS) or more in class 4 location. Due to the stringent testing requirements adopted by HKCG, the condition of pipeline transmission network in Hong Kong is not at disproportionate risk compared to other similar facilities worldwide, it is considered appropriate to adopt the generic failure frequencies without adjustments on defective pipes or welds.

3.4.5 Equipment Malfunction and Improper Operations

3.4.5.1 The failure cases in relation to equipment malfunction include malfunctioning of control/ relief systems etc. This is not applicable to HKCG HP gas pipelines as they are in general all welded and normally do not consist of any control/ relief instruments etc. Hence, the cause of equipment malfunction is considered covered by the generic frequencies and not be assessed separately in this assessment.

3.4.5.2 From time to time, HKCG receives voluminous notifications from other utility companies or contractors regarding their construction works. HKCG replies expediently to each enquiry with clear marking of the existing pipeline alignments. For works which may jeopardise the safety of the gas system, engineers will closely liaise with the party concerned and a trench inspector will monitor the progress of the works. The trench inspectors are well-trained and can provide valuable advice to the roadwork contractors on the safety precaution required to avoid damage of pipelines and proper site equipment maintenance works. As such, failure due to improper operations was considered covered by the generic failure frequencies and not assessed separately in this assessment.

3.4.6 Spontaneous and Partial Failures

3.4.6.1 Offtake stations control and regulate pressures of gas inflows from high pressure network and are sensitive to interferences. In case of minor accident, interferences would disturb inflow of gas in the transmission system. In case of overpressure, pipeline would be overloaded and lead to full bore rupture followed by an instantaneous gas release. In cold partial failure, it results in continuous gas release to the atmosphere through a pipe crack or leak.

4. FREQUENCY ANALYSIS

4.1 General

4.1.1.1 Subsequent to the hazard identification and analysis, the next step is to estimate the likelihoods of various release scenarios. There are combinations of hazard initiating events, as identified in previous section, which would lead to a town gas release.

4.2 Generic Failure Frequency

4.2.1.1 The failure rate for underground pipeline hazards from the Guidance Note [1] was adopted in this assessment. A failure rate of 1.0×10^{-5} per km per year would be adopted for the HP gas pipeline running along the San Tam Road.

4.3 Hole Size Distribution

4.3.1.1 The distribution of the overall failure frequency into different failure sizes was based on the Guidance Note [1], and the hole size distribution adopted in this assessment is presented in **Table 4.1**. Although the probability of a full bore rupture is extremely low due to the design factor of 0.3 and wall thickness of 12.7mm, it was considered in this QRA for completeness. **Table 4.2** summarises the failure rates for all identified failure scenarios.

Table 4.1 Hole Size Distributions

Category	Hole Size	Distribution (%)
Rupture	Full bore	1
Puncture	100 mm	19
Hole	50 mm	30
Leak	25 mm	30
Leak	10mm	20

Table 4.2 Estimated Occurrence frequencies of Significant Town Gas Releases from the HP Gas Pipeline

Release Case	Frequency of Occurrence (km^{-1} $Year^{-1}$)
Spontaneous Failure of HP Gas Pipeline (Full Bore Rupture)	1.00E-07
Partial Failure of HP Gas Pipeline (100 mm Leak)	1.90E-06
Partial Failure of HP Gas Pipeline (50 mm Leak)	3.00E-06
Partial Failure of HP Gas Pipeline (25 mm Leak)	3.00E-06
Partial Failure of HP Gas Pipeline (10 mm Leak)	2.00E-06

4.4 Orientation of Release

4.4.1.1 The consequences following a gas release are dependent on the release rate and the orientation of the release. Failures that occur on the top portion of the pipeline/ process equipment would result in vertical jet releases (unobstructed) and are governed by momentum jet dispersion / momentum jet fires. Failures that occur from the bottom portion of the pipeline/ process equipment would lose momentum due to impingement / obstruction with the surrounding earth and therefore are governed by buoyant plume rise followed by Gaussian dispersion. The orientation of releases is dependent upon the cause of failures. Failures due to third party damage are more likely to occur from the top while corrosion failures are more likely to occur at the bottom and/or side. In this assessment, equal probability of vertical and inclined (i.e. 45°) releases were assumed for the partial failure of underground pipeline.

4.5 Event Tree Analysis

4.5.1.1 The hazard event outcomes following a gas release were evaluated by the event tree analysis as presented in **Annex C**.

5. CONSEQUENCE AND IMPACT ANALYSIS

5.1 Introduction

5.1.1.1 Consequence and impact analysis will be conducted using SAFETI to provide a quantitative estimate of the likelihood and number of fatalities associated with the range of possible outcomes, such as fire ball, jet fire and flammable cloud from the identified failure cases.

5.2 Source Term

5.2.1.1 Source term modelling was carried out to determine the maximum release rate that may be expected should a loss of containment occur. All the releases will be modeled assuming 6.2km pipeline section (which has an inventory of about 38 tonnes), i.e. the section between the upstream isolation valve at Castle Peak Road – Chau Tau and the downstream isolation valve at Fairview Park Boulevard roundabout.

5.3 Consequence Modelling

5.3.1.1 This section gives a brief description of the physical effects models that were used to assess the effects zones for the following hazardous outcomes:

(a) Fireball;

(b) Jet fire;

(c) Flash fire;

(d) Vapour Cloud Explosion (VCE); and

(e) Unignited toxic release.

5.3.2 Fireball

5.3.2.1 The release rate following a rupture, if ignition is immediate, would be too high to give a stable flame, and the initial 'quasi instantaneous' release is characterised as a fireball. The fireball is limited to a maximum duration of 30 seconds. The combustion would develop into a stable jet fire once the instantaneous release has been burnt and the release rate has become sufficiently steady for a flame to stabilise as stated by Bilo and Kinsman [6]. A release from a hole, if ignited, gives a stable flame close to the hole and produces a jet fire.

5.3.2.2 The principal hazard of a fireball arises from the massive transient dose of thermal radiation. Due to the large size and intensity of a fireball, its effects are not significantly influenced by weather or wind direction. The thermal radiation from a fireball at given distances from the fireball centre were estimated using SAFETI's built-in fireball modelling suite in which TNO model and HSE model were adopted. The modelling suite is set such that it decides the most appropriate one in the effect modelling. With the source term inventory assuming 6.2km pipeline section (i.e. the pipe segment between the upstream and downstream isolation valves), the mass of fireball is around 38 tonnes and the radius of fireball is 98m. Duration of the fireball was found to be 15.1 seconds.

5.3.3 Jet Fire

5.3.3.1 A jet fire occurs following the ignition and combustion of a flammable fluid issuing continuously from a pipeline, which burns close to the release source. The jet fire which follows the fire ball was assumed to be directed vertically upwards out of the crater. The jet fire shape is the frustum of a cone, while the location and orientation of the frustum are dependent on a number of factors such as release rate and wind speed.

5.3.3.2 Combustion in a jet fire occurs in the form of a strong turbulent diffusion flame that is strongly influenced by the initial momentum of the release. The principal hazards from a jet fire are thermal radiation and the potential for knock-on effects. Jet fires also dissipate thermal radiation and causes casualty and damage to the population and property nearby.

5.3.4 Gas Dispersion and Flash Fire

5.3.4.1 As town gas is pressurised in the transmission network, it is heavier than air at the initial release stage. As the gas expands, it rises rapidly due to the buoyancy nature of the gas under atmospheric conditions. It will propagate and be diluted as a result of air entrainment with the influence of wind.

5.3.4.2 The principal hazard arising from a cloud of dispersing town gas is the delayed ignition of the flammable cloud that cause a flame to flash back to the release location and develop into a stable jet or crater fire. The potential for vapour cloud explosion is not considered significant for a buoyant gas plume and thus was not further considered in this assessment.

5.3.4.3 Large scale experiments on the dispersion and ignition of flammable gas clouds show that ignition is unlikely when the average concentration of the gas is below its Lower Flammable Limit (LFL) or above its Upper Flammable Limit (UFL). The hazard distance was calculated by the Unified Dispersion Model (UDM) in the Phast Risk. It estimates the profile of a dispersing cloud in segments according to properties of the propagating cloud. For simplicity of presenting the hazardous extent of the clouds, the cloud dispersion segment is generally described as a half/ full ellipse by the following parameters,

(a) Downwind distance to the LFL of the cloud - major semi-axis of the ellipse;

(b) Crosswind distance to the LFL of the cloud - minor semi-axis of the ellipse;

(c) Downwind displacement – downwind distance to centre of ellipse.

5.3.4.4 It was considered that there would be no scope for escape within the LFL of a flammable cloud in a flash fire. Therefore, a fatality probability of 100% of persons present within the flammable cloud was assumed for flash fires.

5.3.5 Vapour Cloud Explosion

5.3.5.1 A vapour cloud explosion can occur when a flammable vapour is ignited in a confined or partially confined situation. When there is a large amount of pressurised gas rapidly releasing to the atmosphere from a pressurised tank, a vapour cloud could be formed, dispersed and mixed with the surrounding air. If the vapour cloud is passing through a confined / semi-confined environment and gets ignited, the confinement could limit the degree of expansion of the burning cloud and create an overpressure and explosion.

5.3.5.2 The risk model was accounted for the VCE hazard according to probabilities for delayed ignition in consequence modelling. The program models the delayed ignition effect by considering the flammable cloud area and location of ignition sources at each time step. Potential damage from a VCE is caused by overpressure.

5.3.6 Unignited Toxic Release

5.3.6.1 Following a loss of containment event involving toxic substances (i.e. unignited CO release), the resulting toxic gas may disperse over long distances from the source and cause fatalities. Toxic gas dispersion was predicted by UDM in the Phast Risk.

5.4 Impact Assessment

5.4.1 Probit Equations

5.4.1.1 The estimation of the fatality/ injury caused by a physical effect such as thermal radiation or overpressure requires the use of probit equations, which describe the probability of fatality as a function of some physical effect. The probit equations take the following general form

$$Y = a + b \ln(V)$$

where Y is the probit;
a and b are constants determined from experiments; and
V is a measure of the physical effect such as thermal dose, peak overpressure etc.

5.4.1.2 The probit is an alternative way of expressing the probability of fatality and is derived from a statistical transformation of the probability of fatality. The relationship between fatality probabilities and probits is given in [5].

5.4.2 Probit Equations For Thermal Impact

5.4.2.1 Fatality rates due to exposure to thermal radiation from a fire were determined by the following probit function which is set as the default in the SAFETI:

a = -36.38

b = 2.56

V = t x $I^{4/3}$

where I = thermal radiation intensity at the target (W/m^2); and

t = duration of exposure (s).

5.4.2.2 For jet fires, the exposure duration was estimated as 20s, which was assumed as the time taken for people to take evasive action such as seeking refuge etc.

5.4.3 Probit Equations For Toxic Impact

5.4.3.1 As shown in **Table 3.1**, the composition of town gas contains by volume of about 20% CO_2 and 3% CO, while the composition of process gas contains by volume of about 30% CO_2. Both gases have the potential to cause adverse health effects at population centres if allowed to disperse without ignition.

5.4.3.2 Carbon dioxide (CO_2) is not classified as a toxic or harmful gas, but is considered an asphyxiant gas. It is a potent stimulant to respiration and both a depressant and excitant of the central nervous system. The CO_2 content in fresh air varies around 0.037%. Concentrations of 20% to 30% can result in unconsciousness and convulsions within one minute of exposure [7].

5.4.3.3 Carbon monoxide (CO) is a highly toxic gas capable of causing harm at very low concentrations. It combines with haemoglobin in the blood, thus displacing oxygen. The IDLH (Immediately Dangerous to Life and Health) value for CO is 1200ppm (0.12%) [7], but concentrations at 0.0035% are enough to cause headache and dizziness.

5.4.3.4 While both gases are odourless, town gas has been odourised with THT. As such, populations under the exposure of town gas are warned olfactorily, allowing the affected individuals to react and escape exposure. It is expected that there is a significant interval between the start of the exposure and the onset of incapacitation which would prevent escape action. Therefore, escaping from the affected area is a practicable action and has a high success rate.

5.4.3.5 Since town gas is lighter than air, the release will disperse upwards under normal wind conditions until its concentration equilibrates with the surrounding air, where it is then free to move in any direction. Assuming no immediate ignition has occurred, the surrounding population of the HP gas pipeline is unlikely to be fully exposed to the emerging gas cloud. As the gas cloud continues to disperse, its CO_2 and CO concentration will begin to dilute and significantly reducing its toxicity over time.

5.4.3.6 The gas mixture for the fatality calculation was assumed to be 100% CO as a conservative approach. The following probit equation for CO, from the built-in material database of Phast Risk, was applied to the risk model,

$$Pr = -7.21 + \ln(Ct)$$

where C is gas concentration in ppm and t is the exposure time in minute.

5.5 Ignition Sources

5.5.1.1 Information on ignition sources located within the study area was identified to calculate the risk from flammable materials. Such data was included in the risk model for each type of ignition source (i.e. point sources, line sources and area sources). The risk calculation program (MPACT) in SAFETI predicts the probability of a flammable cloud being ignited (delayed ignition) as the cloud moves downwind over ignition sources.

5.5.2 Point Sources

5.5.2.1 No major point source was identified in the vicinity of the HP gas pipeline.

5.5.3 Line Sources

5.5.3.1 Roads are defined as line sources in SAFETI. The following assumptions were applied to estimate the presence factor of the line source and the ignition probability:

(a) Probability of ignition for a vehicle was taken as 0.4 in 60 seconds; and

(b) Traffic density was based on the projected traffic flow adopted for population estimation, as shown in **Table 5.1**.

Table 5.1 Summary of Line Ignition Source

ID	Traffic Speed (km/hr)	Traffic Density in Year 2032 (veh / hr)		Traffic Density in Year 2039 (veh / hr)	
		Daytime	Night-time	Daytime	Night-time
R1	50	186	69	425	145
R2	50	652	261	1419	570
R3	50	250	106	1071	462
R4	50	323	126	1212	520
R5	50	453	184	582	241
R6	100	7051	2758	9910	3923
R7	100	6524	2579	8011	3205
R8	100	7007	2776	9520	3884
R9	100	4872	1977	5485	2350
R10	100	6402	2713	7448	3312
R11	50	774	292	1443	545
R12	50	619	262	2410	1048
R13	50	222	94	721	256
R14	50	305	85	1179	462
R15	50	246	100	835	378
R16	50	238	97	674	301
R17	50	179	79	729	309
R18	50	286	83	540	192

ID	Traffic Speed (km/hr)	Traffic Density in Year 2032 (veh / hr)		Traffic Density in Year 2039 (veh / hr)	
		Daytime	Night-time	Daytime	Night-time
R19	50	244	96	612	247
R20	50	213	85	607	240
R21	50	227	97	696	292
R22	50	516	208	925	357
R23	50	645	264	684	280
R24	50	519	226	567	246
R25	50	453	202	880	392
R26	50	61	27	901	381
R27	50	36	14	671	289
R28	50	0	0	913	366
R29	50	0	0	1011	430
R30	50	95	29	676	285
R31	50	519	187	826	299
R32	50	394	159	894	313
R33	50	1237	622	1825	894
R34	50	593	202	1127	371
R35	50	1082	534	1370	715
R36	50	362	153	422	181
R37	50	21	9	21	9
R38	50	388	166	282	115
R39	50	1281	556	1958	860
R40	50	0	0	206	85
R41	50	44	114	44	115
R42	50	968	968	1274	1274
R43	50	1015	1015	1364	1364
R44	50	442	442	708	708
R45	50	395	395	583	583
R46	50	594	594	748	748

5.5.4 Area Source

5.5.4.1 SAFETI considers a residential population as an ignition source (as a result of activities such as cooking, smoking, heating appliances etc.). The ignition probability was derived from the population densities in the concerned area by the software.

5.6 Ignition Probability

5.6.1.1 In general, the probability of immediate or delayed ignitions depends on the scale of release, the presence and location of ignition sources, and the weather conditions.

5.6.1.2 For town gas release analysis, immediate ignition probabilities for pipelines were taken from the Guidance Note [1], as summarised in **Table 5.2**. For all scale of release, the delayed ignition probability was assumed to be at least 40% of immediate unignited probability [1].

Table 5.2 Ignition Probabilities

Leak Size	Ignition Probability (Gas Release)
Minor (<< 1kg/s)	0.01
Major (1-50 kg/s)	0.07
Massive (>50kg/s)	0.3

5.7 Protection Factors

5.7.1.1 With reference to previous practice of assessments with similar nature in Hong Kong, protection factors were considered and applied to the concerned population groups if applicable.

Indoor Protection Factors

5.7.1.2 It was generally assumed that the respective outdoor/ indoor population are 5% and 95% at the time of an accident [1].

5.7.1.3 A protection factor was also considered for indoor population due to impacts from thermal radiation and toxic gas as summarised below:

Fireball

5.7.1.4 Lower proportions of those persons indoors would be fatally injured by the thermal radiation from the fireball and it was assumed that 50% of persons indoors within the fireball radius would be killed.

Flash fire and toxic event

5.7.1.5 The fatality rate for indoor persons was assumed to be one tenth of the outdoor fatality rate.

Jet Fire

5.7.1.6 For jet fires, the intensity of the radiation and thus the short exposure time leaves little scope for escape for individuals exposed to jet flames, the fatality probability for indoor persons was assumed to be one tenth of the outdoor fatality probability.

Shielding Factors

5.7.1.7 Shielding factors are used to allow for the shielding of buildings by other buildings from fireball effects. Shielding factors are determined by consideration of the following:

- The proportion of the building within the fireball diameter. For buildings wholly within the fireball, shielding is afforded only to the people at the back of the building;
- For buildings wholly outside the fireball, the proportion of the building not in the direct line of sight of the HP Gas Pipeline is considered protected. Outside the fireball diameter, only radiant heat effects are considered. Radiant heat waves from the flame surface travel in straight lines and therefore only affects that part of a building directly in front; and
- For buildings which are partly inside and partly outside the fireball diameter, that proportion of the building outside the fireball diameter is considered shielded by the rest of the building.

Height Protection Factors

5.7.1.8 The impacted areas of jet fire and flash fire are limited and do not cover the entire building for high rise. To be conservative, no height protection factor was adopted in this Study.

6. RISK EVALUATION

6.1 Introduction

6.1.1.1 In this section, the risks arising from the HP gas pipeline were evaluated in terms of both individual and societal risks.

6.1.1.2 Individual risk is a measure of the risk to a chosen individual at a particular location. As such, this was evaluated by summing the contributions to that risk across a spectrum of incidents that could occur at a particular location.

6.1.1.3 Societal risk is a measure of the overall impact of an activity upon the surrounding community. As such, the likelihoods and consequences of the range of incidents postulated for that particular activity were combined to create a cumulative picture of the spectrum of the possible consequences and their frequencies. This is usually presented in the form of a FN curve and the acceptability of the results can be assessed against the societal risk criterion under the risk guidelines.

6.2 Individual Risk

Risk Level

6.2.1.1 The predicted individual risk levels for the HP gas pipeline are shown in **Plate 6-1**. The associated risk levels were based on 100% occupancy with no allowance made for shelter or escape, as specified in the user manual of Phast Risk.

6.2.1.2 The HKRG criterion for individual risk is that no person off-site should be subject to an additional risk of 1×10^{-5} per year.

Acceptability

6.2.1.3 As observed in the figure, the maximum individual risk is less than 1×10^{-8} per year. Given that there is no off-site risk with frequency greater than 1×10^{-5} per year, no off-site individual would be exposed to risk level greater than 1×10^{-5} per year. The level of individual risk associated with the operation of the HP gas pipeline, and the individual risk imposed on the Project is considered acceptable and in compliance with the HKRG.

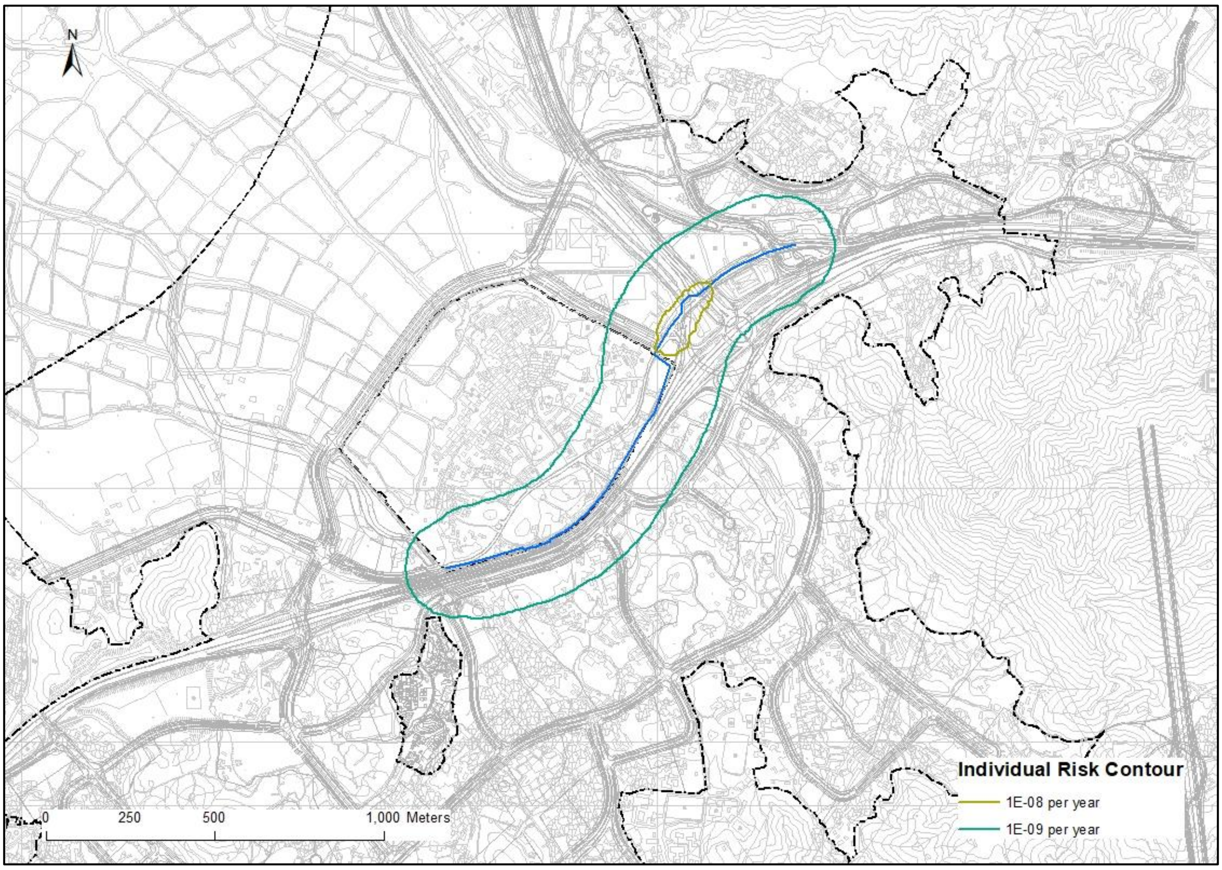

Plate 6-1 Individual Risk Contour for the HP Gas Pipeline

6.3 Societal Risk

Risk Level

6.3.1.1 The societal risks were evaluated for the range of incidents with the potential for fatalities in the vicinity of the HP gas pipeline as shown in **Plate 6-2**. The societal risk is more complex than that of individual risk but, in essence, comprises three regions:

(a) "Unacceptable" - a region within which the risks may be regarded as unacceptable;

(b) "Acceptable" - a region within which the risks may be regarded as acceptable; and

(c) "ALARP" - a region between the two in which measures should be taken to demonstrate the risks as "as low as reasonably practicable" (ALARP). In other words, consideration is given not only to the level of risk but also the cost and practicality of reducing it.

6.3.1.2 Numerically, the upper bound of the ALARP region (and hence the borderline of "unacceptability") can be summarised as:

(a) 1 chance in 1,000 per year of an incident resulting in 1 or more fatalities;

(b) 1 chance in 10,000 per year of an incident resulting in 10 or more fatalities;

(c) 1 chance in 100,000 per year of an incident resulting in 100 or more fatalities; and

(d) not more than 1,000 fatalities at a frequency of greater than 1 chance in a billion (1,000,000,000) per year.

Acceptability

6.3.1.3 As observed in **Plate 6-2**, the societal risks associated with operation of the highest risk 1.6km HP gas pipeline fall within the "Acceptable" region in both assessment years. The maximum number of fatalities was estimated as about 460 during construction phase and 770 during operation phase of the Project.

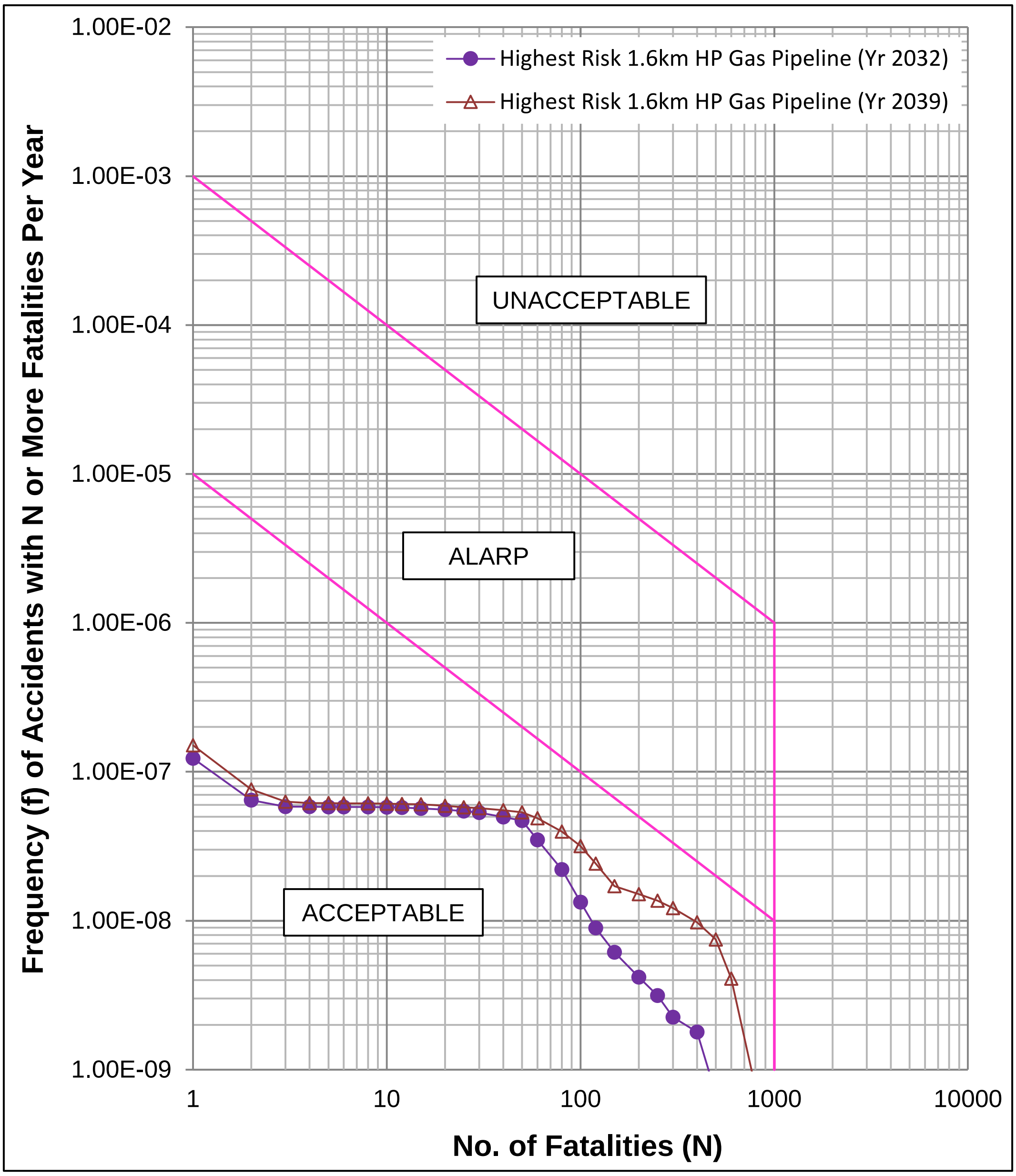

Plate 6-2 Societal Risk Curve in Comparison with HKRG

Table 6.1 Societal Risk Summary

No. of Fatalities	Frequency (/year)	
	Year 2032 (Construction Phase)	Year 2039 (Operation Phase)
1	1.23E-07	1.51E-07
2	6.45E-08	7.61E-08
3	5.83E-08	6.32E-08
4	5.82E-08	6.16E-08
5	5.82E-08	6.15E-08
6	5.81E-08	6.15E-08
8	5.80E-08	6.13E-08
10	5.78E-08	6.11E-08
12	5.75E-08	6.09E-08
15	5.69E-08	6.04E-08
20	5.56E-08	5.91E-08
25	5.46E-08	5.79E-08
30	5.32E-08	5.70E-08
40	4.96E-08	5.53E-08
50	4.70E-08	5.35E-08
60	3.49E-08	4.88E-08
80	2.21E-08	3.97E-08
100	1.33E-08	3.17E-08
120	8.96E-09	2.42E-08
150	6.14E-09	1.71E-08
200	4.18E-09	1.51E-08
250	3.15E-09	1.36E-08
300	2.25E-09	1.22E-08
400	1.79E-09	9.75E-09
500	6.86E-10	7.48E-09
600	-	4.08E-09
800	-	7.61E-10

6.4 Potential Loss of Life (PLL)

6.4.1.1 The total PLL in Year 2032 (construction phase) and Year 2039 (operation phase) were found to be 5.57×10^{-6} per year and 1.22×10^{-5} per year respectively. Fireball events from town gas release was identified as the major contributor during operation phase, with an estimated 9.53×10^{-6} per year (i.e. about 78% of the total PLL).

7. CONCLUSIONS AND RECOMMENDATIONS

7.1.1.1 A hazard assessment was conducted to assess the risks associated with the operation of the HP gas pipeline during the construction and operation phases of the Project.

7.1.1.2 The individual risk associated with the operation of the HP gas pipeline, and the individual risk imposed on the Project would comply with the HKRG as stipulated in EIAO-TM Annex 4. The societal risks expressed in the form of FN curves would fall within the "Acceptable" region of HKRG for both construction and operation phases of the Project. The increase in fatalities during the operation phase of the Project would be mainly attributed by the population induced by the Project.

8. REFERENCES

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Annex A

Population Data

Popu_ID	Land_ID	Description	Maximum Population in 2032	Maximum Population in 2039	Indoor Ratio in 2032	% Occupancy in 2032				Population in 2032				Shielding Factor [FB]	Shielded Population in 2032				Indoor Ratio in 2039	% Occupancy in 2039				Population in 2039				Shielding Factor [FB]	Shielded Population in 2039			
						Weekday		Weekend		Weekday		Weekend			Weekday		Weekend			Weekday		Weekend		Weekday		Weekend			Weekday		Weekend	
						Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night		Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night
E01	-	Maple Gardens	532	532	0.95	0.5	1	0.7	1	266	532	372	532	0.5	133	266	186	266	0.95	0.5	1	0.7	1	266	532	372	532	0.5	133	266	186	266
E02	-	Scenic Heights	106	106	0.95	0.5	1	0.7	1	53	106	74	106	0.5	27	53	37	53	0.95	0.5	1	0.7	1	53	106	74	106	0.5	27	53	37	53
E03	-	Mai Po San Tsuen No. 201-201C	47	47	0.95	0.5	1	0.7	1	24	47	33	47	0.5	12	24	17	24	0.95	0.5	1	0.7	1	24	47	33	47	0.5	12	24	17	24
E04	-	Open Storage	39	39	0	1	0.1	1	0.1	39	4	39	4	0	39	4	39	4	0	1	0.1	1	0.1	39	4	39	4	0	39	4	39	4
E05	-	Mai Po San Tsuen	3164	3164	0.95	0.5	1	0.7	1	1582	3164	2215	3164	0.5	791	1582	1108	1582	0.95	0.5	1	0.7	1	1582	3164	2215	3164	0.5	791	1582	1108	1582
E06	-	Tsing Lung Tsuen, Fan Tin Tsuen, Wing Ping Tsuen	1788	1788	0.95	0.5	1	0.7	1	894	1788	1252	1788	0.5	447	894	626	894	0.95	0.5	1	0.7	1	894	1788	1252	1788	0.5	447	894	626	894
E07	-	Pak Shek Au	954	954	0.95	0.5	1	0.7	1	477	954	668	954	0.5	239	477	334	477	0.95	0.5	1	0.7	1	477	954	668	954	0.5	239	477	334	477
P01	A.5.1	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P02	OU(ESS).5.12	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P03	G.5.3	Existing Mai Po ESS	125	84	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	84	8	42	8	0.5	42	4	21	4
P04	G.5.1	Sport Centre	125	1018	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	1018	102	509	102	0.5	509	51	255	51
P05	RSc.2.1	Public Housing	9899	9899	0.95	0.5	1	0.7	1	4950	9899	6929	9899	0.5	2475	4950	3465	4950	0.95	0.5	1	0.7	1	4950	9899	6929	9899	0.5	2475	4950	3465	4950
P06	RSc.2.2	Public Housing	7603	7603	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802
P07a	OU(EPP).5.3	Food Waste Pretreatment Facilities	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P07b	OU(EPP).5.3	Effluent Polishing Plant	200	200	0.95	1	0.1	0.5	0.1	200	20	100	20	0.5	100	10	50	10	0.95	1	0.1	0.5	0.1	200	20	100	20	0.5	100	10	50	10
P08	OU(GFS).5.1	Green Fuel Station	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10
P09	G.5.2	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P10	GB.5.3	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P11	OU(ESS).5.6	132kV ESS	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P12	G.5.5	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P13	G.5.6	Reserve (Potential Education Facilities)	125	1680	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0	0.5	0	1680	0	840	0	0.5	840	0	420	0
P14	GB.5.4	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P15	OU(SPS).5.7	Sewage Pumping Station	30	30	0.95	1	0.1	0.5	0.1	30	3	15	3	0.5	15	2	8	2	0.95	1	0.1	0.5	0.1	30	3	15	3	0.5	15	2	8	2
P16	A.2.1	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P17	O.2.4	Open Space	484	484	0	1	1	1	1	484	484	484	484	0	484	484	484	484	0	1	1	1	1	484	484	484	484	0	484	484	484	484
P18	V	Village Type Development	440	440	0.95	0.5	1	0.7	1	220	440	308	440	0.5	110	220	154	220	0.95	0.5	1	0.7	1	220	440	308	440	0.5	110	220	154	220
P19	G.5.7	Cultural & Recreational Complex	32	1502	0	1	0.1	0.5	0.1	32	3	16	3	0	32	3	16	3	0.95	1	0.1	0.5	0.1	1502	150	751	150	0.5	751	75	376	75
P20	O.5.1	Open Space	534	534	0	1	1	1	1	534	534	534	534	0	534	534	534	534	0	1	1	1	1	534	534	534	534	0	534	534	534	534
P21	G.5.7	Cultural & Recreational Complex	93	4280	0	1	0.1	0.5	0.1	93	9	46	9	0	93	9	46	9	0.95	1	0.1	0.5	0.1	4280	428	2140	428	0.5	2140	214	1070	214
P22	V.3.1	Village Resite	78	78	0.95	0.5	1	0.7	1	39	78	55	78	0.5	20	39	28	39	0.95	0.5	1	0.7	1	39	78	55	78	0.5	20	39	28	39
P23	GB.5.5	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P24	G.5.13	Reserve	125	30	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	30	3	15	3	0.5	15	2	8	2
P25	OU(RAF).5.2	Vent Shaft	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P26	G.5.14	Sport Centre	125	1018	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	1018	102	509	102	0.5	509	51	255	51
P27	A.1.13	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P28	A.1.15	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P29	A.1.16	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P30	OU(RAF).1.2	Vent Shaft	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P31	OU(LSW).1.1	Logistics, Storage and Warehouse	2833	2833	0.95	1	0.1	0.5	0.1	2833	283	1417	283	0.5	1417	142	709	142	0.95	1	0.1	0.5	0.1	2833	283	1417	283	0.5	1417	142	709	142
P32	OU(RTS/RRF).1.9	Refuse Transfer Station cum Resource Recovery Facilities	50	50	0.95	1	0.1	0.5	0.1	50	5	25	5	0.5	25	3	13	3	0.95	1	0.1	0.5	0.1	50	5	25	5	0.5	25	3	13	3
P33	OU(DSC).1.6	District Cooling System	25	25	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2
P34	OU(ESS).1.7	400kV ESS	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P35	OU(RCP).1.8	RCP	10	10	0.95	1	0.1	0.5	0.1	10	1	5	1	0.5	5	1	3	1	0.95	1	0.1	0.5	0.1	10	1	5	1	0.5	5	1	3	1
P36	A.1.9	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P37	A.1.7	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P38	A.1.8	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P39	OU(VB)	Chau Tau Ventilation Building	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P40	A.1.6	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P41	OU(I&T)3.1.7	Information and Technology - Zone 3	3536	3536	0.95	1	0.1	0.5	0.1	3536	354	1768	354	0.5	1768	177	884	177	0.95	1	0.1	0.5	0.1	3536	354	1768	354	0.5	1768	177	884	177
P42	OU(I&T)3.1.8	Information and Technology - Zone 3	7442	7442	0.95	1	0.1	0.5	0.1	7442	744	3721	744	0.5	3721	372	1861	372	0.95	1	0.1	0.5	0.1	7442	744	3721	744	0.5	3721	372	1861	372
P43	OU(I&T)2.1.2	Information and Technology - Zone 2	80	1194	0	1	0.1	0.5	0.1	80	8	40	8	0	80	8	40	8	0.95	1	0.1	0.5	0.1	1194	119	597	119	0.5	597	60	299	60
P44	A.1.10	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P45	OU(I&T)2.1.1	Information and Technology - Zone 2	2788	2788	0.95	1	0.1	0.5	0.1	2788	279	1394	279	0.5	1394	140	697	140	0.95	1	0.1	0.5	0.1	2788	279	1394	279	0.5	1394	140	697	140
P46	OU(ESS).1.4	132kV ESS	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P47	A.1.4	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P48	OU(MU)2.1.1	Mixed use (Chau Tau Station)	80	17826	0	1	0.1	0.5	0.1	80	8	40	8	0	80	8	40	8	0.95	1	1	1	1	17826	17826	17826	17826	0.5	8913	8913	8913	8913
P49	G.1.4	HyD Depot	1	1	0.95	1	1	1	1	1	1	1	1	0.5	1	1	1	1	0.95	1	1	1	1	1	1	1	1	0.5	1	1	1	1
P50	O.1.2	Open space	343	343	0	1	1	1	1	343	343	343	343	0	343	343	343	343	0	1	1	1	1	343	343	343	343	0	343	343	343	343
P51	G.1.5	Divisional Police Station cum Operational Base, Petrol Station and Dangerous Goods Storage	125	515	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	515	52	258	52	0.5	258	26	129	26
P52	OU(ESS).1.10	132kV ESS	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P53	OU(LSW).1.2	Logistics, Storage and Warehouse	220	220	0.95	1	0.1	0.5	0.1	220	22	110	22	0.5	110	11	55	11	0.95	1	0.1	0.5	0.1	220	22	110	22	0.5	110	11	55	11
P54	OU(DSC).1.11	District Cooling System	25	25	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2	0.95	1	0.1	0.5	0.1	25	3	13	3	0.5	13	2	7	2
P55	O.1.3	Open space	410	410	0	1	1	1	1	410	410	410	410	0	410	410	410	410	0	1	1	1	1	410	410	410	410	0	410	410	410	410
P56	OU(I&T)3.1.9	Information and Technology - Zone 3	80	5228	0	1	0.1	0.5	0.1	80	8	40	8	0	80	8	40	8	0.95	1	0.1	0.5	0.1	5228	523	2614	523	0.5	2614	262	1307	262
P57	OU(WRP).5.2	Water Reclamation Plant	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P58	E.2.1	2 Primary School	129	1678	0	1	0.1	0.5	0.1	129	13	65	13	0	129	13	65	13	0.95	1	0	0.5	0	1678	0	839	0	0.5	839	0	420	0
P59	OU(RCP).5.5	RCP	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P60	GB.5.1	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P61	GB.5.2	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P62	E.3.3	Secondary School	129	1329	0	1	0.1	0.5	0.1	129	13	65	13	0	129	13	65	13	0.95	1	0	0.5	0	1329	0	665	0	0.5	665	0	333	0
P63	A.1.17	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P64	O.5.2	Open Space	28	28	0	1	1	1	1	28	28	28	28	0	28	28	28	28	0	1	1	1	1	28	28	28	28	0	28	28	28	28
P65	OU(GFS).1.1	Green Fuel Station	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10	0	1	1	1	1	10	10	10	10	0	10	10	10	10
P66	A.1.5	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P67	OU(I&T)3.1.5	Information and Technology - Zone 3	1135	1135	0.95	1	0.1	0.5	0.1	1135	114	568	114	0.5	568	57	284	57	0.95	1	0.1	0.5	0.1	1135	114	568	114	0.5	568	57	284	57
P68	OU(I&T)3.1.4	Information and Technology - Zone 3	1580	1580	0.95	1	0.1	0.5	0.1	1580	158	790	158	0.5	790	79	395	79	0.95	1	0.1	0.5	0.1	1580	158	790	158	0.5	790	79	395	79
P69	A.1.3	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P70	OU(I&T)3.1.6	Information and Technology - Zone 3 (Government Data Centre)	240	240	0.95	1	0.1	0.5	0.1	240	24	120	24	0.5	120	12	60	12	0.95	1	0.1	0.5	0.1	240	24	120	24	0.5	120	12	60	12

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2032) Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	2	73	12	1	26	34	30	4	0	3	186
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	3	18
Road R2													
Total Vehicle per hour	0.16	50	9	299	50	5	49	115	100	16	0	7	652
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R3													
Total Vehicle per hour	0.34	50	5	160	27	3	0	25	21	9	0	0	250
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road R4													
Total Vehicle per hour	0.69	50	6	183	30	3	3	45	39	11	0	4	323
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	1	1	1	3	0	3	16
Road R5													
Total Vehicle per hour	0.7	50	7	232	39	4	21	73	63	13	0	0	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	5	2	2	4	0	0	22
Road R6													
Total Vehicle per hour	0.58	100	106	3416	568	62	134	1266	1081	189	6	224	7051
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	28	7	2	13	10	8	23	0	66	158
Road R7													
Total Vehicle per hour	0.64	100	99	3197	532	58	131	1166	996	176	4	164	6524
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	7	2	14	10	8	23	0	54	148
Road R8													
Total Vehicle per hour	0.83	100	106	3440	572	62	131	1244	1064	189	5	192	7007
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	10	3	18	14	11	32	0	81	210
Road R9													
Total Vehicle per hour	0.68	100	77	2474	412	45	108	816	698	136	3	105	4872
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	24	6	2	12	8	6	19	0	37	115
Road R10													
Total Vehicle per hour	1.18	100	109	3518	586	64	108	903	772	192	4	147	6402
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	59	14	4	21	14	11	46	0	89	260
Road R11													
Total Vehicle per hour	0.19	50	7	238	39	4	3	142	121	14	5	201	774
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	39	49
Road R12													
Total Vehicle per hour	0.37	50	7	217	36	4	0	34	29	12	7	273	619
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	103	113
Road R13													
Total Vehicle per hour	0.32	50	3	101	17	2	0	29	25	5	1	38	222
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20
Road R14													
Total Vehicle per hour	0.27	50	4	115	18	2	3	70	59	7	1	26	305
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	8	16
Road R15													
Total Vehicle per hour	0.45	50	4	133	22	2	0	37	32	7	0	7	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R16													
Total Vehicle per hour	0.39	50	3	110	18	2	0	41	36	6	1	20	238
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	9	17
Road R17													
Total Vehicle per hour	0.13	50	2	74	12	1	0	11	10	4	2	62	179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	9	16
Road R18													
Total Vehicle per hour	0.15	50	3	103	17	2	3	83	70	6	0	0	286
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8
Road R19													
Total Vehicle per hour	0.37	50	2	56	9	1	52	36	30	3	1	53	244
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	7	1	1	1	0	21	35
Road R20													
Total Vehicle per hour	0.54	50	1	43	7	1	52	28	24	3	1	53	213
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	9	1	1	1	0	30	46
Road R21													
Total Vehicle per hour	0.44	50	2	65	11	1	67	13	11	4	1	51	227
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	10	1	1	1	0	23	40
Road R22													
Total Vehicle per hour	0.2	50	3	110	18	2	89	78	66	6	4	139	516
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	6	1	1	1	0	29	42
Road R23													
Total Vehicle per hour	0.45	50	9	281	47	5	17	86	73	16	3	109	645
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	3	0	50	66
Road R24													
Total Vehicle per hour	1.11	50	7	226	38	4	17	55	47	12	3	109	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	6	0	124	153
Road R25													
Total Vehicle per hour	0.86	50	5	161	27	3	0	31	27	9	5	185	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	163	176
Road R26													
Total Vehicle per hour	0.67	50	1	27	4	0	0	4	3	2	1	21	61
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	15	22
Road R27													
Total Vehicle per hour	0.63	50	0	7	1	0	0	4	3	0	1	21	36
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	14	21
Road R28													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0
Road R29													
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0
Road R30													
Total Vehicle per hour	0.67	50	1	22	4	0	0	8	6	1	1	52	95
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	36	43
Road R31													
Total Vehicle per hour	1.62	50	7	219	36	4	5	125	107	12	0	4	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	10	3	1	3	6	5	9	0	7	45
Road R32													
Total Vehicle per hour	0.21	50	4	130	21	2	0	56	49	7	3	121	394
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	26	33

Road R33													
Total Vehicle per hour	0.6	50	28	918	154	17	0	38	32	49	0	0	1237
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	16	4	1	0	1	1	12	0	0	36
Road R34													
Total Vehicle per hour	0.42	50	7	238	39	4	12	127	108	14	1	42	593
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	2	2	2	3	0	19	34
Road R35													
Total Vehicle per hour	0.31	50	23	730	123	13	0	73	63	38	0	19	1082
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	1	1	5	0	6	24
Road R36													
Total Vehicle per hour	0.59	50	4	125	21	2	0	37	32	7	3	131	362
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	79	89
Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R38													
Total Vehicle per hour	0.38	50	4	139	23	3	0	41	35	8	3	131	388
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	51	60
Road R39													
Total Vehicle per hour	0.6	50	19	603	101	11	45	182	155	32	3	130	1281
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	11	3	1	9	3	3	8	0	80	119
Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20
Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2032) Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	1	32	6	0	13	7	6	2	0	1	69
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	2	12
Road R2													
Total Vehicle per hour	0.16	50	5	149	29	1	24	23	21	6	0	3	261
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	2	1	1	1	0	1	10
Road R3													
Total Vehicle per hour	0.34	50	2	76	15	0	0	5	4	3	0	0	106
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R4													
Total Vehicle per hour	0.69	50	3	83	16	1	1	9	8	4	0	2	126
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	2	12
Road R5													
Total Vehicle per hour	0.7	50	4	115	22	1	10	14	13	5	0	0	184
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	52	1673	322	8	66	242	216	73	4	102	2758
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	14	4	1	7	2	2	9	0	31	71
Road R7													
Total Vehicle per hour	0.64	100	49	1583	304	7	64	224	200	69	3	75	2579
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	7	2	2	9	0	25	66
Road R8													
Total Vehicle per hour	0.83	100	53	1704	328	8	64	239	214	74	3	88	2776
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	9	3	3	13	0	37	93
Road R9													
Total Vehicle per hour	0.68	100	38	1239	238	5	53	158	142	54	2	48	1977
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	4	1	6	2	2	8	0	17	53
Road R10													
Total Vehicle per hour	1.18	100	55	1778	341	8	53	175	157	77	3	67	2713
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	8	1	10	3	3	19	0	41	116
Road R11													
Total Vehicle per hour	0.19	50	4	112	22	1	1	27	24	5	4	93	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	18	26
Road R12													
Total Vehicle per hour	0.37	50	3	98	19	1	0	6	5	4	5	121	262
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	46	54
Road R13													
Total Vehicle per hour	0.32	50	2	52	10	0	0	5	5	2	1	17	94
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	6	13
Road R14													
Total Vehicle per hour	0.27	50	2	38	8	0	1	13	10	2	0	10	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	3	11
Road R15													
Total Vehicle per hour	0.45	50	2	65	12	0	0	7	7	3	0	3	100
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R16													
Total Vehicle per hour	0.39	50	2	56	11	0	0	8	8	2	0	10	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R17													
Total Vehicle per hour	0.13	50	1	38	7	0	0	2	2	2	1	26	79
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R18													
Total Vehicle per hour	0.15	50	2	41	8	0	1	16	13	2	0	0	83
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8

Road R19													
Total Vehicle per hour	0.37	50	1	25	5	0	26	7	6	1	1	25	96
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	4	1	1	1	0	10	21

Road R20													
Total Vehicle per hour	0.54	50	1	19	4	0	26	5	5	1	1	25	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	14	26

Road R21													
Total Vehicle per hour	0.44	50	1	27	5	0	33	3	2	1	1	24	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	11	23

Road R22													
Total Vehicle per hour	0.2	50	2	54	10	0	44	15	13	2	3	64	208
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23													
Total Vehicle per hour	0.45	50	4	134	26	1	9	17	15	6	2	51	264
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24													
Total Vehicle per hour	1.11	50	4	113	22	0	9	11	10	5	2	51	226
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	58	74

Road R25													
Total Vehicle per hour	0.86	50	2	80	15	0	0	6	5	3	3	86	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	76	85

Road R26													
Total Vehicle per hour	0.67	50	0	12	2	0	0	1	1	1	0	10	27
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R27													
Total Vehicle per hour	0.63	50	0	3	1	0	0	1	1	0	0	10	14
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R28													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R29													
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R30													
Total Vehicle per hour	0.67	50	0	8	2	0	0	1	1	0	1	17	29
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	12	19

Road R31													
Total Vehicle per hour	1.62	50	3	108	21	1	3	24	21	5	0	2	187
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	2	2	1	4	0	3	21

Road R32													
Total Vehicle per hour	0.21	50	2	62	12	0	0	11	10	3	2	56	159
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	14	480	92	2	0	7	6	20	0	0	622
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	1	1	5	0	0	21

Road R34													
Total Vehicle per hour	0.42	50	4	102	20	1	6	24	21	5	1	19	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	9	18

Road R35													
Total Vehicle per hour	0.31	50	12	394	75	1	0	14	13	16	0	9	534
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	3	15

Road R36													
Total Vehicle per hour	0.59	50	2	60	12	0	0	7	6	3	2	61	153
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	37	44

Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	2	69	13	0	0	8	7	3	2	61	166
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31

Road R39													
Total Vehicle per hour	0.6	50	9	320	61	1	22	35	31	13	2	60	556
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	1	1	4	0	37	58

Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	32	28	2	0	0	114
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20

Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9

Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Note:
[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

			Traffic Flow (veh/hr) at Daytime (Year 2039)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	6	185	30	3	26	86	74	11	0	3	425
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	6	2	2	4	0	3	24
Road R2													
Total Vehicle per hour	0.16	50	22	725	120	13	49	238	203	40	0	7	1419
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	1	1	3	0	2	17
Road R3													
Total Vehicle per hour	0.34	50	20	661	110	12	0	124	107	37	0	0	1071
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	6	0	0	20
Road R4													
Total Vehicle per hour	0.69	50	23	733	122	13	3	148	126	40	0	4	1212
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	1	3	3	12	0	3	43
Road R5													
Total Vehicle per hour	0.7	50	9	287	48	5	21	106	91	15	0	0	582
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	2	2	5	0	0	24
Road R6													
Total Vehicle per hour	0.58	100	152	4909	816	89	133	1785	1522	270	6	228	9910
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	9	3	13	14	11	32	0	68	191
Road R7													
Total Vehicle per hour	0.64	100	124	4007	667	73	131	1416	1210	220	4	159	8011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	36	9	3	14	12	10	29	0	52	166
Road R8													
Total Vehicle per hour	0.83	100	154	4969	827	90	131	1557	1330	272	5	185	9520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	58	14	4	18	17	14	46	0	79	252
Road R9													
Total Vehicle per hour	0.68	100	94	3046	508	55	108	748	640	166	3	116	5485
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	7	2	12	7	6	23	0	41	129
Road R10													
Total Vehicle per hour	1.18	100	136	4409	736	80	108	853	730	238	4	153	7448
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	73	17	5	21	14	11	58	0	92	293
Road R11													
Total Vehicle per hour	0.19	50	17	560	93	10	3	269	229	32	6	225	1443
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	2	2	3	0	44	58
Road R12													
Total Vehicle per hour	0.37	50	43	1389	231	25	0	262	223	77	4	157	2410
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	0	3	2	12	0	60	98
Road R13													
Total Vehicle per hour	0.32	50	10	336	55	6	0	136	116	20	1	41	721
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	14	27
Road R14													
Total Vehicle per hour	0.27	50	18	566	94	10	3	232	197	31	1	28	1179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	1	2	2	4	0	8	25
Road R15													
Total Vehicle per hour	0.45	50	17	561	93	10	0	66	56	31	0	0	835
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	6	0	0	20

Road R16													
Total Vehicle per hour	0.39	50	12	401	67	7	0	75	64	22	1	25	674
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	0	1	1	4	0	11	25

Road R17													
Total Vehicle per hour	0.13	50	13	424	70	8	0	88	75	24	1	26	729
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R18													
Total Vehicle per hour	0.15	50	6	204	34	4	3	136	115	11	1	28	540
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	5	13

Road R19													
Total Vehicle per hour	0.37	50	9	275	45	5	52	84	71	16	1	53	612
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	7	1	1	3	0	21	39

Road R20													
Total Vehicle per hour	0.54	50	8	266	44	5	52	87	74	15	1	53	607
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	9	2	1	4	0	30	54

Road R21													
Total Vehicle per hour	0.44	50	10	315	52	6	67	95	82	17	1	51	696
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	10	2	1	4	0	23	47

Road R22													
Total Vehicle per hour	0.2	50	10	329	54	6	89	149	127	19	4	139	925
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	29	44

Road R23													
Total Vehicle per hour	0.45	50	9	295	49	5	17	97	83	16	3	109	684
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	4	0	50	67

Road R24													
Total Vehicle per hour	1.11	50	8	244	41	4	17	62	53	13	3	121	567
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	7	0	138	168

Road R25													
Total Vehicle per hour	0.86	50	14	459	76	8	0	72	62	25	4	159	880
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	2	2	9	0	140	170

Road R26													
Total Vehicle per hour	0.67	50	15	478	80	9	0	121	103	26	2	68	901
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	3	2	8	0	47	74

Road R27													
Total Vehicle per hour	0.63	50	11	346	58	6	0	75	64	19	2	89	671
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	5	0	58	77

Road R28													
Total Vehicle per hour	0.2	50	15	491	81	9	0	127	108	28	1	52	913
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	11	22

Road R29													
Total Vehicle per hour	0.15	50	17	542	90	10	0	136	116	30	2	68	1011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	11	21

Road R30													
Total Vehicle per hour	0.67	50	11	340	56	6	0	78	66	19	3	98	676
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	2	6	0	67	88

Road R31													
Total Vehicle per hour	1.62	50	12	376	62	7	5	182	156	21	0	4	826
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	4	1	3	8	7	15	0	7	64

Road R32													
Total Vehicle per hour	0.21	50	9	297	49	5	0	211	181	17	3	121	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	2	1	2	0	26	36

Road R33													
Total Vehicle per hour	0.6	50	39	1265	212	23	0	118	100	67	0	0	1825
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	22	5	2	0	2	2	17	0	0	51

Road R34													
Total Vehicle per hour	0.42	50	15	481	78	9	12	251	215	29	1	36	1127
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	2	3	3	5	0	16	39

Road R35													
Total Vehicle per hour	0.31	50	30	965	163	17	0	71	61	49	0	13	1370
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	2	1	0	1	1	7	0	5	27

Road R36													
Total Vehicle per hour	0.59	50	5	164	27	3	0	50	42	9	3	118	422
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	72	83

Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	2	69	11	1	0	33	28	4	3	131	282
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	51	58

Road R39													
Total Vehicle per hour	0.6	50	31	991	166	18	45	268	229	52	4	154	1958
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	17	4	1	9	5	4	13	0	95	149

Road R40													
Total Vehicle per hour	0.2	50	4	129	21	2	0	23	19	7	0	0	206
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2039)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	3	76	15	1	13	17	16	4	0	1	145
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R2													
Total Vehicle per hour	0.16	50	11	358	69	2	24	46	41	16	0	3	570
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	1	12
Road R3													
Total Vehicle per hour	0.34	50	10	327	63	2	0	24	22	14	0	0	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	0	11
Road R4													
Total Vehicle per hour	0.69	50	11	364	70	2	1	28	25	16	0	2	520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	1	1	1	5	0	2	22
Road R5													
Total Vehicle per hour	0.7	50	5	151	29	1	10	21	19	6	0	0	241
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	76	2439	469	11	66	343	304	107	4	105	3923
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	7	3	3	13	0	31	85
Road R7													
Total Vehicle per hour	0.64	100	62	2005	385	9	64	273	243	87	3	73	3205
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	5	1	7	3	2	12	0	24	73
Road R8													
Total Vehicle per hour	0.83	100	77	2489	478	11	64	300	268	108	3	85	3884
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	8	1	9	4	3	19	0	36	110
Road R9													
Total Vehicle per hour	0.68	100	47	1548	297	6	53	145	131	67	2	53	2350
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	6	2	2	10	0	19	60
Road R10													
Total Vehicle per hour	1.18	100	69	2263	434	9	53	165	149	97	3	70	3312
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	38	10	1	10	3	3	24	0	43	133
Road R11													
Total Vehicle per hour	0.19	50	9	265	51	1	1	51	45	12	4	104	545
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	21	30
Road R12													
Total Vehicle per hour	0.37	50	21	690	133	3	0	50	44	30	3	73	1048
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	5	0	28	47
Road R13													
Total Vehicle per hour	0.32	50	5	146	28	1	0	26	23	7	1	19	256
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	7	15
Road R14													
Total Vehicle per hour	0.27	50	9	288	55	1	1	44	38	12	1	13	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	4	15
Road R15													
Total Vehicle per hour	0.45	50	9	278	54	1	0	13	12	12	0	0	378
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road R16													
Total Vehicle per hour	0.39	50	6	206	39	1	0	15	13	9	0	12	301
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	5	15

Road R17													
Total Vehicle per hour	0.13	50	7	208	40	1	0	17	15	9	1	13	309
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R18													
Total Vehicle per hour	0.15	50	3	102	20	0	1	26	22	4	1	13	192
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	2	10

Road R19													
Total Vehicle per hour	0.37	50	4	130	25	1	26	16	14	6	1	25	247
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	4	1	1	1	0	10	22

Road R20													
Total Vehicle per hour	0.54	50	4	123	24	1	26	17	15	6	1	25	240
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	14	28

Road R21													
Total Vehicle per hour	0.44	50	5	157	30	1	33	18	17	7	1	24	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	11	25

Road R22													
Total Vehicle per hour	0.2	50	5	150	29	1	44	29	26	7	3	64	357
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23													
Total Vehicle per hour	0.45	50	5	144	28	1	9	19	17	6	2	51	280
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24													
Total Vehicle per hour	1.11	50	4	123	24	1	9	12	11	5	2	56	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	64	80

Road R25													
Total Vehicle per hour	0.86	50	7	226	44	1	0	14	13	10	3	74	392
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	0	1	1	4	0	65	81

Road R26													
Total Vehicle per hour	0.67	50	7	239	46	1	0	23	21	10	1	31	381
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	22	36

Road R27													
Total Vehicle per hour	0.63	50	5	171	33	1	0	15	13	8	2	41	289
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	27	38

Road R28													
Total Vehicle per hour	0.2	50	8	231	45	1	0	24	22	11	1	24	366
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R29													
Total Vehicle per hour	0.15	50	8	274	53	1	0	26	23	12	1	31	430
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R30													
Total Vehicle per hour	0.67	50	5	164	32	1	0	15	13	7	2	45	285
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	31	42

Road R31													
Total Vehicle per hour	1.62	50	6	178	34	1	3	35	32	8	0	2	299
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	2	2	2	6	0	3	29

Road R32													
Total Vehicle per hour	0.21	50	5	139	27	1	0	41	37	6	2	56	313
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	20	673	129	2	0	23	20	28	0	0	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	1	1	7	0	0	26

Road R34													
Total Vehicle per hour	0.42	50	7	198	39	2	6	49	44	10	1	17	371
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	8	19

Road R35													
Total Vehicle per hour	0.31	50	15	540	103	1	0	14	13	22	0	6	715
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	2	16

Road R36													
Total Vehicle per hour	0.59	50	3	84	16	0	0	10	8	4	2	55	181
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	33	41

Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	1	32	6	0	0	6	6	1	2	61	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31

Road R39													
Total Vehicle per hour	0.6	50	16	526	101	2	22	52	46	22	3	71	860
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	5	1	1	6	0	44	71

Road R40													
Total Vehicle per hour	0.2	50	2	61	12	0	0	4	4	3	0	0	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	33	28	2	0	0	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Note:

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Annex B

Aircraft Crash Frequency Calculation

Annex B - Aircraft Crash Frequency Calculation

The model considers specific factors such as target area of the hazardous facility and its longitudinal (x) and perpendicular (y) distances from the runway threshold for landing and take-off movement. The aircraft crash frequency per unit ground area (per km^2) is calculated as:

$$g(x,y) = NRF(x,y) \qquad (1)$$

Where N is the number of runway movements per year; R is the probability of an accident per movement (landing or takeoff). F(x,y) gives the spatial distribution of crashes and is given by:

For aircraft landing, for x > -3.275km,

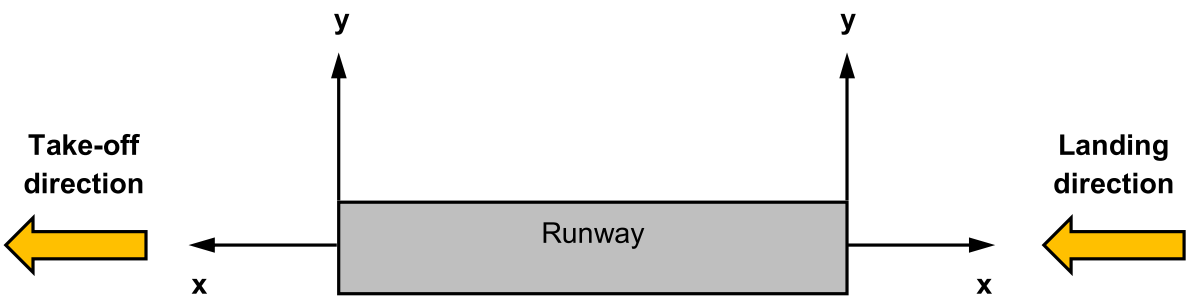
$$F_L(x,y) = \frac{(x+3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625e^{-\frac{|y|}{0.4}} + 0.005e^{-\frac{|y|}{5}}\right] \qquad (2)$$

For aircraft takeoff, for x > -0.6km,

$$F_T(x,y) = \frac{(x+0.6)}{1.44} e^{\frac{-(x+0.65)}{1.2}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635e^{-4.1|y|} + 0.08e^{-|y|}\right] \qquad (3)$$

Equations (2) and (3) are valid only for the specified range of x values. If x lies outside this range, the impact probability is zero. This case applies for 07L and 07R runways for arrival flight path and 25L and 25R runways for departure flight path.

Distances between the proposed magazine and the runways are measured and transformed into longitudinal (x) and perpendicular (y) distances in the Aircraft Crash Coordinate System according to the following figure.



The probability of an accident per movement R is interpreted from NTSB data for fatal accidents in the U.S. involving scheduled airline flights during the period 1986-2005. The 10-year moving average suggested a downward trend with recent years showing a rate of about 2×10^{-7} per flight. There are only 13.5% of accidents associated with the approach to landing, 15.8% associated with take-off and 4.2% are related to the climb phase of the flight[1]. Thus it is assumed that the accident frequency for the approach to landings is taken as 2.7×10^{-8} per flight and for take-off is 4.0×10^{-8} per flight.

[1] Aviation Statistical Reports, US National Transportation Safety Board.

Annex B - Aircraft Crash Frequency Calculation

The number of runway movements of aircraft N is provided by yearly statistics of the Hong Kong International Airport in 2009-2018[2]. Due to the social unrest since mid-2019 and the outbreak of COVID-19, the number of runway movement in 2019 to 2021 was considered to be not representative, as such, the numbers of movements in 2032 and 2039 were estimated by linear regression of the data from 2009 to 2018.

The movement numbers for both landing and take-off adopted in the calculation were divided by 4 to take into account that only a quarter of landing or take-off use a specific runway.

The aircraft crash frequency is finally obtained by multiplying g(x,y) to target area which is estimated to be 2.30×10^{-3} km^2 for the HP gas pipeline.

The calculations are presented in **Table 1** and the total crash frequency per year in construction phase (Year 2032) and operation phase (Year 2039) are calculated as 2.4×10^{-13} per year and 3.4×10^{-13} per year respectively and are summarised in **Table 2**.

Table 1 Calculation for Aircraft Crash Frequency

Year	Runway	x (km)	y (km)	F(x,y)	N (per year)	R (per flight)	Crash frequency (per unit area)	Target area (km^2)	Crash Frequency (per year)
2032	25R Landing	16.3	18.0	1.6E-08	103723	2.7E-08	4.3E-11	2.30E-03	1.0E-13
2032	25L Landing	14.6	20.7	2.2E-08	103723	2.7E-08	6.1E-11	2.30E-03	1.4E-13
2032	07R Landing	x > -3.275km							0.0E+00
2032	07L Landing	x > -3.275km							0.0E+00
2032	07C Landing	No landings at 07C							0.0E+00
2032	25C Landing	No landings at 25C							0.0E+00
2032	07C Take-off	14.7	19.1	1.1E-14	103716	4.0E-08	4.6E-17	2.30E-03	1.1E-19
2032	07R Take-off	14.6	20.7	2.7E-15	103716	4.0E-08	1.1E-17	2.30E-03	2.6E-20
2032	25L Take-off	x > -0.6km							0.0E+00
2032	25C Take-off	x > -0.6km							0.0E+00
2032	07L Take-off	No take-off at 07L							0.0E+00
2032	25R take-off	No take-off at 25R							0.0E+00
2039	25R Landing	16.3	18.0	1.6E-08	144456	2.7E-08	6.1E-11	2.30E-03	1.4E-13
2039	25L Landing	14.6	20.7	2.2E-08	144456	2.7E-08	8.5E-11	2.30E-03	2.0E-13
2039	07R Landing	x > -3.275km							0.0E+00
2039	07L Landing	x > -3.275km							0.0E+00
2039	07C Landing	No landings at 07C							0.0E+00
2039	25C Landing	No landings at 25C							0.0E+00
2039	07C Take-off	14.7	19.1	1.1E-14	144454	4.0E-08	6.5E-17	2.30E-03	1.5E-19
2039	07R Take-off	14.6	20.7	2.7E-15	144454	4.0E-08	1.6E-17	2.30E-03	3.6E-20
2039	25L Take-off	x > -0.6km							0.0E+00
2039	25C Take-off	x > -0.6km							0.0E+00
2039	07L Take-off	No take-off at 07L							0.0E+00
2039	25R take-off	No take-off at 25R							0.0E+00

Table 2 Total Aircraft Crash Frequency

	Landing	Take-off	Total
Year 2032	2.4E-13	1.3E-19	2.4E-13
Year 2039	3.4E-13	1.8E-19	3.4E-13

[2] “Air Traffic Statistics.” Civil Aviation Department, HKSAR. https://www.cad.gov.hk/english/statistics.html

Annex C

Event Tree Analysis

Event Tree for the High Pressure (HP) Gas Pipeline

E1 **Full bore rupture of gas pipe**

Spontaneous Failure (freq/ km/ yr)	Release Orientation	Immediate Ignition	Delay Ignition	Event Outcome	Outcome Probability (freq/ yr)
1.00E-07		yes 3.00E-01		**Fire Ball**	3.00E-08
		no 7.00E-01	yes 4.00E-01	**Flashfire**	2.80E-08
			no 6.00E-01	**Toxic Release**	4.20E-08

E2 **100mm pipe leak of gas pipe**

Partial Failure (freq/ km/ yr)	Release Orientation	Immediate Ignition	Delay Ignition	Event Outcome	Outcome Probability (freq/ yr)
1.90E-06	5.00E-01 Vertical	yes 7.00E-02		**Vertical Jet Fire**	6.65E-08
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	3.53E-07
			no 6.00E-01	**Toxic Release**	5.30E-07
	5.00E-01 Inclined	yes 7.00E-02		**Inclined Jet Fire**	6.65E-08
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	3.53E-07
			no 6.00E-01	**Toxic Release**	5.30E-07

E3 **50mm pipe leak of gas pipe**

Partial Failure (freq/ km/ yr)	Release Orientation	Immediate Ignition	Delay Ignition	Event Outcome	Outcome Probability (freq/ yr)
3.00E-06	5.00E-01 Vertical	yes 7.00E-02		**Vertical Jet Fire**	1.05E-07
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	5.58E-07
			no 6.00E-01	**Toxic Release**	8.37E-07
	5.00E-01 Inclined	yes 7.00E-02		**Inclined Jet Fire**	1.05E-07
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	5.58E-07
			no 6.00E-01	**Toxic Release**	8.37E-07

E4 **25mm pipe leak of gas pipe**

Partial Failure (freq/ km/ yr)	Release Orientation	Immediate Ignition	Delay Ignition	Event Outcome	Outcome Probability (freq/ yr)
3.00E-06	5.00E-01 Vertical	yes 7.00E-02		**Vertical Jet Fire**	1.05E-07
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	5.58E-07
			no 6.00E-01	**Toxic Release**	8.37E-07
	5.00E-01 Inclined	yes 7.00E-02		**Inclined Jet Fire**	1.05E-07
		no 9.30E-01	yes 4.00E-01	**Flash Fire**	5.58E-07
			no 6.00E-01	**Toxic Release**	8.37E-07

E5 **10mm pipe leak of gas pipe**

Partial Failure (freq/ km/ yr)	Release Orientation	Immediate Ignition	Delay Ignition	Event Outcome	Outcome Probability (freq/ yr)
2.00E-06	5.00E-01 Vertical	yes 1.00E-02		**Vertical Jet Fire**	1.00E-08
		no 9.90E-01	yes 4.00E-01	**Flash Fire**	3.96E-07
			no 6.00E-01	**Toxic Release**	5.94E-07
	5.00E-01 Inclined	yes 1.00E-02		**Inclined Jet Fire**	1.00E-08
		no 9.90E-01	yes 4.00E-01	**Flash Fire**	3.96E-07
			no 6.00E-01	**Toxic Release**	5.94E-07

Reference: Cox, Lees and Ang, 1990
Ignition probability for gas leakage size <1kg/s = 0.01
Ignition probability for gas leakage size 1-50kg/s = 0.07
Ignition probability for gas leakage size >50kg/s = 0.3

APPENDIX 13.3 HAZARD TO LIFE ASSESSMENT FOR PROPOSED GREEN FILLING STATIONS

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1. INTRODUCTION

1.1 Background

1.1.1.1 This section identifies the hazardous scenarios associated with the operation of two green fuel stations (GFS), which are proposed to provide LPG filling services, during construction and operation of the Project, and presents the analysis and findings of the Quantitative Risk Assessment (QRA) undertaken.

1.1.1.2 The two GFSs store LPG in bulk quantities of less than 25 tonnes separately. They are Notifiable Gas Installation (NGI) under the Gas Safety Ordinance (Cap. 51)(GSO), but not Potentially Hazardous Installation (PHI) under Chapter 12 of the HKPSG. For planning the location of GFS with LPG filling facilities, Section 3.7 of Chapter 12 of the HKPSG has listed some general requirements, including the applicable separation distances between the LPG filling facilities and different types of land uses. Nonetheless, the suitability of incorporating LPG filling facilities in a filling station and the separation distance from other land uses are still subject to the outcome of a QRA.

1.2 Hazard to Life Assessment Objectives and Risk Criteria

1.2.1 Objectives

1.2.1.1 The Hazard to Life Assessment requirements for the two proposed GFS are shown below:

(a) Identify hazardous scenarios associated with operation of the two proposed GFS, and then determine a set of relevant scenarios to be included in a QRA;

(b) Execute a QRA of the set of hazardous scenarios determined in (a), expressing population risks in both individual and societal terms;

(c) Compare individual and societal risks with the criteria for evaluating hazard to life as stipulated in Annex 4 of the TM; and

(d) Identify and assess practicable and cost-effective risk mitigation measures.

1.2.2 EIAO-TM Risk Criteria

1.2.2.1 Annex 4 of the EIAO-TM specifies the Individual and Societal Risk Guidelines. The Hong Kong Risk Guidelines (HKRG) per the EIAO-TM Annex 4 states that the individual risk is the predicted increase in the chance of fatality per year to an individual due to a potential hazard. The individual risk guidelines require that the maximum level of individual risk should not exceed 1 in 100,000 per year i.e. 1×10^{-5} per year. Societal risk expresses the risks to the whole population. It is expressed in terms of lines plotting the cumulative frequency (F) of N or more deaths in the population from incidents at the installation. Two F-N risk lines are used in the HKRG that demark "Acceptable" or "Unacceptable" societal risks. To avoid major disasters, there is a vertical cut-off line at the 1000 fatality level extending down to a frequency of 1 in a billion years. The intermediate region indicates the acceptability of societal risk is borderline and should be reduced to a level which is "as low as reasonably practicable" (ALARP). It seeks to ensure that all practicable and cost-effective measures that can reduce risk are considered. The HKRG is presented graphically in **Plate 1.1**.

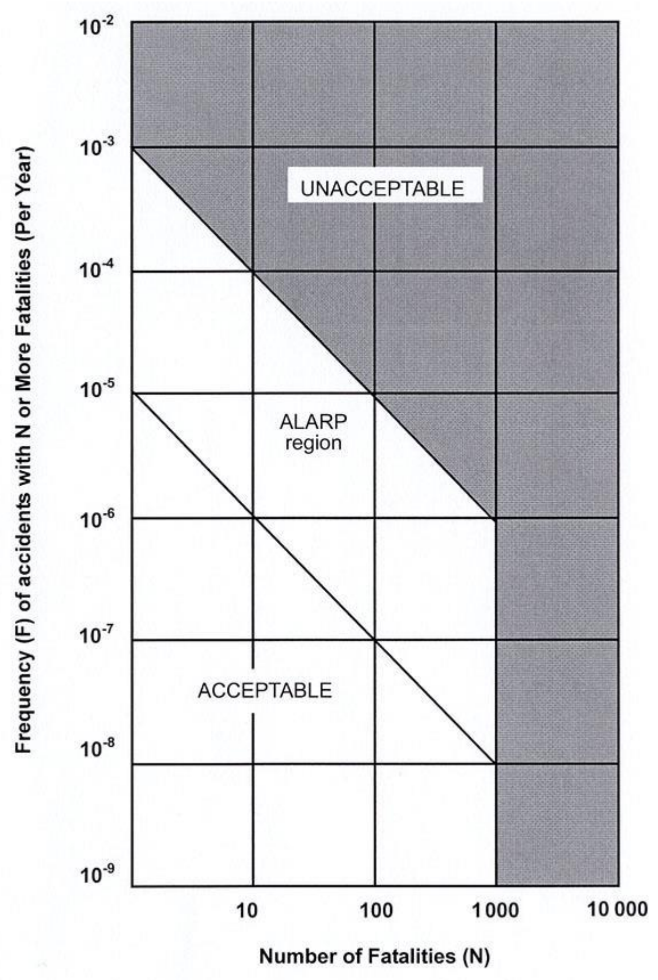

Plate 1.1 Societal Risk Guidelines

1.3 Scope of Work

1.3.1.1 The scope of this QRA is outlined as follows:

(a) to identify potential hazards and to estimate the associated frequencies by reviewing the LPG system design and historical data;

(b) to determine the level of risk posed by the two GFSs with a QRA;

(c) to present the QRA results in the form of iso-risk contours and “FN” curve for individual and societal risks respectively; and

(d) to compare the QRA results with the HKRG, and to propose risk mitigation measures if necessary.

1.3.1.2 The following boundaries have been set for this QRA:

(a) The consideration of risks associated with the transport of LPG by road tankers have been restricted to those related to their final approach to the GFSs; and

(b) The risk assessment has been limited to those events that have the potential of causing off-site fatalities.

1.4 Assessment Scenario

1.4.1.1 Based on the currently envisaged construction programme, the proposed GFSs will be commenced in 2031/32. The hazard assessment covers the following two scenarios:

(a) The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFS, and the HP Gas Pipeline to the existing, committed and planned population in 2032. This scenario accounted for the commencement of the EPP and the two GFSs, and also the presence of the construction workers for areas of the proposed development located along the San Tam Road.

(b) Year 2039 (Operation phase) – The risk imposed by the operation of the biogas facilities in the proposed EPP and two GFSs, and the HP Gas Pipeline to the existing, committed and planned population in 2039. This scenario accounted for the ultimate situation with all the planned land users of the proposed development being considered.

2. SITE DESCRIPTION

2.1 Study Area

2.1.1.1 There are two GFSs proposed within the project site. Station #1 is proposed in the Planning Area 1 and Station #2 is proposed in the Planning Area 5. Study areas defined by extending 200m radius from each station, as shown in **Plate 2.1**, were adopted in this QRA.

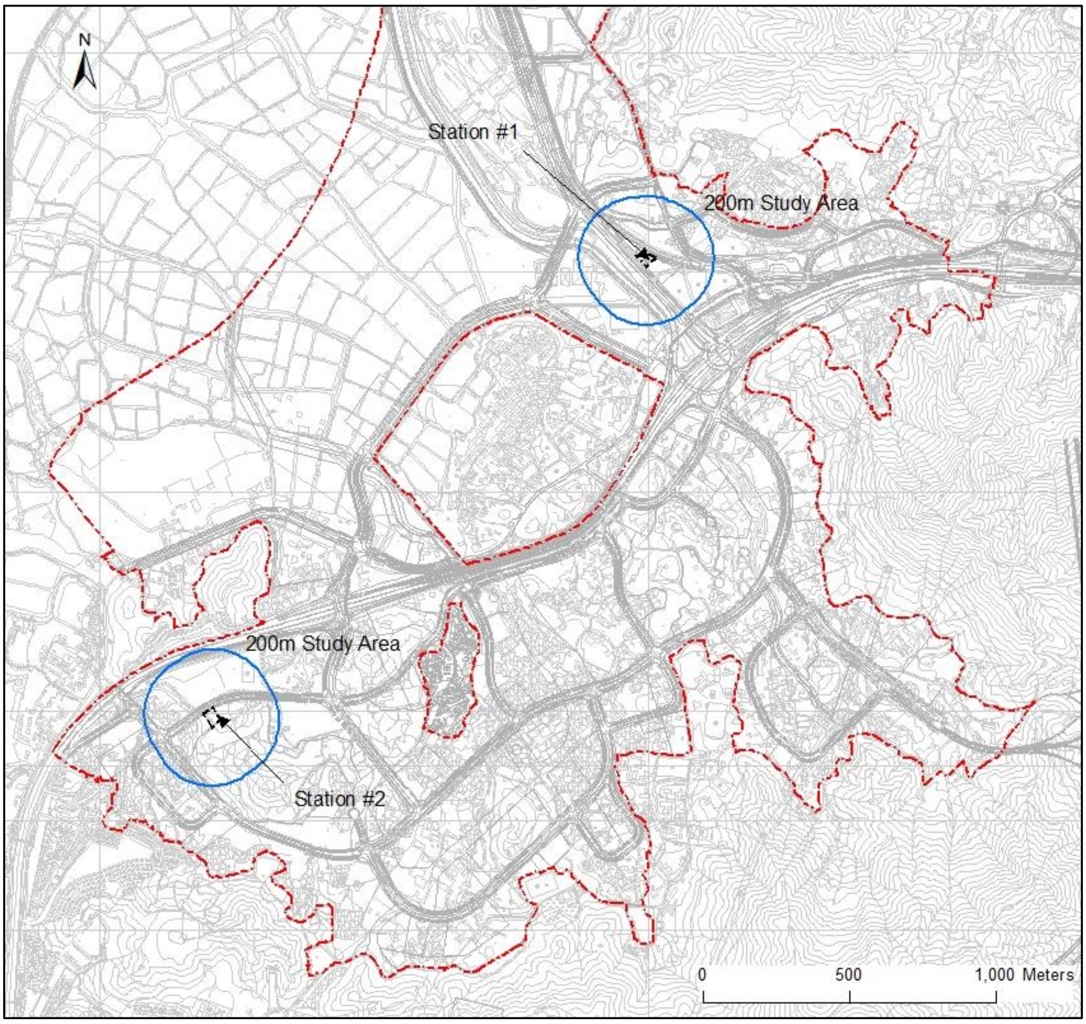

Plate 2.1 Location Plan of GFSs

2.2 The Green Fuel Stations

2.2.1.1 According to LPG throughput estimates, the LPG storage and filling facilities of the two GFSs are proposed to be identical. For each station, two 25.4kL (water capacity) underground LPG storage vessels, which will be filled to the maximum permissible level (85% of the maximum capacity), will be provided. There will also be six LPG dispensers and twelve dispensing nozzles for vehicle refuelling in each station.

2.2.1.2 The storage vessels will be designed, manufactured and tested in accordance with the requirements of the Gas Standard Office (GSO) of Electrical and Mechanical Services Department (EMSD). According to the gas safety requirements as stated in Section 3.7.2 of Chapter 12 in HKPSG, the vent pipes of pressure relief valves for the underground storage vessel will not be obstructed by any obstacles, and the discharge outlets of the vent pipes will be at least 4.5m from any openings of a building or any non-flameproof electrical equipment.

2.3 LPG Delivery and Transfer

2.3.1.1 LPG will be delivered to the GFSs by road tankers. The maximum capacity of each road tanker is about 9 tonnes. Based on the estimates, it is assumed that around 610 vehicles will use the LPG filling facilities of each station, the daily LPG consumption at each station will be around 17 tonnes and that 1-2 LPG deliveries will be necessary. Annual LPG deliveries of 730 were assumed for each station in this QRA.

2.3.1.2 Based on an LPG pumping rate of 200 L / minute, the LPG road tanker's residence time at each GFS will be around 85 minutes, including 70 minutes for LPG unloading and another 15 minutes spent on site for setting up and preparation.

2.3.1.3 The road tankers will be operated in accordance with the standard requirements of the stations' operator. The standard procedures for the LPG delivery are summarised as follows:

(a) Two persons, the driver and his assistant, will be present during the delivery operation;

(b) A dedicated unloading area will be available for the unloading operation. There is a possibility of a road tanker reversing in the unloading area. The road tanker will face towards run-out so that it may leave rapidly should it be required to do so;

(c) The condition of all connections and hoses will be checked by the driver;

(d) The storage vessel will be filled to a maximum of 85% of its liquid level capacity;

(e) During delivery, the driver will wait in close proximity to the "emergency-cut-off switch" while the assistant attends to the delivery process.

2.4 Population

2.4.1 Surrounding Populations

2.4.1.1 Societal risk is a measure of the consequence magnitude and the frequency of the hazardous events. To establish the impact of any release (the number of people likely to be affected) in the future, it is necessary to know the future surrounding population levels. These would include residential population, government and institutional population and transport population but exclude staff of the filling stations since they are considered as voluntary risk takers.

2.4.1.2 **Plate 2.2** and **Plate 2.3** show the location of population groups included in the QRA and the population within the study area is listed in **Table 2.1**. Details of population at different time modes are tabulated in **Annex A**.

Land and Building Population

2.4.1.3 Estimation of land and building populations was based on the latest information provided by Civil Engineering and Development Department (CEDD). The numbers of population were estimated based on the following assumptions:

(a) The amenity areas were assumed to be unmanned, while population in open areas were estimated based on a density of $100m^2$/ person; and

(b) An average of 5% population was considered to be outdoor for residential, institution and industrial population, while 100% population was assumed to be outdoor for construction workers, users in open spaces and open storages area.

Table 2.1 Land and Building Population Data

ID	Description	Population	
		Year 2032 – Construction Phase	Year 2039 – Operation Phase
P03	G.5.3 - Existing Mai Po ESS	125	84
P04	G.5.1 - Sport Centre	125	1018
P06	RSc.2.2 - Public Housing	7603	7603
P07a	OU(EPP).5.3 - Food Waste Pretreatment Facilities	100	100
P07b	OU(EPP).5.3 - Effluent Polishing Plant	200	200
P09	G.5.2 - Reserve	0	0
P41	OU(I&T)3.1.7 - Information and Technology - Zone 3	3536	3536
P45	OU(I&T)2.1.1 - Information and Technology - Zone 2	2788	2788
P46	OU(ESS).1.4 - 132kV ESS	0	0
P47	A.1.4 - Amenity	0	0
P48	OU(MU)2.1.1 - Mixed use (Chau Tau Station)	80	17826
P57	OU(WRP).5.2 - Water Reclamation Plant	100	100
P60	GB.5.1 - Green Belt	0	0
P66	A.1.5 - Amenity	0	0
P67	OU(I&T)3.1.5 - Information and Technology - Zone 3	1135	1135
P68	OU(I&T)3.1.4 - Information and Technology - Zone 3	1580	1580
P69	A.1.3 - Amenity	0	0
P70	OU(I&T)3.1.6 - Information and Technology - Zone 3 (Government Data Centre)	240	240

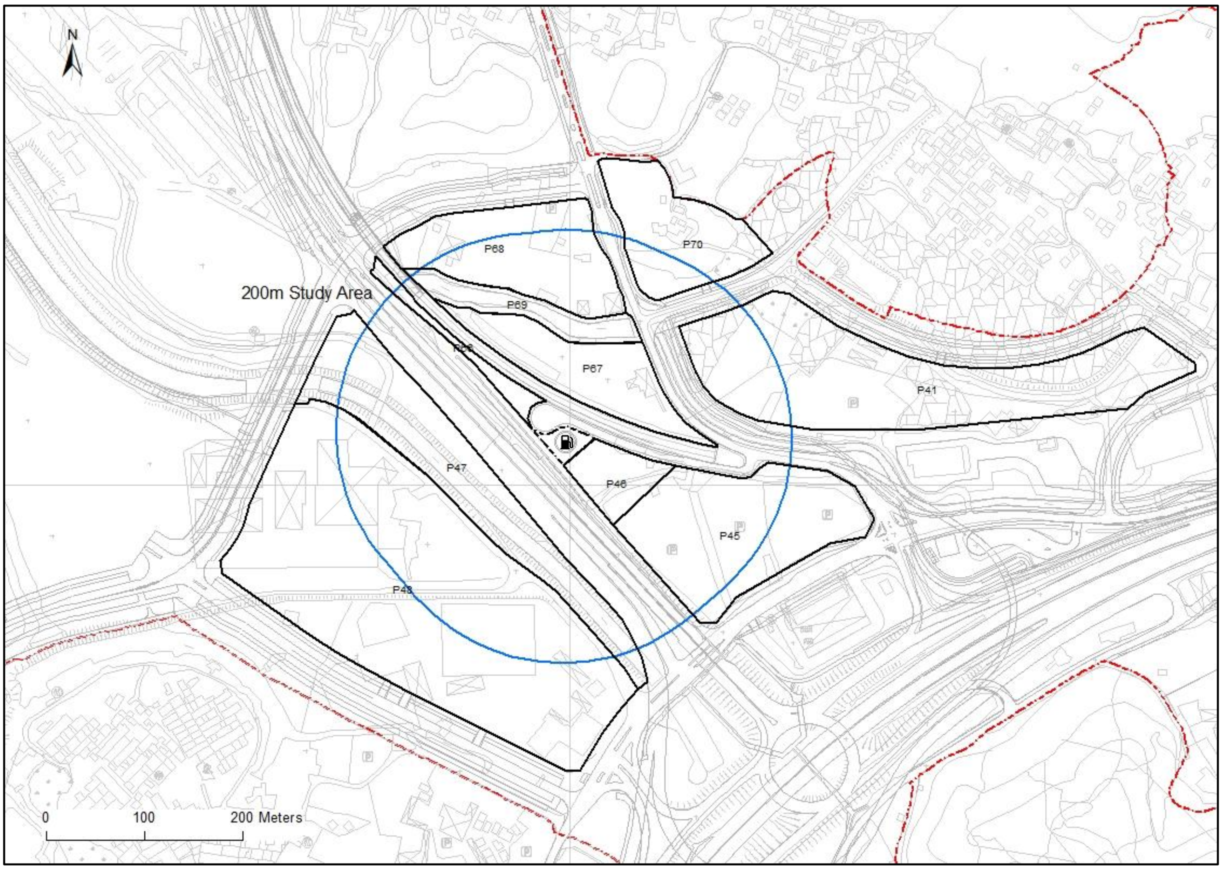

Plate 2.2 Population Groups Considered for Station #1

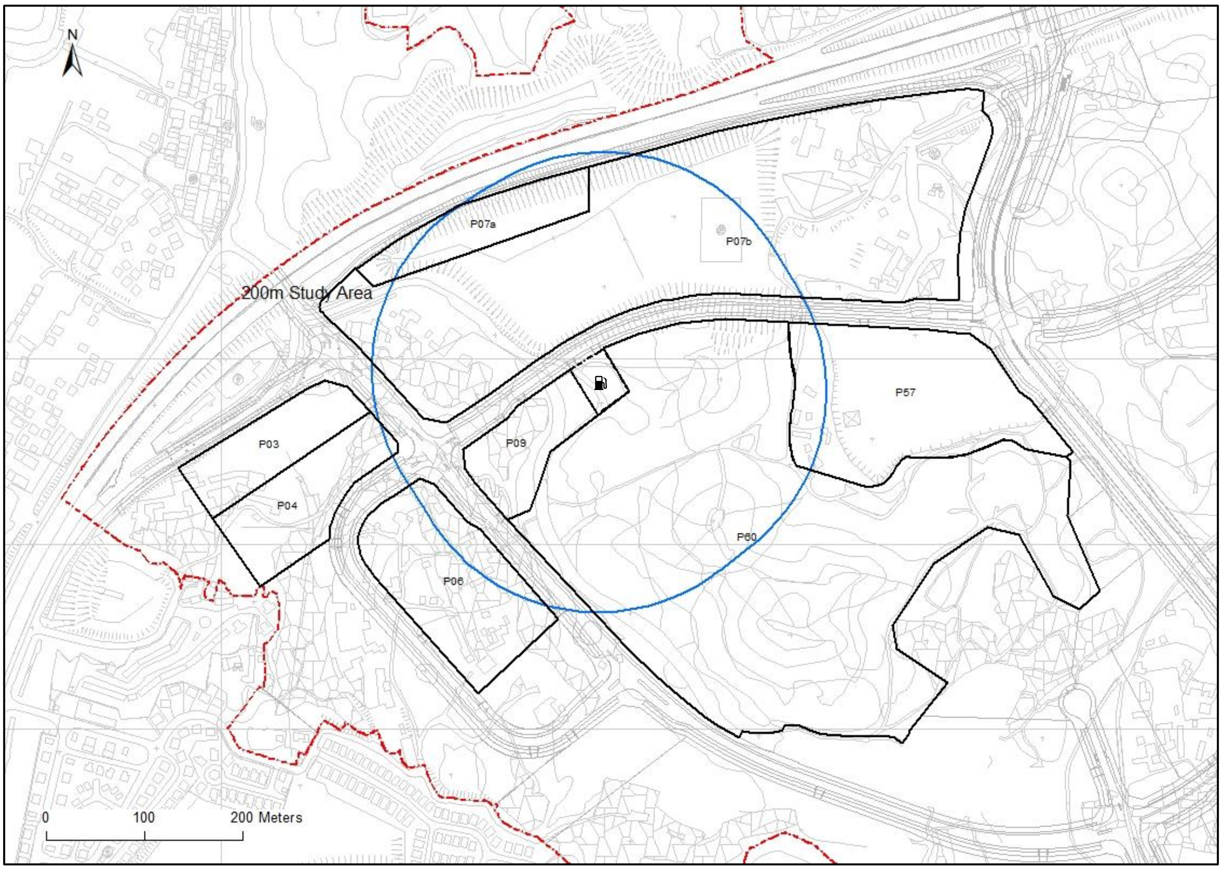

Plate 2.3 Population Groups Considered for Station #2

Traffic Population

2.4.1.4 The traffic data was based on the latest Annual Traffic Census (ATC) published by Transport Department (TD) [2] and the Traffic Impact Assessment (TIA) report prepared for this Assignment. The traffic population was predicted based on the following equation:

$$Traffic\ Population = \frac{No.of\ Person\ per\ vehicle \times No.of\ Vehicle\ per\ hour \times Road\ Length}{Speed}$$

2.4.1.5 Based on the latest ATC [2], the occupancies for each vehicle type and vehicle mix were taken at the core station no. 5016 (San Tin Highway, Castle Peak Road and San Tam Road (from Kam Tin Road to Fairview Park Boulevard) were selected to represent the road traffic for this assessment.

2.4.1.6 The traffic population considered in this assessment, which was assumed to be 100% outdoor, is summarized in **Table 2.2** and detailed in **Annex A**. The locations of roads considered for construction and operation phases are presented in **Plate 2.4**.

Table 2.2 Estimated Road Population

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R1	50	18	12	24	14
R2	50	14	10	17	12
R3	50	9	7	20	11
R4	50	16	12	43	22
R5	50	22	13	24	13
R6	100	158	71	191	85
R7	100	148	66	166	73
R8	100	210	93	252	110
R9	100	115	53	129	60
R10	100	260	116	293	133
R11	50	49	26	58	30
R12	50	113	54	98	47
R13	50	20	13	27	15
R14	50	16	11	25	15
R15	50	13	9	20	12
R16	50	17	11	25	15
R17	50	16	11	13	9
R18	50	8	8	13	10
R19	50	35	21	39	22
R20	50	46	26	54	28
R21	50	40	23	47	25
R22	50	42	24	44	24
R23	50	66	35	67	35
R24	50	153	74	168	80
R25	50	176	85	170	81
R26	50	22	14	74	36
R27	50	21	14	77	38
R28	50	0	0	22	13
R29	50	0	0	21	13
R30	50	43	19	88	42
R31	50	45	21	64	29
R32	50	33	20	36	20
R33	50	36	21	51	26
R34	50	34	18	39	19
R35	50	24	15	27	16
R36	50	89	44	83	41
R37	50	7	7	7	7
R38	50	60	31	58	31
R39	50	119	58	149	71
R40	50	7	7	7	7

ID	Traffic Speed (km/hr)	Maximum Population			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R41	50	7	7	7	7
R42	50	10	10	12	12
R43	50	20	20	24	24
R44	50	10	10	13	13
R45	50	9	9	10	10
R46	50	10	10	12	12

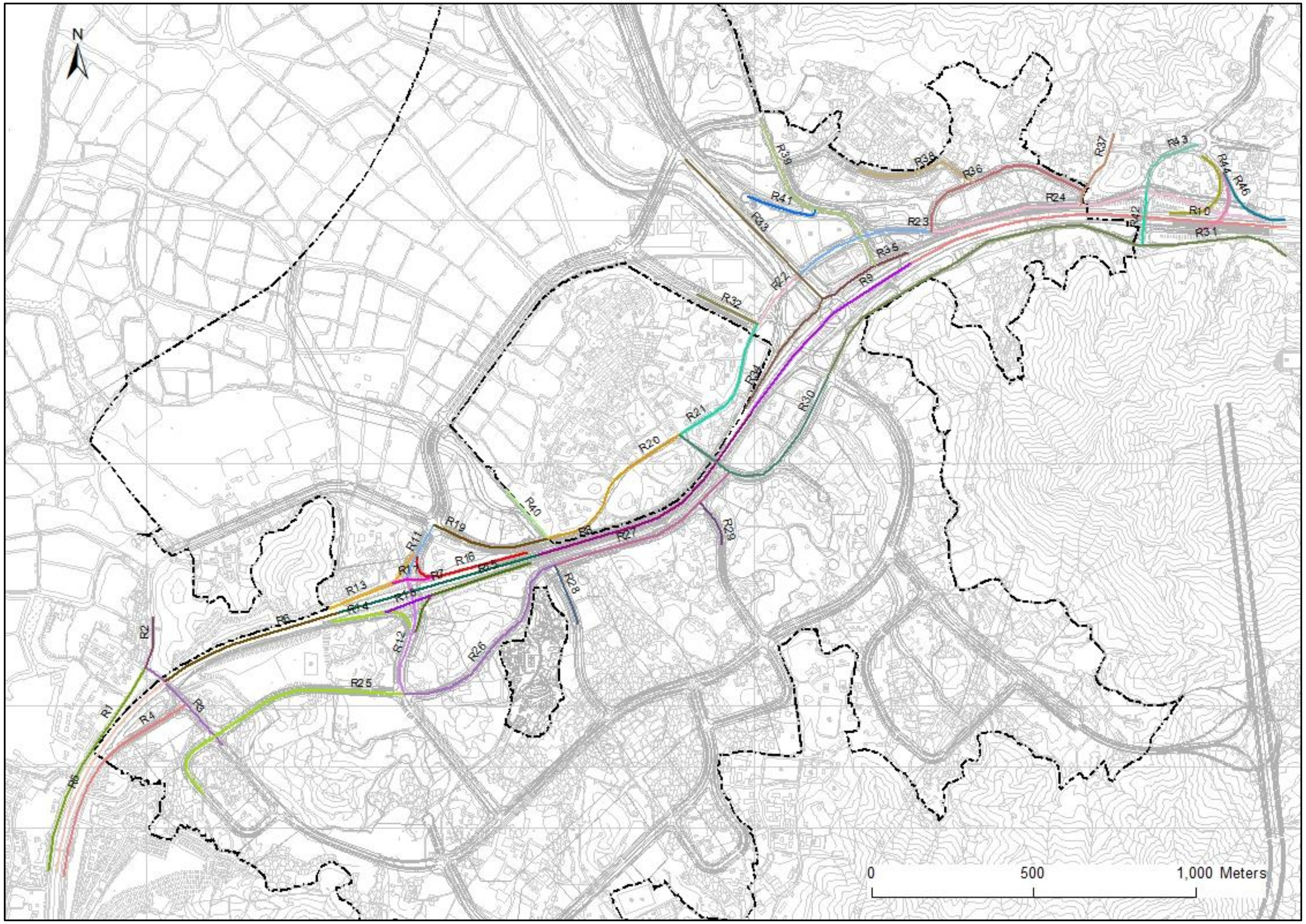

Plate 2.4 Locations of Road Population Groups

2.4.2 Time Modes and Occupancies of Population Groups

2.4.2.1 Four time modes as detailed in **Table 2.3** were applied in this hazard assessment to reflect the temporal distribution of population and to address the variation in levels of activities that could lead to a release and the variation in population in the assessment area with time.

Table 2.3 Definitions of Time Modes

Day Category	Time Period		Time Mode
Weekday	Daytime	(07:00 to 19:00)	35.71%
	Night	(19:00 to 07:00)	35.71%
Weekend	Daytime	(07:00 to 19:00)	14.29%
	Night	(19:00 to 07:00)	14.29%

2.5 Meteorology

2.5.1.1 Meteorological data is required for consequence modelling and risk calculation. Consequence modelling (dispersion modelling) requires wind speed and stability class to determine the degree of turbulent mixing potential whereas risk calculation requires wind-rose frequencies for each combination of wind speed and stability class.

2.5.1.2 Meteorological data was obtained from Wetland Park Weather Station (2021) where wind speed, stability class, weather class and wind direction are available. This data represented the weather conditions for the whole year in 2021 and has already taken into account seasonal variations and was therefore considered applicable for the assessment. **Table 2.4** shows the wind speed-stability frequencies.

Table 2.4 Stability Category-Wind Speed Frequencies at Wetland Park Weather Station

Daytime							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
0.0-1.9	25.55	7.91	0.00	13.77	0.00	14.46	61.69
2.0-3.9	7.62	14.30	6.36	6.34	1.76	0.36	36.74
4.0-5.9	0.00	1.05	0.27	0.18	0.00	0.00	1.50
6.0-7.9	0.00	0.00	0.00	0.05	0.00	0.00	0.05
Over 8.0	0.00	0.00	0.00	0.02	0.00	0.00	0.02
All (%)	33.17	23.26	6.63	20.36	1.76	14.82	100.00
Night-time							
Wind Speed (m/s)	**A**	**B**	**C**	**D**	**E**	**F**	**Total (%)**
0.0-1.9	0.00	0.00	0.00	3.76	0.00	82.06	85.82
2.0-3.9	0.00	0.00	0.00	2.25	8.83	2.44	13.52
4.0-5.9	0.00	0.00	0.00	0.52	0.07	0.00	0.59
6.0-7.9	0.00	0.00	0.00	0.07	0.00	0.00	0.07
Over 8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
All (%)	0.00	0.00	0.00	6.60	8.90	84.50	100.00

2.5.1.3 According to **Table 2.4**, six combinations (2B, 1D, 3D, 6D, 2E and 1F) and five combinations (1D, 3D, 7D, 2E and 1F) of wind speed and stability class were chosen for daytime and night-time meteorological conditions respectively. These combinations were considered adequate to reflect the full range of observed variations in these quantities. It is not necessary and efficient to consider every combination observed. The principle is to group these combinations into representative weather classes that together cover all conditions observed.

2.5.1.4 Once the weather classes have been selected, frequencies for each wind direction for each weather class can then be determined. The frequency distributions for the daytime and night-time meteorological conditions are summarised in **Table 2.5**.

Table 2.5 Weather Class-Wind Direction Frequencies at Wetland Park Weather Station

Daytime							
Direction	**2B**	**1D**	**3D**	**6D**	**2E**	**1F**	**Total (%)**
0 – 30	4.53	1.99	0.82	0.00	0.55	3.21	11.10
30 – 60	6.01	1.30	1.89	0.10	0.60	1.10	11.00
60 – 90	12.03	2.02	3.96	0.02	1.00	1.02	20.05
90 – 120	3.59	1.47	2.69	0.00	0.65	1.49	9.89
120 – 150	2.47	0.50	1.30	0.00	0.42	0.67	5.36
150 – 180	5.58	0.82	2.96	0.00	0.72	1.02	11.10
180 – 210	6.19	0.42	2.59	0.00	0.57	0.62	10.39
210 – 240	3.64	0.12	0.52	0.00	0.07	0.15	4.50
240 – 270	2.07	0.20	0.15	0.00	0.00	0.15	2.57
270 – 300	2.67	0.45	0.17	0.00	0.05	0.20	3.54
300 – 330	4.04	0.32	0.12	0.00	0.00	0.22	4.70
330 – 360	4.11	0.57	0.37	0.00	0.00	0.75	5.80
All (%)	56.93	10.18	17.54	0.12	4.63	10.60	100.00

Night-time						
Direction	**1D**	**3D**	**7D**	**2E**	**1F**	**Total (%)**
0 – 30	0.83	0.32	0.00	1.52	20.93	23.60
30 – 60	0.48	1.47	0.11	2.96	4.32	9.34
60 – 90	0.48	0.37	0.00	2.06	4.46	7.37
90 – 120	0.32	1.15	0.00	4.46	7.98	13.91
120 – 150	0.08	0.27	0.00	1.23	5.37	6.95
150 – 180	0.16	0.03	0.00	7.29	12.01	19.49
180 – 210	0.13	0.21	0.00	6.41	5.47	12.22
210 – 240	0.05	0.05	0.00	0.35	0.43	0.88
240 – 270	0.03	0.00	0.00	0.03	0.27	0.33
270 – 300	0.00	0.00	0.00	0.03	0.29	0.32
300 – 330	0.08	0.03	0.00	0.03	0.72	0.86
330 – 360	0.51	0.19	0.00	0.27	3.76	4.73
All (%)	3.15	4.09	0.11	26.64	66.01	100.00

3. HAZARD IDENIFICATION AND ANALYSIS

3.1 Introduction

3.1.1.1 A hazard is described as the property of a material or activity with the potential to do harm. A release of flammable gas such as LPG has the potential to cause fire or explosion if ignited. Without ignition, the gas vapours will disperse harmlessly. Under normal conditions, the LPG at the GFSs will be stored and handled in contained and controlled manners. For LPG to pose a hazard to the people in the surrounding area, a release must occur as a result of a failure of that containment or as a result of faulty transfer procedures.

3.1.1.2 This section of the report summarises all possible failure cases and associated failure rates that could lead to a release of LPG. The failure rates adopted throughout this report are quoted from the paper "*Quantitative Risk Assessment for LPG Installations (Reeves, Minah and Chow, 1997)*" [1]. Furthermore, reference for certain frequencies was drawn from approved EIA Reports [3][12] and QRA studies [7][9] where necessary and appropriate. In addition, possible initiating events are identified.

3.2 Behaviour of LPG Releases

3.2.1.1 LPG is a mixture of butane and propane. The gas is twice as heavier as air. For a release of LPG, the nature of the combustion will depend on the timing of ignition and the size of the release.

3.2.1.2 Release of several tonnes of LPG, if ignited immediately, will produce a fireball. Initially, the gas concentration in the mixture will be above the Upper Flammable Limit (UFL). As burning occurs around the edges of the release, this will entrain more air into the mixture and more combustion will take place. The process accelerates until the mixture rising above the ground as a ball of fire. A fireball may also result from a boiling liquid expanding vapour explosion (BLEVE). This results from the bursting of a vessel (owing to a high internal pressure and a weakening of the vessel material, as a result of a fire for example). The vessel contents rapidly vaporise and are ignited.

3.2.1.3 If not ignited immediately, the gas will disperse and dilute. If ignition occurs when the gas concentration is between lower Flammable Limit (LFL) and Upper Flammable Limit (UFL), a flame front will propagate to produce a flash fire.

3.2.1.4 For small releases, immediate ignition will produce a long vigorous jet flame from the point of release. As for large releases, delayed ignition will generally produce a flash fire.

3.2.1.5 For all sizes of release the LPG will disperse harmlessly if there is no source of ignition.

3.3 Hazard Identification

3.3.1 Spontaneous Failures

<u>Failure of Storage Vessel</u>

3.3.1.1 A failure of a vessel can result from: (i) a cold catastrophic failure leading to instantaneous release of the full inventory; and (ii) a partial failure leading to continuous release of the full inventory via a 25mm hole. The causes of failure are summarised as follows:

(a) Spontaneous failure due to corrosion, fatigue, etc.

(b) Overfilling

(c) Earthquake

Failure of Road Tanker

3.3.1.2 The causes of failure of a road tanker are similar to those of a storage vessel. Furthermore, road tankers are vulnerable to collision with other road vehicles during delivery.

Guillotine Failure of Liquid Filling Line to Storage Vessel

3.3.1.3 Failure of the liquid line is possible as a result of corrosion or fatigue, vehicle impact and external events. Only guillotine failure of the LPG pipework was considered in this QRA as partial failure of the pipeworks is an insignificant contributor to the overall risk levels. The failure would result in LPG leaking from the full bore of the pipe. Moreover, part of the pipeworks will be installed aboveground. Failure of the aboveground portion of the liquid filling line can result from vehicle impact while failure of the underground portion of the liquid filling line can result from earthquakes.

Guillotine Failure of Liquid Line to Dispenser

3.3.1.4 The causes of failure of this line are similar to those of the liquid filling line to the storage vessel, namely mainly corrosion or fatigue. Moreover, the failure of the underground portion of the pipework can result from external events while the aboveground portion of the pipework can result from vehicle impact. Releases would result in leakage from the full bore of the pipe.

Guillotine Failure of Liquid Line from Tanker Pipe to Loading Hose

3.3.1.5 The causes of failure of this line are similar to those of the liquid filling line to the storage vessel, namely mainly corrosion or fatigue. Moreover, the failure can result from vehicle impact and other external events.

Failure of Dispenser

3.3.1.6 The causes of failure of the dispensers could be corrosion, fatigue, vehicle impact (vehicle visiting the filling station) and other external events, which would result in a release from the dispenser pipework.

Failure of Flexible Hose

3.3.1.7 The loading hose could fail due to the following causes:

(a) Fatigue

(b) Hose misconnection

(c) Hose disconnection during loading or unloading process

(d) Vehicle impact

(e) Operator / driver error

Failure of Vapour Return Line

3.3.1.8 Similar to the liquid line, failure of the vapour return line is credible which would result in vapour leak equivalent to the diameter of the line. Moreover, the failure of vapour return line can result from external events.

Release from Storage Vessel Pump Flange

3.3.1.9 A release from the submersible pump on the storage vessel is not credible as the LPG release would flow back into the storage vessel. The release however would take place from the flanges associated with the pump fitting.

Release from Storage Tank Drain Valve

3.3.1.10 The storage tank drain valve is open to drain out accumulated water several times per year. A release from the drain valve is possible as a result of human error, i.e. the operator fails to close it by accident.

Leak from Vehicle Vessel

3.3.1.11 Similar to the failure of the LPG storage vessel and road tanker, a leak from a vehicle vessel could be spontaneously caused by impact by other vehicles or refuelling error. However, the LPG inventory of a vehicle vessel is small compared to that of the storage vessel and road tanker, and therefore the effect is insignificant.

3.3.2 Loading / Unloading Failures

3.3.2.1 When LPG releases occur as a direct result of the road tanker unloading operation, the failure events can be regarded as loading failures.

3.3.2.2 The failure events could be categorised as loading failures are listed as follows:

(a) Hose misconnection and disconnection error

(b) Tanker drive-away error

(c) Road tanker collision

(d) Vehicle impact with road tanker during unloading

(e) Storage vessel overfilling

(f) Over-pressurisation of pipework.

Hose Misconnection and Disconnection Error

3.3.2.3 A significant release of LPG during its transfer from the road tanker to the storage vessel could occur as a result of the failure of the transfer hoses and coupling, human error, or vehicle impact.

Tanker Drive-away Error

3.3.2.4 This error could result from: (i) repositioning of the road tanker during delivery; and/or (ii) the driver driving the tanker away before the delivery is completed.

Road Tanker Collision

3.3.2.5 Road tanker collision refers to an event in which an LPG road tanker strikes the facilities of the filling station and causes damages to these facilities. Provision of a dedicated road tanker parking area and unloading area, implementation of speed control, control on the use of dispenser system and implementation of a rigorous training system are safety measures commonly adopted to avoid serious collision incidents. The likelihood of a road tanker collision leading to the failure of the road tanker itself is considered to be insignificant. Underground facilities such as LPG storage vessel and pipework would not be affected by this event since they are installed underground. Collision of an LPG road tanker with other road tankers is considered not possible as concurrent unloading of liquid fuels and LPG at the filling station is not allowed in Hong Kong.

Vehicle Impact with Road Tanker during Unloading

3.3.2.6 There is a possibility that a vehicle collides with the road tanker during unloading operation. When this happens, a release of LPG could occur.

Storage Vessel Overfilling

3.3.2.7 Failure of the LPG storage vessel could occur as a result of overfilling of LPG from the road tanker to the vessel.

Over-pressurisation of Pipework

3.3.2.8 Over-pressurisation could be caused by continuing unloading operation when a storage vessel is overfilled or the isolation valves at the receiving storage vessel are closed. It was considered that the probability of the pipework over-pressurisation would be negligible with all the safety system to be provided at the GFSs, and therefore not considered in this QRA.

3.3.3 External Events

3.3.3.1 A LPG release event could occur due to external events and the consequences could be catastrophic. The related external events are listed as follows:

(a) Earthquake

(b) Aircraft crash

(c) Landslide

(d) Severe environmental event such as typhoon or tsunami

(e) Subsidence

(f) External fire.

3.3.3.2 According to BDEIA [3], an earthquake of Modified Mercali Intensity (MMI) VII could provide enough intensity to result in damage to the storage vessel or pipework, and therefore earthquake was considered in this QRA.

3.3.3.3 Aircrafts crashing into the two GFSs during take-off and landing as well as arrival/departure flight paths were taken into account in this QRA. The method given in HSE (1997) [6] for the calculation of aircraft crash frequency was adopted.

3.3.3.4 Failure of LPG facilities due to landslide is considered possible if the station is located adjacent to natural slope. The two proposed GFSs are bounded by open spaces, roads and buildings with no slope in vicinity of them. Therefore, the probability of landslide is negligible, and this external event was not further considered in this QRA.

3.3.3.5 According to BDEIA [3], loss of LPG content owing to severe environmental event such as typhoon or tsunami (i.e. a tidal wave following an earthquake) was considered to be insignificant as the installation of LPG vessels is situated underground and away from the seashore. Subsidence is usually slow in movement and such movement can be observed and remedial action can be taken in time. Based on the above, the probabilities of severe environmental events and subsidence are very small or negligible, so these external events were not further considered in this QRA.

3.3.3.6 External fire refers to the occurrence of fire event that leads to failure of the road tanker / vessel or other facilities. The key concern is the LPG road tanker being affected by external fires. In Hong Kong, LPG road tankers are covered with Chartek coating. The Chartek coating serves to keep the tanker wall temperatures sufficiently low. Fire extinguishers will also be provided in the two GFSs. The LPG system will be shut down as a closed system once there is external fire threatening the station. Escalation due to fire outside of the GFSs is therefore considered not credible. Fire events, such as vehicle fire, within the GFSs may cause damage to the LPG facilities and these are further elaborated in the “Escalation” section below.

3.3.4 Safety Features

3.3.4.1 Safety features to be installed in the LPG facilities of the GFSs can act in different combination to mitigate LPG releases. Such features are highlighted in the following sections.

Pressure Relief Valve

3.3.4.2 A relief valve is employed to ensure the vessel is not subject to an excessive internal pressure which may cause failure due to overfilling. It also offers protection against excessive pressure build up within the vessel in case of fire situation.

Non-return Valve

3.3.4.3 A non-return valve on the liquid filling line can isolate release immediately. If it functions properly, there will be no significant consequence.

Excess Flow Valve

3.3.4.4 An excess flow valve installed on the road tanker and the storage vessel is expected to mitigate a release from guillotine failure of the pipework or the flexible filling hose.

Emergency Shutdown System

3.3.4.5 An Emergency Shutdown (ESD) system is installed on both the road tankers and the vessel. For a release from the road tanker, the emergency isolation system and the engine emergency stop system can be activated to isolate the release caused by equipment failure and human error. For a release from the vessel, the emergency isolation system can be triggered to enable quick remote closure of all actuated valves at the station and prevent a release at the road tanker unloading / filling point, the liquid supply line and the vapour return line of each dispenser, the liquid outlet / inlet and vapour return line on the vessel.

Double-check Filler Valve

3.3.4.6 A double-check filler valve is provided at the hose connection point on the liquid filling line to prevent a release to be fed back from the vessel. The design of this valve is essentially two non-return valves in series.

Breakaway Coupling

3.3.4.7 One problem identified with road tankers and refilling vehicles is the possibility of them being driven away whilst the hose is still connected, thereby causing damage to the facilities of the GFSs and resulting in the release of LPG. The breakaway coupling is installed to prevent undue spillage of LPG owing to the movement of road tankers and vehicles.

Manual Isolation System

3.3.4.8 A manual valve is installed for the operators/ drivers to shut off the delivery connection manually in case of failure.

3.3.5 Human Error

3.3.5.1 When a failure of equipment or loading process occurs, it is possible for the staff to rectify the problem before a hazard event occurs. Human error of this nature was regarded as a failure case.

3.3.6 Fire Protection / Fighting System

Water Spray System

3.3.6.1 The two proposed GFSs will be installed with a water spray system with their own storage of water supply. When a water spray system is activated, the fire associated with equipment in the filling station such as pipeworks, dispensers and LPG vehicles can be extinguished or prevented from spreading towards a parked road tanker.

Fire Services

3.3.6.2 The fire services will be available within a few minutes in case of a fire. The extinction of fire by fire fighters prevents BLEVE from occurring. Besides, a street fire hydrant is available nearby and fire service water inlet is installed at the perimeter of the GFSs to provide additional fire water supply.

Chartek Coating

3.3.6.3 Chartek coating is a safety feature of all road tankers. The coating has been reported to provide protection for at least 30 minutes in the case of a jet fire. The coating could prevent a hot spot from developing in a jet fire attack on the road tanker, which can cause thermal weakening of the road tanker wall leading to BLEVE.

3.3.7 Escalation

3.3.7.1 BLEVE of a LPG road tanker can happen if the road tanker is impinged by jet fire from the failure of aboveground LPG facilities listed below:

(a) Dispenser

(b) Inlet filling pipework

(c) Liquid supply line to dispenser

(d) Flexible hose during loading to underground vessel

(e) Liquid line from tanker to loading hose

(f) Flexible hose during loading to vehicle is not considered as the jet flame produced will not impinge on the road tanker; and

(g) While Chartek coating can provide 30 minutes protection to the storage tank, the release and jet fire duration is less than 10 min in leak failure of a LPG vehicle. Therefore, jet fire in leak failure of LPG vehicle does not lead to BLEVE of a LPG road tanker.

3.3.8 Summary

3.3.8.1 The possible hazard events for the day-to-day operations of the two proposed GFSs have been identified and reviewed in the previous sections. Among these hazard events, only the possible failure cases considered to have the potential to cause off-site fatality are summarised in **Table 3.1**.

3.3.8.2 The significance of each failure case and adoption of generic frequency are discussed in the next section.

Table 3.1 Identified Failure Cases for the GFSs

Failure Types	Failure Cases
Spontaneous Failure of Pressurised LPG Equipment	• Storage Vessel Failure • Road Tanker Failure • Pipework Failure • Dispenser Failure • Hose Failure • Vapour Return Line Failure • Release from Storage Vessel Pump Flange • Release from Storage Vessel Drain Valve
Loading / Unloading Failure	• Hose Misconnection Error • Hose Disconnection Error • Tanker Drive-away Error • Road Tanker Collision during Unloading • Vehicle Impact with Tanker during Unloading • Storage Vessel Overfilling
External Event	• Earthquake MMI VIII • Aircraft Crash
Safety System Failure	• Pressure Relief Valve Failure • Non-return Valve Failure • Excess Flow Valve Failure • Emergency Shutdown System Failure • Double-check Filler Valve Failure • Breakaway Coupling Failure • Manual Isolation Valve Failure
Human Error	Human Error
Fire Fighting System Failure	• Water Spray System Failure • Fire Services Failure • Chartek Coating Failure
Escalation	• LPG Road Tanker BLEVE Due to Fire in the Filling Facilities • LPG Road Tanker BLEVE Due to Jet Fire from Aboveground LPG Facilities

3.4 Hazard Analysis

3.4.1 Spontaneous Failure of Pressurised LPG Equipment

Storage Vessel Failure

3.4.1.1 A release of LPG could occur as a result of catastrophic failure or partial failure of the storage vessel and such a failure would lead to either a loss of entire contents of the vessel or a continuous release of LPG to atmosphere. A generic failure rate of 1.8×10^{-7} per vessel year [1] was adopted for cold catastrophic failure, and a generic failure rate of 5.0×10^{-6} per vessel year [1] was applied for partial failure. It was assumed that the storage vessels were nominally full for 30% of the time and at 60% of maximum inventory for the other 70% of time.

Road Tanker Failure

3.4.1.2 As discussed in Section 3.3.1.2, the definitions of catastrophic and partial failures of road tanker are similar to those of the storage vessel. It is generally considered that the catastrophic failure rate for LPG road tankers could be higher than that for a fixed storage vessel because of a) stresses experienced by the road tanker owing to vibration during transportation; and b) cyclic loading associated with filling/unloading the road tanker. A failure rate of 2.0×10^{-6} per tanker year [1] was adopted for catastrophic tanker failure, and a failure rate of 5.0×10^{-6} per tanker year [1] was applied for partial failure of road tanker. The road tanker was modelled at maximum content for 20% of the time and at 50% of maximum inventory for the other 80% of the time.

Pipework Failure

3.4.1.3 Reeves et al. (1997) [1] indicated that releases from pipework partial failures were insignificant contributors to the overall risk levels. Based on this, this QRA only considered guillotine failure of LPG pipework as the contribution of a release from the partial failure of pipework to the overall risk levels would be insignificant. A generic rate of 1.0×10^{-6} per meter per year for guillotine failure of the pipework was adopted.

Dispenser Failure

3.4.1.4 The dispenser is a metering device, a hose with a self-sealing connector, four ball valves (with two flanges for each valve) and a certain length of rigid pipework. The only way to estimate the failure frequency would be to account for each of these components and add together. Assuming the dispenser is equivalent to 1m of small bore piping (<100mm) with two flanges joints and four ball valves with eight flange joints, a failure rate of 5.0×10^{-5} per hour for a LPG disperser would be obtained with the following parameters:

(a) 1m piping * 1×10^{-10} per meter per hour [10]

(b) 10 flanges (8 from 4 ball valves, 2 from meter joints) * 3×10^{-7} per flange per hour [11]

(c) 4 ball valves * 0.5×10^{-6} per valve per hour [11]

3.4.1.5 Based on the above, the dispenser failure rate was estimated as $5.0\times10^{-6} \times 8,760$ (1 year = 8760 hours) = 4.38×10^{-2} per year.

Hose Failure

3.4.1.6 The effect of partial failure of the hose is neglected. A generic guillotine failure rate of flexible hose of 1.8×10^{-7} per transfer, for a 2-hour transfer, was assumed thus giving a guillotine failure rate of flexible hose of 9.0×10^{-8} per hour [1].

3.4.1.7 In addition, the vehicle loading process takes about 5 minutes (from the dispenser to the vehicle). Based on the above, the guillotine failure rate of flexible hose for LPG loading to a vehicle was taken to be 7.5×10^{-9} per transfer.

Vapour Return Line Failure

3.4.1.8 A generic failure rate of 1.0×10^{-6} per meter per year was adopted [1].

Release from Storage Vessel Pump Flange

3.4.1.9 A generic failure rate of 1.09×10^{-4} per flange per year[1] was adopted [8].

Release from Storage Vessel Drain Valve

3.4.1.10 For the operator failing to close the drain valve by accident, a failure rate of 2.0×10^{-5} per operation [4] was adopted.

3.4.2 Loading / Unloading Failures

Hose Misconnection Error

3.4.2.1 A significant release of LPG during its transfer from the road tanker to the storage vessel could occur as a result of the failure of the transfer hoses and coupling, human error, or vehicle impact. The likelihood of such an event was taken to be 3.0×10^{-5} per operation [1].

Hose Disconnection Error

3.4.2.2 A rate of 2.0×10^{-6} per operation [1] was adopted for this failure case.

Tanker Drive-away Error

3.4.2.3 Tanker drive-away error refers to an event in which the tanker moves away with the hose still connected. It could result from the tanker driver inadvertently driving the vehicle away before delivery is completed. It was considered that drive-away was unlikely. Even if such errors do occur, it is highly likely that the failure can be immediately rectified since the delivery process would not go unattended. A failure rate of 4×10^{-6} per operation [1] was adopted.

Tanker Collision during Unloading

3.4.2.4 A release of LPG cloud occurs as a result of an incident involving an LPG tanker and LPG equipment during delivery. It was assumed that the failure rate of tanker impact during unloading was 1.5×10^{-4} per delivery [1].

Vehicle Impact with Road Tanker during Unloading

3.4.2.5 A rate of 1.0×10^{-8} per operation [1] was adopted for the case that a vehicle impact into road tanker during unloading.

Storage Vessel Overfilling

3.4.2.6 The practice on-site in unloading LPG to the underground storage vessel is that the vessel will only be filled to 85% of its maximum capacity. It is considered that the probability of the driver overfilling a storage vessel is low. A rate of 2.0×10^{-2} per operation [1] was adopted for this failure case.

3.4.3 External Events

Earthquake MMI VIII

3.4.3.1 A probability of 1.0×10^{-5} per year was adopted for the occurrence of an MMI VIII earthquake. The rate of failure of pipework and partial failure of underground vessel owing to

[1] Referencing the SPC/TECH/OSD/24 - accident/incident data from Health and Safety Executive (HSE) reviewed in March 2007, it stated the failure rate of pump flange is between 4.11×10^{-5} and 1.09×10^{-4} /flange year. Thus, a conservative value of 1.09×10^{-4} /flange year was assumed in this study as this is an updated value in March 2007 to reflect the failure frequency of a pump flange.

earthquakes was assumed to be 0.01 [3], whereas the probability of failure of road tanker and the underground vessels was considered to be zero.

Aircraft Crash

3.4.3.2 The aircraft crash frequency of Station #2 was calculated to represent the frequency for both GFSs as conservative, with consideration that the area of Station #2 is larger than Station #1 and the calculated aircraft crash frequency will be larger. The distance between the nearest arrival/departure flight path for the Hong Kong International Airport (HKIA) and Station #2 is approximately 13.2km. The distance between the Stations #2 and HKIA is about 25.0km, which exceeds the criteria of 5 miles (8km) for the consideration of airfield accident. At such distances, the two proposed GFSs would not come into the flight paths of the critical take-off and landing phases, and therefore only the background crash rate and airway crash rate were taken into account. The frequency of aircraft crash was estimated using the methodology of the HSE (1997) [6]. The model took into account specific factors such as the target area of the station and the distance between the station and the runway threshold. The aircraft crash frequency per year was calculated as:

Frequency (per year) = Background Crash Rate + Airway Crash Rate

Frequency (per year) = (A x Bi)+ (A x Ni x Ri x afac/ alt)

where A is the area of the GFS, N is the number of runway movements per year and Ri is the aircraft in-flight reliability per year per km per aircraft movement. According to the statistics from *Civil International Air Transport* Movements *of Aircraft* [13], there were 429,446 movements per year from July 2018 to June 2019. The detailed calculation of aircraft crash is shown in **Annex B**.

3.4.3.3 The frequency of the event aircraft due to background and airway crash in the Station #2 was estimated to be 4.33×10^{-9} per year, and the same value was adopted in the fault tree analysis for Station #1.

3.4.4 Safety System Failure

3.4.4.1 If the safety system operates as designed, then releases will not present an off-site hazard. There is, however, a potential for failure of the safety system. A typical safety system involves pressure relief valve, non-return valve, excess flow valve, emergency shutdown system, breakaway coupling and double-check filler valve.

Pressure Relief Valve Failure

3.4.4.2 The pressure relief valve avoids the LPG pipework or underground storage vessel from getting overpressure. A generic failure of 1.0×10^{-4} [1] for the pressure relief valve per demand was adopted.

Non-return Valve Failure

3.4.4.3 The non-return valve is intended to avoid the back flow of LPG. A generic failure rate of 0.013 per demand [1] was adopted.

Excess Flow Valve Failure

3.4.4.4 The excess flow valve installed at the road tanker and the storage vessel is expected to be functional when guillotine failure of pipework or flexible hose occurs. Considering different testing interval for road tankers and storage vessels, generic failure rates of 0.013 and 0.13 per demand [1] were adopted for the road tanker and the vessel respectively.

Emergency Shutdown System Failure

3.4.4.5 A generic failure rate of 1.0×10^{-4} per demand [1] was assumed.

Breakaway Coupling Failure

3.4.4.6 Generic failure rates of 0.013 and 0.13 per demand [1] were adopted for the road tanker and the dispenser respectively.

Double-check Filler Valve Failure

3.4.4.7 A double-check filler valve prevents the LPG release to be fed back from the storage vessel. The design has two non-return valves in series. A generic failure rate of 2.6×10^{-3} per demand [1] for common mode failure was adopted.

Manual Isolation Valve Failure

3.4.4.8 A generic failure rate of 0.5 per demand [1] was assumed.

3.4.5 Human Error

3.4.5.1 According to Appendix III of Reactor Safety Study prepared by US Nuclear Regulatory Commission in 1975, an estimation of average error rate of 0.2 to 0.3 was assumed for nuclear power plant personnel in a high-stress situation [4]. In that study, it also stated that the range of 0.2 to 0.3 was to be considered conservative. In this QRA, a probability of 0.2 per demand[2] [3] was assumed to account for the human error in which the operators fail to rectify the problem before any hazard event occurs.

3.4.6 Fire Fighting System Failure

Water Spray System Failure

3.4.6.1 A generic failure rate of 1.5×10^{-2} per demand [1] was adopted to account for the common problems of the water spray system: blocked nozzles and malfunction of the fire detectors.

Failure of Fire Services

3.4.6.2 It was assumed that the fire services would always be available, and therefore zero probability was applied for the failure case of "fire services arrive late". A generic failure

[2] According to the EIA study "Proposed Headquarters and Bus Maintenance Depot in Chai Wan" (BDEIA), by Ling Chan + Partners Limited. (2001)", a probability of 0.2 is assumed for human error. Moreover, from Appendix III of Reactor Safety Study prepared by US Nuclear Regulatory Commission in 1975, an estimation of average error rate of 0.2 to 0.3 was assumed for nuclear power plant personnel in a high-stress situation. In that study, it also stated that the range of 0.2 to 0.3 was to be considered conservative. In this study, a probability of 0.2 (per demand) was assumed to account for the human error in which operators fail to rectify the problem before any hazard event occurs.

rate of 0.5 per demand [1] was assumed for the fire services to be ineffective against a fire attack.

Gas Detection System

3.4.6.3 The system is identified as an additional safety device for the operator to take emergency actions when LPG release occurs. Since the system would not induce additional likelihood of failure events, the system would not be included into the fault tree analysis.

Chartek Coating Failure

3.4.6.4 A generic failure rate of 0.1 per demand [1] was applied for the Chartek coating failing to prevent a hot spot from developing on the road tanker in a jet fire attack owing to poor maintenance.

3.4.6.5 The above initialising events could result in LPG release scenarios. **Table 3.2** summarises the identified failure cases and their corresponding failure rates adopted in this QRA.

Table 3.2 Summary of Identified Failure Cases and Their Corresponding Failure Rates for the GFSs

Failure Types	Failure Rates	Reference Source
Spontaneous Failure of Pressurised LPG Equipment		
Catastrophic Failure of Storage Vessel	1.8×10^{-7} per vessel year	Reference [1]
Partial Failure of Storage Vessel	5.0×10^{-6} per vessel year	Reference [1]
Catastrophic Failure of Road Tanker	2.0×10^{-6} per tanker year	Reference [1]
Partial Failure of Road Tanker	5.0×10^{-6} per tanker year	Reference [1]
Guillotine Failure of Pipework	1.0×10^{-6} per meter per year	Reference [1]
Hose Failure	9.0×10^{-8} per hour	Reference [1]
Dispenser Failure	4.38×10^{-2} per year	Section 3.4.1
Vapour Return Line Failure	1.0×10^{-6} per meter per year	Reference [1]
Release from Storage Vessel Pump Flange	1.09×10^{-4} per year	Reference [8]
Release from Storage Vessel Drain Valve	2.0×10^{-5} per operation	Reference [4]
External Event		
Earthquake (MMI VIII)	1.0×10^{-5} per year	Reference [3]
Aircraft Crash	4.33×10^{-9} per year	Annex B
LPG Loading Failure		
Hose Misconnection Failure	3.0×10^{-5} per operation	Reference [1]

Failure Types	Failure Rates	Reference Source
Hose Disconnection Failure	2.0×10^{-6} per operation	Reference [1]
Tanker Drive-away Error	4.0×10^{-6} per operation	Reference [1]
Road Tanker Collision	1.5×10^{-4} per operation	Reference [1]
Vehicle Impact into Tanker During Unloading	1.0×10^{-8} per operation	Reference [1]
Storage Vessel Overfilling	2.0×10^{-2} per operation	Reference [1]
Safety Features Failure		
Pressure Relief Valve Failure	1.0×10^{-4} per demand	Reference [1] based on ESD system
Non-return Valve Failure	0.013 per demand	Reference [1]
Excess Flow Valve Failure	0.013 per demand for tanker 0.13 per demand for vessel	Reference [1]
Emergency Shutdown System Failure	1.0×10^{-4} per demand	Reference [1]
Breakaway Coupling Failure	0.013 per demand for tanker, 0.13 per demand for dispenser	Reference [1]
Double-check Filler Valve Failure	2.6×10^{-3} per demand	Reference [1]
Human Error		
Human Error	0.2 per demand	Reference [3]
Fire Protection / Fighting System Failure		
Water Spray System Failure	1.5×10^{-2} per demand	Reference [1]
Failure of Fire Services	0.5 per demand	Reference [1]
Chartek Coating Failure	0.1	Reference [1]

3.4.7 Escalation

3.4.7.1 Escalation refers to the situation in which a relatively insignificant accident causing an event with much more significance to occur.

3.4.7.2 Typical hazards that could lead to escalation are:

(a) Shrapnel from LPG storage vessel impacting on an LPG road tanker;

(b) Ignited leak from above ground LPG facilities (jet fire) impinging an LPG road tanker and causing BLEVE; and

(c) Other fire incidents engulfing an LPG road tanker and causing BLEVE

3.4.7.3 As the storage vessel will be installed underground, the knock-on failure on this equipment from other accidents is unlikely to occur. Based on this, knock-on failures on the storage vessel were not further considered.

3.4.7.4 When an LPG road tanker is impacted by the shrapnel from the LPG storage vessel (i.e. catastrophic rupture of vessels occurs), this is already a severe event and no knock-on events significantly worse have been identified.

BLEVE of LPG Road Tanker Caused by Jet Fire from Aboveground LPG Facilities

3.4.7.5 For a jet fire leading to BLEVE of LPG road tanker, the following factors need to be considered:

(a) Frequency of LPG leak from above ground LPG facilities last for at least 30 minutes

(b) Immediate ignition probability of LPG leak from above ground LPG facilities which causes a jet fire

(c) The portion of jet fire impinging at road tanker

(d) The portion of time for road tanker present in the GFS

(e) Failure to prevent BLEVE from occurring

3.4.7.6 The calculation of probability of road tanker BLEVE is shown in **Annex C**. The elaboration of the first three factors is provided below.

Frequency of LPG Leak from Aboveground LPG Facilities Lasting for at Least 30 Minutes

3.4.7.7 It was conservatively assumed that the inventory in the storage vessel at maximum inventory or 60% of maximum inventory would be enough to support a 30-minute leakage. On this basis, the frequencies of aboveground LPG facilities failure shown in **Annex C** were applied to the frequencies of LPG leak lasting for at least 30 minutes.

Immediate Ignition Probability of LPG Leak from Aboveground LPG Facilities

3.4.7.8 Immediate ignition of LPG release from aboveground LPG facilities will cause a jet fire. A probability of 0.05 was adopted in **Annex D** for immediate ignition of LPG leak from aboveground LPG facilities.

The Portion of Jet Fire Impinging at Road Tanker On Site

3.4.7.9 Not all the ignited jet fire from aboveground LPG facilities will impinge into the LPG road tanker. Jet fire due to LPG release from aboveground LPG facilities may impinge into other objects or burn as a free jet. A probability of 0.25 was assumed for the jet fire from most of the aboveground LPG facilities impinge into LPG road tanker on site by considering the relative angular position of the LPG road tanker to LPG facilities such as dispensers. For jet fire caused by liquid supply line between from road tanker and loading hose, probability of 0.5 was assumed.

3.4.7.10 By considering the five factors mentioned above, the calculated frequency of a jet fire from aboveground LPG facilities causing BLEVE of LPG road tanker is 4.14×10^{-9} per year.

BLEVE of LPG Road Tanker Caused by Other Fire Incidents

3.4.7.11 For a fire leading to BLEVE of the LPG road tanker, the factors needed to be considered are as follows:

(a) Frequency of fire incidents occurring in GFS

(b) The proportion of fire incidents severe enough to endanger the road tanker

(c) The portion of time for tanker present in the GFS

(d) Failure to prevent BLEVE from occurring

Frequency of Fire Incidents Occurring in GFS

3.4.7.12 The frequency is estimated by the equation:

Number of fire incidents occurred / number of petrol filling station-year

3.4.7.13 Information on the number of fire incidents occurred was provided by the Hong Kong Fire Services Department (**Annex E**). According to the record, there were 32 fire incidents occurred in petrol filling stations / LPG filling stations from the year of 1995 to 2018. Until 2007, there were 189 commercial petrol filling stations in Hong Kong. In 2011, there were 187 commercial petrol filling stations. The latest record as of December 2019 shows that there were 174 commercial petrol filling stations and 65 LPG filling stations. Assuming that the number of petrol filling stations remained constant from 1995 to 2007 and from 2008 to 2011, and that the number of petrol filling stations and LPG filling stations also remained constant from 2012 to 2019, it was estimated that the frequency of fire incidents = 32 fire incidents / (189×13 + 187×4 + 239×7 petrol filling station-year) = 6.56×10^{-3} fire incident per petrol filling station-year.

3.4.7.14 It should be noted that it was a conservative estimate because all the recorded fire incidents were assumed to be vehicle fire occurred in LPG filling stations.

The Proportion of Fire Incidents Severe Enough to Endanger the Road Tanker

3.4.7.15 Not all the fire incidents recorded/occurred in LPG filling stations will endanger the road tanker. A portion of recorded fire incidents could be false alarms that lead to over-estimation of the fire incident frequency. Moreover, a fire leading to BLEVE of road tanker needs to be of a sufficiently long duration (i.e. 30 minutes). However, most of the fire incidents occurred is small in scale such as fire caused by smoking, small fire in the office of the filling stations, etc. Based on the above, a proportion of 1 in 100 was assumed for severe fire incidents.

3.4.7.16 By considering the four factors mentioned above, the calculated frequency of a fire incident in a GFS causing BLEVE of LPG road tanker is 5.81×10^{-9} per year.

4. HAZARD OCCURRENCE

4.1 Introduction

4.1.1.1 Subsequent to the hazard identification and analysis in the previous section, the next step is to estimate the likelihoods of the various LPG release cases. There are combinations of hazard initiating events, as identified in the previous section, which would lead to an LPG release.

4.1.1.2 Fault Tree Analysis (FTA) permits the hazardous incident ("Significant Failure Events") frequency to be estimated from a logical model of the failure mechanisms of a system. The model is based on the combinations of failures of more basic components, safety systems and human errors. Station-specific circumstances (e.g. number of LPG tanker visit) were taken into account in the FTA.

4.1.1.3 FTA is the use of a combination of simple logic gates, "AND" and "OR" gates, to synthesise a failure model of the hazardous installation. The "Significant Failure Events" frequency is calculated from failure data of more simple events.

4.1.1.4 A basic assumption in FTA is that all failures in a system are binary in nature, a component or operator either performs successfully or fails completely. In addition, the system is assumed to be functioning if all sub-components are operating properly.

4.1.1.5 The steps for an FTA are presented below:

- Hazard identification and selection of the "Significant Failure Events", where the "Significant Failure Events" are considered as significant LPG release cases;
- Construction of fault trees; and
- Quantitative evaluation of the fault trees

4.2 Frequency of Occurrence

4.2.1.1 The fault tree diagrams are provided in **Annex C**. The estimated likelihoods of various releases of LPG at the two proposed GFSs are summarised in **Table 4.1**.

Table 4.1 Estimated Occurrence Frequency of Significant LPG Releases

Release Case	Frequency of Occurrence / Year
Catastrophic Failure of a Storage Vessel (Full Inventory)	1.27E-07
Catastrophic Failure of a Storage Vessel (60% Inventory)	2.97E-07
Catastrophic Failure of Road Tanker (Full Inventory)	4.75E-08
Catastrophic Failure of Road Tanker (50% Inventory)	1.90E-07
Partial Failure of a Storage Vessel (Full Inventory)	3.02E-06
Partial Failure of a Storage Vessel (60% Inventory)	7.05E-06
Partial Failure of Road Tanker (Full Inventory)	1.19E-07
Partial Failure of Road Tanker (50% Inventory)	4.77E-07
Guillotine Failure of Liquid Filling Line to Storage Vessel – release from vessel (Full Inventory in Storage Vessel)	2.85E-11
Guillotine Failure of Liquid Filling Line to Storage Vessel – release from vessel (60% Inventory in Storage Vessel)	6.65E-11
Guillotine Failure of Liquid Filling Line to Storage Vessel – release from road tanker (Full Inventory in Road Tanker)	2.24E-12

Release Case	Frequency of Occurrence / Year
Guillotine Failure of Liquid Filling Line to Storage Vessel – release from road tanker (50% Inventory in Road Tanker)	8.97E-12
Guillotine Failure of Liquid Filling Line to Dispenser (Full Inventory in Storage Vessel)	1.58E-07
Guillotine Failure of Liquid Filling Line to Dispenser (60% Inventory in Storage Vessel)	3.70E-07
Failure of Dispenser (Full Inventory in Storage Vessel)	1.11E-03
Failure of Dispenser (60% Inventory in Storage Vessel)	2.58E-03
Guillotine Failure of Hose during Unloading from Road Tanker to Storage Vessel, LPG Released from Tanker (Full Inventory in tanker)	6.23E-07
Guillotine Failure of Hose during Unloading from Road Tanker to Storage Vessel, LPG Released from Tanker (50% Inventory in tanker)	2.49E-06
Guillotine Failure of Hose during Unloading from Road Tanker to Storage Vessel, LPG Released from Vessel (Full Inventory in vessel)	2.43E-09
Guillotine Failure of Hose during Unloading from Road Tanker to Storage Vessel, LPG Released from Vessel (60% Inventory in vessel)	5.67E-09
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser (Full Inventory in Storage Vessel)	1.41E-01
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from Dispenser (60% Inventory in Storage Vessel)	3.29E-01
Failure of Flexible Hose during Loading to LPG vehicles, LPG Released from vehicle (Full Inventory in Vehicle)	9.40E-01
Release from Storage Vessel Pump Flange (Full Inventory in Storage Vessel)	1.31E-04
Release from Storage Vessel Pump Flange (60% Inventory in Storage Vessel)	3.05E-04
Release from Storage Vessel Drain Valve (Full Inventory in Storage Vessel)	1.44E-04
Release from Storage Vessel Drain Valve (60% Inventory in Storage Vessel)	3.36E-04
Failure of Vapour Return Line (Full Inventory in Storage Vessel)	2.26E-07
Failure of Vapour Return Line (60% Inventory in Storage Vessel)	5.28E-07
Guillotine Failure of Liquid Line from Tanker to Flexible Hose (full inventory in Road Tanker)	1.70E-09
Guillotine Failure of Liquid Line from Tanker to Flexible Hose (50% inventory in Road Tanker)	6.80E-09
BLEVE of Road Tanker (Full Inventory in Road Tanker)	1.99E-09
BLEVE of Road Tanker (50% Inventory in Road Tanker)	7.96E-09

5. CONSEQUENCE AND IMPACT ANALYSIS

5.1 Introduction

5.1.1.1 Consequence and impact analysis was conducted to provide a quantitative estimate of the likelihood and number of deaths associated with the range of possible outcomes (i.e. fireball, jet fire, flash fire etc.) which would result from the failure cases identified in the previous sections. In this QRA, PhastRisk 6.7 was used for such estimation.

5.2 Modelling Input

5.2.1.1 Failure events identified in the previous sections were considered and evaluated through consequence analysis. It was considered that the following failure events may have potential off-site impacts:

(a) Rupture of storage vessel

(b) Rupture of road tanker

(c) Partial failure of storage vessel

(d) Partial failure of road tanker

(e) Guillotine failure of liquid filling line to storage vessel

(f) Pump flange leak

(g) BLEVE of road tanker

5.2.1.2 There are two underground vessels with capacity of 25.4kL (water capacity) each at each GFS. The storage vessels were assumed to be filled to a maximum permissible level (85% of the maximum capacity) in this QRA. Replenishment of LPG was assumed to be 730 deliveries per year for each GFS, which can be arranged either daytime or night-time.

5.3 Ignition Source

5.3.1 General

5.3.1.1 To calculate the risk from flammable materials, information on ignition sources presented in the study area needs to be identified. Such data was included in the risk model for each type of ignition source (i.e. point sources, line sources and area sources). The risk calculation program (MPACT) in PhastRisk predicts the probability of a flammable cloud being ignited (delayed ignition) as the cloud moves downwind over ignition sources.

5.3.2 Point Source

5.3.2.1 According to HSE (1997) [5], compressors could be categorised as a strong ignition source with an ignition probability of greater than 0.5 but smaller than 1. Although a vehicle using the GFS is close to a release source, it is classified as a weak ignition source with ignition probability between 0.05 and 0.5. Based on the above, the following assumptions were applied to estimate the presence factor of the point source and the ignition probability.

(a) Probability of ignition for a compressor is taken as 0.75 in 60 seconds; and

(b) Presence factor of the ignition source is assumed to be 1.

5.3.3 Line Sources

5.3.3.1 Roads are defined as line sources in PhastRisk. The following assumptions were applied to estimate the presence factor of the line source and the ignition probability:

(a) The probability of ignition for a vehicle was taken to be 0.4 in 60 seconds [9]; and

(b) The traffic density was based on the projected traffic flow for roads shown in **Table 2.2**, and are summarized in **Error! Reference source not found.** and **Error! Reference source not found.**.

Table 5.1 Summary of Road Ignition Sources

ID	Traffic Speed (km/hr)	Traffic Density (veh/hr)			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R1	50	186	69	425	145
R2	50	652	261	1419	570
R3	50	250	106	1071	462
R4	50	323	126	1212	520
R5	50	453	184	582	241
R6	100	7051	2758	9910	3923
R7	100	6524	2579	8011	3205
R8	100	7007	2776	9520	3884
R9	100	4872	1977	5485	2350
R10	100	6402	2713	7448	3312
R11	50	774	292	1443	545
R12	50	619	262	2410	1048
R13	50	222	94	721	256
R14	50	305	85	1179	462
R15	50	246	100	835	378
R16	50	238	97	674	301
R17	50	179	79	729	309
R18	50	286	83	540	192
R19	50	244	96	612	247
R20	50	213	85	607	240
R21	50	227	97	696	292
R22	50	516	208	925	357
R23	50	645	264	684	280
R24	50	519	226	567	246
R25	50	453	202	880	392
R26	50	61	27	901	381
R27	50	36	14	671	289
R28	50	0	0	913	366
R29	50	0	0	1011	430
R30	50	95	29	676	285
R31	50	519	187	826	299
R32	50	394	159	894	313
R33	50	1237	622	1825	894
R34	50	593	202	1127	371
R35	50	1082	534	1370	715

ID	Traffic Speed (km/hr)	Traffic Density (veh/hr)			
		Year 2032		Year 2039	
		Daytime	Night-time	Daytime	Night-time
R36	50	362	153	422	181
R37	50	21	9	21	9
R38	50	388	166	282	115
R39	50	1281	556	1958	860
R40	50	0	0	206	85
R41	50	44	114	44	115
R42	50	968	968	1274	1274
R43	50	1015	1015	1364	1364
R44	50	442	442	708	708
R45	50	395	395	583	583
R46	50	594	594	748	748

5.3.4 Area Sources

5.3.4.1 PhastRisk considers a residential population as an ignition source (as a result of activities such as cooking, smoking, heating appliances etc.). The ignition probability was derived from the population densities in the concerned area by PhastRisk.

5.4 Ignition Probability

5.4.1.1 Immediate ignition probabilities of 0.9 and 0.05 [1] were adopted for instantaneous release and continuous release of LPG, respectively. These ignition probabilities were applied to event trees and were adopted in PhastRisk as shown in **Annex D**.

5.5 Protection Factors

5.5.1 Protection afforded to persons indoors in a building

5.5.1.1 It was generally assumed that the respective outdoor/ indoor population are 5% and 95% at the time of an accident [1].

5.5.1.2 For flash fire consequence, the fatality rate for indoor persons was assumed to be one tenth of the outdoor fatality rate.

5.5.1.3 For fireball, it was assumed that 50% of indoor persons would be killed.

5.5.2 Protection afforded to persons by being on the upper floors of building

5.5.2.1 Cloud height decreases further away from the source. Most dispersed clouds for LPG will have a cloud height lower than 10m [1]. To be conservative, no height protection factor was applied in this QRA.

5.5.3 Protection afforded to persons by being on the upper floors of building

5.5.3.1 Shielding protection factors for fireball events were applied to the population surrounding the GFSs [1].

5.5.3.2 For building wholly within the fireball diameter, population at the back of the building were considered protected.

5.5.3.3 For building wholly outside the fireball diameter, population without direct line of sight of the LPG facilities were considered protected.

5.5.3.4 While for building partly inside and partly outside of the fireball diameter, population outside the fireball diameter were considered shielded by the rest of the building.

5.5.3.5 The actual population affected by fireball events were also detailed in **Annex A**.

6. RISK EVALUATION

6.1 Introduction

6.1.1.1 In this section, the risks arising from the LPG supply facilities are evaluated in terms of both individual and societal risks.

6.1.1.2 Individual risk is a measure of the risk to a chosen individual at a particular location. As such, this is evaluated by summing the contributions to that risk across a spectrum of incidents that could occur at a particular location.

6.1.1.3 Societal risk is a measure of the overall impact of an activity upon the surrounding community. As such, the likelihoods and consequences of the range of incidents postulated for that particular activity are combined to create a cumulative picture of the spectrum of the possible consequences and their frequencies. This is usually presented as an FN curve and the acceptability of the results can be judged against the societal risk criterion under the HKRG.

6.2 Individual Risk

6.2.1 Risk Level

6.2.1.1 The predicted individual risk (IR) levels associated with operation of the two GFSs are shown in **Plate 6.1** and **Plate 6.2**. The risk levels were estimated based on 100% occupancy with no allowance made for shelter or escape, which can be referred from the user manual of *PhastRisk*.

6.2.1.2 The 1×10^{-5} per year risk contour was not found for both stations; while the 1×10^{-6}, 1×10^{-7}, 1×10^{-8} and 1×10^{-9} per year risk contours extend 30m, 60m, 110m and 140m from the center of the stations respectively. Based on the operational details for the two proposed GFSs, the predicted results show that no off-site individual would be exposed to risk levels greater than 1×10^{-5} per year.

6.2.2 Acceptability

6.2.2.1 Based on the results above, the level of individual risk posed by operation of the two proposed GFSs on the surrounding population is considered acceptable as it meets the HKRG.

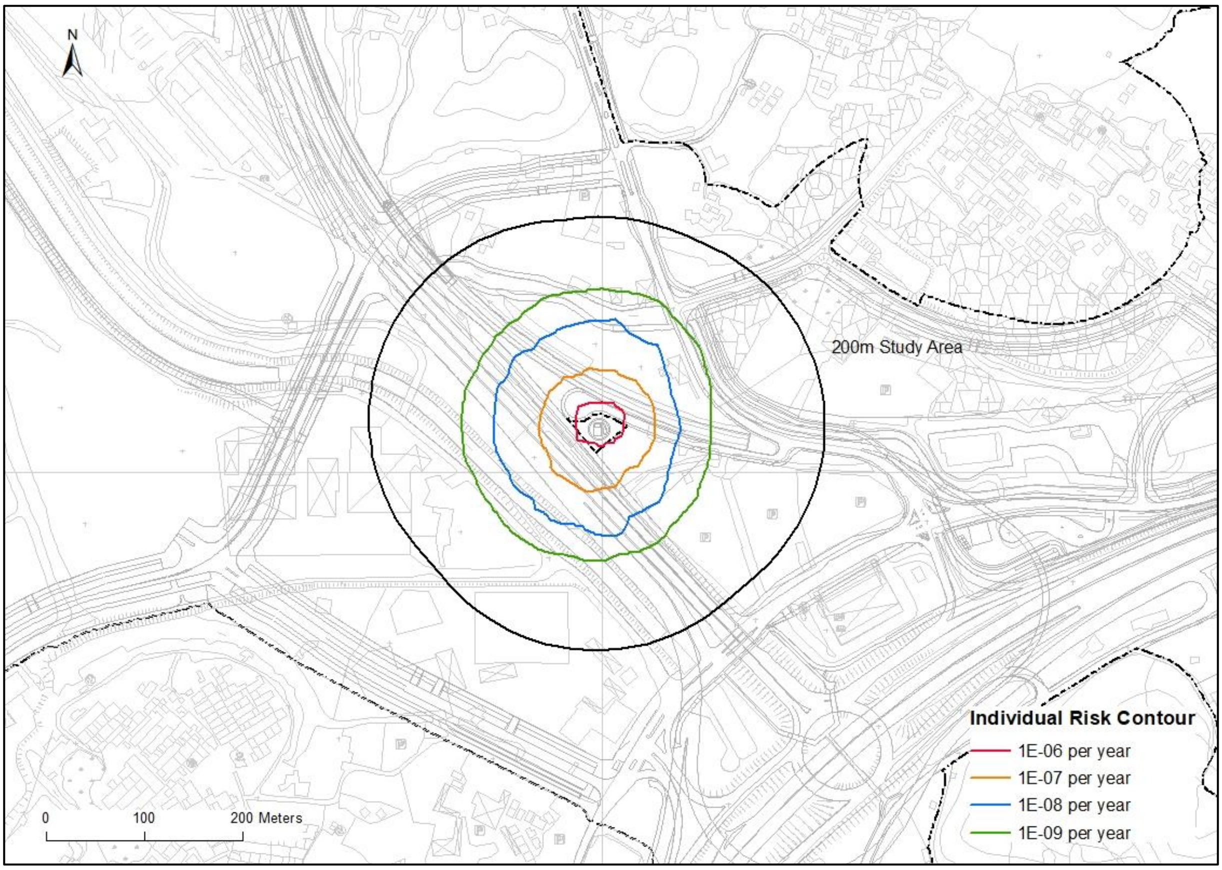

Plate 6.1 **Individual Risk Contours for the Proposed Station #1**

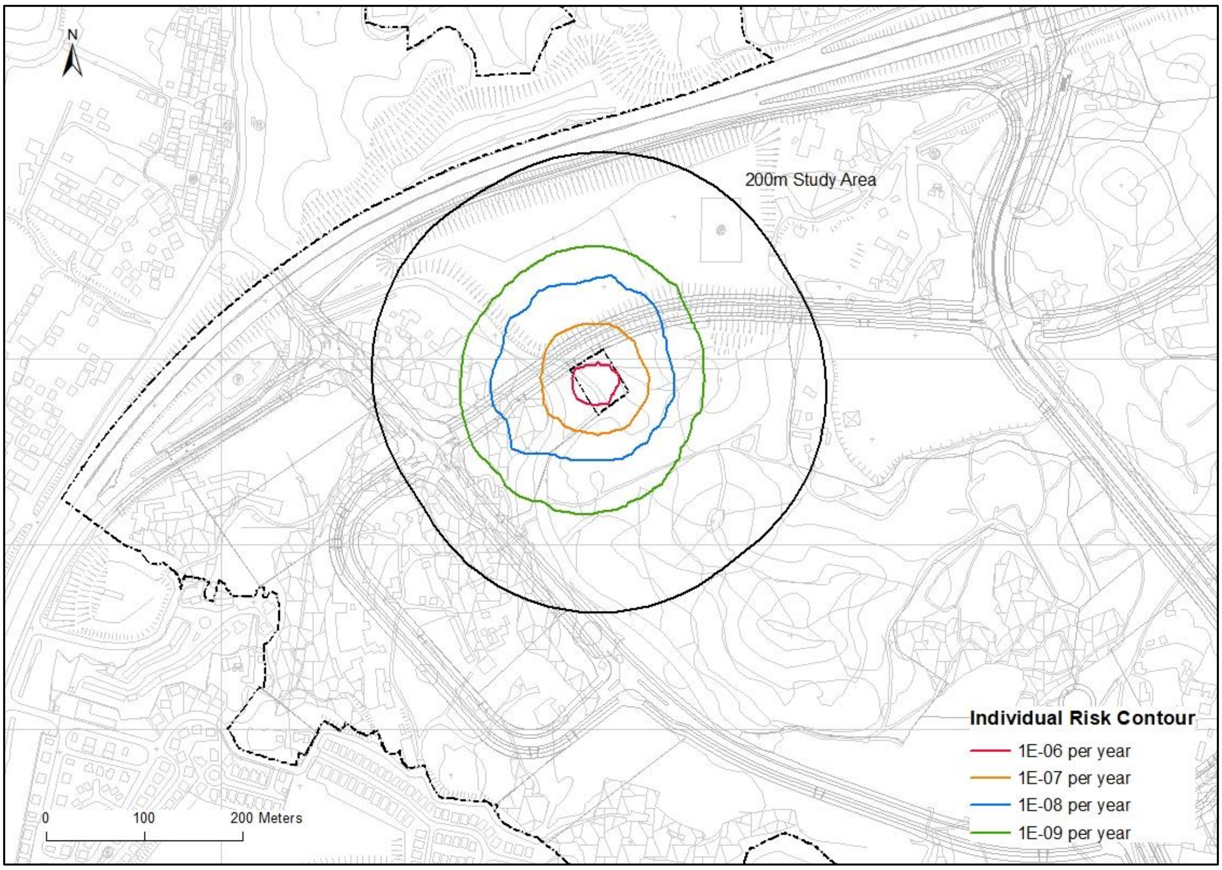

Plate 6.2 **Individual Risk Contours for the Proposed Station #2**

6.3 Societal Risk

6.3.1 Risk Level

6.3.1.1 The societal risks were evaluated for the range of incidents with the potential for fatalities in the vicinity of the two proposed GFSs and are shown in **Plate 6.3** and **Plate 6.4**, in form of F-N curves for comparison with the HKRG.

6.3.1.2 The societal risk is more complex than that for individual risk but, in essence, comprises three regions:

(a) Unacceptable – a region within which the risks may be regarded as unacceptable

(b) Acceptable – a region within which the risks may be regarded as acceptable

(c) ALARP – a region between the two in which measures should be taken to demonstrate the risks as "as low as reasonably practicable" (ALARP). In other words, consideration is given not only to the level of risk but also the cost and practicality of reducing it

6.3.1.3 Numerically, the upper bound of the ALARP region (and hence the borderline of "unacceptability") can be summarised as:

(a) 1 chance in 1,000 per year of an incident resulting in 1 or more fatalities;

(b) 1 chance in 10,000 per year of an incident resulting in 10 or more fatalities;

(c) 1 chance in 100,000 per year of an incident resulting in 100 or more fatalities; and

(d) not more than 1,000 fatalities at a frequency of greater than 1 chance in a billion (1,000,000,000) per year.

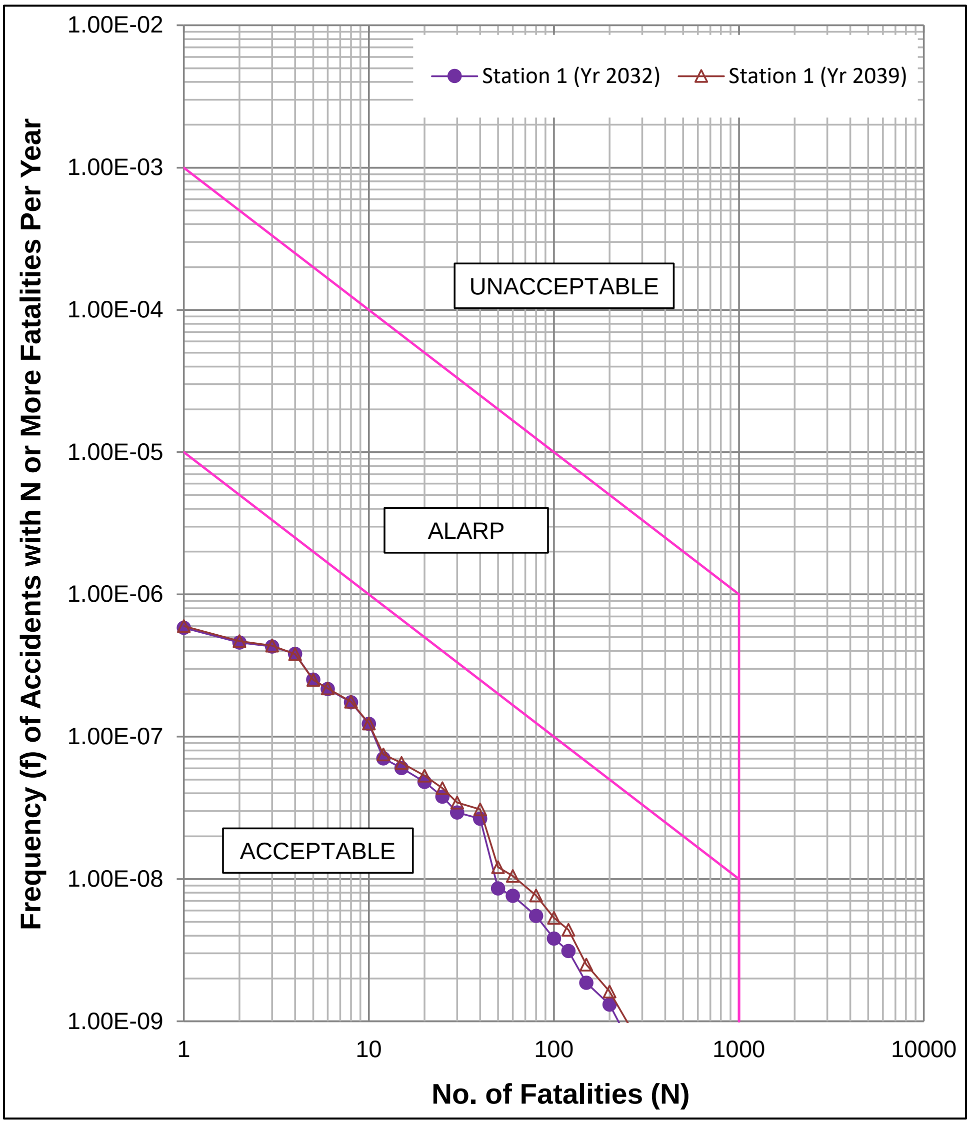

Plate 6.3 **Societal Risk Curves for the Proposed Station #1**

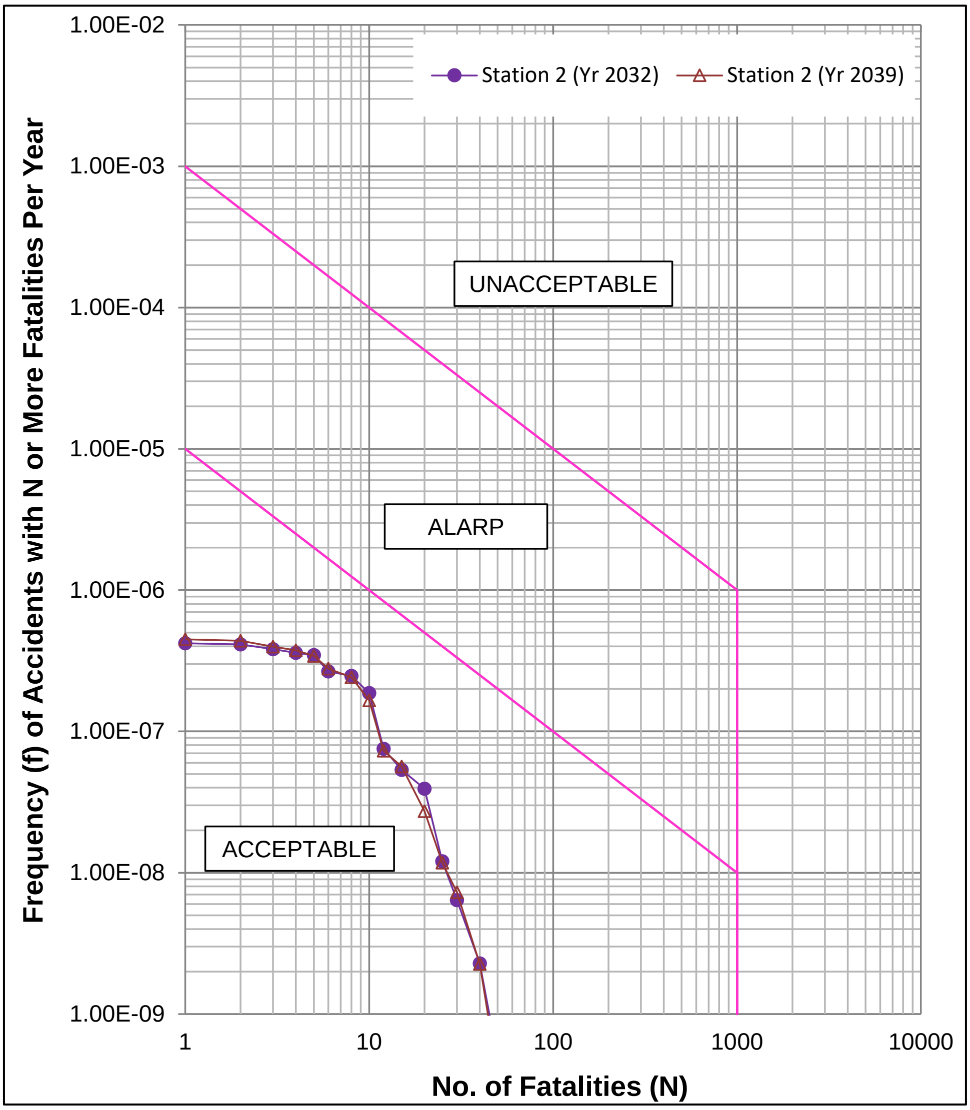

Plate 6.4 **Societal Risk Curves for the Proposed Station #2**

6.3.2 Acceptability

6.3.2.1 As shown in **Plate 6.3** and **Plate 6.4**, the societal risk associated with operation of both stations falls in the "Acceptable" region during both construction and operation phases, and therefore the associated societal risk is considered acceptable.

6.3.3 Potential Loss of Life (PLL)

6.3.3.1 The total PLLs and top five most significant risk contributing events for the assessed scenario for Station #1 and Station #2 are tabulated in Error! Reference source not found. a nd Error! Reference source not found., respectively. The total PLLs for the Station #1 are 5.16×10^{-6} per year and 5.62×10^{-6} per year in 2032 and 2039 respectively; while the total PLLs for the Station #2 are 3.83×10^{-6} per year and 3.89×10^{-6} per year in 2032 and 2039 respectively. The most significant event was the cold catastrophic failure of road tanker for all cases.

Table 6.1 Breakdown of PLL for Station #1

Event Description	Year 2032		Year 2039	
	Potential Loss of Life (PLL) per year	% of Total PLL	Potential Loss of Life (PLL) per year	% of Total PLL
Road Tanker Rupture (100% of inventory)	1.24E-06	24.0	1.28E-06	22.7
Road Tanker Rupture (50% of inventory)	1.22E-06	23.7	1.24E-06	22.0
Road Tanker Leak (50% of inventory)	1.08E-06	20.9	1.07E-06	19.1
Storage Vessels Rupture (100% Inventory)	5.45E-07	10.6	8.48E-07	15.1
Storage Vessels Rupture (60% Inventory)	5.10E-07	9.9	6.26E-07	11.1
Others	5.68E-07	11.0	5.64E-07	10.0
Total	**5.16E-06**	**100**	**5.62E-06**	**100**

Table 6.2 Breakdown of PLL for Station #2

Event Description	Year 2032		Year 2039	
	Potential Loss of Life (PLL) per year	% of Total PLL	Potential Loss of Life (PLL) per year	% of Total PLL
Road Tanker Rupture (50% of inventory)	1.38E-06	36.1	1.36E-06	35.0
Road Tanker Leak (50% of inventory)	9.45E-07	24.7	9.54E-07	24.5
Road Tanker Rupture (100% of inventory)	6.84E-07	17.9	6.72E-07	17.3
Road Tanker Leak (100% of inventory)	2.70E-07	7.1	2.59E-07	6.7
Storage Vessels Rupture (60% Inventory)	2.49E-07	6.5	3.17E-07	8.1
Others	2.98E-07	7.8	3.29E-07	8.5
Total	**3.83E-06**	**100**	**3.89E-06**	**100**

7. CONCLUSIONS AND RECOMMENDATION

7.1 Conclusions

7.1.1.1 A full QRA was carried out for the 2 green fuel stations, which are proposed to provide LPG filling services, within the project site. The assessment was conducted based on LPG throughput estimates by the Consultant, and also information collected from Census and Statistics Department, Hong Kong Observatory, Planning Department and Transport Department.

7.1.1.2 The predicted individual risks for both stations comply with the HKRG as stipulated in HKPSG with no off-site population subject to individual risk levels exceeding the criterion of 1×10^{-5} per year. The predicted societal risks for both stations also fall into the "Acceptable" region.

7.1.1.3 Based on the above results, the assessment finds that the operation of the 2 green fuel stations would not result in unacceptable risks to the overall population around the stations.

7.2 Recommendations

7.2.1.1 As shown in the previous sections, the level of individual and societal risks for the 2 proposed green fuel stations would be acceptable on risk grounds based on the information and data available at the time of preparing this report.

7.2.1.2 The future land uses, in particular those associated with significant population increase when compared with those assumed in this QRA, in the vicinity of the two proposed GFSs should be carefully assessed using QRA to ensure that the risk levels to any new population are acceptable. In addition, the QRA should be reviewed and updated when the LPG delivery frequency and throughput exceeds those specified in the assessment as a significant increase in the throughput of the GFSs and/or the number of LPG road tanker deliveries would also increase the risk outcomes. Should usage of the GFS other than LPG filling services is proposed in the future, the QRA should be reviewed.

8. REFERENCES

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Annex A

Population Data

Popu_ID	Land_ID	Description	Maximum Population in 2032	Maximum Population in 2039	Indoor Ratio in 2032	% Occupancy in 2032				Population in 2032				Shielding Factor [FB]	Shielded Population in 2032				Indoor Ratio in 2039	% Occupancy in 2039				Population in 2039				Shielding Factor [FB]	Shielded Population in 2039			
						Weekday		Weekend		Weekday		Weekend			Weekday		Weekend			Weekday		Weekend		Weekday		Weekend			Weekday		Weekend	
						Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night		Day	Night	Day	Night	Day	Night	Day	Night		Day	Night	Day	Night
P03	G.5.3	Existing Mai Po ESS	125	84	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	84	8	42	8	0.5	42	4	21	4
P04	G.5.1	Sport Centre	125	1018	0	1	0.1	0.5	0.1	125	13	63	13	0	125	13	63	13	0.95	1	0.1	0.5	0.1	1018	102	509	102	0.5	509	51	255	51
P06	RSc.2.2	Public Housing	7603	7603	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802	0.95	0.5	1	0.7	1	3802	7603	5322	7603	0.5	1901	3802	2661	3802
P07a	OU(EPP).5.3	Food Waste Pretreatment Facilities	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P07b	OU(EPP).5.3	Effluent Polishing Plant	200	200	0.95	1	0.1	0.5	0.1	200	20	100	20	0.5	100	10	50	10	0.95	1	0.1	0.5	0.1	200	20	100	20	0.5	100	10	50	10
P09	G.5.2	Reserve	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P41	OU(I&T)3.1.7	Information and Technology - Zone 3	3536	3536	0.95	1	0.1	0.5	0.1	3536	354	1768	354	0.5	1768	177	884	177	0.95	1	0.1	0.5	0.1	3536	354	1768	354	0.5	1768	177	884	177
P45	OU(I&T)2.1.1	Information and Technology - Zone 2	2788	2788	0.95	1	0.1	0.5	0.1	2788	279	1394	279	0.5	1394	140	697	140	0.95	1	0.1	0.5	0.1	2788	279	1394	279	0.5	1394	140	697	140
P46	OU(ESS).1.4	132kV ESS	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0	0.95	1	0.1	0.5	0.1	0	0	0	0	0.5	0	0	0	0
P47	A.1.4	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P48	OU(MU)2.1.1	Mixed use (Chau Tau Station)	80	17826	0	1	0.1	0.5	0.1	80	8	40	8	0	80	8	40	8	0.95	1	1	1	1	17826	17826	17826	17826	0.5	8913	8913	8913	8913
P57	OU(WRP).5.2	Water Reclamation Plant	100	100	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5	0.95	1	0.1	0.5	0.1	100	10	50	10	0.5	50	5	25	5
P60	GB.5.1	Green Belt	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P66	A.1.5	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P67	OU(I&T)3.1.5	Information and Technology - Zone 3	1135	1135	0.95	1	0.1	0.5	0.1	1135	114	568	114	0.5	568	57	284	57	0.95	1	0.1	0.5	0.1	1135	114	568	114	0.5	568	57	284	57
P68	OU(I&T)3.1.4	Information and Technology - Zone 3	1580	1580	0.95	1	0.1	0.5	0.1	1580	158	790	158	0.5	790	79	395	79	0.95	1	0.1	0.5	0.1	1580	158	790	158	0.5	790	79	395	79
P69	A.1.3	Amenity	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
P70	OU(I&T)3.1.6	Information and Technology - Zone 3 (Government Data Centre)	240	240	0.95	1	0.1	0.5	0.1	240	24	120	24	0.5	120	12	60	12	0.95	1	0.1	0.5	0.1	240	24	120	24	0.5	120	12	60	12

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2032)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	2	73	12	1	26	34	30	4	0	3	186
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	3	18
Road R2													
Total Vehicle per hour	0.16	50	9	299	50	5	49	115	100	16	0	7	652
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R3													
Total Vehicle per hour	0.34	50	5	160	27	3	0	25	21	9	0	0	250
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road R4													
Total Vehicle per hour	0.69	50	6	183	30	3	3	45	39	11	0	4	323
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	1	1	1	3	0	3	16
Road R5													
Total Vehicle per hour	0.7	50	7	232	39	4	21	73	63	13	0	0	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	5	2	2	4	0	0	22
Road R6													
Total Vehicle per hour	0.58	100	106	3416	568	62	134	1266	1081	189	6	224	7051
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	28	7	2	13	10	8	23	0	66	158
Road R7													
Total Vehicle per hour	0.64	100	99	3197	532	58	131	1166	996	176	4	164	6524
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	7	2	14	10	8	23	0	54	148
Road R8													
Total Vehicle per hour	0.83	100	106	3440	572	62	131	1244	1064	189	5	192	7007
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	10	3	18	14	11	32	0	81	210
Road R9													
Total Vehicle per hour	0.68	100	77	2474	412	45	108	816	698	136	3	105	4872
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	24	6	2	12	8	6	19	0	37	115
Road R10													
Total Vehicle per hour	1.18	100	109	3518	586	64	108	903	772	192	4	147	6402
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	59	14	4	21	14	11	46	0	89	260
Road R11													
Total Vehicle per hour	0.19	50	7	238	39	4	3	142	121	14	5	201	774
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	39	49
Road R12													
Total Vehicle per hour	0.37	50	7	217	36	4	0	34	29	12	7	273	619
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	103	113
Road R13													
Total Vehicle per hour	0.32	50	3	101	17	2	0	29	25	5	1	38	222
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20
Road R14													
Total Vehicle per hour	0.27	50	4	115	18	2	3	70	59	7	1	26	305
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	8	16
Road R15													
Total Vehicle per hour	0.45	50	4	133	22	2	0	37	32	7	0	7	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R16													
Total Vehicle per hour	0.39	50	3	110	18	2	0	41	36	6	1	20	238
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	9	17

Road R17													
Total Vehicle per hour	0.13	50	2	74	12	1	0	11	10	4	2	62	179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	9	16

Road R18													
Total Vehicle per hour	0.15	50	3	103	17	2	3	83	70	6	0	0	286
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8

Road R19													
Total Vehicle per hour	0.37	50	2	56	9	1	52	36	30	3	1	53	244
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	7	1	1	1	0	21	35

Road R20													
Total Vehicle per hour	0.54	50	1	43	7	1	52	28	24	3	1	53	213
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	9	1	1	1	0	30	46

Road R21													
Total Vehicle per hour	0.44	50	2	65	11	1	67	13	11	4	1	51	227
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	10	1	1	1	0	23	40

Road R22													
Total Vehicle per hour	0.2	50	3	110	18	2	89	78	66	6	4	139	516
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	6	1	1	1	0	29	42

Road R23													
Total Vehicle per hour	0.45	50	9	281	47	5	17	86	73	16	3	109	645
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	3	0	50	66

Road R24													
Total Vehicle per hour	1.11	50	7	226	38	4	17	55	47	12	3	109	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	6	0	124	153

Road R25													
Total Vehicle per hour	0.86	50	5	161	27	3	0	31	27	9	5	185	453
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	163	176

Road R26													
Total Vehicle per hour	0.67	50	1	27	4	0	0	4	3	2	1	21	61
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	15	22

Road R27													
Total Vehicle per hour	0.63	50	0	7	1	0	0	4	3	0	1	21	36
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	14	21

Road R28													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R29													
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R30													
Total Vehicle per hour	0.67	50	1	22	4	0	0	8	6	1	1	52	95
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	36	43

Road R31													
Total Vehicle per hour	1.62	50	7	219	36	4	5	125	107	12	0	4	519
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	10	3	1	3	6	5	9	0	7	45

Road R32													
Total Vehicle per hour	0.21	50	4	130	21	2	0	56	49	7	3	121	394
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	26	33

Road R33													
Total Vehicle per hour	0.6	50	28	918	154	17	0	38	32	49	0	0	1237
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	16	4	1	0	1	1	12	0	0	36
Road R34													
Total Vehicle per hour	0.42	50	7	238	39	4	12	127	108	14	1	42	593
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	2	2	2	3	0	19	34
Road R35													
Total Vehicle per hour	0.31	50	23	730	123	13	0	73	63	38	0	19	1082
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	1	1	5	0	6	24
Road R36													
Total Vehicle per hour	0.59	50	4	125	21	2	0	37	32	7	3	131	362
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	79	89
Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R38													
Total Vehicle per hour	0.38	50	4	139	23	3	0	41	35	8	3	131	388
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	51	60
Road R39													
Total Vehicle per hour	0.6	50	19	603	101	11	45	182	155	32	3	130	1281
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	11	3	1	9	3	3	8	0	80	119
Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20
Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10
Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9
Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Night-time (Year 2032)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	1	32	6	0	13	7	6	2	0	1	69
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	2	12
Road R2													
Total Vehicle per hour	0.16	50	5	149	29	1	24	23	21	6	0	3	261
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	2	1	1	1	0	1	10
Road R3													
Total Vehicle per hour	0.34	50	2	76	15	0	0	5	4	3	0	0	106
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7
Road R4													
Total Vehicle per hour	0.69	50	3	83	16	1	1	9	8	4	0	2	126
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	2	0	2	12
Road R5													
Total Vehicle per hour	0.7	50	4	115	22	1	10	14	13	5	0	0	184
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	52	1673	322	8	66	242	216	73	4	102	2758
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	14	4	1	7	2	2	9	0	31	71
Road R7													
Total Vehicle per hour	0.64	100	49	1583	304	7	64	224	200	69	3	75	2579
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	7	2	2	9	0	25	66
Road R8													
Total Vehicle per hour	0.83	100	53	1704	328	8	64	239	214	74	3	88	2776
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	9	3	3	13	0	37	93
Road R9													
Total Vehicle per hour	0.68	100	38	1239	238	5	53	158	142	54	2	48	1977
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	4	1	6	2	2	8	0	17	53
Road R10													
Total Vehicle per hour	1.18	100	55	1778	341	8	53	175	157	77	3	67	2713
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	8	1	10	3	3	19	0	41	116
Road R11													
Total Vehicle per hour	0.19	50	4	112	22	1	1	27	24	5	4	93	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	18	26
Road R12													
Total Vehicle per hour	0.37	50	3	98	19	1	0	6	5	4	5	121	262
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	46	54
Road R13													
Total Vehicle per hour	0.32	50	2	52	10	0	0	5	5	2	1	17	94
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	6	13
Road R14													
Total Vehicle per hour	0.27	50	2	38	8	0	1	13	10	2	0	10	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	3	11
Road R15													
Total Vehicle per hour	0.45	50	2	65	12	0	0	7	7	3	0	3	100
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R16												
Total Vehicle per hour	0.39	50	2	56	11	0	0	8	8	2	0	10	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R17												
Total Vehicle per hour	0.13	50	1	38	7	0	0	2	2	2	1	26	79
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	4	11

Road R18												
Total Vehicle per hour	0.15	50	2	41	8	0	1	16	13	2	0	0	83
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	0	8

Road R19												
Total Vehicle per hour	0.37	50	1	25	5	0	26	7	6	1	1	25	96
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	4	1	1	1	0	10	21

Road R20												
Total Vehicle per hour	0.54	50	1	19	4	0	26	5	5	1	1	25	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	14	26

Road R21												
Total Vehicle per hour	0.44	50	1	27	5	0	33	3	2	1	1	24	97
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	5	1	1	1	0	11	23

Road R22												
Total Vehicle per hour	0.2	50	2	54	10	0	44	15	13	2	3	64	208
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23												
Total Vehicle per hour	0.45	50	4	134	26	1	9	17	15	6	2	51	264
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24												
Total Vehicle per hour	1.11	50	4	113	22	0	9	11	10	5	2	51	226
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	58	74

Road R25												
Total Vehicle per hour	0.86	50	2	80	15	0	0	6	5	3	3	86	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	76	85

Road R26												
Total Vehicle per hour	0.67	50	0	12	2	0	0	1	1	1	0	10	27
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R27												
Total Vehicle per hour	0.63	50	0	3	1	0	0	1	1	0	0	10	14
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	7	14

Road R28												
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R29												
Total Vehicle per hour	0.15	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		0	0	0	0	0	0	0	0	0	0	0

Road R30												
Total Vehicle per hour	0.67	50	0	8	2	0	0	1	1	0	1	17	29
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	12	19

Road R31												
Total Vehicle per hour	1.62	50	3	108	21	1	3	24	21	5	0	2	187
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	2	2	1	4	0	3	21

Road R32												
Total Vehicle per hour	0.21	50	2	62	12	0	0	11	10	3	2	56	159
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	14	480	92	2	0	7	6	20	0	0	622
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	1	1	5	0	0	21

Road R34													
Total Vehicle per hour	0.42	50	4	102	20	1	6	24	21	5	1	19	202
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	9	18

Road R35													
Total Vehicle per hour	0.31	50	12	394	75	1	0	14	13	16	0	9	534
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	3	15

Road R36													
Total Vehicle per hour	0.59	50	2	60	12	0	0	7	6	3	2	61	153
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	37	44

Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	2	69	13	0	0	8	7	3	2	61	166
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31

Road R39													
Total Vehicle per hour	0.6	50	9	320	61	1	22	35	31	13	2	60	556
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	1	1	4	0	37	58

Road R40													
Total Vehicle per hour	0.2	50	0	0	0	0	0	0	0	0	0	0	0
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	32	28	2	0	0	114
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	16	516	85	9	0	168	143	30	0	0	968
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 43													
Total Vehicle per hour	0.24	50	16	531	88	10	0	170	145	30	1	25	1015
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	7	20

Road 44													
Total Vehicle per hour	0.32	50	8	259	43	5	0	61	52	14	0	0	442
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 45													
Total Vehicle per hour	0.23	50	7	210	34	4	0	69	58	13	0	0	395
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	0	9

Road 46													
Total Vehicle per hour	0.25	50	11	358	60	6	0	75	64	20	0	0	594
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Note:

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

	Road Length (km)	Designed Speed (km/h)	Traffic Flow (veh/hr) at Daytime (Year 2039)										
			Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	6	185	30	3	26	86	74	11	0	3	425
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	6	2	2	4	0	3	24
Road R2													
Total Vehicle per hour	0.16	50	22	725	120	13	49	238	203	40	0	7	1419
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	1	1	3	0	2	17
Road R3													
Total Vehicle per hour	0.34	50	20	661	110	12	0	124	107	37	0	0	1071
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	6	0	0	20
Road R4													
Total Vehicle per hour	0.69	50	23	733	122	13	3	148	126	40	0	4	1212
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	1	3	3	12	0	3	43
Road R5													
Total Vehicle per hour	0.7	50	9	287	48	5	21	106	91	15	0	0	582
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	5	2	2	5	0	0	24
Road R6													
Total Vehicle per hour	0.58	100	152	4909	816	89	133	1785	1522	270	6	228	9910
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	40	9	3	13	14	11	32	0	68	191
Road R7													
Total Vehicle per hour	0.64	100	124	4007	667	73	131	1416	1210	220	4	159	8011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	36	9	3	14	12	10	29	0	52	166
Road R8													
Total Vehicle per hour	0.83	100	154	4969	827	90	131	1557	1330	272	5	185	9520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	58	14	4	18	17	14	46	0	79	252
Road R9													
Total Vehicle per hour	0.68	100	94	3046	508	55	108	748	640	166	3	116	5485
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	30	7	2	12	7	6	23	0	41	129
Road R10													
Total Vehicle per hour	1.18	100	136	4409	736	80	108	853	730	238	4	153	7448
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		2	73	17	5	21	14	11	58	0	92	293
Road R11													
Total Vehicle per hour	0.19	50	17	560	93	10	3	269	229	32	6	225	1443
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	2	2	3	0	44	58
Road R12													
Total Vehicle per hour	0.37	50	43	1389	231	25	0	262	223	77	4	157	2410
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	0	3	2	12	0	60	98
Road R13													
Total Vehicle per hour	0.32	50	10	336	55	6	0	136	116	20	1	41	721
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	2	1	3	0	14	27
Road R14													
Total Vehicle per hour	0.27	50	18	566	94	10	3	232	197	31	1	28	1179
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	1	2	2	4	0	8	25
Road R15													
Total Vehicle per hour	0.45	50	17	561	93	10	0	66	56	31	0	0	835
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	6	0	0	20

Road R16													
Total Vehicle per hour	0.39	50	12	401	67	7	0	75	64	22	1	25	674
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	0	1	1	4	0	11	25

Road R17													
Total Vehicle per hour	0.13	50	13	424	70	8	0	88	75	24	1	26	729
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	2	0	4	13

Road R18													
Total Vehicle per hour	0.15	50	6	204	34	4	3	136	115	11	1	28	540
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	5	13

Road R19													
Total Vehicle per hour	0.37	50	9	275	45	5	52	84	71	16	1	53	612
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	7	1	1	3	0	21	39

Road R20													
Total Vehicle per hour	0.54	50	8	266	44	5	52	87	74	15	1	53	607
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	1	1	9	2	1	4	0	30	54

Road R21													
Total Vehicle per hour	0.44	50	10	315	52	6	67	95	82	17	1	51	696
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	10	2	1	4	0	23	47

Road R22													
Total Vehicle per hour	0.2	50	10	329	54	6	89	149	127	19	4	139	925
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	6	1	1	2	0	29	44

Road R23													
Total Vehicle per hour	0.45	50	9	295	49	5	17	97	83	16	3	109	684
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	3	2	1	4	0	50	67

Road R24													
Total Vehicle per hour	1.11	50	8	244	41	4	17	62	53	13	3	121	567
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	7	2	2	7	0	138	168

Road R25													
Total Vehicle per hour	0.86	50	14	459	76	8	0	72	62	25	4	159	880
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	2	2	9	0	140	170

Road R26													
Total Vehicle per hour	0.67	50	15	478	80	9	0	121	103	26	2	68	901
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	0	3	2	8	0	47	74

Road R27													
Total Vehicle per hour	0.63	50	11	346	58	6	0	75	64	19	2	89	671
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	1	5	0	58	77

Road R28													
Total Vehicle per hour	0.2	50	15	491	81	9	0	127	108	28	1	52	913
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	11	22

Road R29													
Total Vehicle per hour	0.15	50	17	542	90	10	0	136	116	30	2	68	1011
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	11	21

Road R30													
Total Vehicle per hour	0.67	50	11	340	56	6	0	78	66	19	3	98	676
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	7	2	1	0	2	2	6	0	67	88

Road R31													
Total Vehicle per hour	1.62	50	12	376	62	7	5	182	156	21	0	4	826
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	4	1	3	8	7	15	0	7	64

Road R32													
Total Vehicle per hour	0.21	50	9	297	49	5	0	211	181	17	3	121	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	2	1	2	0	26	36

Road R33													
Total Vehicle per hour	0.6	50	39	1265	212	23	0	118	100	67	0	0	1825
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	22	5	2	0	2	2	17	0	0	51

Road R34													
Total Vehicle per hour	0.42	50	15	481	78	9	12	251	215	29	1	36	1127
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	2	3	3	5	0	16	39

Road R35													
Total Vehicle per hour	0.31	50	30	965	163	17	0	71	61	49	0	13	1370
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	2	1	0	1	1	7	0	5	27

Road R36													
Total Vehicle per hour	0.59	50	5	164	27	3	0	50	42	9	3	118	422
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	3	0	72	83

Road R37													
Total Vehicle per hour	0.25	50	0	12	2	0	0	3	3	1	0	0	21
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	2	69	11	1	0	33	28	4	3	131	282
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	51	58

Road R39													
Total Vehicle per hour	0.6	50	31	991	166	18	45	268	229	52	4	154	1958
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	17	4	1	9	5	4	13	0	95	149

Road R40													
Total Vehicle per hour	0.2	50	4	129	21	2	0	23	19	7	0	0	206
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	0	14	2	0	0	14	12	1	0	0	44
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Road Population

			Traffic Flow (veh/hr) at Night-time (Year 2039)										
	Road Length (km)	Designed Speed (km/h)	Motorcycle	Private Car	Taxi	Private Light Bus	Public Light Bus	Light Goods Vehicle	Medium/ Heavy Goods Vehicles	Non-franchised Bus	Franchised Bus (Single Deck)	Franchised Bus (Double Deck)	Total
Road R1													
Total Vehicle per hour	0.7	50	3	76	15	1	13	17	16	4	0	1	145
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	3	1	1	2	0	2	14
Road R2													
Total Vehicle per hour	0.16	50	11	358	69	2	24	46	41	16	0	3	570
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	1	12
Road R3													
Total Vehicle per hour	0.34	50	10	327	63	2	0	24	22	14	0	0	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	0	11
Road R4													
Total Vehicle per hour	0.69	50	11	364	70	2	1	28	25	16	0	2	520
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	1	1	1	5	0	2	22
Road R5													
Total Vehicle per hour	0.7	50	5	151	29	1	10	21	19	6	0	0	241
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	3	1	1	2	0	0	13
Road R6													
Total Vehicle per hour	0.58	100	76	2439	469	11	66	343	304	107	4	105	3923
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	20	6	1	7	3	3	13	0	31	85
Road R7													
Total Vehicle per hour	0.64	100	62	2005	385	9	64	273	243	87	3	73	3205
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	18	5	1	7	3	2	12	0	24	73
Road R8													
Total Vehicle per hour	0.83	100	77	2489	478	11	64	300	268	108	3	85	3884
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	29	8	1	9	4	3	19	0	36	110
Road R9													
Total Vehicle per hour	0.68	100	47	1548	297	6	53	145	131	67	2	53	2350
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	15	4	1	6	2	2	10	0	19	60
Road R10													
Total Vehicle per hour	1.18	100	69	2263	434	9	53	165	149	97	3	70	3312
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	38	10	1	10	3	3	24	0	43	133
Road R11													
Total Vehicle per hour	0.19	50	9	265	51	1	1	51	45	12	4	104	545
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	1	1	1	1	0	21	30
Road R12													
Total Vehicle per hour	0.37	50	21	690	133	3	0	50	44	30	3	73	1048
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	8	2	1	0	1	1	5	0	28	47
Road R13													
Total Vehicle per hour	0.32	50	5	146	28	1	0	26	23	7	1	19	256
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	7	15
Road R14													
Total Vehicle per hour	0.27	50	9	288	55	1	1	44	38	12	1	13	462
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	4	15
Road R15													
Total Vehicle per hour	0.45	50	9	278	54	1	0	13	12	12	0	0	378
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road R16													
Total Vehicle per hour	0.39	50	6	206	39	1	0	15	13	9	0	12	301
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	5	15

Road R17													
Total Vehicle per hour	0.13	50	7	208	40	1	0	17	15	9	1	13	309
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	2	9

Road R18													
Total Vehicle per hour	0.15	50	3	102	20	0	1	26	22	4	1	13	192
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	1	1	1	1	0	2	10

Road R19													
Total Vehicle per hour	0.37	50	4	130	25	1	26	16	14	6	1	25	247
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	4	1	1	1	0	10	22

Road R20													
Total Vehicle per hour	0.54	50	4	123	24	1	26	17	15	6	1	25	240
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	14	28

Road R21													
Total Vehicle per hour	0.44	50	5	157	30	1	33	18	17	7	1	24	292
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	5	1	1	2	0	11	25

Road R22													
Total Vehicle per hour	0.2	50	5	150	29	1	44	29	26	7	3	64	357
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	3	1	1	1	0	14	24

Road R23													
Total Vehicle per hour	0.45	50	5	144	28	1	9	19	17	6	2	51	280
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	2	1	1	2	0	24	35

Road R24													
Total Vehicle per hour	1.11	50	4	123	24	1	9	12	11	5	2	56	246
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	4	1	1	3	0	64	80

Road R25													
Total Vehicle per hour	0.86	50	7	226	44	1	0	14	13	10	3	74	392
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	6	2	1	0	1	1	4	0	65	81

Road R26													
Total Vehicle per hour	0.67	50	7	239	46	1	0	23	21	10	1	31	381
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	22	36

Road R27													
Total Vehicle per hour	0.63	50	5	171	33	1	0	15	13	8	2	41	289
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	27	38

Road R28													
Total Vehicle per hour	0.2	50	8	231	45	1	0	24	22	11	1	24	366
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R29													
Total Vehicle per hour	0.15	50	8	274	53	1	0	26	23	12	1	31	430
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	5	13

Road R30													
Total Vehicle per hour	0.67	50	5	164	32	1	0	15	13	7	2	45	285
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	2	0	31	42

Road R31													
Total Vehicle per hour	1.62	50	6	178	34	1	3	35	32	8	0	2	299
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	2	2	2	6	0	3	29

Road R32													
Total Vehicle per hour	0.21	50	5	139	27	1	0	41	37	6	2	56	313
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	13	20

Road R33													
Total Vehicle per hour	0.6	50	20	673	129	2	0	23	20	28	0	0	894
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	12	3	1	0	1	1	7	0	0	26

Road R34													
Total Vehicle per hour	0.42	50	7	198	39	2	6	49	44	10	1	17	371
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	1	1	1	2	0	8	19

Road R35													
Total Vehicle per hour	0.31	50	15	540	103	1	0	14	13	22	0	6	715
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	1	1	3	0	2	16

Road R36													
Total Vehicle per hour	0.59	50	3	84	16	0	0	10	8	4	2	55	181
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	2	1	1	0	1	1	1	0	33	41

Road R37													
Total Vehicle per hour	0.25	50	0	6	1	0	0	1	1	0	0	0	9
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R38													
Total Vehicle per hour	0.38	50	1	32	6	0	0	6	6	1	2	61	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	24	31

Road R39													
Total Vehicle per hour	0.6	50	16	526	101	2	22	52	46	22	3	71	860
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	9	3	1	5	1	1	6	0	44	71

Road R40													
Total Vehicle per hour	0.2	50	2	61	12	0	0	4	4	3	0	0	85
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R41													
Total Vehicle per hour	0.23	50	1	43	7	1	0	33	28	2	0	0	115
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	1	1	1	0	1	1	1	0	0	7

Road R42													
Total Vehicle per hour	0.16	50	21	674	111	12	0	225	192	38	0	0	1274
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Road 43													
Total Vehicle per hour	0.24	50	22	722	120	13	0	227	194	41	1	25	1364
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	5	2	1	0	2	2	4	0	7	24

Road 44													
Total Vehicle per hour	0.32	50	14	442	73	8	0	79	67	25	0	0	708
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	4	0	0	13

Road 45													
Total Vehicle per hour	0.23	50	10	330	54	6	0	89	75	19	0	0	583
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	3	1	1	0	1	1	2	0	0	10

Road 46													
Total Vehicle per hour	0.25	50	14	452	75	8	0	94	80	25	0	0	748
Person per vehicle [1]	-		1.0	1.4	1.9	4.5	15.9	1.3	1.2	20.3	0.0	50.9	-
No. of Person	-		1	4	1	1	0	1	1	3	0	0	12

Note:
[1] Person per vehicle is based on the average occupancy at core stations 5016 in Year 2019 from Transport Department - The Annual Traffic Census 2019

Annex B

Aircraft Crash Frequency Calculation

ANNEX B AIRCRAFT CRASH FREQUENCY CALCULATION

Introduction

The distance between the nearest arrival/departure flight path and the proposed Station #2 is about 13.2 km. The distance between the proposed Station #2 and Chek Lap Kok International Airport is 25 km, the separation distance is over 8 km, which fulfills the criteria of not considering the airfield accident. At such distances, the GFS is not covered by critical takeoff and landing phases. The frequency of aircraft crash is estimated using the methodology of the HSE (1997). Civil aircraft is the main type using the airport. According to the statistic of Civil International Air Transport Movements of Aircraft, there are 429,446 movements between July 2018 and June 2019 inclusively.

Frequency Calculation

The frequency of aircraft crash of a particular aircraft type is calculated with reference to *Health and Safety Executives - The Calculation of Aircraft Crash Risk in the UK* prepared by J P Byrue in 1997, given by the following equation:

Frequency (per year) = Background Crash Rate + Airway Crash Rate

Frequency (per year) = $(A \times B_i) + (A \times N_i \times R_i \times afac/\ alt)$*, where*

- A = area of the GFS (in km^2)
- N_i = number of aircraft movement (for aircraft type i)
- B_i = background crash rate for aircraft (for aircraft type i, in per year per km^2)
- R_i = aircraft in-flight reliability (for aircraft type i, crashes per year per km per aircraft movement)
- alt = altitudes of airways (in km)
- afac = area factor used in airway calculation

The parameters of the above equation are listed as follows:

- Area of the Station #2 (A): 2.1×10^{-3} km^2 = 2,100m^2
- Number of aircraft movement (N):
  - There is 429,446 aircraft movement annually.
- Background aircraft crash rate (B_i):
  - The background crash rate for airliners is 2×10^{-6} per year per km^2
- Aircraft in-flight crash rate (R_i):
  - It is taken as 4.7×10^{-11} per year per km per movement
- Altitudes of airways (alt):
  - altitudes of airways is taken as 5 km
- Area factor (afac):
  - area factor (afac) is taken as 0.015 from Table 9 of Byrne (1997) with corresponding x1 = 2.64
    (x1 = x/alt where x = the minimum horizontal distance from airway/ flight path to the site which is taken as 13.2 km)

By substituting the parameters into the equation listed above, the annual aircraft crash rate can be estimated and listed as follows:

- Crash rate for airliners = 4.33×10^{-9} per year

Therefore, the frequency of aircraft crash at Station #2
= 4.33×10^{-9} per year.

Probability of LPG equipment failure due to aircraft crash

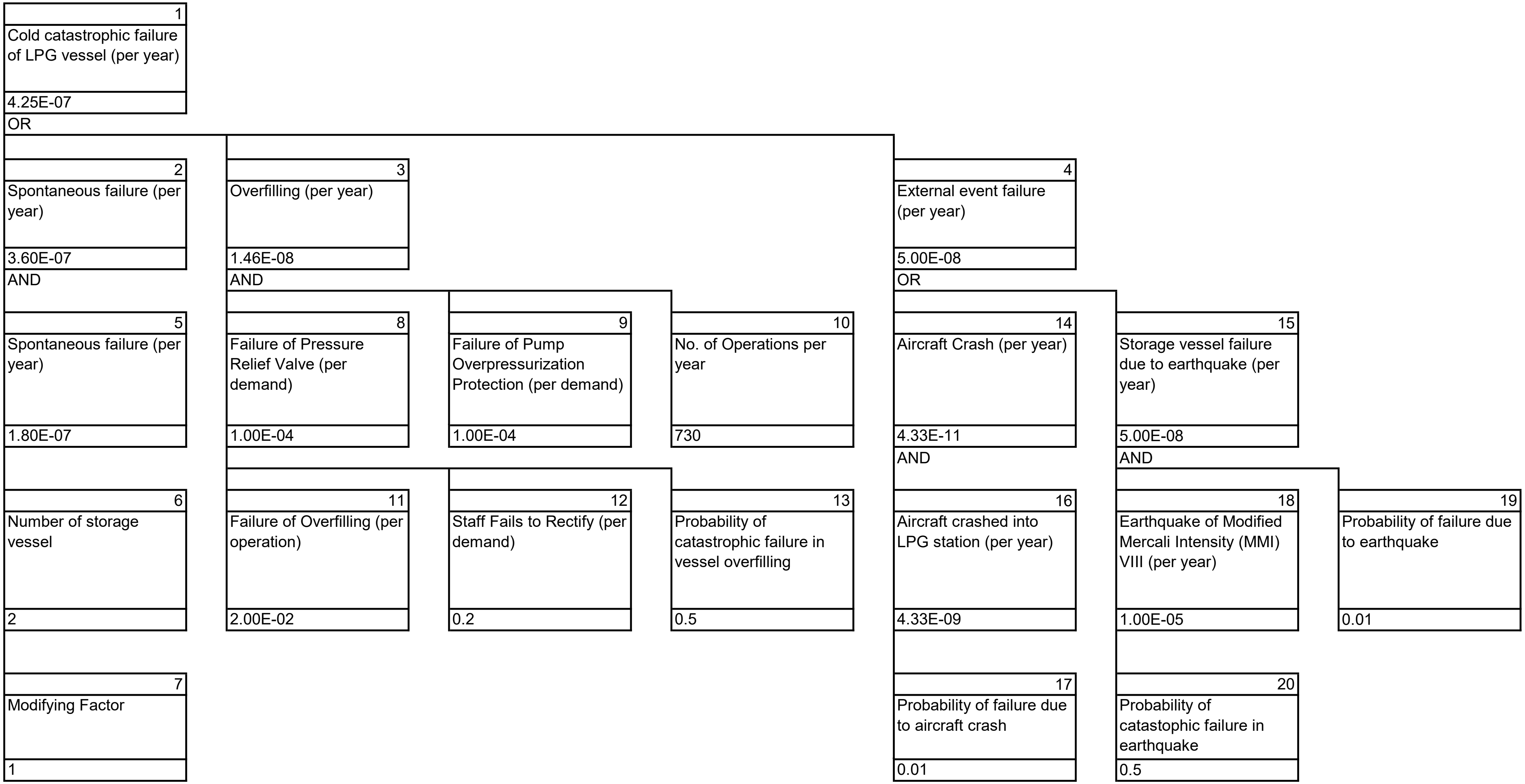
It is assumed that when there is an aircraft crash, the LPG liquid-line pipework (i.e. 'liquid inlet pipeline to storage vessel' and 'liquid line to dispenser') and dispenser will definitely fail (i.e. probability = 1). For 'vapour return line', it is assumed that the probability is 10 times lower than that of liquid-line pipework because the vapour return line is installed underground. The 'liquid line from tanker to flexible hose' is not considered because aircraft crash to tanker will lead to 'road tanker failure', which has a greater consequence.

For failure of road tanker, it is assumed that the probability of 'road tanker rupture' and 'road tanker partial failure' given that there is an aircraft crash are 0.1 and 0.9 respectively. For failure of storage vessel, it is assumed that the probability of failure is 10 times lower than that of road tanker because the LPG storage vessel is installed underground. Therefore, it is assumed that the probability of 'storage vessel rupture' and 'storage vessel partial failure' given that there is an aircraft crash are 0.01 and 0.09 respectively.

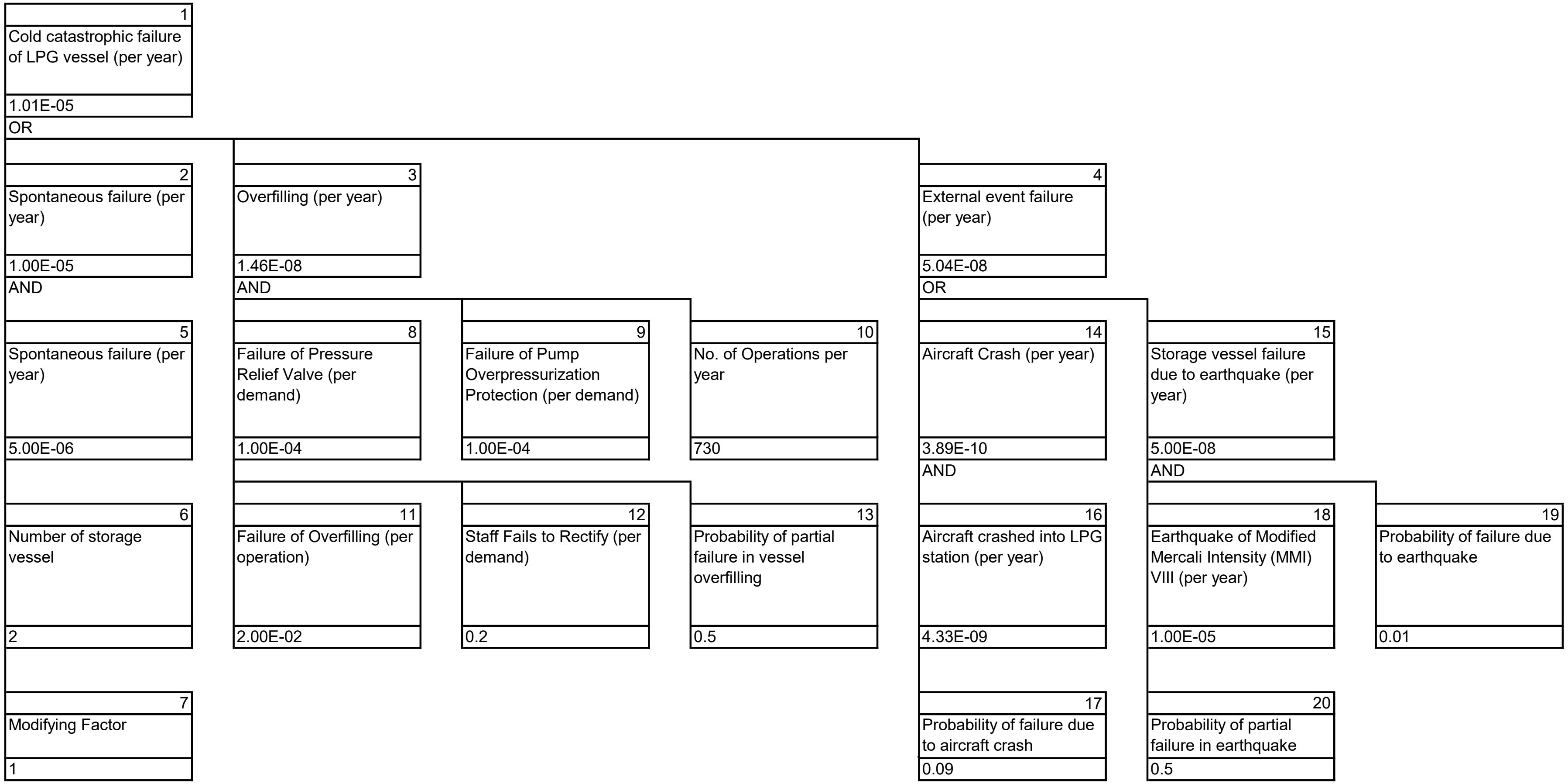
Annex C

Fault Tree Analysis

A-1 ***Cold Catastrophic Failure of an LPG Vessel***



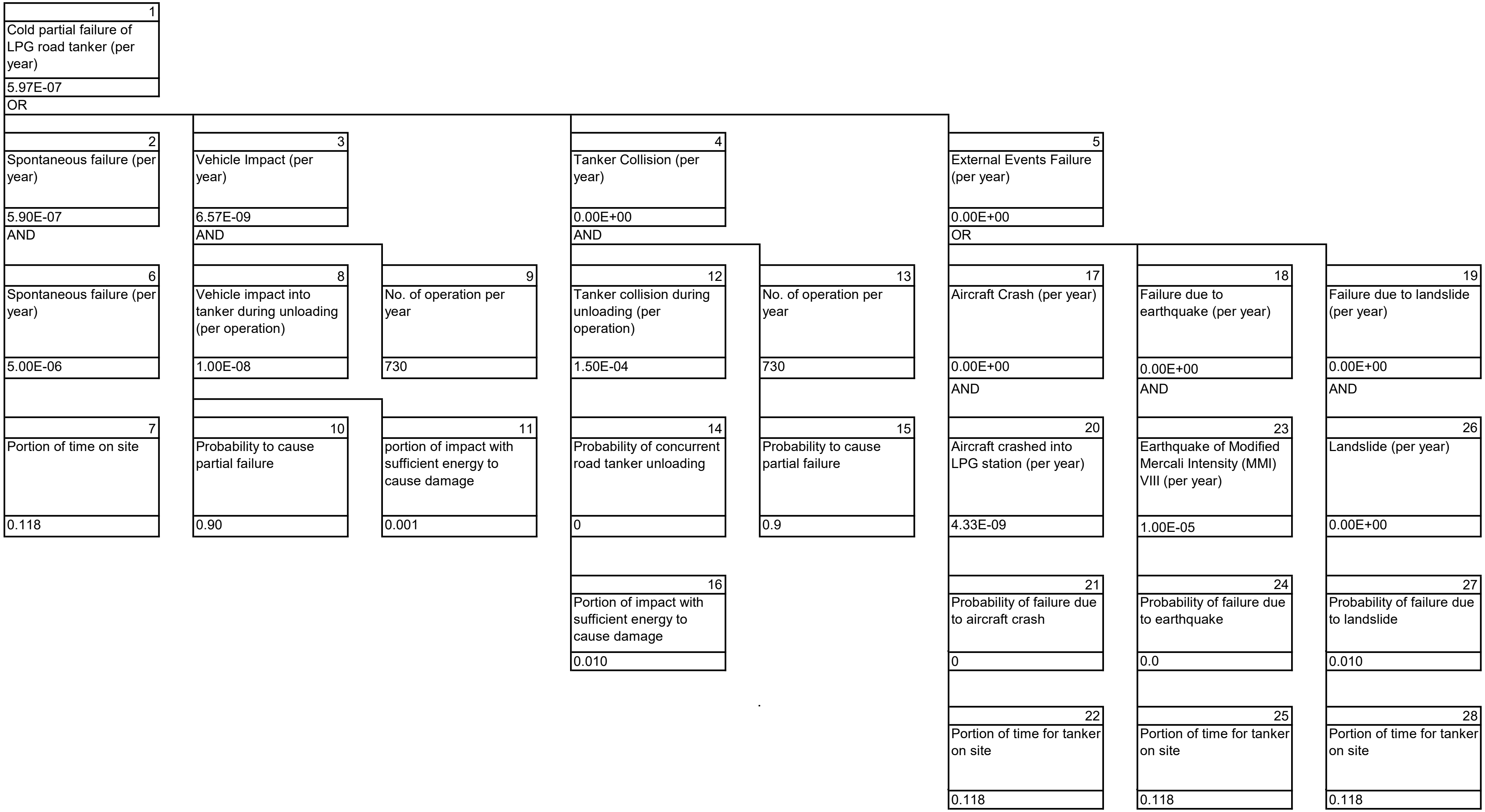
A-2 ***Cold Partial Failure of an LPG Vessel***



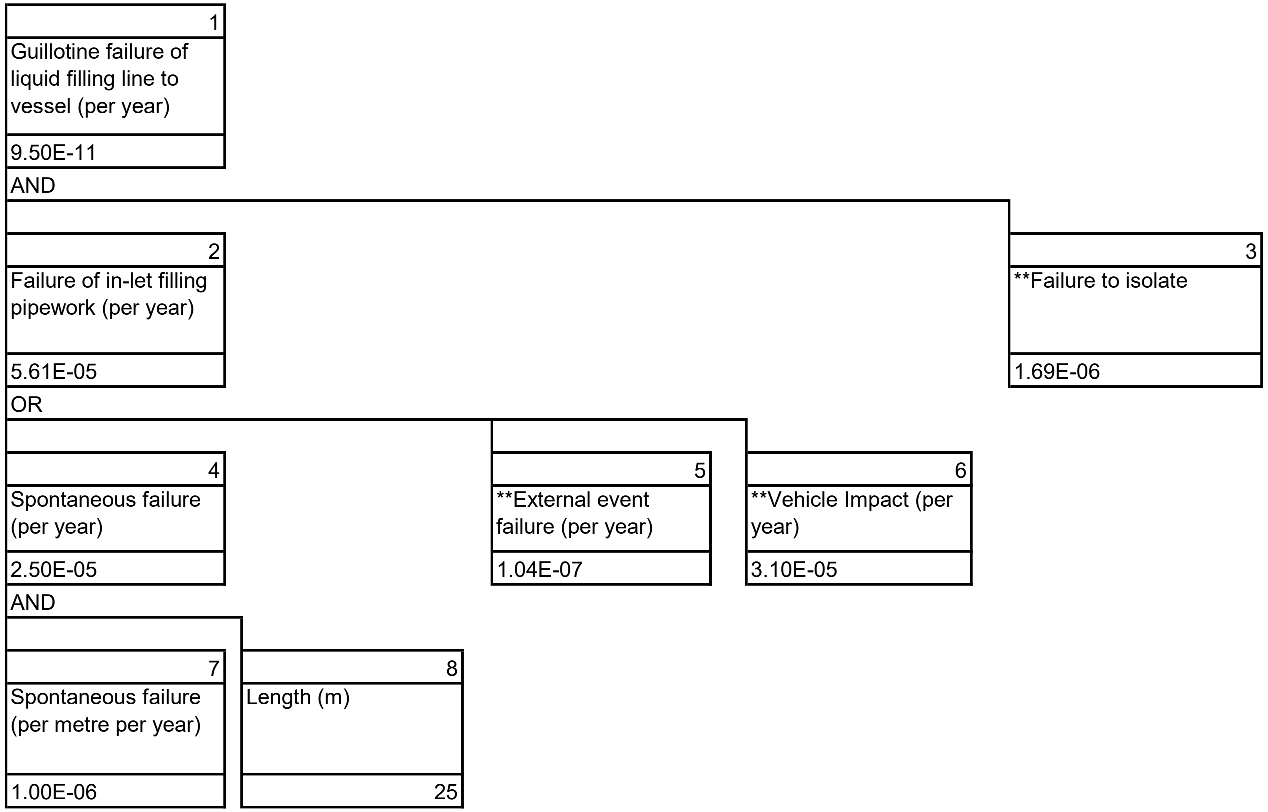
A-3 ***Cold Catastrophic Failure of Road Tanker***

- **1** Cold catastrophic failure of LPG road tanker (per year) — 2.37E-07 — OR
  - **2** Spontaneous failure (per year) — 2.36E-07 — AND
    - **6** Spontaneous failure (per year) — 2.00E-06
    - **7** Portion of time on site — 0.118
  - **3** Vehicle Impact (per year) — 7.30E-10 — AND
    - **8** Vehicle impact into tanker during unloading (per operation) — 1.00E-08
    - **9** No. of operation per year — 730
    - **10** Probability to cause rupture — 0.10
    - **11** portion of impact with sufficient energy to cause damage — 0.001
  - **4** Tanker Collision (per year) — 0.00E+00 — AND
    - **12** Tanker collision during unloading (per operation) — 1.50E-04
    - **13** No. of operation per year — 730
    - **14** Probability of concurrent road tanker unloading — 0
    - **15** Probability to cause rupture — 0.1
    - **16** Portion of impact with sufficient energy to cause damage — 0.010
  - **5** External Events Failure (per year) — 5.11E-10 — OR
    - **17** Aircraft Crash (per year) — 5.11E-10 — AND
      - **20** Aircraft crashed into LPG station (per year) — 4.33E-09
      - **21** Probability of failure due to aircraft crash — 1
      - **22** Portion of time for tanker on site — 0.118
    - **18** Failure due to earthquake (per year) — 0.00E+00 — AND
      - **23** Earthquake of Modified Mercali Intensity (MMI) VIII (per year) — 1.00E-05
      - **24** Probability of failure due to earthquake — 0.0
      - **25** Portion of time for tanker on site — 0.118
    - **19** Failure due to landslide (per year) — 0.00E+00 — AND
      - **26** Landslide (per year) — 0.00E+00
      - **27** Probability of failure due to landslide — 0.005
      - **28** Portion of time for tanker on site — 0.118

A-4 ***Cold Partial Failure of Road Tanker***



A-5a ***Guillotine Failure of In-let Filling Pipework (release from the vessel)***

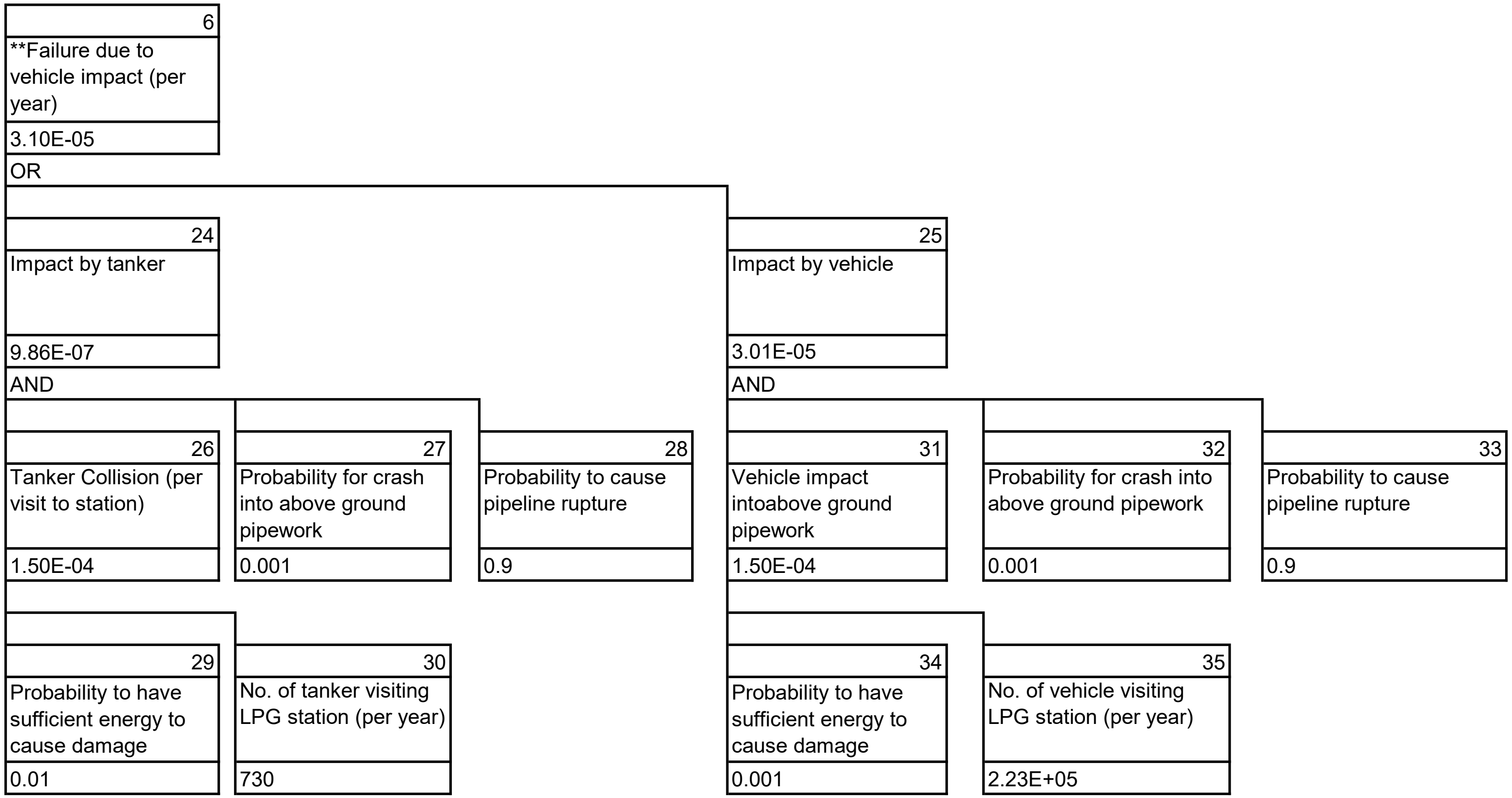


A-5a ***Guillotine Failure of In-let Filling Pipework (release from the vessel) (Con't)***

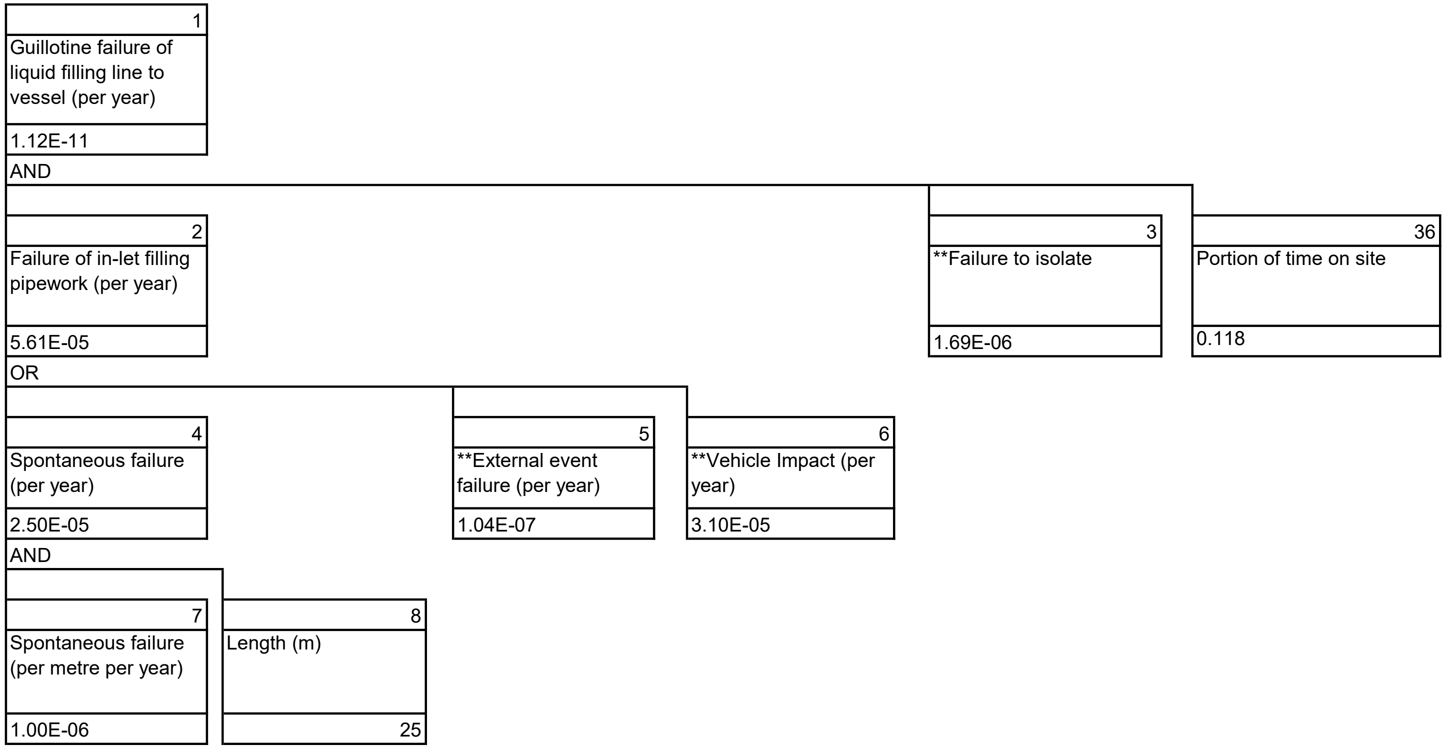
- **3** — **Failure to isolate — 1.69E-06
  - AND
    - **9** — Emergency Isolation System (EIS) is not effective — 1.00E-01
      - OR
        - **13** — fail to activate EIS (per demand) — 0.1
        - **14** — failure of EIS (per demand) — 1.00E-04
    - **10** — Non-return valve failure (per demand) — 0.013
    - **11** — Manual Valve Failure (per demand) — 0.50
    - **12** — Double-check valve Failure (per demand) — 2.60E-03

- **5** — **External event failure (per year) — 1.04E-07
  - OR
    - **15** — Failure due to earthquake (per year) — 1.00E-07
      - AND
        - **16** — Earthquake of Modified Mercali Intensity (MMI) VIII (per year) — 1.00E-05
        - **17** — Probability of failure due to earthquake — 0.01
    - **18** — Aircraft Crash (per year) — 4.33E-09
      - AND
        - **19** — Aircraft crashed into LPG station (per year) — 4.33E-09
        - **20** — Probability of failure due to aircraft crash — 1
    - **21** — Failure due to landslide (per year) — 0.00E+00
      - AND
        - **22** — Landslide (per year) — 0.00E+00
        - **23** — Probability of failure due to landslide — 0.01

A-5a ***Guillotine Failure of In-let Filling Pipework (release from the vessel) (Con't)***



A-5b ***Guillotine Failure of In-let Filling Pipework (release from road tanker)***



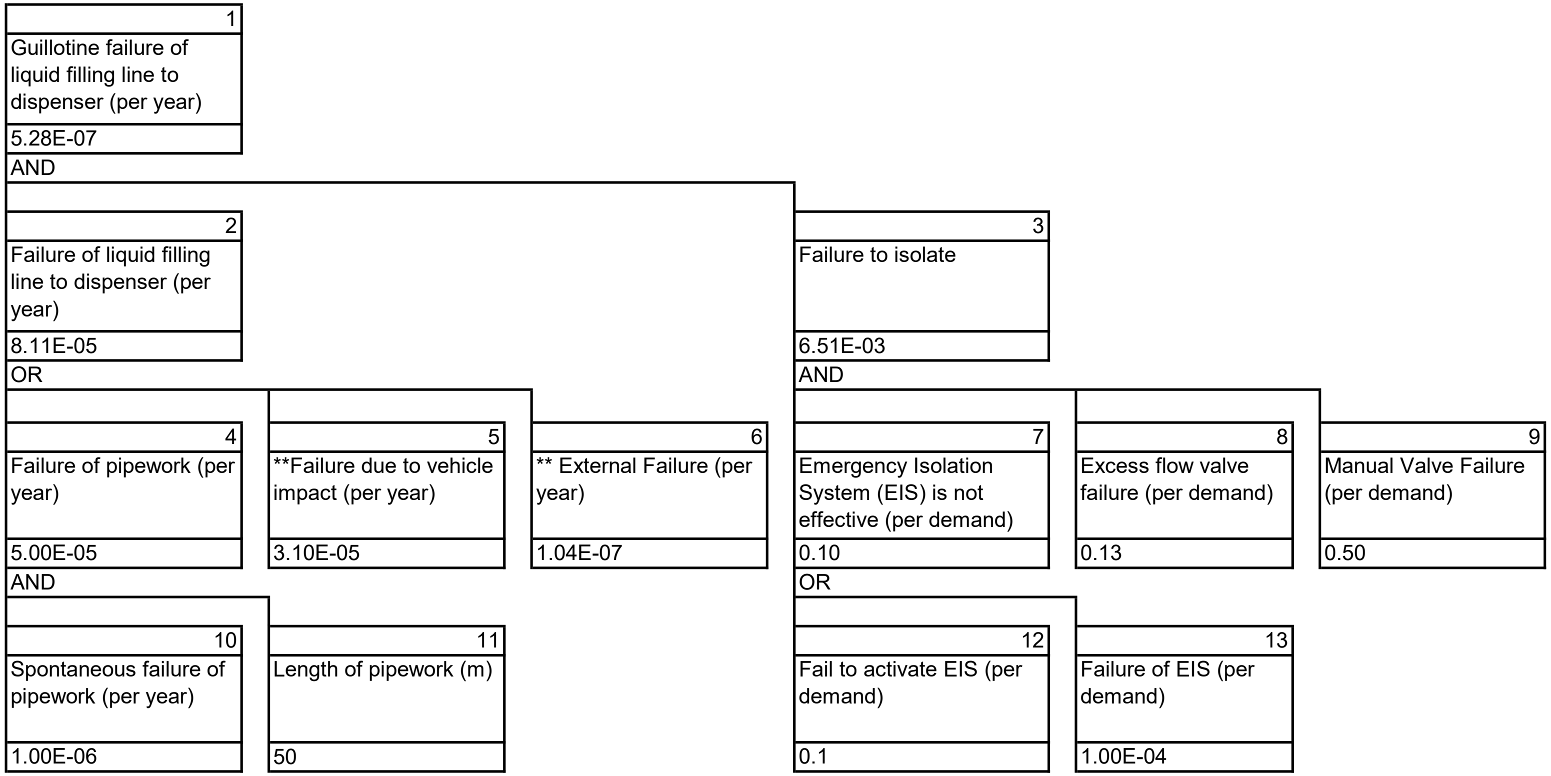
- 3 — **Failure to isolate — 1.69E-06 — AND
  - 9 — Emergency Isolation System (EIS) is not effective — 1.00E-01 — OR
    - 13 — fail to activate EIS (per demand) — 0.1
    - 14 — failure of EIS (per demand) — 1.00E-04
  - 10 — Non-return valve failure (per demand) — 0.013
  - 11 — Manual Valve Failure (per demand) — 0.50
  - 12 — Double-check valve Failure (per demand) — 2.60E-03

- 5 — **External event failure (per year) — 1.04E-07 — OR
  - 15 — Failure due to earthquake (per year) — 1.00E-07 — AND
    - 16 — Earthquake of Modified Mercali Intensity (MMI) VIII (per year) — 1.00E-05
    - 17 — Probability of failure due to earthquake — 0.01
  - 18 — Aircraft Crash (per year) — 4.33E-09 — AND
    - 19 — Aircraft crashed into LPG station (per year) — 4.33E-09
    - 20 — Probability of failure due to aircraft crash — 1
  - 21 — Failure due to landslide (per year) — 0.00E+00 — AND
    - 22 — Landslide (per year) — 0.00E+00
    - 23 — Probability of failure due to landslide — 0.01

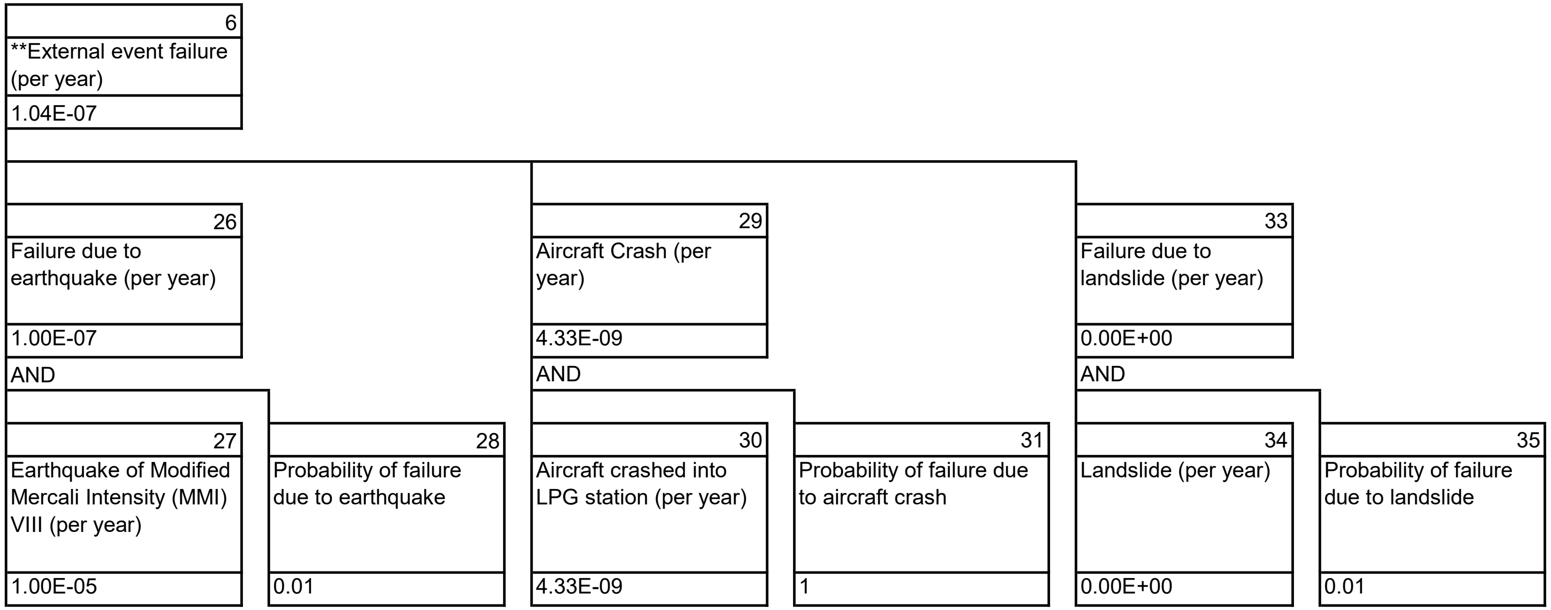
A-5b ***Guillotine Failure of In-let Filling Pipework (release from road tanker) (Con't)***

- **6** – **Failure due to vehicle impact (per year): 3.10E-05 — OR
  - **24** – Impact by tanker: 9.86E-07 — AND
    - **26** – Tanker Collision (per visit to station): 1.50E-04
      - **29** – Probability to have sufficient energy to cause damage: 0.01
      - **30** – No. of tanker visiting LPG station (per year): 730
    - **27** – Probability for crash into above ground pipework: 0.001
    - **28** – Probability to cause pipeline rupture: 0.9
  - **25** – Impact by vehicle: 3.01E-05 — AND
    - **31** – Vehicle impact intoabove ground pipework: 1.50E-04
      - **34** – Probability to have sufficient energy to cause damage: 0.001
      - **35** – No. of vehicle visiting LPG station (per year): 222650
    - **32** – Probability for crash into above ground pipework: 0.001
    - **33** – Probability to cause pipeline rupture: 0.9

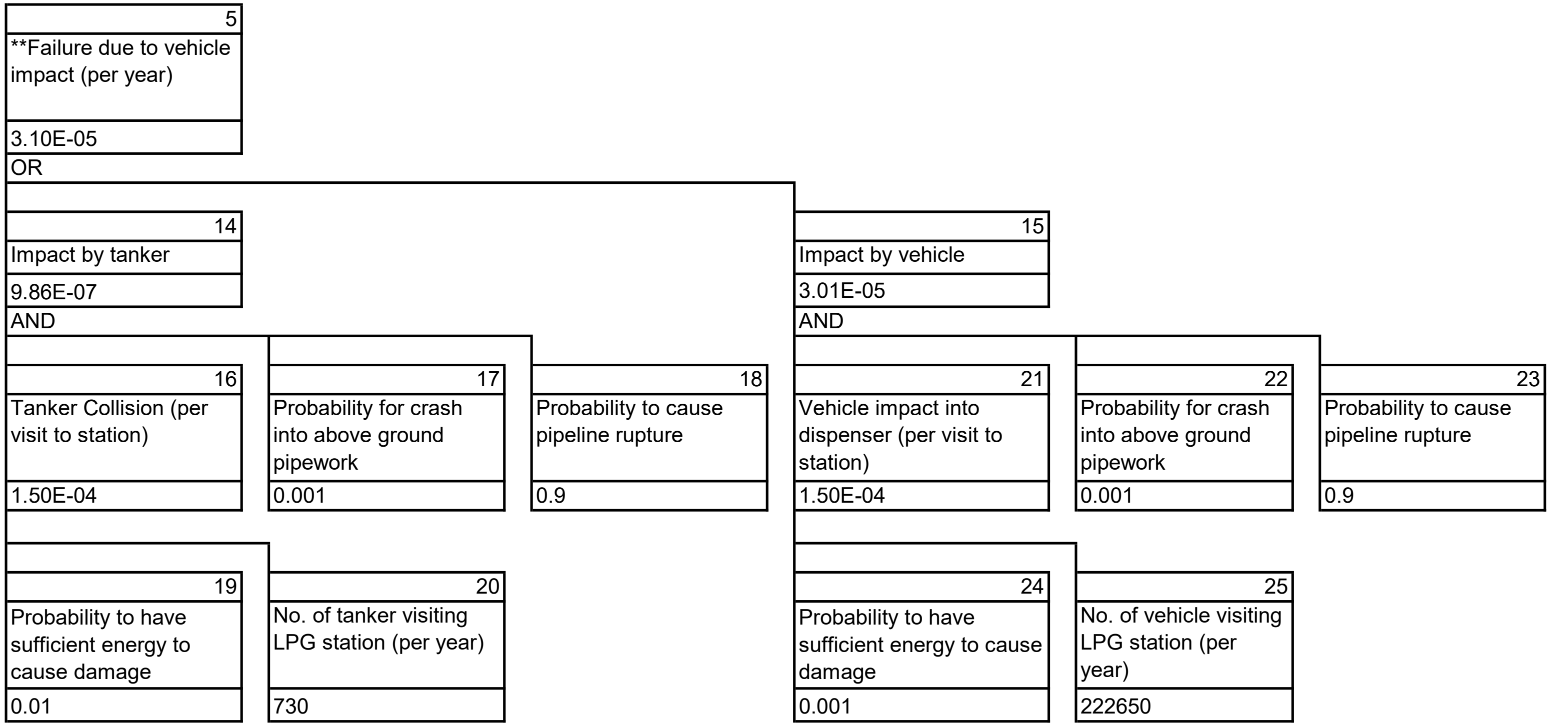
A-6 ***Guillotine Failure of Liquid Supply Line to Dispenser***



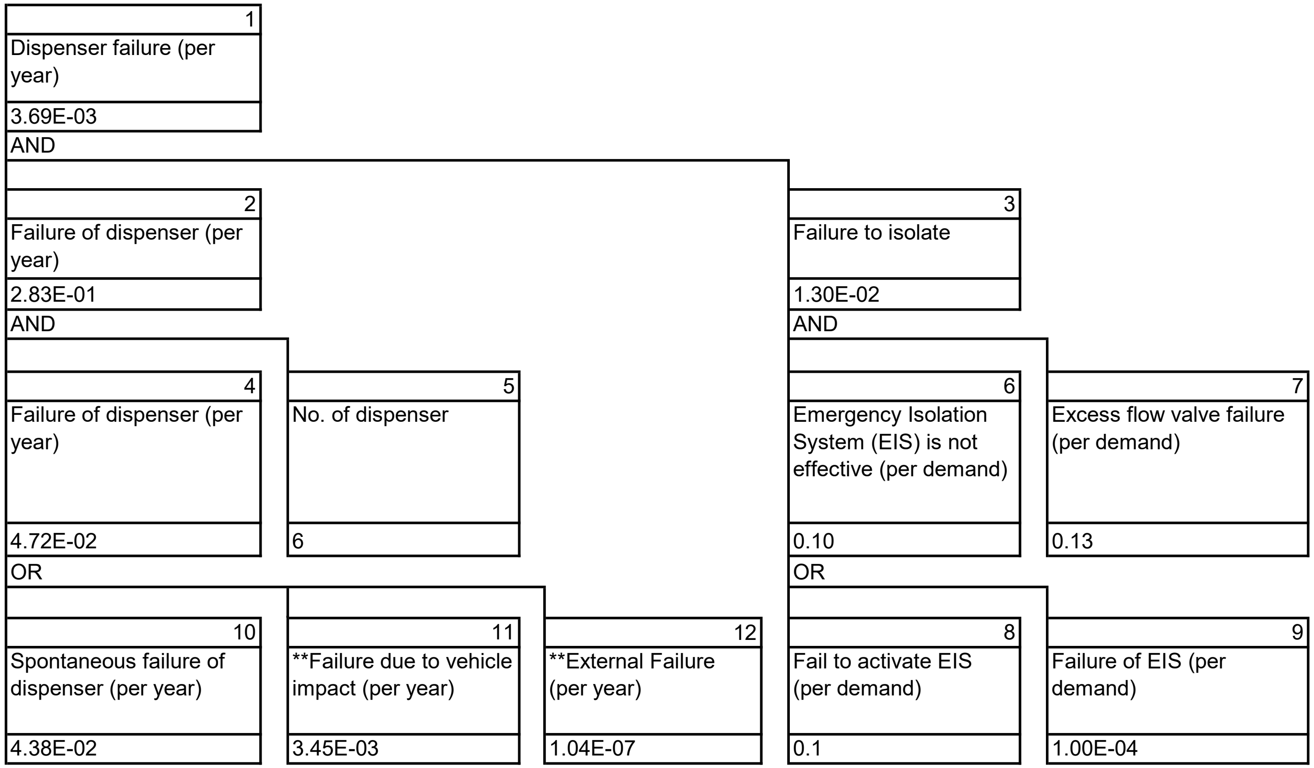
A-6 ***Guillotine Failure of Liquid Supply Line to Dispenser (Con't)***



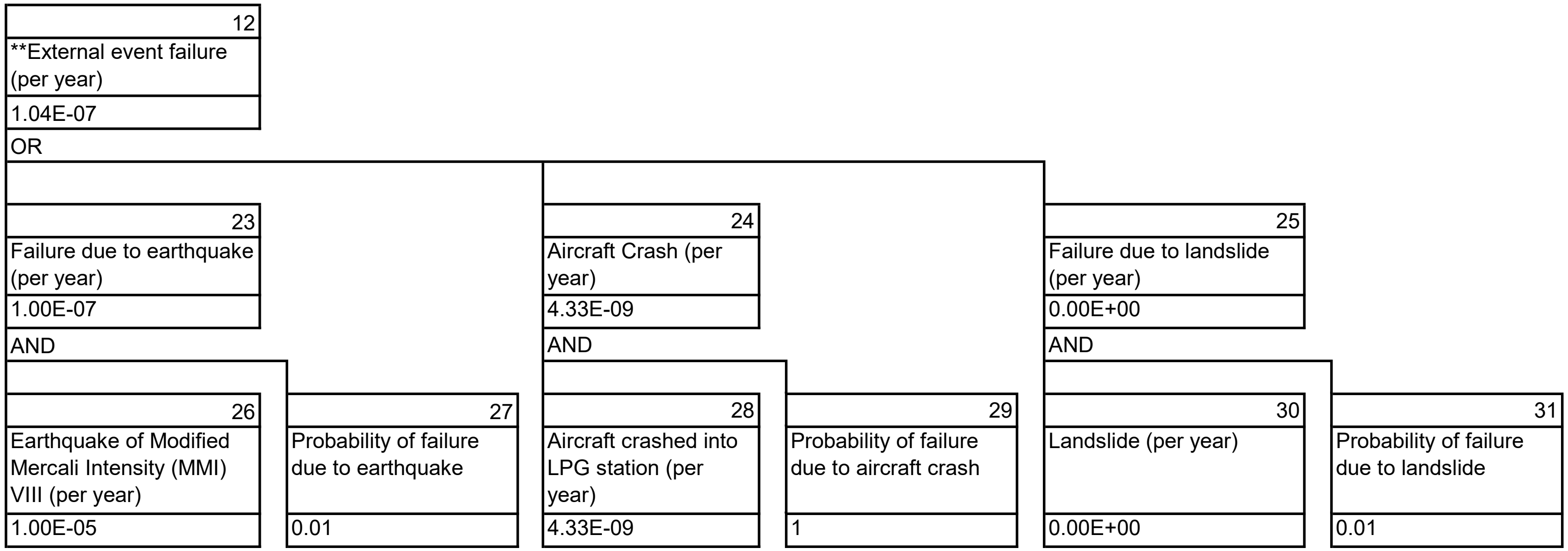
A-6 ***Guillotine Failure of Liquid Supply Line to Dispenser (Con't)***

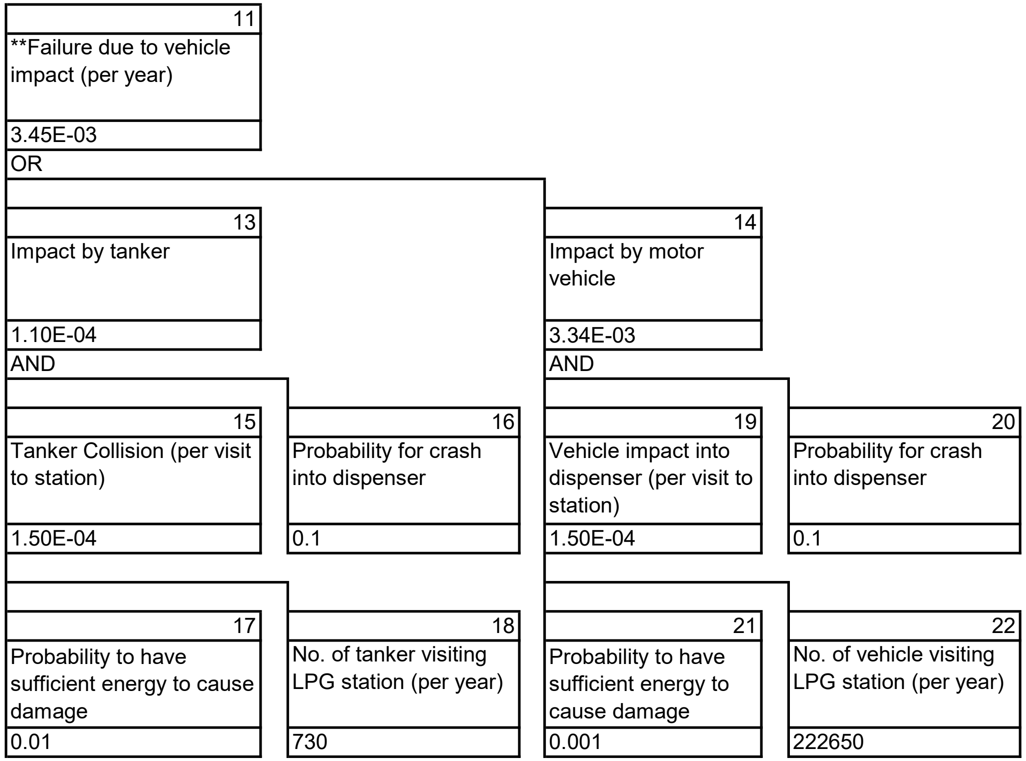


A-7 ***Failure of Dispenser***



A-7 ***Failure of Dispenser (con't)***




11
**Failure due to vehicle impact (per year)
3.45E-03
OR
13
Impact by tanker
1.10E-04
AND
14
Impact by motor vehicle
3.34E-03
AND
15
Tanker Collision (per visit to station)
1.50E-04
16
Probability for crash into dispenser
0.1
19
Vehicle impact into dispenser (per visit to station)
1.50E-04
20
Probability for crash into dispenser
0.1
17
Probability to have sufficient energy to cause damage
0.01
18
No. of tanker visiting LPG station (per year)
730
21
Probability to have sufficient energy to cause damage
0.001
22
No. of vehicle visiting LPG station (per year)
222650

Failure of Flexible Hose during Loading to Storage Vessel (LPG released from the Hose Connecting to Road Tanker)

- **1** Failure during loading (per year) — 3.11E-06 — AND
  - **2** Leaking during loading (per operation) — 6.56E-06 — OR
    - **5** Hose misconnection (per operation) — 6.00E-06 — AND
      - **10** Hose misconnection (per operation) — 3.00E-05
      - **11** Operator fails to rectify the problem — 0.2
    - **6** Driver away failure (per operation) — 5.20E-08 — AND
      - **12** Tanker drives away (per operation) — 4.00E-06
      - **13** Breakaway coupling failure (per demand) — 0.013
    - **7** Spontaneous failure (per operation) — 1.05E-07
    - **8** Hose disconnection (per operation) — 4.00E-07 — AND
      - **14** Hose disconnection (per operation) — 2.00E-06
      - **15** Operator fails to rectify the problem — 2.00E-01
    - **9** Vehicle impact (per operation) — 9.72E-10 — AND
      - **16** Vehicle impact into tanker during unloading (per — 1.00E-08
      - **17** Portion of time for tanker refilling — 0.097
  - **3** No. of filling per year — 730
  - **4** ** Failure to isolate leak from tanker — 6.51E-04

- **4** **Failure to isolate — 6.51E-04 — AND
  - **18** Emergency Isolation System (EIS) is not effective — 1.00E-01 — OR
    - **21** fail to activate EIS (per demand) — 0.1
    - **22** failure of EIS (per demand) — 1.00E-04
  - **19** Excess flow valve failure (per demand) — 0.013
  - **20** Manual Valve Failure (per demand) — 0.50

A-8b ***Failure of Flexible Hose during Loading to Storage Vessel (LPG released from the Hose Connecting to vessel)***

- 1 Failure during loading (per year) — 8.10E-09
  - AND
    - 2 Leaking during loading (per operation) — 6.56E-06
      - OR
        - 5 Hose misconnection (per operation) — 6.00E-06
          - AND
            - 10 Hose misconnection (per operation) — 3.00E-05
            - 11 Operator fails to rectify the problem — 0.2
        - 6 Driver away failure (per operation) — 5.20E-08
          - AND
            - 12 Tanker drives away (per operation) — 4.00E-06
            - 13 Breakaway coupling failure (per demand) — 0.013
        - 7 Spontaneous failure (per operation) — 1.05E-07
        - 8 Hose disconnection (per operation) — 4.00E-07
          - AND
            - 14 Hose disconnection (per operation) — 2.00E-06
            - 15 Operator fails to rectify the problem — 0.2
        - 9 Vehicle impact (per operation) — 9.72E-10
          - AND
            - 16 Vehicle impact into tanker during unloading (per operation) — 1.00E-08
            - 17 Portion of time for tanker refilling — 0.097
    - 3 No. of filling per year — 730
    - 4 ** Failure to isolate leak from tanker — 1.69E-06

- 4 **Failure to isolate — 1.69E-06
  - AND
    - 18 Emergency Isolation System (EIS) is not effective — 1.00E-01
      - OR
        - 22 Fail to activate EIS (per demand) — 0.1
        - 23 Failure of EIS (per demand) — 1.00E-04
    - 19 Non-return valve failure (per demand) — 0.013
    - 20 Manual Valve Failure (per demand) — 0.50
    - 21 Double Check Valve Failure (per demand) — 2.60E-03

A-9a Failure of Flexible Hose during Loading to Vehicle (LPG released from the Hose Connecting to Dispenser)

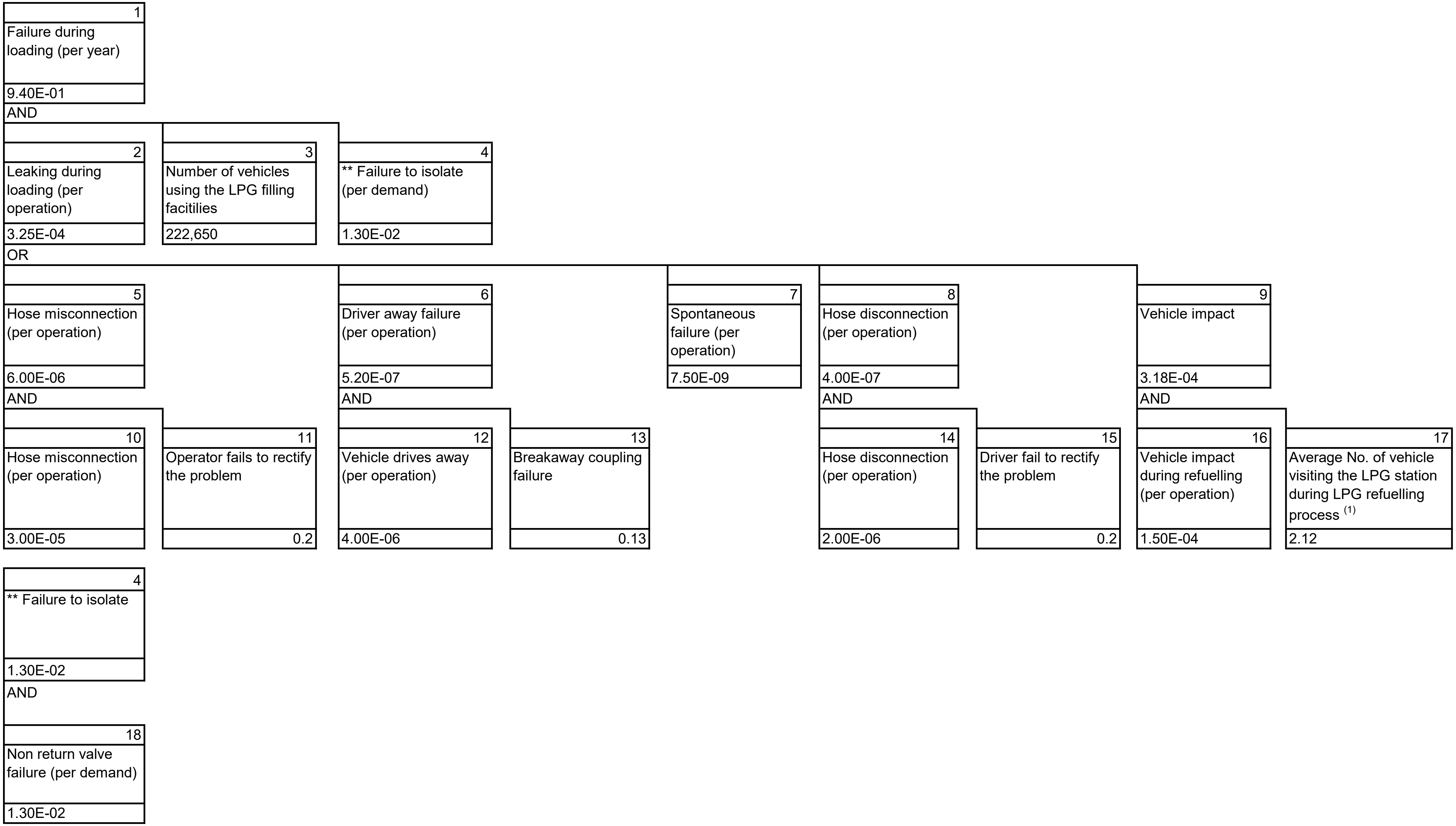
- **1** Failure during loading (per year) — 4.70E-01
  - AND
    - **2** Leaking during loading (per operation) — 3.25E-04
      - OR
        - **5** Hose misconnection (per operation) — 6.00E-06
          - AND
            - **10** Hose misconnection (per operation) — 3.00E-05
            - **11** Operator fails to rectify the problem — 0.2
        - **6** Driver away failure (per operation) — 5.20E-07
          - AND
            - **12** Vehicle drives away (per operation) — 4.00E-06
            - **13** Breakaway coupling failure — 0.13
        - **7** Spontaneous failure (per operation) — 7.50E-09
        - **8** Hose disconnection (per operation) — 4.00E-07
          - AND
            - **14** Hose disconnection (per operation) — 2.00E-06
            - **15** Driver fail to rectify the problem — 0.2
        - **9** Vehicle impact — 3.18E-04
          - AND
            - **16** Vehicle impact during refuelling (per operation) — 1.50E-04
            - **17** Average No. of vehicle visiting the LPG station during LPG refuelling process (1) — 2.12
    - **3** Number of vehicles using the LPG filling facitilies — 222,650
    - **4** ** Failure to isolate (per demand) — 6.51E-03

- **4** ** Failure to isolate — 6.51E-03
  - AND
    - **18** Emergency Isolation System (EIS) is not effective — 1.00E-01
      - OR
        - **21** Fail to activate EIS (per demand) — 0.1
        - **22** Failure of EIS (per demand) — 1.00E-04
    - **19** Manual Valve Failure (per demand) — 0.50
    - **20** Excess flow valve failure (per demand) — 0.13

Remarks:

(1) = (daily no. of vehicle visit/24 hours)/(60 mins) * average time of filling

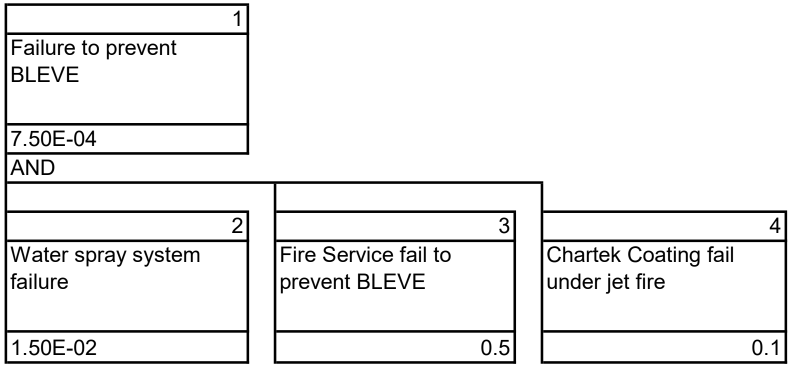
A-9b ***Failure of Flexible Hose during Loading to Vehicle (LPG released from the Hose Connecting to Vehicle)***



Remarks:

(1) = (daily no. of vehicle visit/24 hours)/(60 mins) * average time of refilling

A-10 ***Failure to Prevent BLEVE***



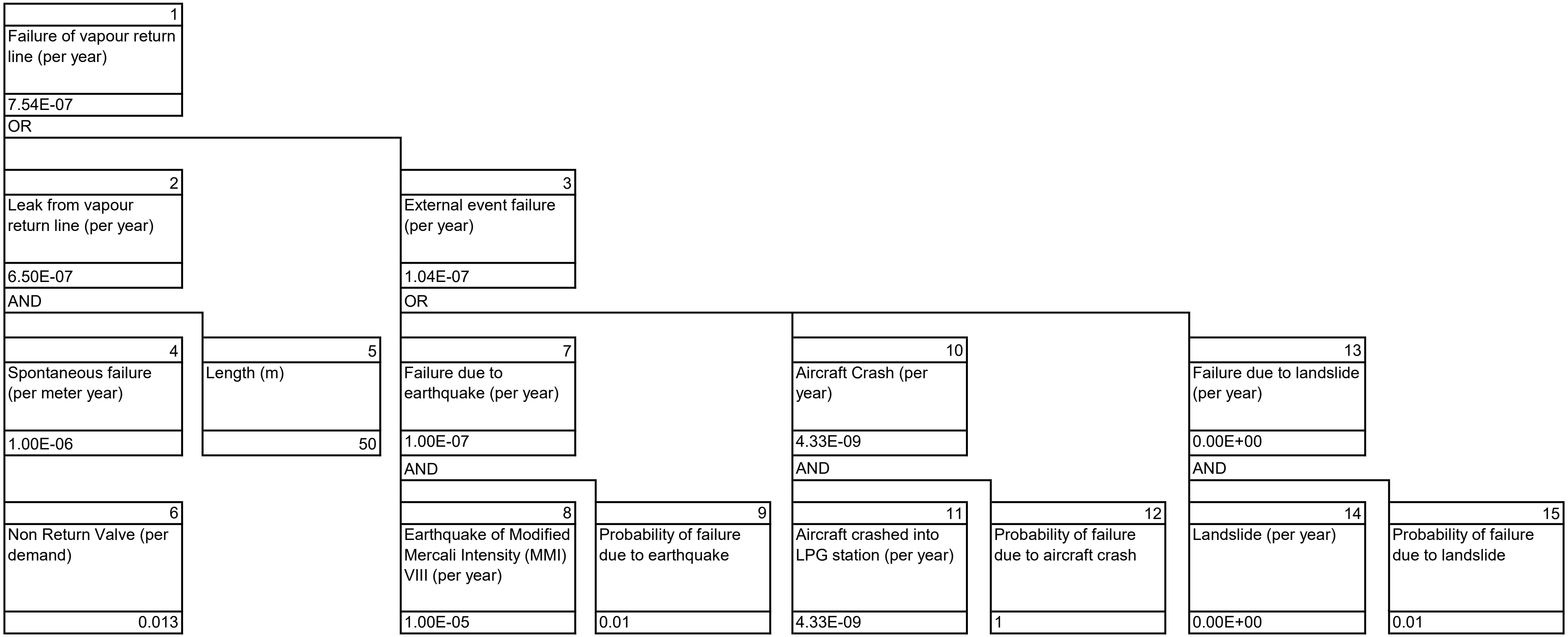
A-11 ***Leak From Pump Flange***

1	
Leak from Pump Flange (per year)	
4.36E-04	
AND	
2	3
Flange Faliure (per year)	No. of Flange
1.09E-04	4

A-12 ***Leak From Drain Valve***

1	
Leak from drain valve (per year)	
4.80E-04	
AND	
2	3
Valve fails to close (per operation)	No. of operation per year
2.00E-05	24

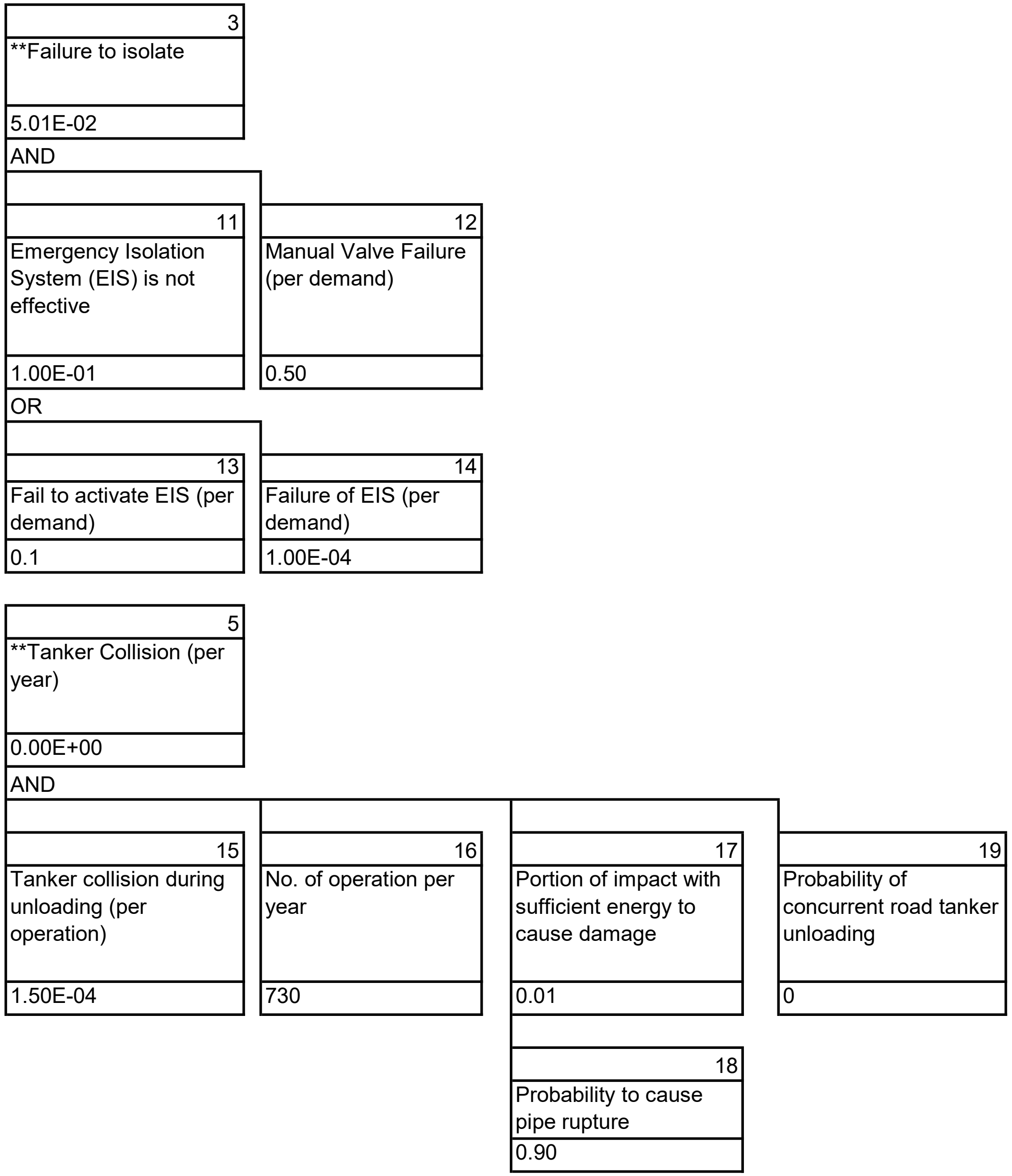
A-13 ***Failure of Vapour Return Line***



Guillotine Failure of liquid line from Road Tanker to loading hose

- **1** Guillotine failure of liquid line from tanker to loading hose (per year) — 8.50E-09
  - AND
    - **2** Guillotine failure of liquid line from tanker to loading hose (per year) — 1.70E-07
      - OR
        - **4** Spontaneous failure (per year) — 5.90E-08
          - AND
            - **8** Spontaneous failure (per metre per year) — 1.00E-06
            - **9** Length (m) — 0.5
            - **10** Portion of time on site — 0.118
        - **5** **Tanker Collision (per year) — 0.00E+00
        - **6** **Vehicle impact (per year) — 6.57E-09
        - **7** **External event failure (per year) — 1.04E-07
    - **3** **Failure to isolate — 5.01E-02

- **6** **Vehicle Impact (per year) — 6.57E-09
  - AND
    - **20** Vehicle impact into tanker during unloading (per operation) — 1.00E-08
    - **21** No. of operation per year — 730
    - **22** Portion of impact with sufficient energy to cause damage — 0.001
    - **23** probability to cause pipe rupture — 0.9


3
**Failure to isolate
5.01E-02
AND
11
Emergency Isolation System (EIS) is not effective
1.00E-01
12
Manual Valve Failure (per demand)
0.50
OR
13
Fail to activate EIS (per demand)
0.1
14
Failure of EIS (per demand)
1.00E-04
5
**Tanker Collision (per year)
0.00E+00
AND
15
Tanker collision during unloading (per operation)
1.50E-04
16
No. of operation per year
730
17
Portion of impact with sufficient energy to cause damage
0.01
19
Probability of concurrent road tanker unloading
0
18
Probability to cause pipe rupture
0.90

Guillotine Failure of liquid line from Road Tanker to loading hose (Con't)

- **7** — **External event failure (per year) — 1.04E-07
  - OR
    - **24** — Failure due to earthquake (per year) — 1.00E-07
      - AND
        - **25** — Earthquake of Modified Mercali Intensity (MMI) VIII (per year) — 1.00E-05
        - **26** — Probability of failure due to earthquake — 0.01
    - **27** — Aircraft Crash (per year) — 4.33E-09
      - AND
        - **28** — Aircraft crashed into LPG station (per year) — 4.33E-09
        - **29** — Probability of failure due to aircraft crash — 1
    - **30** — Failure due to landslide (per year) — 0.00E+00
      - AND
        - **31** — Landslide (per year) — 0.00E+00
        - **32** — Probability of failure due to landslide — 0.01

A-15a **BLEVE of LPG road tanker due to fire from LPG dispenser**

1	BLEVE of road tanker (per year)	4.08E-09

AND (1 = 2 × 3 × 4 × 5 × 6)

2	LPG dispenser failure (per year)	3.69E-03
3	Portion of release become jet fire	0.05
4	Portion of jet fire impinge on road tanker *	0.25
5	Portion of time for tanker on site	0.118
6	Failure to prevent BLEVE	7.50E-04

AND (6 = 7 × 8 × 9)

7	Water spray system failure	1.50E-02
8	Fire Service fail to prevent BLEVE	0.5
9	Chartek Coating fail under jet fire	0.1

* considering the road tanker unloading bay is within a quadant of a dispenser

A-15b **BLEVE of LPG road tanker due to fire from In-let Filling Pipework**

1	BLEVE of road tanker (per year)	2.35E-16

AND (1 = 2 × 3 × 4 × 5 × 6)

2	Failure of In-let filling pipework (per year)	1.06E-10
3	Portion of release become jet fire	0.05
4	Portion of jet fire impinge on road tanker **	0.5
5	Portion of time for tanker on site	0.118
6	Failure to prevent BLEVE	7.50E-04

AND (6 = 7 × 8 × 9)

7	Water spray system failure	1.50E-02
8	Fire Service fail to prevent BLEVE	0.5
9	Chartek Coating fail under jet fire	0.1

** considering the fire jet either towards or away from a road tanker

A-15c BLEVE of LPG road tanker due to fire from Liquid Supply Line to Dispenser

- 1 BLEVE of road tanker (per year): 1.17E-12
  - AND
    - 2 Failure of Liquid Supply Line to Dispenser (per year): 5.28E-07
    - 3 Portion of release become jet fire: 0.05
    - 4 Portion of jet fire impinge on road tanker **: 0.5
    - 5 Portion of time for tanker on site: 0.118
    - 6 Failure to prevent BLEVE: 7.50E-04
      - AND
        - 7 Water spray system failure: 1.50E-02
        - 8 Fire Service fail to prevent BLEVE: 0.5
        - 9 Chartek Coating fail under jet fire: 0.1

** considering the fire jet either towards or away from a road tanker

A-15d BLEVE of LPG road tanker due to fire from Flexible Hose during loading to underground vessel

- 1 BLEVE of road tanker (per year): 5.86E-11
  - AND
    - 2 Failure of Flexible Hose during loading to vessel (per year): 3.12E-06
    - 3 Portion of release become jet fire: 0.05
    - 4 Portion of jet fire impinge on road tanker **: 0.5
    - 5 Failure to prevent BLEVE: 7.50E-04
      - AND
        - 6 Water spray system failure: 1.50E-02
        - 7 Fire Service fail to prevent BLEVE: 0.5
        - 8 Chartek Coating fail under jet fire: 0.1

** considering the fire jet either towards or away from a road tanker

A-15e **BLEVE of LPG road tanker due to fire from Liquid Line (from tanker to loading hose)**

1	BLEVE of road tanker (per year)	1.59E-13

AND

2	Failure of Liquid Line from tanker to loading hose (per year)	8.50E-09
3	Portion of release become jet fire	0.05
4	Portion of jet fire impinge on road tanker **	0.5
5	Failure to prevent BLEVE	7.50E-04

5: AND

6	Water spray system failure	1.50E-02
7	Fire Service fail to prevent BLEVE	0.5
8	Chartek Coating fail under jet fire	0.1

** considering the fire jet either towards or away from a road tanker

A-15f **BLEVE of LPG road tanker due to other fire incidents**

1	BLEVE of road tanker (per year)	5.81E-09

AND

2	Fire incident from petrol filling facilities (per year)	6.56E-03
3	Portion of fire incident which is serious enough to endanager road tanker	0.01
4	Portion of time for tanker on site	0.118
5	Failure to prevent BLEVE	7.50E-04

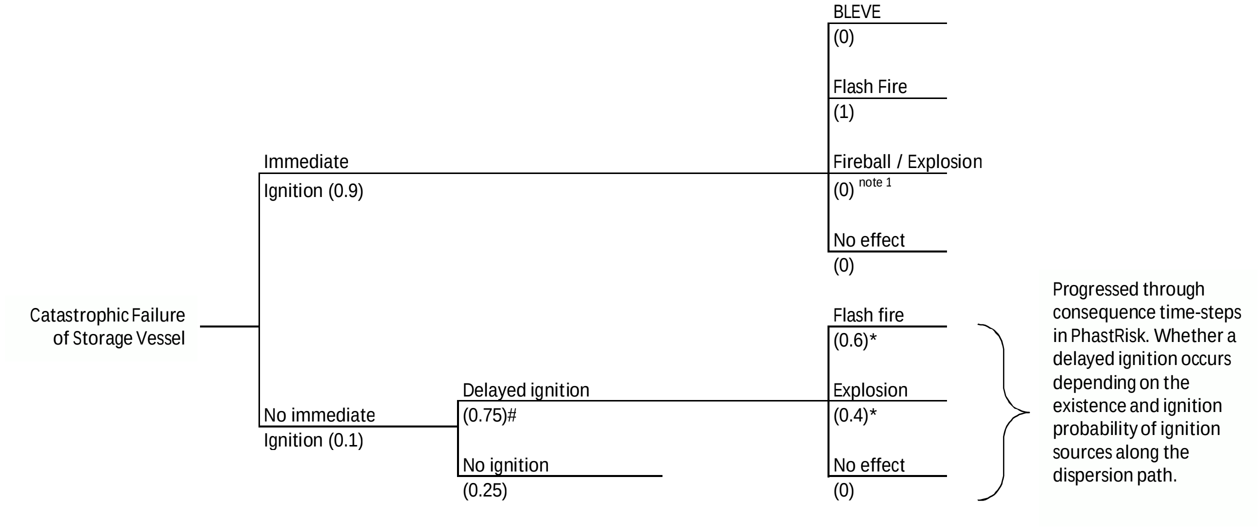
5: AND

6	Water spray system failure	1.50E-02
7	Fire Service fail to prevent BLEVE	0.5
8	Chartek Coating fail under jet fire	0.1

Annex D

Event Tree Analysis

Catastrophic Failure of Storage Vessel (Instantaneous release without rainout)

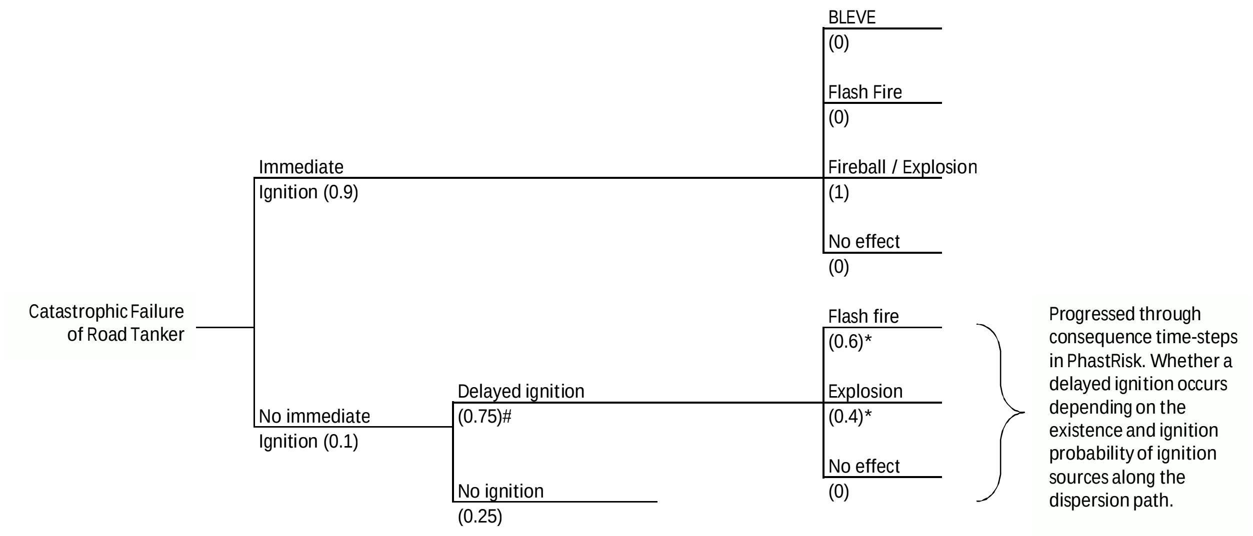


Note 1: applicable to mounded or underground tank only

* default in PhastRisk - based on TNO Purple Book

delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

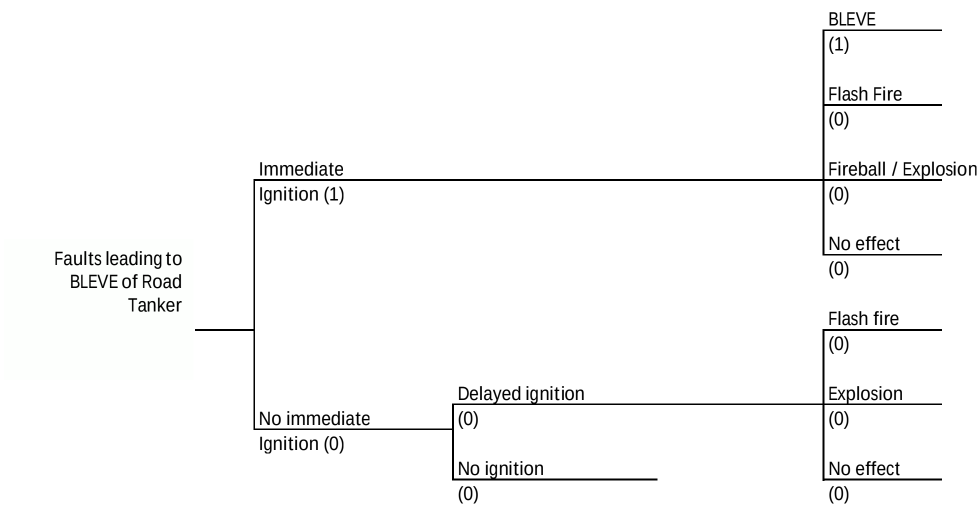
Catastrophic Failure of Road Tanker (Instantaneous release without rainout)



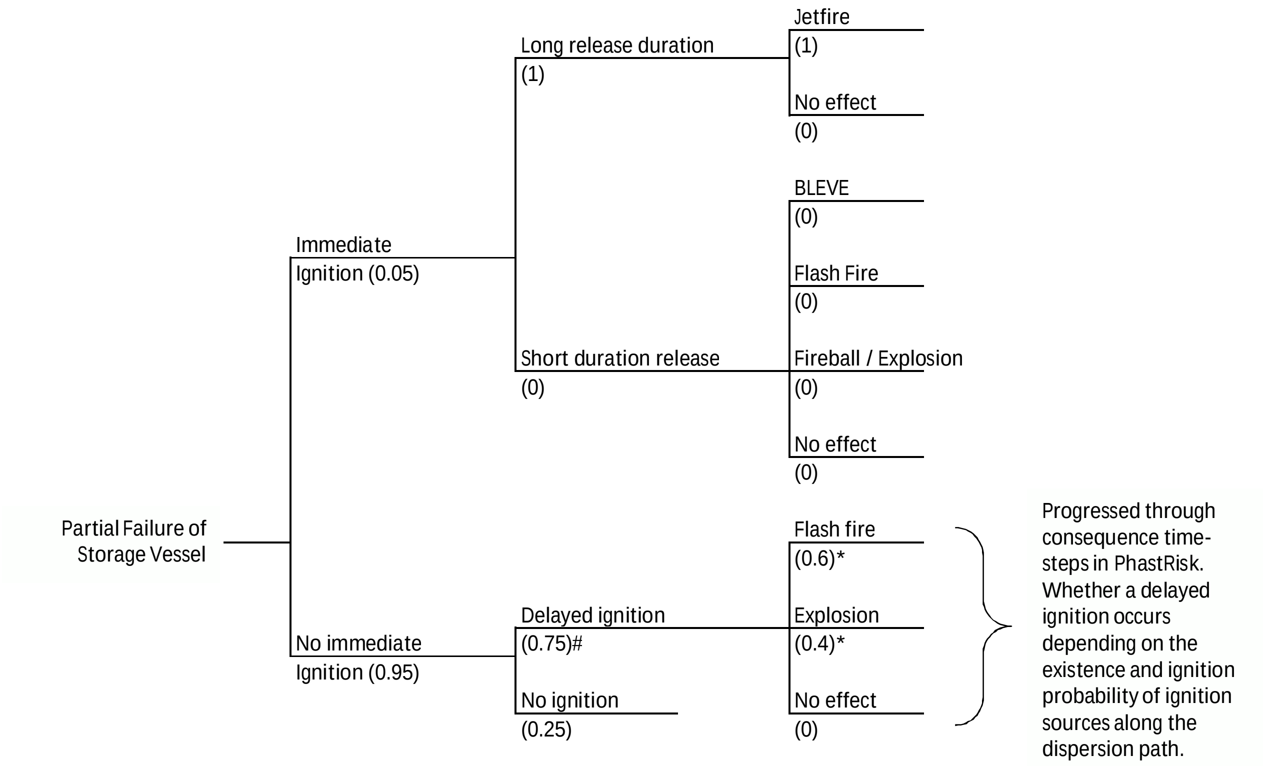
* default in PhastRisk - based on TNO Purple Book

delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

Faults leading to BLEVE of Road Tanker (Instantaneous release without rainout)

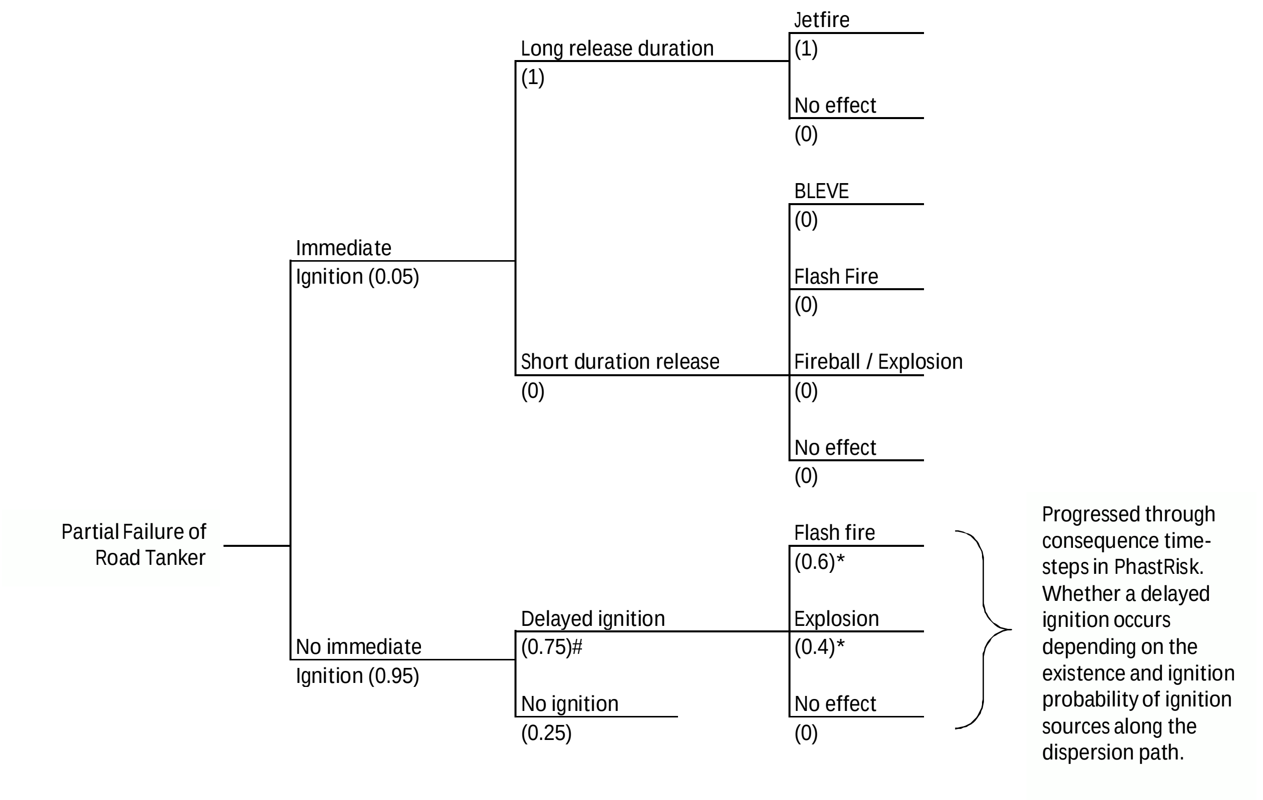


Partial Failure of Storage Vessel (Continuous release without rainout)



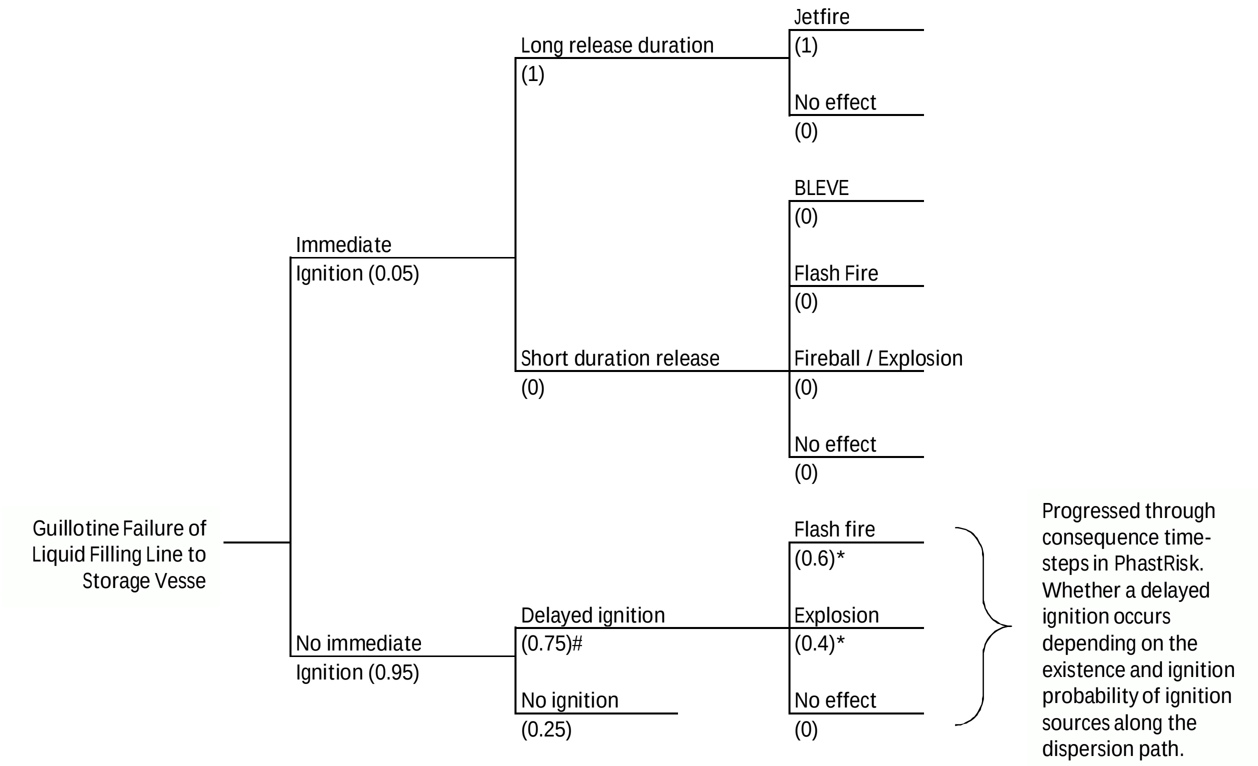
* default in PhastRisk - based on TNO Purple Book
\# delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

Partial Failure of Road Tanker (Continuous release without rainout)



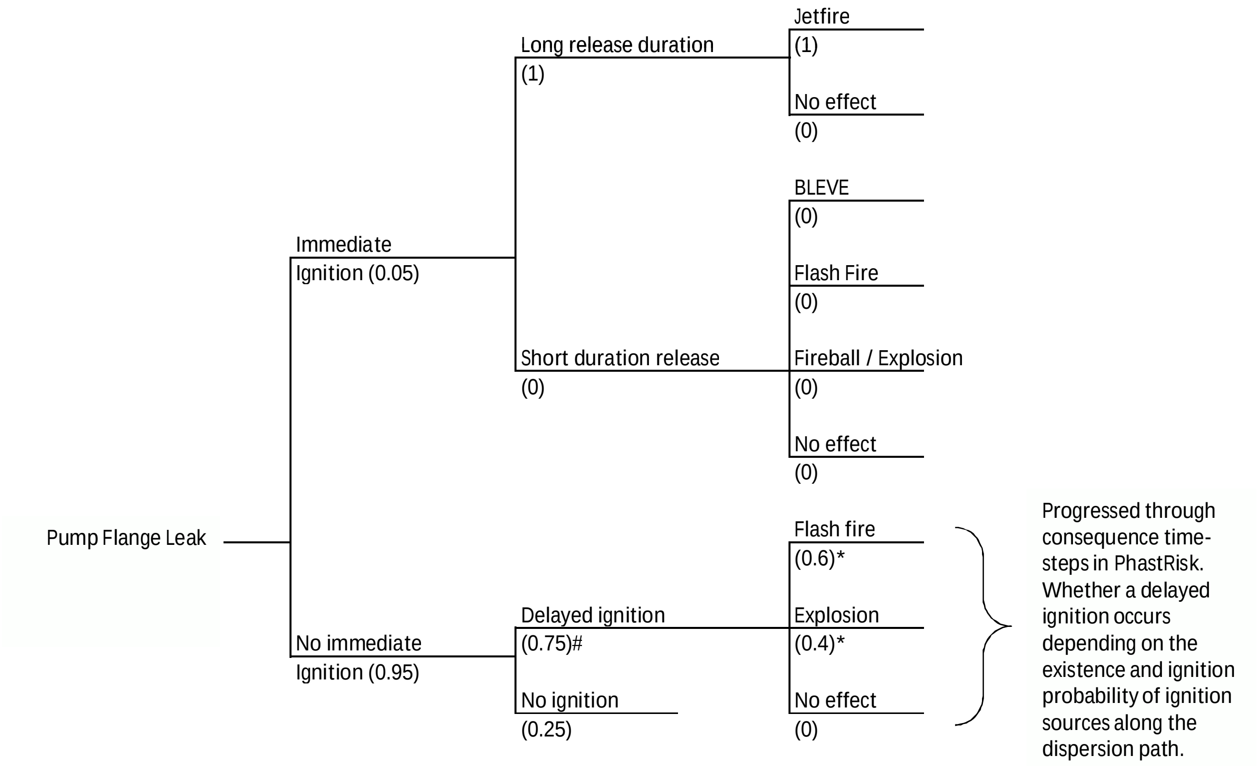
* default in PhastRisk - based on TNO Purple Book
\# delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

Guillotine Failure of Liquid Filling Line to Storage Vessel (Continuous release without rainout)



* default in PhastRisk - based on TNO Purple Book
delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

Pump Flange Leak (Continuous release without rainout)



* default in PhastRisk (p=0.6 for flash fire; p=0.4 for explosion) - based on TNO Purple Book.
delayed ignition probability varies from 0.4 to 0.75 for specified ignition sources and together with ignition due to population

Annex E

Information from Fire Services Department

消防處
香港九龍尖沙咀東部康莊道1號
消防總部大廈

FIRE SERVICES DEPARTMENT
FIRE SERVICES HEADQUARTERS BUILDING,
No.1 Hong Chong Road,
Tsim Sha Tsui, Kowloon,
Hong Kong.

本處檔號 OUR REF. : (2) in FSD/GR AI 22/03
來函檔號 YOUR REF. : R01501/c/wwck/3
電訊掛號 Telex : 39607 HKFSD HX (24 小時 Hours FAX)
圖文傳真 FAX: : 852-2739 5879
電話 TEL NO. : 852-2733 7818

6 June 2003

Maunsell Environment Management Consultants Ltd.
Room 1213-1219, Grand Central Plaza, Tower 2,
138 Shatin Rural Committee Road,
Shatin, New Territories,
Hong Kong.
(Attn.: Mr. Arthur Lee)

By fax only : 2891 0305

Dear Mr. Lee,

Quantitative Risk Assessment (QRA) of a LPG Compound at Repulse Bay

I refer to your letter of 28 May 2003.

I wish to inform you that we do not have any record of fire incidents under petrol filling station category before 1995, as such, I can only provide you below with the number of incidents in Petrol Filling Stations after 1995:-

Year	Number of Incidents in Petrol Filling Station
1995	4
1996	2
1997	2
1998	4
1999	1
2000	2
2001	0
2002	1
2003 (Up to March)	0

Yours faithfully,

(TSANG Wan-hing)
for Director of Fire Services

Ref. Number and date should be quoted in reference to this letter
凡提及本信時請引述檔號及日期

TOTAL P.01

消 防 處
香港九龍尖沙咀東康莊道1號
消防總部大廈

FIRE SERVICES DEPARTMENT
FIRE SERVICES HEADQUARTERS BUILDING
No.1 Hong Chong Road
Tsim Sha Tsui East Kowloon
Hong Kong

本處檔號	Our Ref.:	(2) in FSD/GR AI 9/08
來函檔號	Your Ref.:	
電子郵件	E-mail:	hkfsdenq@hkfsd.gov.hk
圖文傳真	Fax:	852-2739 5879
電　　話	Tel No.:	852-2733 7818

26 June 2008

ENSR Asia(HK) Ltd
11/F Grand Central Plaza, Tower 2,
138 Shatin Rural Committee, Shatin,
Hong Kong

By fax only : 2891 0305

Dear Mr. Hung,

Code on Access to Information
Fire Incidents Records under
Fuel Filling Station
From 2003 to present

I refer to your email dated 20 June 2008.

2. Please be advised that the number of incidents in Fuel Filling Station as follows:-

Year	Number of Incidents in Fuel (Petrol/LPG/Petrol cum LPG) Filling Station
2003	1
2004	0
2005	2
2006	0
2007	0
2008 (up to Feb)	0

Yours faithfully,

(CHUI Man-leung)
for Director of Fire Services

REF. NUMBER AND DATE SHOULD BE QUOTED IN REFERENCE TO THIS LETTER
凡提及本信時請引述編號及日期

消 防 處
香港九龍尖沙咀東康莊道 1 號
消防總部大廈

FIRE SERVICES DEPARTMENT
FIRE SERVICES HEADQUARTERS BUILDING
No.1 Hong Chong Road
Tsim Sha Tsui East Kowloon
Hong Kong

本處檔號 Our Ref. : (139) in FSD GR 6-5/5 R
來函檔號 Your Ref. : 60268214/C/atym12100812
電子郵件 E-mail : hkfsdenq@hkfsd.gov.hk
圖文傳真 Fax : 852-2739 5879
電 話 Tel No. : 852-2733 7818

AECOM RECEIVED ON 2012 OCT 22 A 11:34

18 October 2012

AECOM
8/F, Grand Central Plaza; Tower 2,
138 Shatin Rurai Committee Road, Shatin,
Hong Kong
(Attn: Ms. Angie TAI, Assistant Environmental Consultant)

Dear Ms. TAI,

Request for Fire Incidents Records under
Fuel Filling Station Category from Year 2008 to Present

Reference is made to your letter dated 8 October 2012.

Please be advised that the statistical information pertaining to the captioned subject is as follows:-

Year	**Number of Incidents in Fuel (Petrol/LPG/Petrol cum LPG) Filling Station**
2008	0
2009	3
2010	1
2011	0
2012 (Jan to Jun)	0

Should you have any queries, please feel free to contact Miss CHAN at 2733 7532.

Yours sincerely,

(YEUNG Ping-kwai)
for Director of Fire Services

消 防 處
香港九龍尖沙咀東部康莊道1號
消防總部大廈

FIRE SERVICES DEPARTMENT
FIRE SERVICES HEADQUARTERS BUILDING,
No.1 Hong Chong Road,
Tsim Sha Tsui East, Kowloon,
Hong Kong.

本處檔號 **OUR REF.** : (143) in FSD GR 6-5/4 R Pt. 15
來函檔號 **YOUR REF.** : 60544159/C/LCWW1705242
電子郵件 **E-mail** : hkfsdenq@hkfsd.gov.hk
圖文傳真 **FAX NO.** : 2739 5879
電 話 **TEL NO.** : 2733 7741

15 June 2017

AECOM Asia Co. Ltd.
8/F, Grand Central Plaza, Tower 2,
138 Shatin Rural Committee Road,
Shatin, Hong Kong.
(Attn: Ms. Benita KUNG, Associate Environment)

Dear Ms. KUNG,

Request for Fire Incidents Records
<u>under Fuel Filing Station Category from Year 2012 to Present</u>

Reference is made to your letter dated 24.5.2017.

Please be advised that the statistical information pertaining to the captioned subject is as follows:-

Year	**Number of Incidents in Fuel (Petrol/LPG/Petrol cum LPG) Filing Station**
2012	1
2013	1
2014	2
2015	0
2016	0
2017 (Jan to May)	1

If you have further questions, please feel free to contact the undersigned.

Yours sincerely,

(CHEU Yu-kok)
for Director of Fire Services

Ref. number and date should be quoted in reference to this letter
凡提及本信時請引述編號及日期

消 防 處
香港九龍尖沙咀東部康莊道1號
消防總部大廈

FIRE SERVICES DEPARTMENT
FIRE SERVICES HEADQUARTERS BUILDING,
No.1 Hong Chong Road,
Tsim Sha Tsui East, Kowloon,
Hong Kong.

本處檔號 OUR REF. : (54) in FSD GR 6-5/4 R Pt. 25
來函檔號 YOUR REF. : 60611423/C/TWYC1912021
電子郵件 E-mail : hkfsdenq@hkfsd.gov.hk
圖文傳真 FAX NO. : 2739 5879
電 話 TEL NO. : 2733 7741

19 December 2019

AECOM Asia Co. Ltd.
8/F, Grand Central Plaza, Tower 2,
138 Shatin Rural Committee Road,
Shatin, Hong Kong.
(Attn: Ms. Connie TSAI, Senior Environmental Consultant)

Dear Ms. TSAI,

Request for Fire Incidents Records
under Fuel Filling Station Category from Year 2017 to Present

Reference is made to your letter dated 2.12.2019.

Please be advised that the statistical information pertaining to the captioned subject is as follows:-

Year	**Number of Incidents in Fuel (Petrol/LPG/Petrol cum LPG) Filling Station**
2017	3
2018	2
2019 (Jan to Nov)	0

If you have further questions, please feel free to contact the undersigned.

Yours sincerely,

(TANG Long-kiu)
for Director of Fire Services