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**.

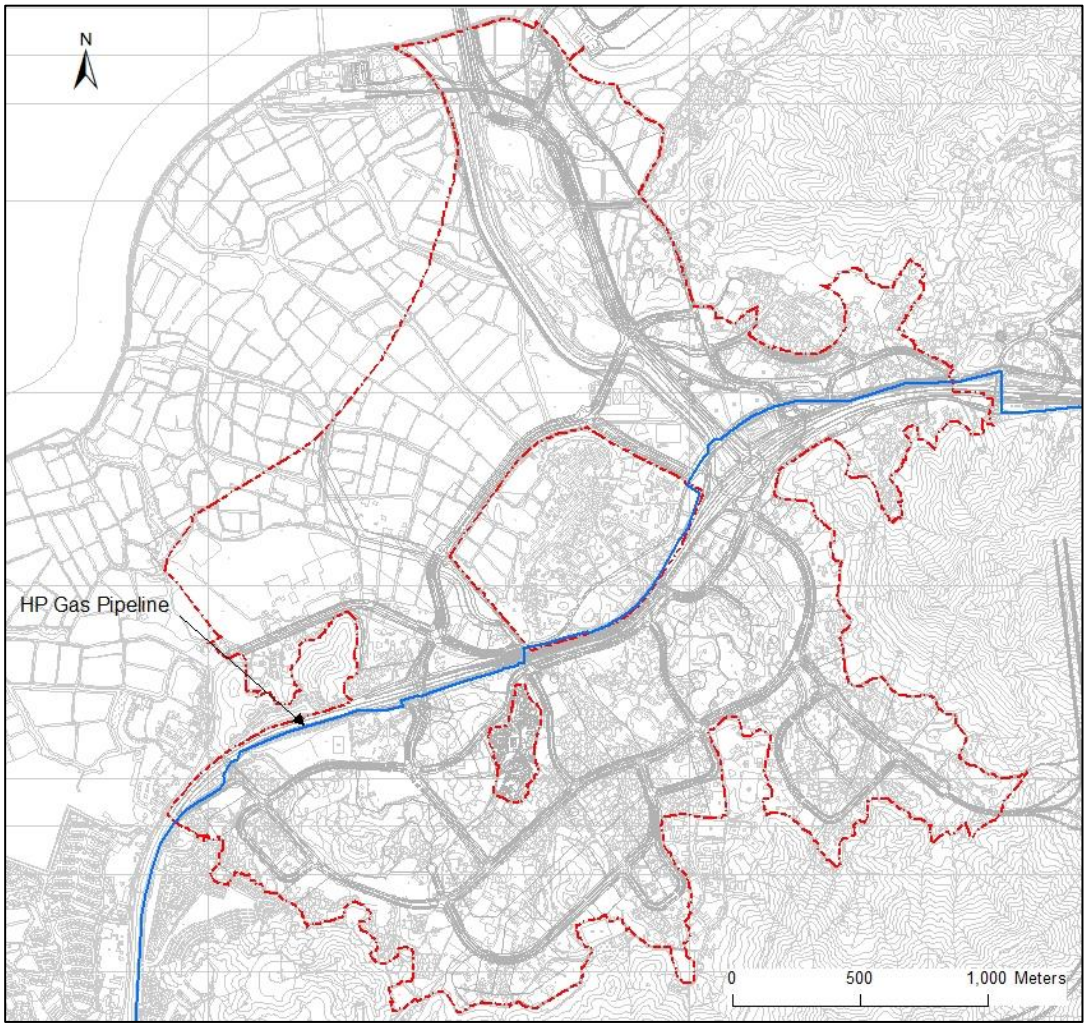

Plate 1-1 Location of the Project Site

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**.

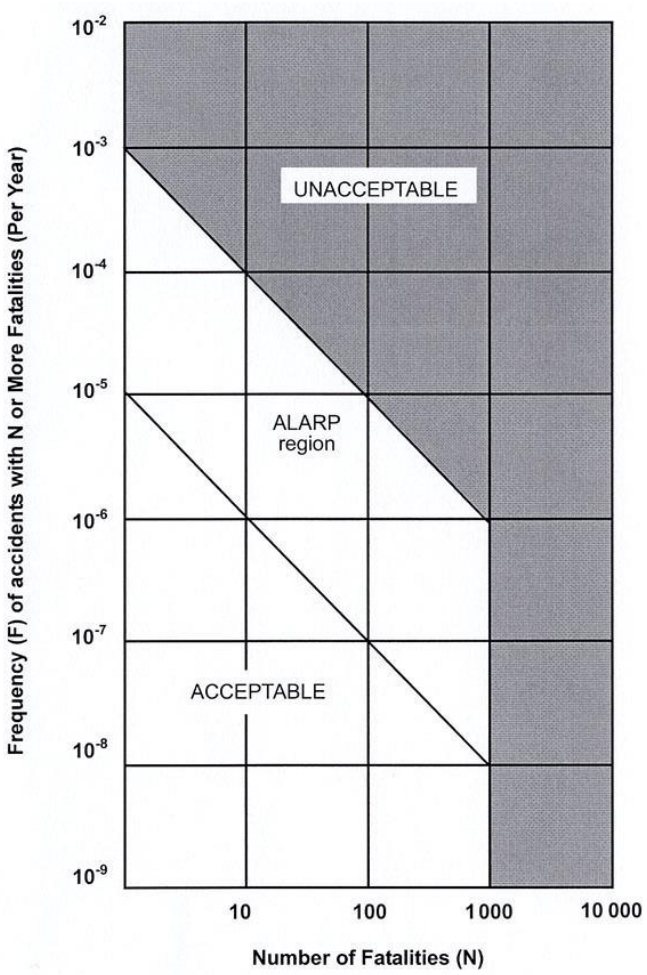

Plate 1-2 Societal Risk Guidelines

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.

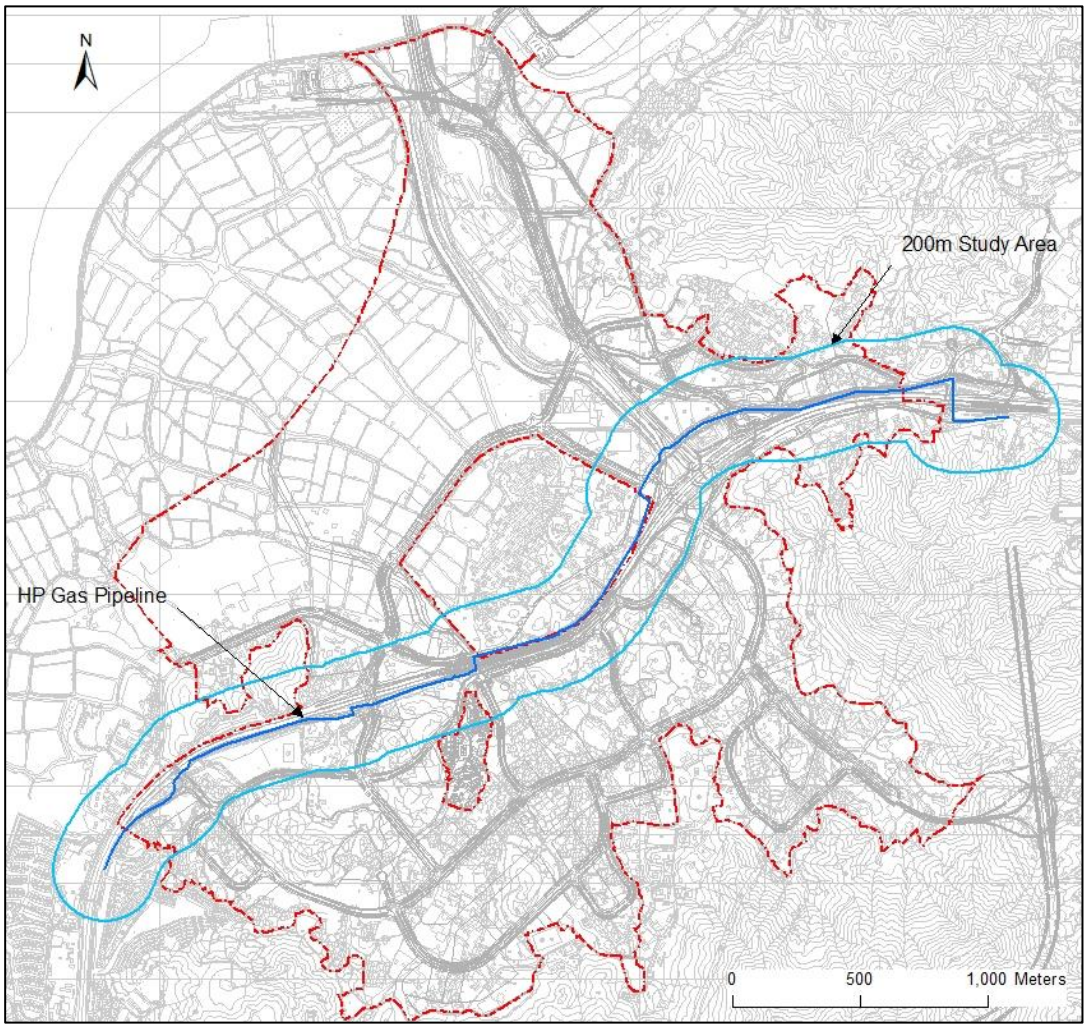

Plate 2-1 Study Area for HP Gas Pipeline

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**.

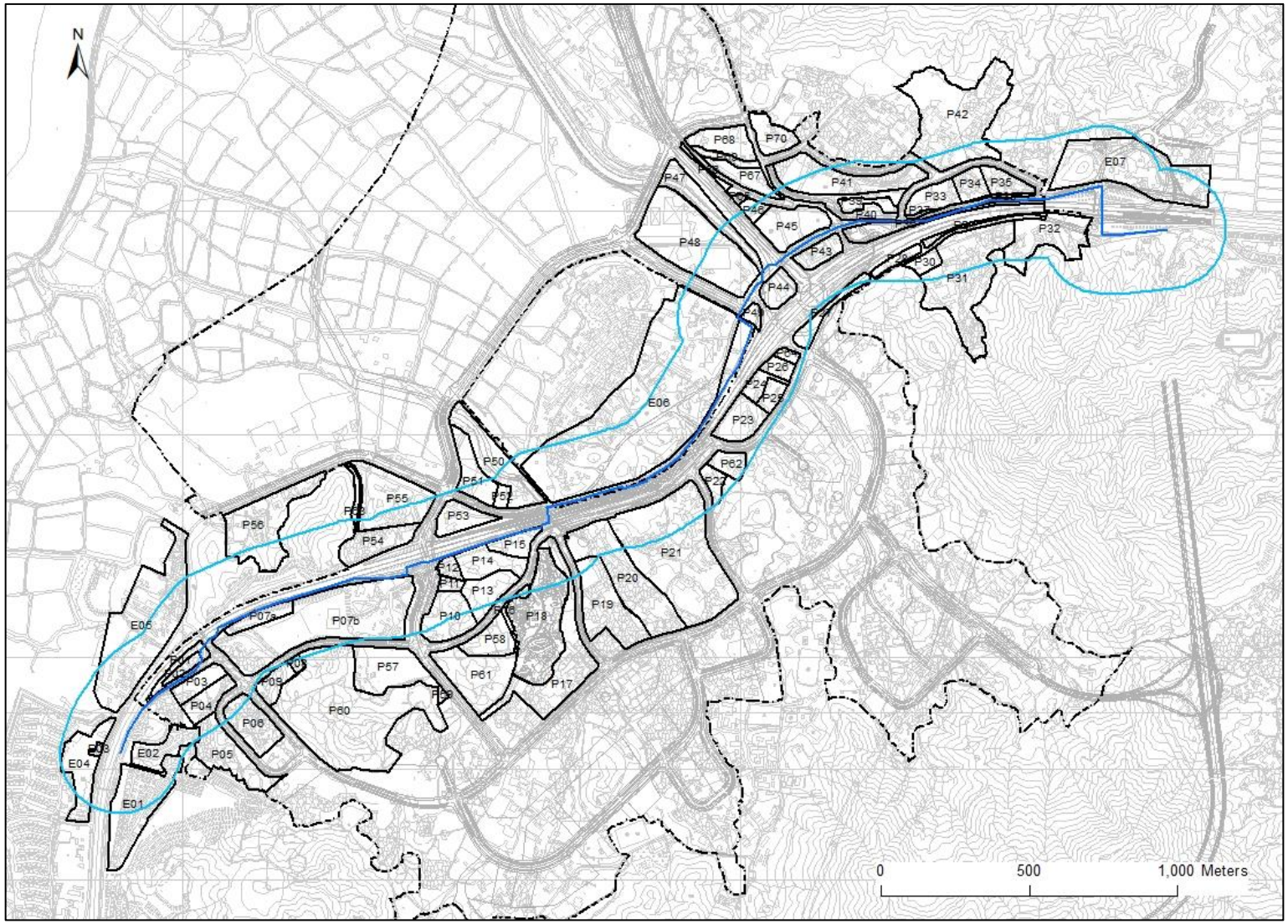

Plate 2-2 Locations of Land and Population Groups

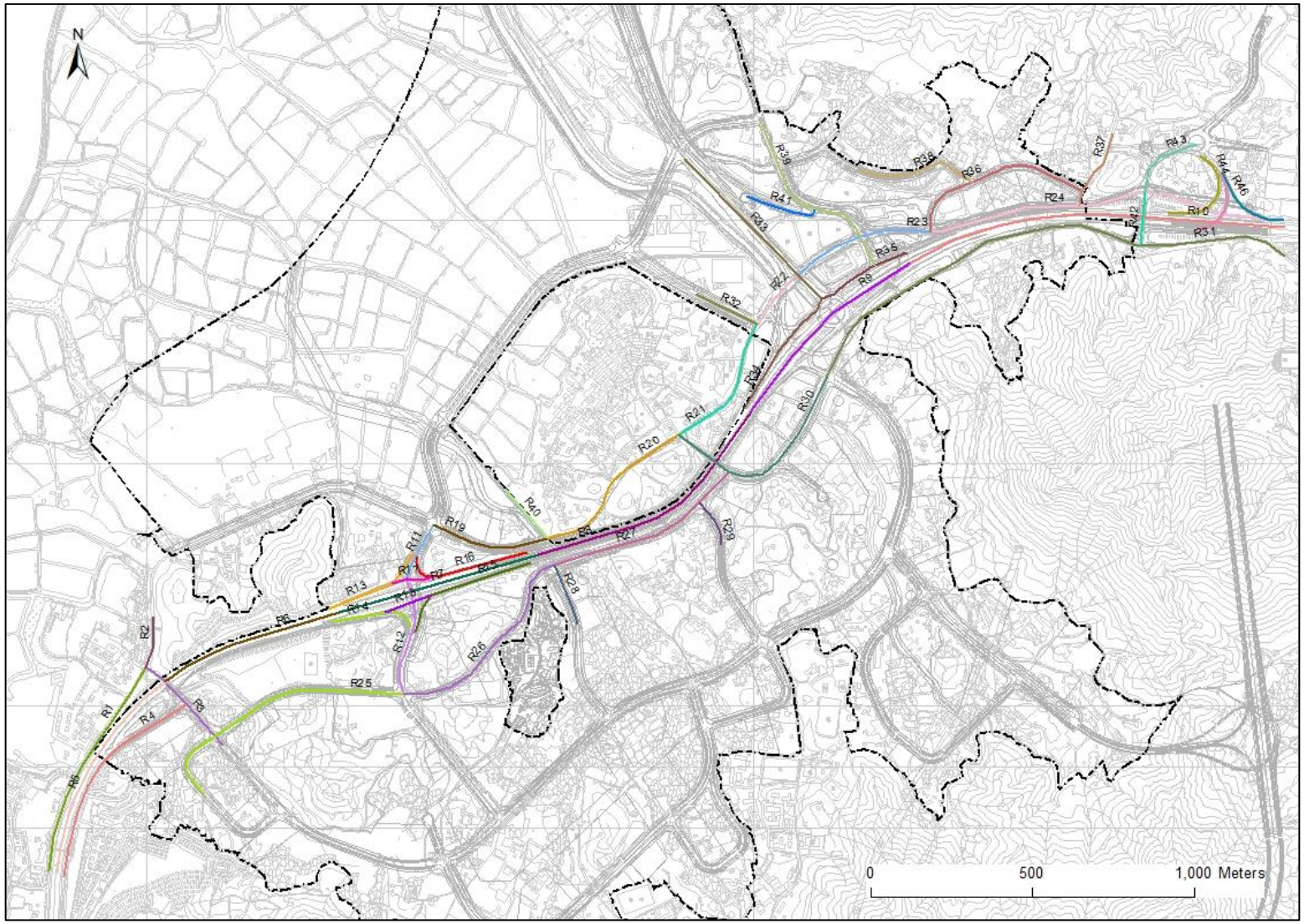

Plate 2-3 Locations of Road Population Groups

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**.

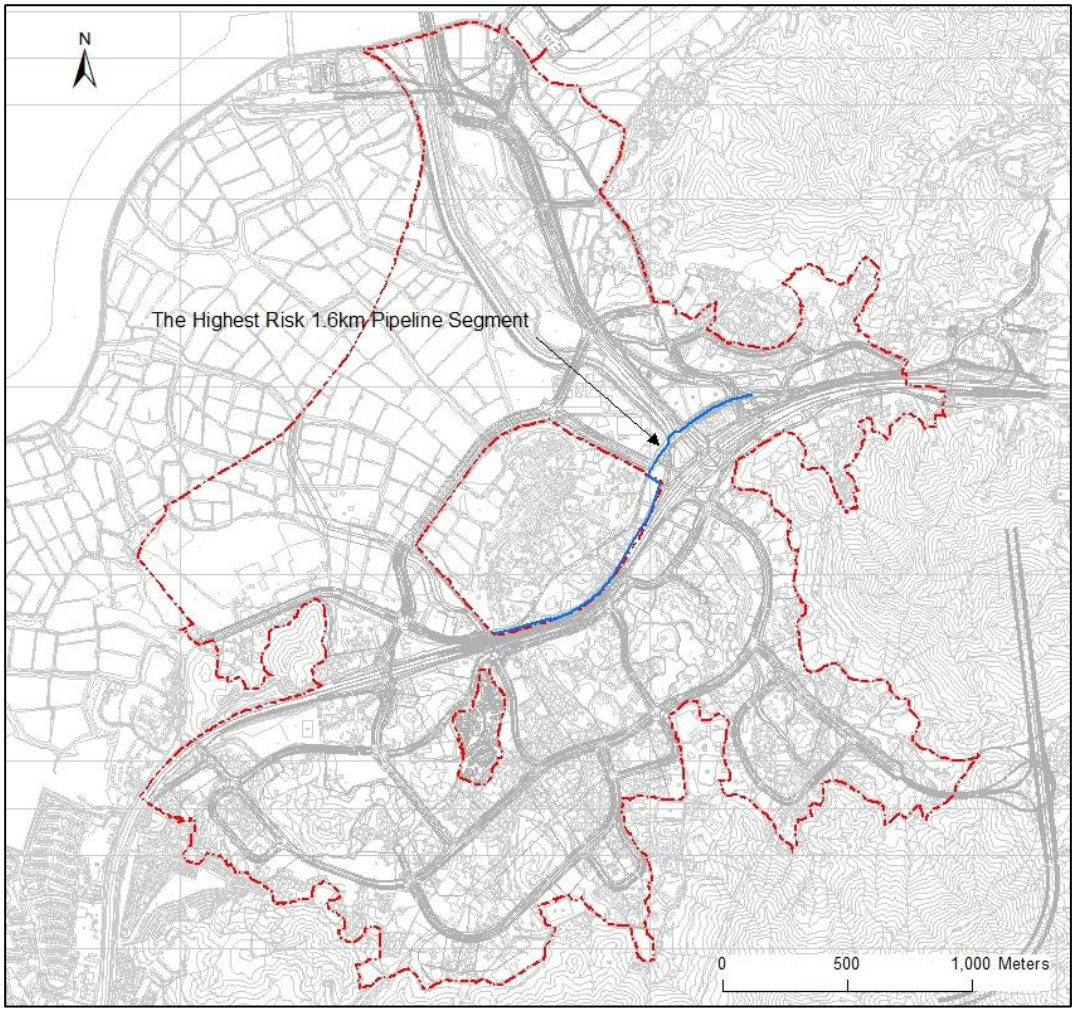

Plate 3-1 The Highest Risk 1.6km Pipeline Segment

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

$V = t \times I^{4/3}$

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.

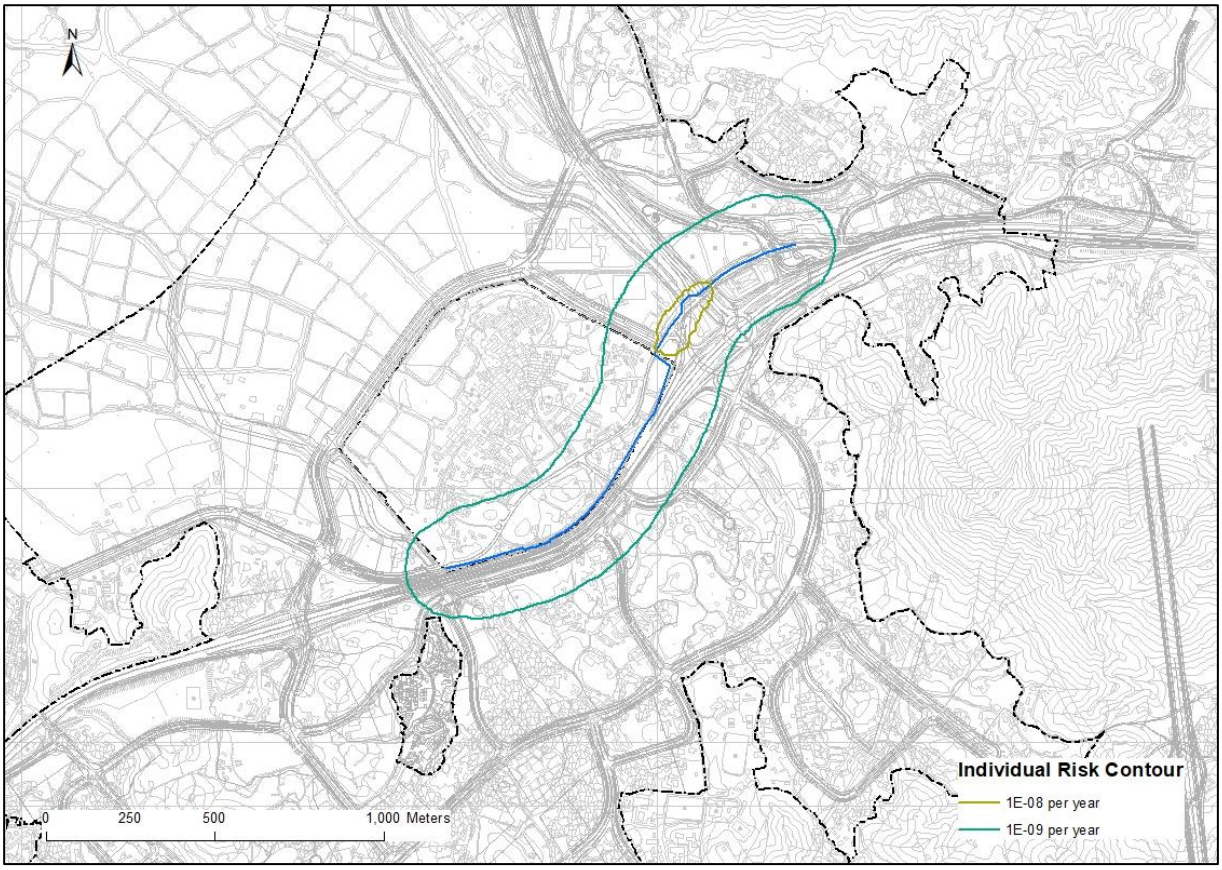

Plate 6-1 Individual Risk Contour for the HP Gas Pipeline

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.

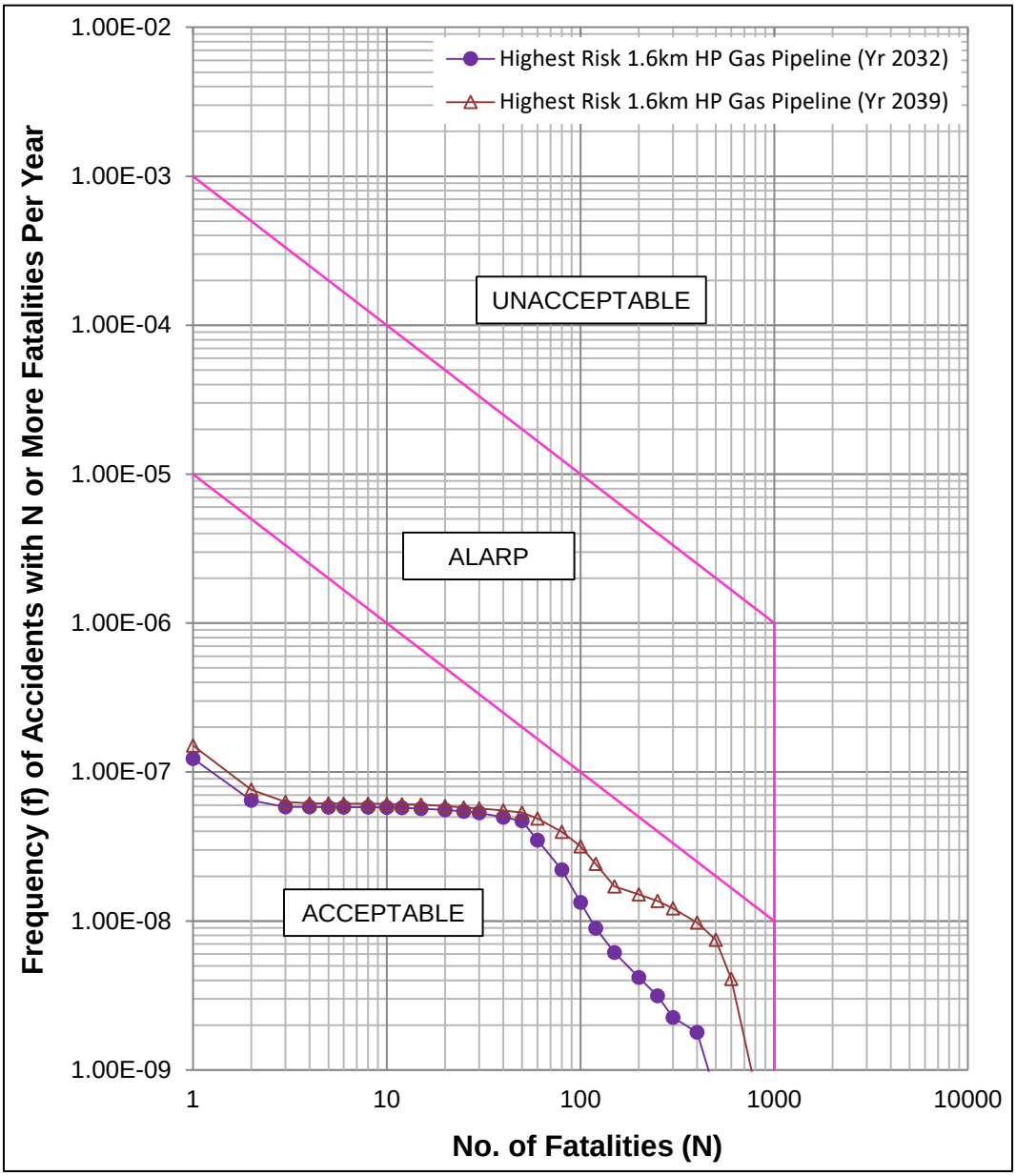

Plate 6-2 Societal Risk Curve in Comparison with HKRG

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			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

	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 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:

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

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,

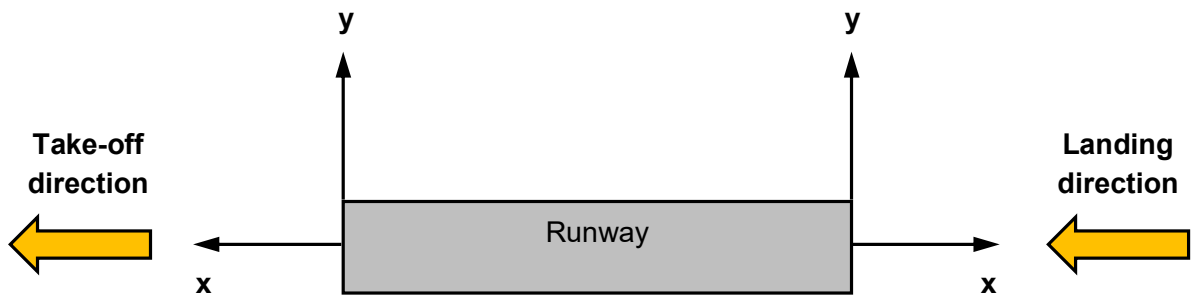
$$F_L(x,y) = \frac{(x+3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625e^{-\frac{|y|}{0.4}} + 0.005e^{-\frac{|y|}{5}}\right] \quad (2)$$

For aircraft takeoff, for x > -0.6km,

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

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 2009-20182. 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

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