9 HAZARD ASSESSMENT

9.1 Introduction

This assessment is based on the criteria and guidelines for evaluation and assessment of hazard to life as stated in Annex 4 of the TM-EIAO and covers the scope outlined in Section 3.4.11 of the EIA Study Brief.

9.2 Scope of Hazard to Life Assessment

A summary of the requirements on the Hazard Assessment for the Project as specified in Section 3.4.11 of the EIA study brief (ESB-156/2006) is reproduced below.

Ma Tau Kok Gas Works (MTKGW) – The Applicant shall investigate methods to avoid and/ or minimise risks from drawing towngas into the tunnel through the supply-air-only ventilation building at the junction of To Kwa Wan Road and San Ma Tau Street, in the event of potential gas leak from MTKGW. The Applicant shall carry out hazard assessment to evaluate potential hazardous scenarios from MTKGW to the operation of the Project. The hazard assessment shall include the following:

1. *Identification of hazardous scenarios requiring Quantitative Risk Assessment (QRA) associated with the draw in of towngas leak from the MTKGW;*
2. *Execution of a QRA expressing population risks in both individual and societal terms;*
3. *Comparison of individual and societal risks with the criteria for evaluating hazard to life stipulated in Annex 4 of the TM-EIAO; and*
4. *Identification and assessment of practicable and cost-effective risk mitigation measures, including the consideration for alternative siting for the supply-air-only ventilation building at the junction of To Kwa Wan Road and San Ma Tau Street.*

Explosives – The Applicant shall investigate alternative construction method to avoid the use of explosives. If there is use of explosives for the construction activities and the storage or blasting location is in close vicinity of populated areas, LPG fuelling station and/ or Potentially Hazardous Installation site (e.g. Ma Tau Kok Gas Works), the Applicant shall carry out hazard assessment as follow:

1. *Identify hazardous scenarios associated with the transport, storage and use of explosives and then determine a set of relevant scenarios to be included in a Quantitative Risk Assessment (QRA);*
2. *Execute a QRA of the set of hazardous scenarios determined in (1), expressing population risks in both individual and societal terms;*
3. *Compare individual and societal risks with the criteria for evaluating hazard to life stipulated in Annex 4 of the TM-EIAO; and*
4. *Identify and assess practicable and cost-effective risk mitigation measures.*

During the design development of the Project, the originally proposed fresh air supply ventilation building at the junction of To Kwa Wan Road and San Ma Tau Street has been removed. Hence studying on the possibility of released towngas being drawn into the Central Kowloon Route (CKR) tunnel is not necessary.

Different tunnel construction methods have been considered for CKR in the alternative construction method technical report [9-34], and non-blasting method has been adopted where it is feasible.

The two basic methods for constructing a bored tunnel are the tunnel boring machine (TBM) method and the drill-and-blast method. The TBM method entails using a TBM to bore through the ground to form a circular tunnel, which is then lined with concrete. However, each bore of the CKR tunnel will have a minimum width of about 17m, which is considered large for a bored tunnel. Hence, an extremely large and powerful TBM would be required for CKR. Currently, such large TBM does not exist. Besides, CKR will pass through very hard granite that could cause extreme wear and tear to the TBM and cause excessive downtime.

By comparison, the drill-and-blast method is considered the most practicable and effective method for constructing the bored tunnel section of CKR. This method is the traditional method for boring through hard rocks, such as granite, and has been used successfully in many previous road projects in Hong Kong. It entails a cyclic process of drilling small holes into the tunnel face, filling the holes with explosives and blasting the rock into smaller fragments to ease removal of rocks. Given that CKR is located in an urban environment, the blasting will be strictly controlled to minimise vibrations at the various buildings and structures above the tunnel.

In certain locations, the drill-and-break method (i.e. a non-blasting technique) will be used. The drill-and-break method normally entails an alternative cyclic process of drilling the tunnel face with small drills to form a “Swiss cheese” structure in the rock, which can then be broken up using rock breakers. This method is however laborious, and will only be used when the work channel is passing close to various sensitive structures.

In view of the presence of existing MTRC Tsuen Wan Line (TWL), East Rail Line (ERL), future Kwun Tong Line Extension (KTE) and Shatin to Central Link (SCL), to control the blasting vibration within the Railway Protection Limits required by MTRC, a low charge weight will be applied at blasting sections near the Tsuen Wan Line, East Rail Line, future Kwun Tong Line Extension and Shatin to Central Link to minimise the vibrations.

Due to the limited daily mucking out capacity, one blasting operation cycle per day will be adopted in CKR. Besides, owing to lack of suitable locations, it is considered that no temporary explosive magazine should be established. Sufficient time for execution of the blasting works is put into consideration in the project implementation programme with the assumptions that one explosive delivery per day is achieved, sufficient time will be allowed for execution of each blast. Delivery of explosives (cartridged emulsion explosives and detonators) and explosive accessories (detonating cords and cast boosters) will be performed by Mines Division daily from the Government Explosives Depot, using Mines Division’s explosive delivery vehicles, arriving at Ho Man Tin (HMT) access point of CKR project. Explosives required at all three access points will be unloaded at the HMT offloading point. Explosives required at Yau Ma Tei (YMT) and Ma Tau Kok (MTK) access points will then be delivered from HMT access points by the appointed contractors using approved vehicles. Risks arising from the transport and use of explosives will be evaluated according to the location and frequency of blasting for the Project. The overall layout plan for Central Kowloon Route is shown in **Appendix 9.1**.

The scope of this Hazard to Life Assessment report includes the following items:

- Transport of explosives (cartridged emulsion explosives and other blasting accessories including detonator, detonating cord and cast booster) from the Mines Division vehicle offloading point (proposed offloading point is at Ho Man Tin) to other CKR construction sites (Yau Ma Tei and Ma Tau Kok); and
- Use of explosives during construction of the CKR, including the use of cartridged and bulk emulsion explosives.

9.3 Hazard to Life Assessment Objectives and Risk Criteria

The main objective of this Hazard to Life Assessment is to demonstrate that the Risk Criteria set in Annex 4 of the TM-EIAO will be met during the construction of the CKR, and to identify practical mitigation measures where applicable to ensure the risk criteria are met, with particular focus on:

- Identifying hazardous scenarios during transport and use of explosives for blasting operations;
- Preparing a Quantitative Risk Assessment (QRA) to estimate risks to the surrounding population in both individual and societal terms;
- Comparing individual and societal risks with the Risk Criteria set in Annex 4 of the TM-EIAO to determine the acceptability of the CKR Project in terms of risk; and
- Recommending practicable and cost effective risk mitigation measures to demonstrate the compliance with the Risk Criteria, if the risk is not "Acceptable".

As set out in Annex 4 of the TM-EIAO, the risk criteria comprise two components as follows:

1. Individual Risk Criteria: The maximum level of off-site individual risk should not exceed 1 in 100,000 per year, i.e. 1×10^{-5} per year.
2. Societal Risk Criteria: The Societal Risk Criteria can be presented graphically as in **Appendix 9.2**. It is expressed in terms of F-N curves, which are lines plotting the frequency of occurrence (F) with N or more fatalities per year at the facility of concern. There are three areas shown:

- Acceptable where risks are adequately low that no action is necessary;
- Unacceptable where risks are so high that they should usually be reduced regardless of the cost or else the hazardous activity should not proceed; and
- ALARP (As Low As Reasonably Practicable) where the risks associated with the hazardous activity should be reduced to a level "as low as reasonably practicable", in which the priority of measures is established on the basis of practicability and cost to implement versus risk reduction achieved.

9.4 Approach of the Hazard to Life Assessment

This section outlined the approach adopted in this Hazard Assessment (HA) for transport and use of explosives in the Project. The HA consists of the following tasks:

1. Data/ Information Collection
2. Hazard Identification
3. Frequency Assessment
4. Consequence Assessment
5. Risk Analysis
6. Risk Mitigation and Recommendations

Data/ Information Collection

Relevant data/ information for the Project, such as population data, types and properties of explosives, blasting location and schedules, recommended charge weights, and explosives transport conditions, have been collected.

Population data in the vicinity of the blasting locations are obtained through detailed estimation based on population planning data and site survey. Road traffic population have been considered using representative figures from the Annual Traffic Census [9-38] to estimate the road traffic population. Pedestrian densities have also been applied to account for the pedestrian population along the explosives delivery route.

Hazard Identification

A review of industry incidents involving explosives, registered in relevant databases, has been carried out with regard to the types of explosives used and the operations for the CKR Project. Incidents which are applicable in the context of the CKR Project have been analysed in **Section 9.10**. Potential causes of hazard events have been carefully identified, and a set of relevant scenarios to be included in the HA for further assessment has been determined with reference to similar studies. Details of hazard identification are given in **Section 9.9**.

Frequency Assessment

The likelihoods of occurrence of the identified hazardous scenarios have been estimated using best available incident data. Frequency data used in recent risk assessments regarding explosives, such as the MTR West Island Line (WIL) EIA [9-1], MTR Express Rail Link (XRL) EIA [9-12], and Kwun Tong Line Extension EIA [9-39] have been referred and adopted. The frequencies documented in relevant data source have been reviewed to reflect the specific operations at the blasting locations along the CKR Project. Details of frequency assessment for transport and use of explosives are given in **Section 9.11** and **Section 9.12** respectively.

Consequence Assessment

The consequences have been established for every outcome developed from initial event by using internationally well recognised consequence modelling software to assess the impacts from overpressure, building collapse, fireball and thermal radiation, excessive ground vibration and other possible hazards. Quantity of explosives at a hazardous source is estimated from the blasting and the Project explosives transport schedule. Fatality probabilities of various hazardous event outcomes have been evaluated at a number of end-point criteria in each type of hazard outcome. Details of consequence assessment are illustrated in **Section 9.13.**

Risk Analysis

From the above analyses, societal and individual risk levels are calculated for the whole CKR Project during construction using internationally well recognised risk summation software. By summing up all hazard events, individual risk and societal risk associated during the construction of the Project are obtained and compared with the criteria set out in Annex 4 of the TM-EIAO to determine their acceptability. Details of risk analysis are given in **Section 9.14.**

Risk Mitigation and Recommendations

If the estimated off-site individual risk level is found to be higher than 1 x 10^{-5} per year or the societal risk level is found to be at the "ALARP" or "Unacceptable" region, risk mitigation measures will be identified to reduce the risk level for the compliance of the risk guidelines. Risk levels of the mitigated scenario will be assessed. Cost-Benefit Analysis (CBA) is a widely used method to evaluate the cost-effectiveness of mitigation measures and may be used to demonstrate whether reasonably practicable measures have been taken to reduce risk levels.

9.5 Project Description and Assessment Information

Project Overview

Highways Department (HyD) of the Hong Kong SAR Government proposes to construct a 3-lane trunk road across Central Kowloon, linking West Kowloon in the west and the proposed Kai Tak Development (KTD) in the east. It will connect with West Kowloon Highway at Yau Ma Tei Interchange with the road network at Kowloon Bay and the future Trunk Road T2 at KTD, which will connect to the Tseung Kwan O – Lam Tin Tunnel (TKO – LTT). This route is known as Central Kowloon Route (CKR). CKR, Trunk Road T2 and TKO – LTT will form a strategic highway link, namely Route 6, connecting West Kowloon and Tseung Kwan O.

The construction of CKR was previously targeted for completion in 2016. The current target is to start construction of CKR in 2015 for completion and commissioning in end 2020. The construction programme for the Project (bored tunnel) in time chainage diagram is illustrated in **Appendix 9.3**.

In view of the topography and geology of the Ho Man Tin and Ma Tau Kok areas, the central section of CKR comprises mainly of deep bored tunnel. The proposed bored tunnel would run in underlying rock strata below ground to avoid affecting the buildings, roads and utilities at ground level.

The deep bored tunnel will be constructed by the drill-and-blast method. This is commonly used for excavation of hard rock tunnels. In view of tunnelling by TBM is not feasible given the large diameters involved and the extreme wear and tear expected due to the hard rock strata, it is an economical method and less restricted by site conditions and equipment set-up by the drill-and-blast method.

The location of the tunnel section where the drill-and-blast method will be used is shown in the legend of "proposed bored tunnel" in **Appendix 9.1**. The Longitudinal Profile is shown in **Appendix 9.4**. The three access points of the tunnel construction are marked as A (Yau Ma Tei near Shanghai Street), B (Ho Man Tin near service reservoir) and C (Ma Tau Kok near Kowloon City Pier Bus Terminus). Delivery routes between the Delivery Point (B) and the Access Points (A and C) are shown in **Appendix 9.5**. Explosives will only be used for blasting from Chainage 1440 to 4230. The proposed blasting strategy, which has been adopted in this Hazard Assessment, is summarised below:

- There is no dedicated explosive magazine for the CKR project.
- Mines Division will directly deliver explosives (detonators, cartridged emulsion explosives) and explosive accessories (detonating cords and cast boosters) to the HMT access point, and contractors are responsible to deliver explosives to the other two access points (i.e. from HMT to YMT and from HMT to MTK). The explosive delivery by the Mines Division and the contractors will be once per day and six days per week.
- There is no overnight storage of explosives at the CKR worksites.
- As a contingency measure, it is feasible to destroy limited quantities of unused mini-cast boosters, detonating cords and detonators on-site in accordance with Section 5.4 of Mines Division Practice Note No. 1.
- Occasionally, there would be unused cartridged emulsion explosives at the work sites. Unused cartridged emulsion explosives will be transported by Mines Division from Ho Man Tin to Government Explosives Depot for temporary storage, which is permitted as an emergency contingency measure. Nevertheless, contractors are required to transport the unused cartridged emulsion explosives from YMT to HMT and from MTK to HMT.
- This assessment also consider the potential uncertainties. These uncertainties may include the longer period of trial blasting when compared with the hazard assessment assumption, unforeseen ground conditions which restrict the use of bulk emulsion explosives, the use of low allowable charge weight due to the presence of sensitive receivers which restrict the use of bulk emulsion explosives, actual construction programme may differ from the envisaged construction programme, resulting in a higher number of explosive delivery trips (from HMT to YMT and from HMT to MTK). Return trips of unused explosives (from YMT to HMT and from MTK to HMT) will be generally avoided, nevertheless, are possible due to some uncertainties in the project implementation, therefore they are also considered in this assessment. Overall, these uncertainties (additional explosive deliveries as well as return trips of unused explosives) are addressed by 20% increase in the number of explosives delivery trips based on previous project experience as a contingency scenario.
- There will be only one blast per blast face per day.
- In the blasting design, bulk emulsion explosives will be used as far as practicable; the demarcation charge weight of the cartridged emulsion explosives and bulk emulsion explosives is 0.5 kg per delay.
- Non-electric detonators (i.e. shock tube detonators) will be adopted in the CKR project, which is the basis for the hazard assessment of use of explosives in accordance with previous EIA studies. If the CKR contractor decides to use electronic detonator in the future (i.e. construction stage), they should carry

out and submit the quantitative risk assessment amendment for the use of the specific electronic detonators to EPD and relevant parties to seek the corresponding statutory approval.

Types of Explosives Used

Three types of explosives will be used for the CKR tunnel construction by the drill-and-blast method, namely:

- Cartridged emulsion explosives;
- Bulk emulsion explosives; and
- Detonators, cast boosters and detonating cords.

Both cartridged and bulk emulsion explosives contain mainly ammonium nitrate, water, and a hydrocarbon such as fuel oil. Cartridged emulsion explosives also contain 2-3% aluminium powder, which is added to increase the explosion temperature and hence its power.

Cartridged Emulsion Explosives

Cartridged emulsion explosives (CEE) are small diameter explosives packages. They are used for mining, quarrying and general blasting work. They are packaged in a range of plastic films with the tips clipped at each end, or wrapped in waxed paper. They are classified as Dangerous Goods (DG) Category 1 “explosive” in Hong Kong, and have an equivalence of 0.96 kg TNT per kg of CEE.

Cartridged emulsion explosives are detonator sensitive, and hence do not require the use of a booster to make them detonate. When cartridged emulsion explosives are used, the required number of sticks equivalent to the design charge weight will be loaded into each blast hole.

CEEs will normally be used during the “trial blast” phase of a project. For hazard assessment purpose, cartridged emulsion explosives will be adopted where the MIC (maximum instant charge) does not exceed 0.5kg/delay. Once successful trial blasts have been concluded, it is expected that contractors will prefer using bulk emulsion explosives for safety, economic and flexibility reasons.

Bulk Emulsion Explosives

Bulk emulsion explosive has a similar composition to CEEs except that it does not contain aluminium. Before sensitising, the bulk emulsion has a density of 1,380-1,400 kg/m^3. It is not considered as an “explosive” and is classified as a DG Category 7 “strong supporter of combustion” in Hong Kong.

The bulk emulsion precursor (BEP) is stable under normal conditions and there is no major fire hazard before sensitisation. Hazards associated with bulk emulsion precursor are mainly due to its oxidising properties causing irritation to eyes and skin. Explosion is considered possible only under prolonged fire, supersonic shock or very high energy projectile impact.

Prior to sensitizing, it is not considered as an explosive, and hence transport of bulk emulsion precursor is not within the scope of this study.

Detonators, Cast Boosters and Detonating Cords

Detonators are small devices that are used to safely initiate blasting explosives in a controlled manner. Detonators are classified as DG Category 1 "explosive" in Hong Kong. Although detonators contain the most sensitive types of explosives in common use, they are constructed in a manner such that they may be handled and used with minimal risk. They are packaged in a manner that, if accidentally initiated, they should have no serious effects outside the package.

Non-electric detonators initiate detonation mainly by chemical reactions. They are manufactured with in-built delays that are of various durations. This is to facilitate effective blasting to allow blast holes to be initiated sequentially one at a time, rather than instantaneously, thereby enhancing the practical effects of the blast and reducing the effects of vibration.

The small quantity of explosive in a detonator is usually inadequate to reliably initiate many bulk explosives so they are used in conjunction with larger, less sensitive explosives – a cast booster – to boost the explosion. A cast booster is a small device, in which a detonator is inserted and the whole assembly is then placed in the end of the blasthole, once assembled it is called a primer.

Detonating cord is a thin, flexible tube with an explosive core. It detonates continually along its length and is suitable for initiating other explosives that are detonator sensitive, such as cartridged emulsion. The core of the cord is a compressed powdered explosive, usually PETN, and it is initiated by the use of a detonator. These explosives are used as part of the initiating system to initiate the main blasting explosives.

9.6 Transport of Explosives for the CKR Project

Delivery of explosives and accessories (cartridged emulsion explosives and detonators, etc.) will be performed by Mines Division daily from the Government Explosives Depot, using Mines Division's explosives delivery vehicles, arriving at Ho Man Tin (HMT) access point of the CKR Project. All of the explosives required at all access points will be unloaded at the HMT offloading point. Explosives required at Yau Ma Tei (YMT) and Ma Tau Kok (MTK) access points will then be delivered from HMT access point by the appointed contractors using approved trucks.

The type and quantity of explosives to be used at each Access Point for each month during the construction period where blasting is required are estimated and summarised in **Table 9.1**. Based on the estimates from **Table 9.1**, **Table 9.2** shows the amount of Category 1 Dangerous Goods explosives carried by Mines Division / contractor's vehicles.

To collect data of rock characteristics and for ground vibration prediction, trial blasting will be carried out at the initial stage of shaft blasting (Access Point B) and tunnel blasting (Access Points A, B & C). Cartridged emulsion explosives will be used in the trial blasting. One blast per face per day will be arranged. After trial blasting, bulk emulsion explosives will be used instead, where the amount of Category 1 Dangerous Goods explosives required to be transported will be significantly reduced. Bulk emulsion explosives will be adopted as far as practicable. Information on estimated delivery schedule of Category 1 Dangerous

Goods (cartridged emulsion explosives, detonators etc.) by contractor's approved vehicles are shown in **Appendix 9.6**.

The maximum quantity of explosives that a contractor can transport is limited to 200 kg on a Mines Division approved truck. Detonators excluding detonating cord shall be transported in a separate approved truck, which shall not be carrying other types of Category 1 Dangerous Goods at the same time. Detonator packages will be classified as HD 1.4B or HD 1.4S (articles which present no significant hazard outside their packaging). Packaged in such a way, the consequences potentially leading to fatalities will be limited to remain within the explosive truck boundaries. For accidental initiation of small amount of explosives, the UK HSE has estimated only the persons in close proximity to the explosion in the work room could be killed or injured. Therefore, accidental detonation of the detonators on the delivery truck is not further assessed in this study, which is consistent with the WIL EIA [9-1].

As a contingency measure, limited quantities of the unused mini-cast boosters, detonators and detonating cords, those explosives would be destroyed on site. Moreover, the destruction of explosives should only be carried out in a controlled blast covered by the Blasting Permit issued under the Dangerous Goods Ordinance. The destruction of large amounts of explosives at underground blasting sites will not be permitted.

Mines Division will permit limited quantities of unused explosives to be stored temporarily in Government Explosives Depot, as an emergency contingency measure.

Table 9.1 Amount of Explosives Required at Each Access Point

Month-year	Bulk Emulsion Explosive Consumption from Access Point A	Bulk Emulsion Explosive Consumption from Access Point B	Bulk Emulsion Explosive Consumption from Access Point C	Cartridged Emulsion Explosive Consumption from Access Point A	Cartridged Emulsion Explosive Consumption from Access Point B	Cartridged Emulsion Explosive Consumption from Access Point C	Detonator	Cast Booster	Total Explosive Required	Number of Blast Faces in a Day	Access Points for the Month
	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day		
Jul-15	0	0	0	0	170.1	0	0.8	112.1	283	1	B
Aug-15	0	0	0	0	177.8	0	0.7	96.2	275	1	B
Sep-15	0	217.1	0	0	12.4	0	0.4	58.1	288	1	B
Oct-15	0	370.7	0	0	12.4	0	0.4	58.1	442	1	B
Nov-15	0	396.3	0	0	12.4	0	0.3	38.9	448	1	B
Dec-15	0	850.7	0	0	12.4	0	0.3	42.8	906	1	B
Jan-16	0	853.9	0	0	12.4	0	0.3	35.6	902	1	B
Feb-16	0	749.6	0	0	12.4	0	0.2	27.8	790	1	B
Mar-16	0	777.2	0	0	12.4	0	0.2	27.8	818	1	B
Apr-16	0	815.9	0	0	12.4	0	0.2	27.8	856	1	B
May-16	1088.8	2330	0	8.5	80.2	22.8	1.9	107.9	3640	6	A & B &C
Jun-16	529.9	1510.5	0	6.5	71.3	22.6	1.9	91.5	2234	6	A & B &C
Jul-16	495.7	1256.9	0	22.3	67.4	20.6	2.3	88.1	1953	6	A & B &C
Aug-16	436.2	990.9	0	22.6	67.0	20.7	2.4	92.7	1633	6	A & B &C
Sep-16	510.6	805.5	0	13.7	45.5	17.3	2.9	105.6	1501	6	A & B &C

Month-year	Bulk Emulsion Explosive Consumption from Access Point A	Bulk Emulsion Explosive Consumption from Access Point B	Bulk Emulsion Explosive Consumption from Access Point C	Cartridged Emulsion Explosive Consumption from Access Point A	Cartridged Emulsion Explosive Consumption from Access Point B	Cartridged Emulsion Explosive Consumption from Access Point C	Detonator	Cast Booster	Total Explosive Required	Number of Blast Faces in a Day	Access Points for the Month
	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day		
Oct-16	437.4	736.7	0	11.5	32.8	17.1	3.0	107.6	1346	6	A & B &C
Nov-16	346.6	625.8	0	9.1	24.0	16.9	2.1	104.7	1129	6	A & B &C
Dec-16	0	702.8	0	12.7	42.9	17.2	3.0	107.3	886	6	A & B &C
Jan-17	0	658.3	0	12.7	35.7	17.2	2.9	101.5	828	6	A & B &C
Feb-17	0	717.3	0	12.7	26.2	15.4	3.0	94.2	869	6	A & B &C
Mar-17	0	790.2	0	8.9	38.2	12.1	3.2	107.7	960	6	A & B &C
Apr-17	0	779.8	0	11.4	48.0	12.1	3.2	110.4	965	6	A & B &C
May-17	0	843.2	0	14.9	28.6	14.9	2.8	93.3	998	6	A & B &C
Jun-17	0	850.1	0	14.9	28.7	14.6	2.9	102.1	1013	6	A & B &C
Jul-17	136.9	788.9	0	22.6	45.5	14.6	2.8	116.6	1128	6	A & B &C
Aug-17	162.9	571.7	0	24.4	157.5	14.6	2.4	108.6	1042	6	A & B &C
Sep-17	386.2	573.8	0	6.7	173.7	14.5	2.5	138.4	1296	6	A & B &C
Oct-17	440.3	563.9	0	11.1	174.2	14.5	2.3	125.7	1332	6	A & B &C
Nov-17	517.0	558.0	0	5.2	22.3	14.5	2.2	118.7	1238	6	A & B &C
Dec-17	600.4	572.1	0	6.8	22.1	14.5	2.1	105.9	1324	6	A & B &C
Jan-18	723.6	936.4	0	6.2	50.2	14.8	2.1	104.9	1838	6	A & B &C

Month-year	Bulk Emulsion Explosive Consumption from Access Point A	Bulk Emulsion Explosive Consumption from Access Point B	Bulk Emulsion Explosive Consumption from Access Point C	Cartridged Emulsion Explosive Consumption from Access Point A	Cartridged Emulsion Explosive Consumption from Access Point B	Cartridged Emulsion Explosive Consumption from Access Point C	Detonator	Cast Booster	Total Explosive Required	Number of Blast Faces in a Day	Access Points for the Month
	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day		
Feb-18	723.6	1232.7	0	6.2	54.0	14.5	2.1	105.3	2138	6	A & B &C
Mar-18	822.4	1664.4	0	6.1	70.8	16.0	2.0	100.8	2682	6	A & B &C
Apr-18	822.4	1490	0	11.5	43.0	16.4	2.0	106.3	2492	6	A & B &C
May-18	987.1	1476.7	0	12.8	266.0	16.4	2.3	154.9	2916	6	A & B &C
Jun-18	987.1	1155.5	0	12.8	183.5	18.4	2.5	181.6	2541	4	A & B &C
Jul-18	1023.7	894.6	0	12.3	253.2	18.4	2.3	155.5	2360	4	A & B &C
Aug-18	1023.7	873.2	0	12.3	49.1	18.7	2.0	111.9	2091	4	A & B &C
Sep-18	930.4	799.9	0	11.3	29.9	18.7	1.7	75.6	1867	4	A & B &C
Oct-18	834.3	592.2	0	10.9	22.9	18.3	1.8	89.2	1570	4	A & B &C
Nov-18	0	630.4	0	0	51.6	19.8	1.5	79.4	783	4	B & C
Dec-18	0	621.9	0	0	23.6	21.4	1.3	68.0	736	4	B & C
Jan-19	0	616.9	0	0	23.4	21.3	1.3	70.2	733	4	B & C
Feb-19	0	597.2	0	0	40.1	23.9	1.3	74.6	737	4	B & C
Mar-19	0	484.4	0	0	20.4	23.7	1.2	73.9	604	4	B & C
Apr-19	0	224.1	0	0	260.8	24.7	1.3	88.2	599	4	B & C
May-19	0	128.8	0	0	136.8	25.3	1.3	87.3	379	4	B & C

Month-year	Bulk Emulsion Explosive Consumption from Access Point A	Bulk Emulsion Explosive Consumption from Access Point B	Bulk Emulsion Explosive Consumption from Access Point C	Cartridged Emulsion Explosive Consumption from Access Point A	Cartridged Emulsion Explosive Consumption from Access Point B	Cartridged Emulsion Explosive Consumption from Access Point C	Detonator	Cast Booster	Total Explosive Required	Number of Blast Faces in a Day	Access Points for the Month
	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day	Kg /day		
Jun-19	0	161.6	0	0	200.7	0	0.7	94.8	458	4	B
Jul-19	0	0	0	0	0	0	0	0	0	-	-
Aug-19	0	0	0	0	0	0	0	0	0	-	-

Note:

[1] Site A: Yau Ma Tei (YMT)
[2] Site B: Ho Man Tin (HMT)
[3] Site C: Ma Tau Kok (MTK)
[4] Mines Division's Delivery Point of Explosives is at Site B

Table 9.2 Amount of DG Category 1 Explosives Required at Each Access Point (Carried by Mines Division / Contractor's Vehicles)

Month-year	Explosive Required at Access Point A				Explosive Required at Access Point B				Explosive Required at Access Point C			
	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive
	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day
Jul-15	0	0	0	0	0.8	3.0	112.1	170.1	0	0	0	0
Aug-15	0	0	0	0	0.7	3.0	96.2	177.8	0	0	0	0
Sep-15	0	0	0	0	0.4	3.0	58.1	12.4	0	0	0	0
Oct-15	0	0	0	0	0.4	5.0	58.1	12.4	0	0	0	0
Nov-15	0	0	0	0	0.3	5.0	38.9	12.4	0	0	0	0
Dec-15	0	0	0	0	0.3	9.9	42.8	12.4	0	0	0	0
Jan-16	0	0	0	0	0.3	9.9	35.6	12.4	0	0	0	0
Feb-16	0	0	0	0	0.2	9.9	27.8	12.4	0	0	0	0
Mar-16	0	0	0	0	0.2	9.9	27.8	12.4	0	0	0	0
Apr-16	0	0	0	0	0.2	9.9	27.8	12.4	0	0	0	0
May-16	0.5	9.8	19.1	8.5	0.7	26.1	75.2	80.2	0.8	3.2	13.6	22.8
Jun-16	0.6	5.6	25.2	6.5	0.5	20.2	52.5	71.3	0.8	3.1	13.8	22.6
Jul-16	0.9	5.6	13.5	22.3	0.5	15.3	59.1	67.4	0.9	3.0	15.5	20.6
Aug-16	1.0	5.3	13.5	22.6	0.5	13.2	63.8	67.0	0.9	3.0	15.5	20.7
Sep-16	1.3	6.0	19.4	13.7	0.6	10.5	68.3	45.5	1.0	2.9	18.0	17.3
Oct-16	1.4	5.1	21.9	11.5	0.6	8.4	67.5	32.8	1.0	2.9	18.2	17.1

Month-year	Explosive Required at Access Point A				Explosive Required at Access Point B				Explosive Required at Access Point C			
	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive
	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day
Nov-16	0.6	4.4	24.5	9.1	0.5	7.4	61.8	24.0	1.1	2.8	18.4	16.9
Dec-16	1.4	2.7	23.7	12.7	0.6	9.5	65.4	42.9	1.0	2.8	18.2	17.2
Jan-17	1.4	2.7	23.7	12.7	0.5	7.9	59.6	35.7	1.0	2.8	18.2	17.2
Feb-17	1.4	2.7	23.7	12.7	0.4	8.3	51.0	26.2	1.2	2.8	19.5	15.4
Mar-17	1.5	2.7	26.6	8.9	0.5	9.7	59.1	38.2	1.2	2.8	22.0	12.1
Apr-17	1.4	2.7	24.7	11.4	0.5	10.3	63.8	48.0	1.2	2.8	22.0	12.1
May-17	1.3	2.9	21.9	14.9	0.4	9.4	51.5	28.6	1.1	2.8	19.9	14.9
Jun-17	1.3	2.9	21.9	14.9	0.5	9.4	60	28.7	1.2	2.8	20.1	14.6
Jul-17	1.0	3.6	15.4	22.6	0.7	10.4	81.0	45.5	1.2	2.8	20.1	14.6
Aug-17	0.6	4.1	13.5	24.4	0.6	6.8	75.0	157.5	1.2	2.8	20.1	14.6
Sep-17	0.6	4.9	25.8	6.7	0.7	8.2	92.4	173.7	1.2	2.8	20.1	14.5
Oct-17	0.5	5.7	21.7	11.1	0.7	7.8	83.9	174.2	1.2	2.8	20.1	14.5
Nov-17	0.4	6.7	24.9	5.2	0.6	6.7	73.7	22.3	1.2	2.8	20.1	14.5
Dec-17	0.4	7.9	22.4	6.8	0.5	6.6	63.3	22.1	1.2	2.8	20.1	14.5
Jan-18	0.4	9.2	21.5	6.2	0.5	12.2	63.6	50.2	1.1	2.9	19.9	14.8
Feb-18	0.4	9.2	21.5	6.2	0.5	14.5	63.8	54.0	1.2	2.9	20.1	14.5
Mar-18	0.4	10.7	20	6.1	0.5	20.1	61.8	70.8	1.1	2.9	19.0	16.0

Month-year	Explosive Required at Access Point A				Explosive Required at Access Point B				Explosive Required at Access Point C			
	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive	Detonator	Detonating Cord	Cast Booster	Cartridged Emulsion Explosive
	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day	Kg/day
Apr-18	0.4	10.7	16.0	11.5	0.6	15.6	71.7	43.0	1.1	2.9	18.6	16.4
May-18	0.4	12.3	13.3	12.8	0.9	19.5	123.0	266.0	1.1	2.9	18.6	16.4
Jun-18	0.4	12.3	13.3	12.8	1.1	15.6	151.2	183.5	1.0	2.9	17.1	18.4
Jul-18	0.4	12.6	13.3	12.3	0.9	10.6	125.1	253.2	1.0	2.9	17.1	18.4
Aug-18	0.4	12.6	13.3	12.3	0.6	12.1	81.8	49.1	1.0	3.0	16.9	18.7
Sep-18	0.4	11.4	15.3	11.3	0.4	10	43.4	29.9	1.0	3.0	16.9	18.7
Oct-18	0.4	10.6	16.6	10.9	0.4	6.9	55.5	22.9	1.0	3.0	17.1	18.3
Nov-18	0	0	0	0	0.5	8.2	63.5	51.6	0.9	3.1	16.0	19.8
Dec-18	0	0	0	0	0.4	7.2	53.3	23.6	0.9	3.1	14.7	21.4
Jan-19	0	0	0	0	0.4	7.1	55.5	23.4	0.9	3.2	14.7	21.3
Feb-19	0	0	0	0	0.5	8.3	62.0	40.1	0.8	3.3	12.7	23.9
Mar-19	0	0	0	0	0.5	5.8	61.2	20.4	0.8	3.4	12.7	23.7
Apr-19	0	0	0	0	0.6	4.6	76.4	260.8	0.7	3.5	11.9	24.7
May-19	0	0	0	0	0.6	3.9	76.1	136.8	0.7	3.7	11.3	25.3
Jun-19	0	0	0	0	0.7	5.2	94.8	200.7	0	0	0	0
Jul-19	0	0	0	0	0	0	0	0	0	0	0	0
Aug-19	0	0	0	0	0	0	0	0	0	0	0	0

Note:

TNT Equivalency:

Detonators = 1.4 (i.e. 1.4kg of TNT per 1kg of detonators)

Detonating Cords = 1.4 (i.e. 1.4kg of TNT per 1kg of detonating cords)

Cast Boosters = 1.3 (i.e. 1.3kg of TNT per 1kg of cast boosters)

Cartridged Emulsion Explosives = 0.96 (i.e. 0.96kg of TNT per 1kg of emulsion)

To minimise the transport risk, delivery routes between the Delivery Point (HMT) and the Access Points (YMT and MTK) have been planned to avoid areas of high population density wherever possible, which are shown in **Appendix 9.5**. For example, from Ho Man Tin (Site B) to Ma Tau Kok (Site C), the Contractor's approved vehicles will take "Fat Kwong Street", "Ma Tau Wai Road (south)" and "To Kwa Wan Road" so as to avoid going into the Lok Man Sun Chuen area; from Ho Man Tin (Site B) to Yau Ma Tei (Site A), the vehicles will take "Fat Kwong Street", "Chatham Road" and "Gascoigne Road" instead of the densely populated "Waterloo Road", reason as mentioned above.

The explosives delivery trucks should be approved by Mines Division and should meet the regulatory requirements for transport of explosives. The approved trucks will have the following safety features [9-41]:

- Diesel powered;
- Vehicle's design, construction and strength complied with the Road Traffic Regulations, Chapter 374, Laws of Hong Kong;
- Cargo compartment with sufficient protection, proper storage facilities, and no electric wiring/devices installed inside;
- Isolated fuel tank with adequate protection;
- Battery and fuel isolation switches;
- Forward mounted exhaust with spark arrestor;
- Four fire extinguishers (2 x 2.5 kg dry powder, 2 x 9 L foam fire extinguishers) for a typical vehicle with gross vehicle weight of 9 tonnes or above;
- Lockable receptacles (of wood lined steel or aluminium) mounted on the vehicle tray;
- Fold down/ up explosives warning signs and rectangular red flag; and
- Fire resisting conduits for electrical wiring and fittings.

9.7 Use of Explosives for the CKR Project

Blast Design

The blast design shall consider the quantity and type of explosives needed including MIC (maximum instant charge), number of detonators required, as well as the sensitive receivers at the blasting location. The blasting design will be prepared by the Blasting Engineer, in collaboration with the Registered Shotfirer, checked and approved by the Blasting Competent Supervisor, and then submitted to Mines Division for auditing prior to implementation. The blast design will ensure that each detonator will initiate at a different time delay to allow sequential breaking of the rock.

Blast Loading and Execution

For the CKR Project, on each working day, the collection of the correct quantity of explosives and detonators from the Mines Division and/ or Contractor's approved vehicles will be checked by the Registered Shotfirer, a representative from the supervising engineer (Resident Explosives Supervisor) and a representative from the Contractor, before the blasting actually takes place. The anticipated blasting time will be between 2:00pm to 6:00pm.

To ensure that blasting of different sectors of the blast face occurs in the correct sequence and not simultaneously, the shock tubes from the detonators associated with a particular sector may be bunched together and wrapped with the detonating cord. A bunch block is then attached to the detonating cord. The shock tube tail of the bunch block will itself be ignited by a surface connector. Two surface connectors may be linked in series, with their connected bunch blocks in parallel, to ensure the staggering of the individual detonations across the entire blast face. The bunch block typically has no delay time, as the delay is provided by the surface connector to which its initiating shock tube is connected.

Safe Operating Practices

Vibration Monitoring

It is a requirement to monitor every blast in Hong Kong to record blast induced ground vibrations. When each and every blast is designed, the first parameter to be established is controlling sensitive receiver, which may be a building, structure, slope or utilities; its allowable peak particle velocity (PPV); its radial distance from the blast and the allowable MIC calculated.

A Blasting Engineer is responsible for ensuring that the controlling and other nominated sensitive receivers for each blast are monitored to record the PPV in mm/s. In addition, there may be instances where it is necessary to record air overpressure generated by blasting activities.

Trial Blasts

Trial blasts, conducted with cartridged emulsion explosives, will be carried out for the first series of blasts for the tunnels and different areas or sectors of the project if required. The trial blasts will be used to determine rock characteristics and to collect data to enable site specific constants to be calculated for future vibration prediction (in terms of PPV), and to ensure the blasting monitoring and control procedures are effective. After reliable data is obtained from the trial blasts, Bulk emulsion explosives will be used instead for more effective blasting operations.

Advance Notice of Blasts

As part of the process of issuing a “License to Possess” and a “Permit to Use” dangerous goods, Mines Division will require that highly visible warning notices/ signs be posted at several locations to warn the public that blasting will take place. These warning signs will be posted near the intended blasting location, even though all blasts will be conducted underground. The Contractor is required to display the blasting date and time on the notice.

Public Safety Measures

Public safety measures during the Project can take many forms, such as:

- Site hoarding;
- Security guards;
- Warning signage;
- District Council meetings/ briefings by the Resident Engineer; and

- Public relations programmes.

Additionally, various government departments and industry occasionally provide safety training and inspection, for example the Construction Industry Council (CIC) and the Labour Department.

Safety Management System

Contractors are required by law to have a comprehensive Safety Management System (usually OHSAS-18001) which is to be implemented and supervised by on-site safety teams. Annual checks of documentation and safety records will have to be performed by independent third party auditors.

9.8 Population Estimates

Three types of population have been considered for this assessment:

- Building Population;
- Pedestrian Population; and
- Traffic Population.

Building Population

Buildings along the Explosive Delivery Routes

The proposed explosive delivery routes will pass through densely populated residential and commercial regions in the Central Kowloon area. Building population of the areas in the vicinity of the routes is estimated from the 2009-based Territorial Population and Employment Data Matrix (TPEDM) [9-40], the Outline Zoning Plan (OZP) and the Planning Data Zones (PDZ) zone. The whole Hong Kong Special Administrative Region is delineated into 405 “Planning Data Zones”, abbreviated as “PDZ-405 Zones” (which are identical to the 405 “Planning Vision and Strategy Zones” (PVS-405 Zones) adopted in the 2006-based TPEDM at large).

Population data in year 2017 are estimated in accordance with the construction time and the period of explosives delivery. Population data in year 2017 is projected based on the 2016 and 2021 planning data of the population as extracted from the 2009-based Territory Population and Employment Data Matrices (TPEDM) [9-40]. Construction staff at the project work sites is not considered as off-site population and are not included in population data.

The population data are split into 4 different categories representing different times of the day. This split has been adopted from the one used in the HA for Potential Hazardous Installations (PHIs) (Para. 14A.23) of the Harbour Area Treatment Scheme (HATS) Stage 2A EIA [9-3].

- Weekday day (Mon-Fri 07:00-19:00);
- Weekday night (Mon-Fri 19:00-07:00);
- Weekend day (Sat-Sun 07:00-19:00); and
- Weekend night (Sat-Sun 19:00-07:00).

Indoor population is distinguished from the outdoor population. Indoor population refers to people inside buildings, while outdoor population refers to pedestrians on both sides of the road. The model for estimating fatalities from building population is adopted from the West Island Line (WIL) EIA [9-1]. Cylindrical shaped hazard zones have been applied to estimate the affected population inside buildings, and the height of the cylindrical hazard zone is assumed to be the same as the horizontal hazard distance at 1% fatality probability.

An indoor ratio of 95% is applied to the total population for a building. A presence factor is applied to different types of buildings to account for occupancies during different times of the day. These factors have been assumed with reference to those applied in the HA for PHIs (Para. 14A.23) of HATS Stage 2A EIA [9-3] and the South East Kowloon Development (SEKD) Comprehensive Feasibility Study (CFS) EIA (Para. 9.3.2.9) [9-4]. Day time data for the recreational population group are taken from the population group “Shopping Centre” in HATS Stage 2A EIA [9-3]. Night time data are the average of night time presence factor for population groups "recreational ground" (0%) and "park" (10%) in SEKD CFS EIA [9-4]. Night time presence factor for “Schools” is obtained from the highest value (0.98%) for population locations 3X-R, 3Q-PS, 3Q-SS, 3X-PS, 20, 3M-SS in SEKD CFS EIA and rounded up to 1%. For the 5% night time presence factor for “Schools”, it is an assumption to account for non-curriculum activities during weekend. Since the explosives delivery operation will be arranged at daytime, weekday day and weekend day data are applied to the assessment.

- Residential: weekday day 25%; weekend day 70%; night time 100%;
- Industrial/ commercial: weekday day 100%; weekday night 10%; weekend day 40%, weekend night 5%;
- Recreational: weekday day 50%; weekend day 100%; night time 5%;
- Schools: weekday day 100%; weekend day 5%; night time 1%.

Population of each PDZ zone along the explosives delivery route is obtained and each zone is further broken down into different land uses according to the OZP for further breakdown of Indoor and Outdoor population. **Appendix 9.7** shows the PDZ zone along the explosives delivery route and **Appendix 9.8** listed the detailed breakdown of the population. **Table 9.3** summarises population density for each PDZ-OZP combination. Since the delivery will be carried out at daytime, only daytime population for weekday and weekend is presented in the table.

Table 9.3 Population Density for Roadside Population Area

PDZ	ID	OZP	Population Density (persons/m^2)			
			INDOOR		OUTDOOR	
			WDD	WED	WDD	WED
076	11	R(E)	0.0137	0.0385	0.0007	0.0020
076	12	R(E)	0.0137	0.0385	0.0007	0.0020
076	14	R(A)	0.0917	0.2567	0.0048	0.0135
076	15	R(A)	0.0917	0.2567	0.0048	0.0135
076	16	R(A)	0.0917	0.2567	0.0048	0.0135
076	21	R(A)	0.0917	0.2567	0.0048	0.0135
076	22	R(A)	0.0917	0.2567	0.0048	0.0135
076	23	R(A)	0.0917	0.2567	0.0048	0.0135
076	24	R(A)	0.0917	0.2567	0.0048	0.0135
076	27	G/IC	0.0000	0.0000	0.0107	0.0043
076	28	I	0.1459	0.0583	0.0154	0.0061
075	9	R(A)	0.0655	0.1833	0.0034	0.0096
075	10	R(A)	0.0655	0.1833	0.0034	0.0096
075	11	G/IC	0.2983	0.1193	0.0157	0.0063
075	19	O	0.0000	0.0000	0.0001	0.0003
075	24	R(A)	0.0655	0.1833	0.0034	0.0096
075	26	R(A)	0.0655	0.1833	0.0034	0.0096
075	27	R(A)	0.0655	0.1833	0.0034	0.0096
075	29	R(A)	0.0655	0.1833	0.0034	0.0096
075	30	R(A)	0.0655	0.1833	0.0034	0.0096
075	31	R(A)	0.0655	0.1833	0.0034	0.0096
075	32	R(A)	0.0655	0.1833	0.0034	0.0096
071	2	R(A)	0.0688	0.1925	0.0036	0.0101
071	5	C	0.2893	0.1157	0.0152	0.0061
071	6	R(A)	0.0688	0.1925	0.0036	0.0101
071	8	OU	0.2893	0.1157	0.0152	0.0061
071	9	R(A)	0.0688	0.1925	0.0036	0.0101
071	10	G/IC	0.2893	0.0145	0.0152	0.0008
071	11	R(A)	0.0688	0.1925	0.0036	0.0101
071	13	R(A)	0.0688	0.1925	0.0036	0.0101
071	14	R(A)	0.0688	0.1925	0.0036	0.0101
071	15	R(A)	0.0688	0.1925	0.0036	0.0101
071	16	R(A)	0.0688	0.1925	0.0036	0.0101
071	17	G/IC	0.0723	0.2025	0.0038	0.0107
071	18	O	0.0000	0.0000	0.0001	0.0003
071	19	O	0.0000	0.0000	0.0001	0.0003
071	20	O	0.0000	0.0000	0.0001	0.0003
071	21	G/IC	0.2893	0.0145	0.0152	0.0008
071	22	G/IC	0.2893	0.0145	0.0152	0.0008

PDZ	ID	OZP	Population Density (persons/m^2)			
			INDOOR		OUTDOOR	
			WDD	WED	WDD	WED
071	27	R(A)	0.0688	0.1925	0.0036	0.0101
071	28	R(A)	0.0688	0.1925	0.0036	0.0101
071	29	R(A)	0.0688	0.1925	0.0036	0.0101
071	30	O	0.0000	0.0000	0.0001	0.0003
071	31	O	0.0000	0.0000	0.0001	0.0003
071	32	G/IC	0.1447	0.2893	0.0076	0.0152
071	33	O	0.0000	0.0000	0.0001	0.0003
071	36	G/IC	0.2893	0.0145	0.0152	0.0008
071	39	R(A)	0.0688	0.1925	0.0036	0.0101
073	2	GB	0.0000	0.0000	0.0000	0.0000
073	6	O	0.0000	0.0000	0.0000	0.0000
073	7	G/IC	0.0088	0.0175	0.0005	0.0009
073	8	O	0.0000	0.0000	0.0000	0.0000
073	9	R(A)	0.0322	0.0901	0.0017	0.0047
072	1	G/IC	0.0597	0.0239	0.0031	0.0013
072	10	O	0.0000	0.0000	0.0000	0.0001
072	18	R(A)	0.0436	0.1221	0.0023	0.0064
072	20	G/IC	0.0000	0.0000	0.0000	0.0000
072	23	R(B)	0.0277	0.0776	0.0015	0.0041
072	30	G/IC	0.0597	0.0030	0.0031	0.0002
062	6	G/IC	0.0203	0.0010	0.0011	0.0001
062	11	R(B)	0.0227	0.0636	0.0012	0.0033
062	12	OU	0.0102	0.0203	0.0005	0.0011
062	14	G/IC	0.0102	0.0203	0.0005	0.0011
062	15	O	0.0000	0.0000	0.0000	0.0000
062	16	OU	0.0102	0.0203	0.0005	0.0011
062	17	OU	0.0102	0.0203	0.0005	0.0011
068	1	O	0.0000	0.0000	0.0000	0.0001
068	2	G/IC	0.0816	0.0041	0.0043	0.0002
059	1	G/IC	0.3705	0.0185	0.0195	0.0010
059	2	G/IC	0.3705	0.1482	0.0195	0.0078
059	3	C	0.3705	0.1482	0.0195	0.0078
059	4	C	0.3705	0.1482	0.0195	0.0078
059	18	C	0.3705	0.1482	0.0195	0.0078
060	32	R(A)	0.0864	0.2419	0.0045	0.0127
060	33	R(A)	0.0864	0.2419	0.0045	0.0127
060	34	R(A)	0.0864	0.2419	0.0045	0.0127
060	36	O	0.0000	0.0000	0.0001	0.0002
060	37	C	0.2305	0.0922	0.0121	0.0049
060	38	C	0.2305	0.0922	0.0121	0.0049

PDZ	ID	OZP	Population Density (persons/m^2)			
			INDOOR		OUTDOOR	
			WDD	WED	WDD	WED
060	39	O	0.0000	0.0000	0.0001	0.0002
060	40	G/IC	0.2305	0.0115	0.0121	0.0006
060	41	O	0.0000	0.0000	0.0001	0.0002
060	42	G/IC	0.2305	0.0115	0.0121	0.0006
060	43	O	0.0000	0.0000	0.0001	0.0002
060	52	G/IC	0.2305	0.0115	0.0121	0.0006
060	53	C	0.2305	0.0922	0.0121	0.0049
060	54	O	0.0000	0.0000	0.0001	0.0002
060	55	G/IC	0.2305	0.0922	0.0121	0.0049
060	67	G/IC	0.2305	0.0115	0.0121	0.0006
069	2	G/IC	0.0213	0.0426	0.0011	0.0022
069	4	CDA	0.0900	0.0360	0.0047	0.0019
069	10	OU	0.0426	0.0171	0.0022	0.0009
070	29	R(A)	0.0927	0.2597	0.0049	0.0137
070	30	R(A)	0.0927	0.2597	0.0049	0.0137
070	31	R(A)	0.0927	0.2597	0.0049	0.0137
070	36	R(A)	0.0927	0.2597	0.0049	0.0137
070	37	R(A)	0.0927	0.2597	0.0049	0.0137

Notes:
[1] *WDD = weekday day time;* *WED = weekend day time*

Buildings along the CKR Tunnel Blasting Alignment

Sensitive receivers, including buildings, slopes, utilities and other structures along the proposed CKR tunnel blasting alignment are identified in the Preliminary Blasting Assessment Report and Preliminary Blasting Design supplied by the Consultants are considered in this assessment. They are represented by a point or a number of points, with locations specified by the latitude, longitude and elevation (i.e., "North", "East", and "Level"). A top view of the blasting alignment and sensitive receivers is illustrated in **Appendix 9.9**.

Population in the individual buildings possibly affected by excessive blasting vibrations are collected by a combination of survey, 2006 Population Census **[9-6]** and the Code of Practice for Fire Safety **[9-7]**. A growth factor of 1% per year is taken for this assessment, which is slightly higher than the Average Annual Growth Rate of 0.8% from the Hong Kong Population Projections 2010 – 2039 **[9-8]**, is included in the estimation on conservative approach.

Pedestrian Population

Pedestrians contribute significantly to outdoor population for a busy street. A high-density value of 0.5 persons/m^2 is equivalent to a footpath level of service D, as defined by the Highway Capacity Manual. Pedestrian flow on the pavement was assessed along the explosives delivery routes by site survey carried out in March 2012 during daytime. The site survey also aimed to collect site specific information such as the width of pavement and surrounding conditions of the roads. The results are shown in **Table 9.4**.

Table 9.4 Pavement Population Density on Roads Covered in Site Survey

Road	Road Segment Between		Pavement Population Density (person / m^2)
Nathan Rd	Public Square St	Market St	0.5
Public Square St	Nathan Rd	Shanghai St	0.5
Shanghai St	Kansu St	Public Square St	0.5
Ma Tau Wai Rd	San Lau St & Bailey St	Fat Kwong St	0.2
Ma Tau Wai Rd & To Kwa Wan Rd	San Lau St & Bailey St	Chi Kiang St	0.2
To Kwa Wan Rd	Kwei Chow St	Chi Kiang St	0.2
To Kwa Wan Rd	San Ma Tau St	Kwei Chow St	0.2
San Ma Tau St	To Kwa Wan Rd	Long Yuet St	0.2
Fat Kwong St	Chung Hau St	Yan Fung St	0.05
Fat Kwong St & FO <K66>	Yan Fung St	Ma Tau Wai Rd	0.05
Wo Chung St	Chatham Rd N	Fat Kwong St	0.05
Chatham Rd N	Wuhu St	Chatham Rd N (GL)	0.05
Chatham Rd S	Chatham Rd FO <K20>	Hong Chong Rd	0.05
Gascoigne Rd	Wylie Rd	Chatham Rd FO <K20>	0.05
Gascoigne Rd	Wylie Rd	Ramps to & from Gascoigne Rd near Jordan Rd	0.05
Gascoigne Rd	Pak Hoi St	Jordan Rd	0.05
Gascoigne Rd	Nathan Rd	Pak Hoi St	0.05

Traffic Population

Along the tentative transport route of explosives, other than the population groups discussed above, road traffic population is also considered.

Effect on major roads is analysed and representative figures from the Annual Traffic Census (ATC) [9-38] by the Transport Department is used to estimate the road traffic population. The Annual Average Daily Traffic (AADT) figure (in vehicles per day) is divided equally for 3 time categories: rush hour (4 hrs), daytime (8 hrs) and night time (12 hrs). Average vehicles per hour can then be calculated. Divide the number by the representative speed of the time category: rush hour (20 km/hr), day time (80% of speed limit) and night time (speed limit) the instantaneous number of vehicles can be obtained.

The average occupancy of the vehicle of the road segment (e.g. 3.48 people/vehicle) is either directly obtained or estimated from the representative figures of the core stations (e.g. Core Stations 4211, 4213, 3006, 3014) in the ATC 2010.

Taking Station 4211 for Fat Kwong Street (ATC 2010) as an example:

AADT 20,970 vehicles per day, delivery time Mon-Fri 10:00, speed limit 50 km/hr

Average vehicles per hour = 20,970 vehicles per day/ 3/ 8 hrs (day time) = 874 vehicles per hour

Vehicle speed = 50 km/hr × 80% (day time) = 40 km/hr

Instantaneous no. of vehicles = 874 vehicles per hr/ 40 km per hr = 21.8 vehicles per km

Traffic population = 3.48 people/vehicle × 21.8 vehicle/km = 76 people/km

Population density is obtained by multiplying the instantaneous number of vehicles calculated from the Annual Average Daily Traffic (AADT) figure (in vehicles per day) as per example above with the average occupancy of each vehicle.

The AADT figure of the road segments along Chatham Road North, Fat Kwong Street, To Kwa Wan Road and Gascoigne Road Flyover are obtained from the Annual Traffic Census [9-38] (ATC) 2010 by the Transport Department. **Appendix 9.10** listed the detailed breakdown of the traffic population along the delivery route.

Approved trucks of the contractors will be used to convey explosives from the unloading point of Mines Divisions trucks to other access points during the day time prior to the scheduled blasting. Hence, day time traffic population density is considered in this assessment as shown in **Appendix 9.10**.

9.9 Hazard Identification

Potential causes of hazard events are discussed in the following paragraphs.

Hazard Properties of Ammonium Nitrate

The family of emulsion explosives typically contains over 78% ammonium nitrate, which is a powerful oxidising agent. Ammonium nitrate will not explode due to friction and impact encountered in normal handling. However, it can be detonated under heat and confinement or severe shock, such as that from an explosive.

The sensitivity of ammonium nitrate to detonation is increased by elevated temperature or by contamination.

In a fire, pools of molten ammonium nitrate may be formed, and if the molten mass becomes confined it may explode, particularly if it becomes contaminated. In a fire ammonium nitrate may melt and decompose with the release of toxic fumes (mainly nitrogen oxides).

Accidental Initiation of Explosives by Fire

Numerous tests demonstrate that, when subjected to fire engulfment, many explosives ignite and burn to deflagration, and in some cases detonate. The time for an explosive to ignite is dependent upon its physical characteristics, chemical composition, and the conditions under which it is stored or handled.

It is generally considered that cartridged emulsion explosives are generally less sensitive to fire engulfment as a means of initiation due to the high water content. However, when exposed to heat or fire, the water content of the emulsion will be driven off, leading to possible initiation if the energy levels are high enough, long duration and confinement pressure increases.

Transport accident statistics for ANFO, another type of ammonium nitrate based explosive, indicate a minimum time to deflagration of about 30 minutes. Emulsion is considered more difficult to initiate than ANFO due to its water content.

The consequences of an accidental explosion due to thermal stimulus could be a thermal explosion (cook-off) or detonation or some combination of the two.

Accidental Initiation of Explosives by Impact

The term “impact” here encompasses both shock and friction initiation, because in most accidental situations, it is difficult to distinguish between them. It has been recorded that some explosives can initiate (in the absence of piercing) at an impact velocity as low as 15 m/s. If the container of explosives is pierced, for example by a sharp metal object, then it is likely that the required velocity will be far less than 15 m/s. This is due to localised heat generation resulting from frictional rubbing between layers of explosive, and is referred to as “stab-initiation”. However, the cartridged emulsion explosive is believed to be insensitive to initiation via impact, as demonstrated by the bullet impact test from a high velocity projectile.

Ground Vibration Associated with Use of Explosives

Ground vibration induced by stress wave during rock excavation could be potentially hazardous if the vibration level is high enough to cause damage. Peak Particle Velocity (PPV) is generally used as an indicator of vibration leading to potential damage. Ground vibration is governed by the distance from the blast face to the feature and the MIC.

No more than 5 kg MIC are proposed which will be the upper bound charge weight to be adopted in this assessment.

9.10 Incident Review

This section presents a review of reported safety incidents involving explosives (in industrial applications). Records were retrieved mainly from the UK Health and Safety Executive's (HSE) Explosives Incidents Database Advisory Service (EIDAS), US Mine Safety and Health Administration (MSHA) and Western Australia's Department of Mines and Petroleum (DMP) with regard to the types of explosives used and the operations for the CKR Project. **Appendix 9.11** provides a summary of relevant incidents for each of the categories.

Incidents Related to Transport of Explosives

The UK EIDAS database identified one transport incident, which caused one fatality, multiple injuries and significant property damage. The 1989 Peterborough Incident involved a truck carrying approximately 800 kg of mixed explosives (cerium fuseheads, vulcan fuseheads, detonators, and high explosives) [9-36]. The explosion was initiated by fire and explosion from a box of cerium fusehead combs destined for a local fireworks manufacturer. The cerium fusehead combs were packed in unauthorised and unsafe packaging. Fusehead composition was found to be extremely sensitive both to impact and friction, and presence of rust in the packaging further increased the impact sensitivity significantly. After 12 min of fire, an explosion occurred, which killed one fireman approximately 15 m away from the burning truck by a fragment and injured more than 100 people in the vicinity. This incident initiated enactment of more stringent safety guidelines in the UK, specifically the Road Transport (Carriage of Explosives) Regulations of 1989, which came into force just three months after the incident.

Australia is a significant user and transporters of explosives, consuming approximately 900,000 tonnes of explosives per year (approximately 8% of the world's annual consumption of explosives per year). Western Australia consumes approximately 30% of Australia's explosives amount and publishes accident data. In one of the accidents, the transport vehicle caught fire in the engine compartment due to exhaust leakage. The fire was quickly extinguished and caused no damage to the explosives. No ignition of explosives occurred for vehicle accidents of collision, run-off-road, or overturn [9-9]. A few fire accidents involving explosive pumping / mixing vehicles were also recorded, in Western Australia, but none of these incidents has resulted to fatality or injury.

In the US, explosives transport has had a good safety record. In a study released by National Institute of Occupational Safety and Health (NIOSH)[9-37] analysis of data from 1998 to 2006 revealed that accidents related to the transport of explosives and ammonium nitrate used in mining and construction have resulted in only 5 major injuries, 11 minor injuries, and no fatalities. The safe history of explosives and ammonium nitrate transport is attributed to diligent efforts by government, labour and industry.

Incidents Related to Use of Explosives

Appendix 9.11 provides a summary of incidents arising from use of explosives that have been caused by mishandling, premature blast, misfiring, overcharging, etc. Other incidents, which have led to serious consequence, i.e. fly rocks, damage to property and other severe blast effects, are also included in the table.

The major hazard from blasting operations is resulted mainly from fly rocks. Fly rock is caused by a mismatch of the distribution of explosive energy, type of confinement of the explosive charge, and the mechanical strength of the rock [9-10]. The poor security control in blast area has also led to several safety incidents, i.e., due to persons getting struck by blasted rocks. In the US, injuries from fly rocks and lack of security in the blast area accounted for more than two-thirds of all blasting-related injuries in surface coal, metal, and non-metal mines during the period from 1978 to 2002.

Blast doors will be provided for tunnels and blast cover will be provided for shaft at HMT, and kept closed during blasting, thus the effect of fly rock is not further considered in this assessment. Data from Hong Kong, i.e., from incidents recorded by GEO from 1997 to 2007, reveal that out of the 7 incidents, 6 are due to fly rocks. 3 of which, has caused injuries. One incident is associated with blast induced slope failure. However, all of these incidents relate to surface blasting activities and are therefore not applicable to this assessment.

Scenarios for Hazard Assessment

Further to the Hazard Identification (**Section 9.9**) and Incident Review (**Section 9.10**), the following hazard scenarios were identified for the hazard assessment:

- Accident involving explosives delivered and transferred from Access Point B to Access Point A.
- Accident involving explosives delivered and transferred from Access Point B to Access Point C.
- Excessive vibration generated by the blast face due to human errors and other reasons such as manufacturing defects causing deviation from the confirmed design for the tunnel and ventilation shaft.
- Excessive vibration and air overpressure due to explosion within the tunnel during the transfer of explosives from the Access Point to the blast face.

9.11 Frequency Assessment for Transport of Explosives

Detonation of explosives during road transport can be initiated by heavy impact in a car crash, breakout of fire in the car crash or a vehicle-fire other than car crash. Fault tree analysis in **Appendix 9.12** is used for deriving the frequency of detonation in a truck during road transport by taking into account likelihood of an initiating event and probability of detonation. The resulting frequency of detonation in road transport is estimated 7.69E-10 per km. Likelihood of initiating events and probabilities of detonation have made reference to the XRL EIA[9-12] are tabulated in **Table 9.5**.

Table 9.5 Likelihood of Initiating Events and Probabilities of Detonation

Event	Event Type	Value
Vehicle crash (high impact)	Frequency	5.97E-09/km
Vehicle crash (medium impact)	Frequency	6.82E-08/km
Vehicle crash (low impact)	Frequency	3.94E-07/km
Crash fire	Frequency	1.99E-10/km
Non-crash fire	Frequency	1.30E-09/km
Explosives detonated in fire	Probability	0.5
Explosives subject to significant shock impact (high/medium-impact vehicle crash)	Probability	1
Explosives subject to significant shock impact (low-impact vehicle crash)	Probability	0.1
Explosives detonated in impact	Probability	0.0001
Explosives detonated due to unsafe explosives	Frequency	7.61E-12/km

Delivery schedule and quantity of DG Category 1 Explosives (cartridged emulsion explosives, detonators, etc.) are listed in **Appendix 9.6**. Corresponding transport distance and quantity by the contractors' vehicles are summarised in **Table 9.6**. Note that the conveyance of bulk emulsion precursor (BEP) is not assessed because it is considered stable until the BEP is sensitised at the blast face. As shown in **Table 9.6**, the one-year period between January 2017 and December 2017 indicates the longest transport distance and the highest transport quantity of explosives. Therefore, this period is selected for the assessment, which represents the worst case during the whole project period.

Failure frequencies (detonation of explosives) during delivery in km-year are derived from **Appendix 9.6** according to the delivery route, explosive quantity and number of explosive delivery trucks per year. Calculation is shown in **Table 9.7**. In this assessment, a truck load of 125 equivalent TNT kg (see **Table 9.7**) is assumed in the risk calculation, which is based on the maximum daily explosive demand in Yau Ma Tei and Ma Tau Kok access points (max 47 and 44 equivalent TNT kg) in the one-year study period and potential uncertainties at project construction stage.

Table 9.6 Transport Distance and Quantity of DG Category 1 Explosives (Cartridged Emulsion Explosives, Detonating Cord and Cast Booster)

Month-year	Explosives Transport Distance and Quantity						Total Transport Distance and Quantity in 1 Year	
	Route B to A		Route B to C		Overall			
	km	Equiv. TNT Kg	km	Equiv. TNT Kg	km	Equiv. TNT Kg	km	Equiv. TNT Kg
Jul-15	0	0	0	0	0	0	254	4359
Aug-15	0	0	0	0	0	0	382	6541
Sep-15	0	0	0	0	0	0	509	8722
Oct-15	0	0	0	0	0	0	636	10903
Nov-15	0	0	0	0	0	0	763	13084
Dec-15	0	0	0	0	0	0	890	15265
Jan-16	0	0	0	0	0	0	1018	17447
Feb-16	0	0	0	0	0	0	1145	19628
Mar-16	0	0	0	0	0	0	1272	21810
Apr-16	0	0	0	0	0	0	1399	23991
May-16	72	1123	55	1057	127	2180	1526	26173
Jun-16	72	1123	55	1056	127	2179	1526	26174
Jul-16	72	1123	55	1058	127	2181	1526	26177
Aug-16	72	1123	55	1058	127	2181	1526	26177
Sep-16	72	1123	55	1058	127	2181	1526	26177
Oct-16	72	1123	55	1058	127	2181	1526	26177
Nov-16	72	1123	55	1058	127	2181	1526	26178
Dec-16	72	1123	55	1058	127	2181	1526	26178
Jan-17	72	1123	55	1058	127	2182	1526	26178
Feb-17	72	1123	55	1058	127	2182	1526	26177
Mar-17	72	1123	55	1058	127	2181	1526	26177
Apr-17	72	1123	55	1058	127	2181	1526	26177
May-17	72	1123	55	1058	127	2182	1526	26177

Month-year	Explosives Transport Distance and Quantity						Total Transport Distance and Quantity in 1 Year	
	Route B to A		Route B to C		Overall			
	km	Equiv. TNT Kg	km	Equiv. TNT Kg	km	Equiv. TNT Kg	km	Equiv. TNT Kg
Jun-17	72	1123	55	1059	127	2182	1526	26177
Jul-17	72	1123	55	1059	127	2181	1526	26176
Aug-17	72	1123	55	1059	127	2182	1526	26176
Sep-17	72	1123	55	1058	127	2181	1526	26175
Oct-17	72	1123	55	1058	127	2181	1526	26176
Nov-17	72	1123	55	1058	127	2181	1526	26176
Dec-17	72	1123	55	1058	127	2181	1454	25053
Jan-18	72	1123	55	1058	127	2181	1382	23930
Feb-18	72	1123	55	1058	127	2181	1310	22807
Mar-18	72	1123	55	1058	127	2182	1238	21684
Apr-18	72	1123	55	1058	127	2181	1166	20560
May-18	72	1123	55	1058	127	2181	1094	19436
Jun-18	72	1123	55	1058	127	2181	1022	18313
Jul-18	72	1123	55	1058	127	2181	895	16131
Aug-18	72	1123	55	1058	127	2181	768	13950
Sep-18	72	1123	55	1058	127	2181	641	11769
Oct-18	72	1123	55	1058	127	2181		
Nov-18	0	0	55	1058	55	1058		
Dec-18	0	0	55	1058	55	1058		
Jan-19	0	0	55	1058	55	1058		
Feb-19	0	0	55	1058	55	1058		
Mar-19	0	0	55	1058	55	1058		
Apr-19	0	0	55	1058	55	1058		
May-19	0	0	55	1058	55	1058		
Jun-19	0	0	0	0	0	0		
Jul-19	0	0	0	0	0	0		
Aug-19	0	0	0	0	0	0		

Notes:
[1] Number of Trips per month = [Number of Trips per day] x [6 days per week] x [4 weeks per month].
[2] One blasting cycle per day.
[3] Route B-A = route from Ho Man Tin to Yau Ma Tei, about 3.0 km; Route B-C = route from Ho Man Tin to Ma Tau Kok, about 2.3 km.
[4] The highlighted cell indicates the longest transport distance and the highest transport quantity of explosives in a 12-month period.

Table 9.7 Failure Frequency (Detonation of Explosive) in Delivery Grouped by Delivery Route and Modelled Quantity of Explosives

Route[1]	Modelled Quantity of Explosives (Equiv. TNT kg /day)	No. of Trips per Day	Period of Time (months)	No. of Trips per Year[2]	Failure Frequency in Delivery (/veh.km)	Failure Frequency in Delivery (/km.yr)[3]
B - A	125	1	12	288	7.69E-10	2.21E-07
B - C	125	1	12	288	7.69E-10	2.21E-07

Notes:
[1] Route B-A = route from Ho Man Tin to Yau Ma Tei, about 3.0 km; Route B-C = route from Ho Man Tin to Ma Tau Kok, about 2.3 km.
[2] Number of Trips per year = [Number of Trips per day] x [6 days per week] x [4 weeks per month] x [Period of Time (months)]
[3] Failure Frequency in Delivery (/km.yr) = [Number of Trips per Year] x [Failure Frequency in Delivery (/veh.km)]

Frequency Assessment for Explosive Transport within the Tunnel

After the explosives are unloaded at each work site, the contractor is responsible for transferring the explosives to the blast face using approved diesel vehicles. An overall frequency of accidental initiation of 7.69E-10 per vehicle-km (refer to **Appendix 9.12**) is used for assessing transport of explosives in the tunnel, which is considered conservative for the reason that traffic speed will be much lower than that on the public roads, and only one truck is allowed at any given time. This approach is deemed as conservative in the WIL EIA **[9-1]**.

9.12 Frequency Assessment for Use of Explosives

Excessive ground vibrations may be generated from simultaneous detonation of multiple blast holes due to errors in the blasting process. The WIL EIA **[9-1]** had shown that these could be errors in design, manufacturing, installation, checking and recovery. With such knowledge, fault tree analysis was carried out to determine the type of human errors involved in each scenario. Following such identification an industry-recognised methodology – Human Error Assessment & Reduction Technique (HEART) – was used to derive the human error probabilities involved. These probabilities were then fed into the fault trees to calculate the failure scenarios frequencies. Details of the HEART analysis can be found in Appendix 10 of the WIL EIA **[9-1]**.

Tunnel blasting operations to be carried out in the CKR project follows the same methodology and procedures as those in the WIL project. The same procedures during tunnel blasting operations will also apply to shaft blasting operations for the CKR. Therefore, the analysis framework (i.e. fault trees and human errors fault trees) in WIL are representative of the CKR project's blasting operations, and thus have been adopted for this assessment in the development of failure scenario frequency for the use of explosives. Meanwhile, parameters of the fault trees are reviewed and updated to reflect the particular blasting operation conditions of the CKR Project. The number of sectors and number of blast holes modelled in the frequency assessment for the various sections of the CKR tunnels are summarised in **Table 9.8** below.

Table 9.8 Summary of Number of Blasts, Sectors and Holes

Tunnel Section	No. of sectors per blast face	No. of holes per blast face	No. of holes modelled per blast face	No. of blasts
East Bound tunnel - 1440 to 4230				
Chainage: 1600-2050 2060-3480 3760-4010 4190-4230	10	166 ~ 196	200	1724
Chainage: 1440-1540 2050-2060 3480-3760 4010-4030 4180-4190	10	202 ~ 249	250	509
West Bound tunnel - 1440 to 4230				
Chainage: 1450-1460 1540-1550 1680-3490 3810-4050 4170-4230	10	166 ~ 196	200	1806
Chainage: 1440-1450 1480-1540 1610-1680 3490-3810 4050-4170	10	202 ~ 249	250	753
Chainage: 1460-1480	10	371 ~ 389	400	32
Cross-Passage				
Cross-Passage: Total 29 cross-passages	10	54 ~ 110	120	501
HMT Shaft				
HMT: +25 to +17 mPD +1 to -43 mPD	10	202 ~ 247	250	41
HMT: +13 mPD +9 to +3 mPD	10	263 ~ 280	300	6
HMT: +15 mPD +11 mPD	10	321 ~ 347	350	3

Note:
Non-blasting zones are located at:
EB 1540 ~ 1600; EB 4030 ~ 4180; WB 1550 ~ 1610

Appendix 9.13 summarises the base probabilities and parameters adopted as input of the fault trees for estimating the probabilities of occurrence of the accident scenarios. For comparison, the corresponding values used in WIL HA [9-1] are listed as well.

Fault tree models of accidental simultaneous detonation of 2 MIC to 4 MIC have already been illustrated in WIL HA [9-1], and thus adopted in this assessment. The fault tree model of accidental simultaneous detonation of 5 MIC was developed in this assessment and shown in **Appendix 9.14**.

Upon applying the specified human error probabilities for CKR to the fault trees, the results of the frequencies of excessive ground vibrations due to errors in the blasting processes have been obtained up to 5 MIC. For simultaneous detonation of 6 MIC, considering the probability of each additional error for either design or manufacturing of detonator is 0.01, the occurrence probability for each additional MIC detonated at the same time will be roughly 2 orders of magnitude lower each time. Herein, it is conservatively assumed that the occurrence probabilities of 6 MIC detonated at the same time will be of the same as that for 5 MIC detonated at the same time. The results are summarised in **Table 9.9** below. The frequencies are in of basis per project. In line with the WIL approach [9-1], the risk assessment will be carried out at every 10m chainage interval. The frequencies used, on a 10m interval, are summarised in **Table 9.10.**

Table 9.9 Frequency for Whole Project for Failures Leading to Higher Ground Vibration

CKR Tunnel Blasting Section	Blast Linear Length (m)	Occurrence frequency for multiple MIC detonated at the same time per section (occurrence per project)				
		2 MIC	3 MIC	4 MIC	5 MIC	6 MIC
East Bound tunnel - 1440 to 4230						
Chainage: 1600-2050 2060-3480 3760-4010 4190-4230	2160	1.28E-01	4.55E-04	4.29E-06	4.05E-08	4.05E-08
Chainage: 1440-1540 2050-2060 3480-3760 4010-4030 4180-4190	420	4.09E-02	1.60E-04	1.56E-06	1.43E-08	1.43E-08
West Bound tunnel - 1440 to 4230						
Chainage: 1450-1460 1540-1550 1680-3490 3810-4050 4170-4230	2130	1.34E-01	4.77E-04	4.50E-06	4.24E-08	4.24E-08
Chainage: 1440-1450 1480-1540 1610-1680 3490-3810	580	6.05E-02	2.36E-04	2.31E-06	2.11E-08	2.11E-08

CKR Tunnel Blasting Section	Blast Linear Length (m)	Occurrence frequency for multiple MIC detonated at the same time per section (occurrence per project)				
		2 MIC	3 MIC	4 MIC	5 MIC	6 MIC
4050-4170						
Chainage: 1460-1480	20	3.13E-03	1.49E-05	1.54E-07	1.43E-09	1.43E-09
Cross-Passage						
Cross-Passage: Total 29 cross-passages	385	3.18E-02	9.07E-05	7.92E-07	7.01E-09	7.01E-09
HMT Shaft						
HMT: +25 to +17mPD +1 to -43 mPD	56	3.29E-03	1.29E-05	1.26E-07	1.15E-09	1.15E-09
HMT: +13 mPD +9 to +3 mPD	10	5.17E-04	2.19E-06	2.18E-08	2.01E-10	2.01E-10
HMT: +15 mPD +11 mPD	4	2.76E-04	1.25E-06	1.27E-08	1.17E-10	1.17E-10

Table 9.10 Frequency per 10m for Failures Leading to Higher Ground Vibration

CKR Tunnel Blasting Section	Blast Linear Length (m)	Occurrence Frequency for multiple MIC detonated at the same time per section (occurrence per 10m)				
		2 MIC	3 MIC	4 MIC	5 MIC	6 MIC
East Bound tunnel - 1440 to 4230						
Chainage: 1600-2050 2060-3480 3760-4010 4190-4230	2160	5.94E-04	2.11E-06	1.99E-08	1.88E-10	1.88E-10
Chainage: 1440-1540 2050-2060 3480-3760 4010-4030 4180-4190	420	9.73E-04	3.81E-06	3.72E-08	3.39E-10	3.39E-10
West Bound tunnel - 1440 to 4230						
Chainage: 1450-1460 1540-1550 1680-3490 3810-4050 4170-4230	2130	6.31E-04	2.24E-06	2.11E-08	1.99E-10	1.99E-10
Chainage: 1440-1450 1480-1540 1610-1680 3490-3810 4050-4170	580	1.04E-03	4.08E-06	3.99E-08	3.64E-10	3.64E-10

CKR Tunnel Blasting Section	Blast Linear Length (m)	Occurrence Frequency for multiple MIC detonated at the same time per section (occurrence per 10m)				
		2 MIC	3 MIC	4 MIC	5 MIC	6 MIC
Chainage: 1460-1480	20	1.56E-03	7.46E-06	7.71E-08	7.15E-10	7.15E-10
Cross-Passage						
Cross-Passage Total 29 cross-passages	385	8.25E-04	2.36E-06	2.06E-08	1.82E-10	1.82E-10
HMT Shaft						
HMT: +25 to +17 mPD +1 to -43 mPD	56	5.88E-04	2.30E-06	2.25E-08	2.05E-10	2.05E-10
HMT: +13 mPD +9 to +3 mPD	10	5.17E-04	2.19E-06	2.18E-08	2.01E-10	2.01E-10
HMT: +15 mPD +11 mPD	4	6.90E-04	3.11E-06	3.17E-08	2.93E-10	2.93E-10

Table 9.11 LPG Fuelling Stations and MTKGW Affected by Tunnel Blasting and Underground Explosive Transport in the Tunnel

Hazardous Installations	Allowable PPV Limit	Anticipated Maximum PPV During Accident Scenarios (mm/s)		Impact on Installations During Accident Scenarios
		Blasting in Tunnel (6MIC)	Transport of Explosives in Tunnel	
Ma Tau Kok Gas Works	5 [1]	4.99	4.98	No adverse impact is anticipated.
Esso Princess Margaret Rd LPG Fuelling Station	13 [2]	12.99	12.99	

Sources:
[1] HKCG advisory guidelines for construction works in the vicinity of gas facilities.
[2] Vibration limit is similar to that of gas mains offtake station for LPG stations.

Escalation Impact

In terms of use of explosives and accidental detonation during underground transport of explosives, ground vibration could be generated from these activities, which might impact on nearby installations containing hazardous substances. In this study, such installations along the CKR tunnel alignment include LPG fuelling stations and Ma Tau Kok Gas Works (MTKGW) as shown in **Appendix 9.15**, and the impact on them due to blasting operations of the CKR tunnels has been evaluated. Peak particle velocities (PPV) imposed on the installations under various circumstances are estimated, as shown in **Table 9.11**.

The allowable PPV limit to be imposed by third party activities (such as normal blasting operations) is shown in **Table 9.11**. It is noted that the maximum PPV induced by normal blasting operations of the CKR tunnels on such facilities is below the allowable PPV limit. In an accidental case (i.e. simultaneous detonation of multiple blast holes due to errors in the blasting process or accidental explosion within the tunnel during the transfer of explosives from the Access Point to the blast face), the maximum PPV is still within the allowable PPV limit. Therefore, no adverse impact to the potential hazardous facilities is anticipated.

In terms of road transport of explosives, part of the delivery route from Ho Man Tin to Ma Tau Kok (Route B-C) is located near the MTKGW. Detonation of explosives outside the MTKGW might cause damage to gas holders, above ground pipes and gas production facilities. Housing damage category Ca (minor structural damage) is adopted in the building collapse model to estimate the affected distance $D_{affected}$ causing significant damage to the MTKGW (explained in **Section 9.13** "Building Collapse" subsection).

The closest distance between MTKGW and the explosive transport route (Route B-C) is about 75 m. For the maximum truck load of 125 kg explosives, the calculated affected distances, $D_{affected}$ is only 36 m. Therefore, as shown in **Appendix 9.16**, damage to MTKGW is not anticipated in case of accidental detonation of explosives on the delivery truck, and hence not further considered in the hazard assessment.

9.13 Consequence Assessment

Physical Effects Modelling

The hazard consequences from the transport and use of explosives in the CKR Project are established by using an internationally well recognised consequence model – PHAST in the SAFETI software package and other industry adopted formulas, to assess the impacts from overpressure, building collapse, fireballs, excessive ground vibration and other possible hazards.

Building Collapse

Model derived for high explosive, which was proposed by Gilbert, Lees and Scilly [9-14] are applied to determine the degree of building damage and the fatality probability for nearby buildings in the vicinity of an explosion source.

$$d = k * M^{(1/3)} / [1 + (3175 / M)^2]^{(1/6)}$$

where,
d is distance from explosion source in m

M is mass of TNT explosive in kg
k is a constant and varies according to level of damage

Affected areas with housing damage of Categories A, B, Cb and Ca as described in **Table 9.12** below are determined using the above equation. The vertical impact is considered up to the consequence distance vertically within the affected areas. The number of fatalities is determined by multiplying the affected population within the consequence zone (taking into account the vertical impact) with the corresponding fatality probability.

Table 9.12 Housing Damage Categories in the Gilbert, Less and Scilly Model and the Corresponding Fatality Probabilities

Housing Damage Category	Description	Fatality Probability
A	Houses completely demolished, i.e. with over 75% of external brickwork demolished.	0.62
B	Houses so badly damaged that they are beyond repair and must be demolished when opportunity arises. Property is included in this category if 50-75% of external brickwork is destroyed or in the case of less severe destruction, the remaining walls have gaping cracks rendering them unsafe.	0.086
Cb	Houses which are rendered uninhabitable by serious damage and need repairs so extensive that they must be postponed until after the war. Examples of damage resulting from such conditions include partial or total collapse of roof structures, partial demolition of one or two external walls up to 25% of the whole, and severe damage to the load bearing partitions necessitating demolition and replacement.	0.009
Ca	Houses that are rendered uninhabitable, but can be repaired reasonably quickly under wartime conditions, the damage sustained not exceeding minor structural damage, and partitions and joinery wrenched from fixings.	0

Fireball and Thermal Radiation Effect

The thermal radiation intensity[9-14] calculated and the respective probability of fatality proposed by Eisenberg[9-15] are applied here to calculate the number of fatality.

$$r = 1.75 * M^{(1/3)}$$

where,
r is radius of fireball in m
M is mass of TNT explosive in kg

$E = F_r * Q_c / A_f$
$t = 0.3 * M^{(1/3)}$

where E = surface emissive power (kW/m^2)
F_r = fraction of heat radiated, typical value 0.4

A_f = surface area of fireball (m^2)
Q_c = total heat release rate (kW)
t = duration of fireball (s)

$I = E * t_a * (r/L)^2$

where I = thermal radiation intensity (kW/m^2)
t_a = transmissivity, 0.75 for 70% humidity
L = distance of the target from centre of fireball (m)

The Probit equation for thermal radiation is:

$$Y = -14.9 + 2.56 * \ln(t * I^{(4/3)})$$

Overpressure for Above Ground Explosion

An HSE model, ESTC Outdoor and Indoor Blast Model **[9-11]**, has been adopted. The models predict probability of death, P, for population in 2 different correlations. The model has been designed specifically for use in risk assessment studies and is designed to err on the side of caution providing conservative results by taking into account of flying debris.

ESTC Outdoor Model
P = e^[-5.785 * S + 19.047] / 100

where S is $R/Q^{1/3}$ and within limits of $2.5 < S < 5.3$
R is distance from blast (m)
Q is mass of explosive (kg)
P = 1 if $S \leq 2.5$
P = 0 if $S \geq 5.3$

ESTC Indoor Model
$\text{Log } P = 1.827 - 3.433*\text{Log } S - 0.853*(\text{Log } S)^2 + 0.356*(\text{Log } S)^3$

where S is $R/Q^{1/3}$ and within limits of $3 < S < 55$
P = 1 if $S \leq 3$
P = 0 if $S \geq 55$

Overpressure for Underground Explosion during Transport within the Tunnel

Cartridged emulsion explosives will be used in trial blasts and in the MIC of 0.5kg/ delay, that cartridged emulsion explosives will be transported in the tunnel. The maximum allowable vehicle capacity within the tunnel is 200kg. In case of accidental detonation in the tunnel, overpressures near the unobstructed opening can be estimated by DOD 6055.9-STD**[9-16]** equations C9.7-16 and C9.7-17:

$R(\theta=0) = 220.191\ D_{HYD}((W/V_E)^{0.5}/P_{so})^{1/1.4}$
$R(\theta) = R(\theta=0)/(1+(\theta/56)^2)^{1/1.4}$

where $R(\theta=0)$ is the distance from the opening along the centreline axis, m.

θ is the horizontal angle from the centreline, degree.
D_{HYD} is the effective hydraulic diameter that controls dynamic flow issuing from the opening. $D_{HYD} = 4A/P$, where A is the cross-section area and P is the perimeter of the opening.
P_{so} is the overpressure at distance R(θ), kPa.
W is the charge weight for maximum credible event, kg.
V_E is the total volume engulfed by the blast wavefront within the tunnel system at the time the wavefront arrives at the point of interest, m^3.

In case of accidental detonation of explosives on the truck within the CKR tunnel, the shock wave will be released upwards from opening of the vertical access shaft. The overpressure from the shaft opening can be estimated from US DoD 6055.9-STD equation C9.7-16 and C9.7-17, taking the angle of θ = 90 degrees from the upward centreline.

Overpressure can cause fatalities due to lung haemorrhage of the people outside the portal, which can be evaluated from the probit equation derived by Fugelso, Weiner and Schiffman **[9-14]**:

$$Pr = -77.1 + 6.91 \ln P_0$$

where P_0 is the peak overpressure generated by the blast wave, Pa.

The peak overpressures corresponding to 1%, 50% and 90% fatality level are 100 kPa, 140 kPa and 174 kPa, respectively. Hence, hazard distances of the blast waves can be estimated accordingly.

The hazard distances corresponding to 1%, 50% and 90% fatality level of charge weight (maximum 200 kg explosives allowed) are listed in **Table 9.13**, using US DoD 6055.9-STD equation C9.7-16, C9.7-17 and ESTC models. ESTC outdoor model gives more conservative results than US DoD 6055.9-STD equations. Therefore, ESTC models are adopted to estimate the hazard distances of explosions in the tunnel for conservatism.

Table 9.13 Indicative Hazard Distances of the Blast Waves Generated by Detonation in the Tunnel (for maximum 200 kg explosives allowed)

Fatality	Hazard distance, m		
	US DoD 6055.9-STD(1)	ESTC outdoor model	ESTC indoor model
1%	10.7	19.2	54.5
50%	8.4	15.3	21.2
90%	7.2	14.7	18.3

Notes:
[1] Hazard distances to people outdoors are calculated for a vertical access shaft.

Cratering

US DoD 6055.9-STD **[9-16]** equation C5.2-14 gives the critical cover thickness required to prevent breaching of the chamber cover as

$$C_c = 0.99\, Q^{1/3}$$

where C_c is the critical cover thickness, m.

Q is the explosive quantity, kg.

The calculated critical cover thickness is 5.8 m for the maximum allowable explosive quantity of 200 kg to be transported. The critical cover thickness for explosions on a transport vehicle in the tunnel is expected to be lower due to the increased "decoupling" of the explosives compared with the underground storage chamber. Since the distance from the ground surface to the CKR tunnel is more than 30 m, cratering is deemed incredible and not further considered in this study.

Ground Vibration

Detonation of explosives liberates the chemical energy in a short time, producing shock waves associated with high pressures and temperatures in the confined blasting holes. The surrounding rock mass is crushed instantaneously. The shock wave propagates through the ground media, attenuates as it moves away from its source and causes vibrations of building structures founded on it. Structure damage or collapse can occur if the ground shaking is sufficiently strong, which causes property losses, injuries and fatalities.

The relationship between ground vibration from blasting and structural damage has long been the subject of extensive research. The peak particle velocity is more directly related to structural damage than displacement or acceleration, and widely adopted as the criterion to establish safe vibration levels for building structures. The peak particle velocity (PPV) is predicted from the shock wave propagation law as suggested by the United States Bureau of Mines [9-17]:

$$V = K (D/ E^{d})^{-b}$$

where,
V is the peak particle velocity (mm/s)
K is the "rock constant"
D is the distance between the blasting source and the measuring point (m)
E is the explosives charge weight per delay (kg)
d is the attenuation exponent
b is the attenuation factor

The quantity D/ E^{d}, known as scaled distance, is the normalized factor to account for changes in the explosive charge and the propagation distance from source to the measuring point. Square-root scaling (d = 0.5) or cube-root scaling (d = 0.33) are typically used from the consideration of cylindrical or spherical wave divergence. The value of "rock constant" K is site specific, which largely depends on rock type, geological structure and confinement of the blast. The GEO paper "Prediction of Blast Vibration and Current Practice of Measurement in Hong Kong" by Li & Ng[9-17] states d = 0.5, b = 1.22 and K = 644 at a 84% confidence limit based on the ground vibration data collected since 1984 by the Mines and quarries Division. These values have been used for the blasting design and assessment of the CKR project, in agreement with the general practice in Hong Kong and the guidelines from the Mines Division. The MIC has been designed to induce ground vibrations no more than the limits (e.g. PPV = 25 mm/s for buildings) adopted by the CKR project specification and the HKSAR General Specification for Civil Engineering Works.

An appropriate value of K is necessary for this risk assessment, however, since there is still 16% uncertainty that the ground vibrations might exceed the acceptable limits. From Geoguide 4: Guide to Rock Cavern Engineering, CEDD [9-18], the values of K for the granitic and volcanic rocks in Hong Kong are in the range of 1000 to 1200 for tunnel blasting. And the values of b and d×b vary in the ranges of 1.2 to 1.6 and 0.6 to 0.8, respectively, which gives the attenuation exponent d in the limit of 0.5 to 0.67.

Drill-and-blast operation will be applied to the CKR tunnel alignment constructed in strong rock. The parameters used in this hazard assessment were presented as following:

K = 1200

It is conservative since it is the upper limit for hard rocks in Hong Kong selected from GEO Geoguide 4.

d = 0.5

It is conservative and the best reliable scaling factor applicable for Hong Kong based on GEO paper by Li & Ng [9-17].

b = 1.22

It is a conservative attenuation factor for predicting PPV in far field in the range of 1.2 to 1.6 stated in GEO Geoguide 4[9-18].

Effect of Ground Vibration on Buildings

Strong ground vibrations may cause damage to structures and equipment, which depends on the type of structure, technical installations and the dominant frequency of the vibration. Blast vibrations normally have a frequency of 20 to 200 Hz higher than the natural frequency of most buildings. Therefore, amplification of vibrations due to resonance will not occur.

Geoguide 4[9-18] lists the blast vibration acceptance criteria in various countries. The safe vibration limits used are similar, with a peak particle velocity of 50mm/s or 70mm/s. The threshold values of damage are described as 110mm/s or 115mm/s. These standards are considered to be conservative and universally apply to all types of normal buildings irrespective of building structures and type of foundation. In Hong Kong, 25mm/s has been used for many years as the safety limit normally acceptable for buildings, in order to prevent cosmetic damage. However, in this assessment the values of the peak particle velocity that causes significant structural damage potentially leading to a fatality or multiple fatalities are considered.

Following criteria are deemed to be conservative and used in this study for building damage, which are adopted from the previous WIL EIA study [9-1]:

- PPV = 229 mm/s - Serious building structure damage threshold. PPV at this level is unlikely to cause any structural element to collapse.
- PPV = 100 mm/s –Minor building structure damage and object falling threshold. This is the lower limit causing minor damage to a typical western residential building [9-23], and considered very conservative for

typical concrete buildings in Hong Kong. No damage is expected below this PPV level. A 1% fatality level within a building is assumed due to vibration induced object falling based on the findings in the WIL EIA study [9-1].

Effect of Ground Vibration on Slopes

The consequence models used for the assessment of slope failure due to blasting vibrations are based on the GEO Report 15[9-31], GEO Report 81[9-32] and findings in the WIL EIA report [9-1]. The modified Sarma equation is adopted to estimate slope movement from the detonation of explosives:

$$X_m = 0.0465 \times PPV \times 10^{(1.07-3.83\times PPVc/PPV)}$$

where X_m is the slope movement;

PPV is the peak particle velocity of the blasting vibrations; and

PPVc is the critical velocity of the slope.

The criteria of the slope failure based on the amount of shear displacement or slope movement are:

- 20 mm shear displacement or slope movement causes a 0.01% chance of slope failure.
- 50 mm shear displacement or slope movement causes a 10% chance of slope failure.
- 100 mm shear displacement or slope movement causes a 50% chance of slope failure.
- 200 mm shear displacement or slope movement causes a 100% chance of slope failure.

In addition, a screening criteria of PPV = 90mm/s was adopted [9-1] for screening of slopes which are potentially at risk during the construction of CKR. This PPV level corresponds to 0.01% chance of a slope failure with Factor of Safety (FOS) = 1.1.

The number of fatalities caused by landslide due to slope failure is estimated in GEO Report 81[9-32] as follows:

$$N = \frac{\sum WFPEA}{V}$$

where W is the width of landslide plus adjustment for effective stopping distance;

F is the frequency of passing passengers, which may be taken as the product of the Annual Average Daily Traffic (AADT) and the average number of people in a vehicle;

P is the probability of death due to being caught in the landslide;

E is the extent of the landslide equivalent to the number of lanes affected;

A is an adjustment factor for proportion of normal road usage at the time of the landslide; and

V is the speed of vehicles.

The average vehicle speed is taken to be 30 miles/hr (48 km/h) based on the road conditions along the CKR tunnel alignment. Hence, a stopping distance of about 23 m is assumed based on UK Highway Code data [9-33].

The value of A is taken as unity considering the blasting operations will be conducted largely during normal hours.

The probability of death, P, due to landslides are taken from GEO Report 81[9-32] as 0.8, 0.6 and 0.4 for the $1^{st} \sim 3^{rd}$ lanes away from the slope, and assumed to be 1 for the failure of a retaining wall.

Assuming a conservative travel angle of 30^{o} and a triangular volume, the run out distance for the landslide can be estimated as:

$$L = \sqrt{\frac{2V}{W\tan(30)}}$$

where L is the run out distance in m;

V is the slip volume in m^3; and

W is the slip width in m.

Effect of Ground Vibration on Boulders

Since no boulders were identified in the Preliminary Blasting Assessment Report [9-5], risks due to boulder fall are not considered in this assessment.

Ground Vibration Generated by Accidental Explosion in the Tunnel

For accidental explosion of the truck load within the tunnel during conveyance to the blast site, US DoD 6055.9-STD [9-16] equation C9.7-2 gives the inhabited building distance for low loading density storage:

$$D_{ig} = 2.3\ Q^{1/3}$$

In this study this distance is assumed to cause significant structural damage to the buildings by ground vibrations, i.e., PPV = 229 mm/s. Therefore, for a maximum allowable full load of 200 kg explosives on the truck, the safe distance D_{ig} is 13.5m. This distance is used to estimate a revised rock constant, K, which reflects the “decoupling” of the explosives on the truck compared to the values used for fully “coupled” explosives in the blast holes. A revised value of K = 200, as estimated in the WIL EIA [9-1], is adopted in this assessment.

Hazard effect zones at each blasting location will then be calculated along the blasting zone of the tunnel using the ground vibration correlation in aforementioned section “Ground Vibration”. The explosives charge weight, depending on the different scenarios which cause excessive ground vibration, is entered into the equation together with the ground vibration level end-points described in aforementioned section "Effect of Ground Vibration on Buildings" and "Effect of Ground Vibration on Slopes". If the population group falls into a hazard effect zone, the corresponding number of fatalities can then be calculated.

Consequence Assessment Results for Transport of Explosives

The hazard effect distances for buildings collapse, fireball and thermal radiation and overpressure due to an explosion of explosives during delivery are illustrated below. Equivalent TNT of 125 kg transported by the contractor's approved vehicles is modelled for hazard zones comparison purpose.

Building Collapse

Affected distances for buildings collapse due to an explosion of the explosives during delivery from one Access Point to another are tabulated in **Table 9.14**.

Table 9.14 Affected Distances for Building Collapse

Equivalent TNT (kg)	Affected Distance (m)		
	Fatality Probability		
	0.9	0.5	0.01
125	8	12	21

Fireball and Thermal Radiation

Affected distances for the fireball and thermal radiation effects in an explosion from the explosives during delivery from one Access Point to another are shown in **Table 9.15**.

Table 9.15 Affected Distance for Fireball and Thermal Radiation Effect

Equivalent TNT (kg)	Affected Distance (m)		
	Fatality Probability		
	0.9	0.5	0.01
125	5	6	8

Overpressure

Affected distances due to overpressure in an explosion from the explosives during delivery from one Access Point to another are listed in **Table 9.16**. Extent of outdoor overpressure effect is much greater than fireball/ thermal radiation effect. Affected distances for indoor overpressure are comparable or larger than those given by the building collapse model.

Table 9.16 Affected Distance for Overpressure Effect (ESTC model)

Equivalent TNT (kg)	Affected Distance (m)		
	Fatality Probability		
	0.9	0.5	0.01
Outdoor			
125	12.6	13.1	16.4
Indoor			
125	15.7	18.1	46.5

Hazard Zones

By comparing affected distances from ESTC outdoor/ indoor blast model, the fireball/ thermal radiation model, and the building collapse model, ESTC models (**Table 9.16**) are adopted in this assessment as they give the most conservative estimation. Building, pedestrian and traffic population in close vicinity of the explosive transport routes will be affected by the accidental detonation of the explosives.

Consequence Assessment Results for Use of Explosives

Tunnel blasting operation will be carried out from Chainage 1440 to Chainage 4230. Sensitive receivers along the tunnel alignment and close to the ventilation shaft are assessed for the potential vibration impact. **Appendix 9.20** summarizes the proposed MICs at various tunnel chainages, cross passages and shaft depths.

Effect of Excessive Ground Vibration on Buildings

Sensitive receivers, such as residential buildings, commercial buildings, MTR railways (TWL / ERL / KTE / SCL) and other building structures are considered in the assessment. No building is impacted by ground vibrations up to the minor building structure damage and object falling threshold (100 mm/s) or the serious building structure damage threshold (229 mm/s). The maximum PPV level is 66 mm/s considering simultaneous detonation of 6MIC. Therefore, it is anticipated that no building is subject to minor building structure damage leading to fatality, due to excessive ground vibration in case of simultaneous detonation up to 6 MIC.

Effect of Excessive Ground Vibration on Slopes

The highest ground vibrations expected for slopes may occur at Slope No. 11NW-D/C437 in case of simultaneous detonation of 6MIC. The corresponding max PPV = 81 mm/s, which is lower than the screening criteria of PPV = 90mm/s corresponding to 0.01% chance of a slope failure with Factor of Safety (FOS) = 1.1.

Therefore, it is anticipated that no slope is subject to failure due to excessive ground vibration in case of simultaneous detonation up to 6MIC.

Consequence Assessment Results for Explosive Transport within the Tunnel

Effect of Excessive Ground Vibration on Buildings due to Detonation of Explosives on the Truck within the Tunnel

For the accidental detonation of explosives on the truck within the tunnel, a revised rock constant K = 200 is adopted as explained in **Section 9.13** "Ground Vibration Generated by Accidental Explosion in the Tunnel" subsection. The truck load at various tunnel sections are listed below:

- maximum 7.8 equivalent TNT kg for the tunnels accessed from the YMT access point. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from YMT west portal);
- maximum 14.7 equivalent TNT kg for the tunnels accessed from the MTK access point. Only one loaded truck with maximum 3 numbers of trips of

cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within west bound tunnel of CKR (from MTK east portal). No explosive transportation and no blasting works will be carried out from chainage 4030 to chainage 4180 at east bound tunnel of CKR tunnel;

- maximum 63.4 equivalent TNT kg for the tunnels accessed from the HMT access point to YMT. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from HMT shaft);
- maximum 143.7 equivalent TNT kg for the tunnels accessed from the HMT access point to EB3570 / WB3580. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube within CKR tunnel (from HMT shaft); and
- maximum 26.7 equivalent TNT kg for the tunnels accessed from the HMT access point from EB3570 / WB3580 to MTK. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from HMT shaft).

The resulting ground vibration levels remain within the safe limits for buildings (PPV < 100 mm/s, threshold of 1% fatality) and slopes (PPV < 90mm/s, screening criteria).

Effect of Air Overpressure due to Detonation of Explosives on the Truck within the Tunnel

The ventilation shaft near the Ho Man Tin Government Office is about 20 m in diameter and 103 m in length. The access shafts at Yau Ma Tei and Ma Tau Kok are about 14 m in diameter, 31 m and 35 m in length respectively. Accidental detonation of explosives on the truck within the CKR tunnel accessed from the HMT / YMT / MTK shaft is released from the shaft opening and may cause fatalities due to air overpressure. Air overpressure effects due to accidental detonation of explosives on the truck within the tunnel are listed in **Table 9.17**. Fatality contours at the opening of the HMT / YMT / MTK shaft are overlaid on the map, as shown in **Appendix 9.17**. Overpressure contours at HMT and YMT may extend offsite and affect the neighbouring population. The results for fatalities caused by air overpressure are shown in **Table 9.18**.

Table 9.17 Affected Distance for Overpressure Effect Related to Transport of Explosives within the Tunnel

Equivalent TNT (kg)	Affected Distance (m)		
	Fatality Probability		
	0.9	0.5	0.01
Outdoor			
143.7	13.1	13.7	17.2
63.4	10.0	10.4	13.2
26.7	7.5	7.8	9.9
14.7	6.2	6.4	8.0

Equivalent TNT (kg)	Affected Distance (m)		
	Fatality Probability		
7.8	5.0	5.2	6.5
Indoor			
143.7	16.4	19.0	48.3
63.4	12.5	14.5	37.7
26.7	9.4	10.8	27.7
14.7	7.7	8.9	22.8
7.8	6.2	7.2	18.8

Table 9.18 Fatalities due to Air Overpressure Caused by Accidental Detonation of Explosives on the Truck within the Tunnel

Scenario	Scenario Frequency (per year)	Expected Fatality
Accidental Detonation of Explosives on the Truck within the Tunnel (accessed from the HMT shaft)	1.27E-06	1
Accidental Detonation of Explosives on the Truck within the Tunnel (accessed from the YMT shaft)	3.65E-07	1

9.14 Risk Analysis

From above analyses, consequences and their corresponding frequencies for each representative location are summed up for the whole Project using the risk summation tools in the SAFETI software package. By summing up all hazard events, Individual Risk as well as Societal Risk associated with the identified hazardous scenarios are obtained and compared with the criteria set out in Annex 4 of the TM-EIAO to determine their acceptability.

The determination of acceptability of Societal Risk in the form of F-N curves is based on the criteria described in **Section 9.3**. The off-site Individual Risk levels are checked to see if it is less than 1 x 10^{-5} per year (i.e. 1 in 100,000 years) for use of explosives. For delivery of explosives, as the definitions for on-site and off-site do not apply, the maximum Individual Risk level has to be less than 1 x 10^{-5} per year for the CKR Project.

The Societal Risk Assessment results are presented in **Appendix 9.18** in the form of frequency to number of fatalities (F-N) curves for comparison with the Hong Kong Government Risk Guidelines. The base scenario reflects the scheduled explosive transport in the worst one-year period (the longest transport distance and the highest transport quantity of explosives) of the whole project as described in **Section 9.11**. The contingency scenario reflects an additional 20% increase in the number of explosive delivery trips considering potential project uncertainties leading to extra explosive transport as described in **Section 9.5**. As shown in **Appendix 9.18**, it can be seen that the F-N curves for the base scenario and the contingency scenario fall into the "Acceptable" region. Contribution from the use of explosives is significant only at N = 1. The potential loss of life (PLL) for the base scenario and the contingency scenario are 2.12 x 10^{-5} and 2.52 x 10^{-5} per year respectively. The F-N curves indicate that the construction of the Central Kowloon Route is in compliance with the TM-EIAO in terms of Societal Risk.

Individual Risk for road transport of explosives is presented as Individual Risk contour plots. Indoor and outdoor risk contours are illustrated in **Appendix 9.19**. They are at the magnitude of 10^{-8} and 10^{-9} per year and well below the threshold stipulated in the Risk Guidelines ($1x10^{-5}$ per year). The Individual Risk contours indicate that road transport of explosives for the construction of the Central Kowloon Route is in compliance with the TM-EIAO in terms of Individual Risk.

For tunnel blasting using explosives, it is anticipated that no building is subject to minor building structure damage leading to fatality, due to excessive ground vibration in case of simultaneous detonation up to 6 MIC or accidental detonation during underground transport of explosives. Therefore tunnel blasting using explosives is in compliance with the TM-EIAO in terms of Individual Risk.

9.15 Risks due to Interfaces with Future Shatin to Central Link (SCL)

The proposed Central Kowloon Route (CKR) will pass under the proposed Shatin to Central Link (SCL) near the intersection of Ma Tau Wai Road and Sheung Heung Road. Regular meetings have been held between the CKR and SCL designers to coordinate all issues at the project interface. Key issues coordinated include:

- The SCL construction program was reviewed. CKR will be constructed after the SCL tunnel. E&M work will be conducted in the SCL tunnel when the CKR blasting work is performed near the interface.
- The construction method of CKR is drill-and-blast. CKR tunnel designer takes SCL tunnel as sensitive receiver and comply with the PPV limits on MTR tunnels.
- Close liaison and coordination will be established between CKR blasting contractors and MTR for the daily tunnel blasting work near the interface.
- The separation between proposed SCL tunnels and the proposed CKR was investigated. The minimum clearance between SCL down track tunnel and CKR is 17 m.

The SCL tunnels near the interface will be constructed by Tunnel Boring Machine (TBM) method using twin bored single track TBM drives to be launched at the southern end of To Kwa Wan Station. The TBM will drive through the northern end wall of the Ma Tau Wai Station The vertical alignment will allow a 17 m clearance between the SCL down track tunnel and CKR. Therefore, construction of SCL tunnels near the interface will not cause additional risks due to excessive blasting vibrations.

The CKR tunnels near the interface will be constructed by drill-and-blast method. The risks to the future SCL tunnels near the interface have been assessed in the Risk Analysis under **Section 9.14**.

Further coordination and communication between the SCL and CKR designers/ contractors will be continued to minimise the risks at the project interface.

9.16 Risks due to Interfaces with Future Kwun Tong Line Extension (KTE)

The proposed Central Kowloon Route (CKR) will pass under the proposed Kwun Tong Line Extension (KTE) near the intersection of Nathan Road and Gascoigne Road. Regular meetings have been held between the CKR and KTE designers to coordinate all issues at the project interface. Key issues coordinated include:

- The KTE construction program was reviewed. CKR will be constructed after the KTE tunnel. KTE will be at operation stage when the CKR blasting work is performed near the interface.
- The construction method of CKR is drill-and-blast. CKR tunnel designer takes KTE tunnel as sensitive receiver and comply with the PPV limits on MTR tunnels.
- Close liaison and coordination will be established between CKR blasting contractors and MTR for the daily tunnel blasting work near the interface.
- Blasting induced ground vibrations will be monitored.

Construction of KTE will be completed before the commencement of CKR tunnel blasting near the interface. Therefore, construction of KTE tunnels near the interface will not cause additional risks.

The CKR tunnels near the interface will be constructed by drill-and-blast method. The risks to the future KTE tunnels near the interface have been assessed in the Risk Analysis under **Section 9.14**.

Further coordination and communication between the KTE and CKR designers/ contractors will be continued to minimise the risks at the project interface.

9.17 Conclusion

A quantitative risk assessment has been carried out to evaluate the hazard to life issues associated with the transport and use of explosives during construction of the CKR project in terms of Individual and Societal Risks criteria stipulated in Annex 4 of the Environmental Impact Assessment Ordinance Technical Memorandum (TM-EIAO).

The maximum truck load for explosive transport from Ho Man Tin to Yau Ma Tei and from Ho Man Tin to Ma Tau Kok is 120 kg Gross Weight Cartridged Emulsion Explosives (about 125 equivalent TNT kg).

The maximum truck load for explosive transport within the tunnel is

- maximum 7.5 kg Gross Weight Cartridged Emulsion Explosives (about 7.8 equivalent TNT kg) for the tunnels accessed from the YMT access point. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from YMT west portal);
- maximum 14.1 kg Gross Weight Cartridged Emulsion Explosives (about 14.7 equivalent TNT kg) for the tunnels accessed from the MTK access

point. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within west bound tunnel of CKR (from MTK east portal). No explosive transportation and no blasting works will be carried out from chainage 4030 to chainage 4180 at east bound tunnel of CKR tunnel;

- maximum 60.9 kg Gross Weight Cartridged Emulsion Explosives (about 63.4 equivalent TNT kg) for the tunnels accessed from the HMT access point to YMT. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from HMT shaft);
- maximum 138.0 kg Gross Weight Cartridged Emulsion Explosives (about 143.7 equivalent TNT kg) for the tunnels accessed from the HMT access point to EB3570 / WB3580. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube within CKR tunnel (from HMT shaft); and
- maximum 25.6 kg Gross Weight Cartridged Emulsion Explosives (about 26.7 equivalent TNT kg) for the tunnels accessed from the HMT access point from EB3570 / WB3580 to MTK. Only one loaded truck with maximum 3 numbers of trips of cartridged emulsion explosives and other explosives accessories (excluding detonators) will be allowed within a tunnel tube of CKR tunnel (from HMT shaft).

Potential causes of hazard events have been carefully identified, and a set of relevant scenarios have been developed for the CKR project, including:

- Accident involving explosives delivered and transferred by the contractor using approved trucks, from the Mines Division vehicle offloading point at Ho Man Tin to the other access points at Yau Ma Tei and Ma Tau Kok (after delivery of explosives by Mines Division vehicle at Ho Man Tin).
- Excessive vibration generated by the blast face due to human errors and other reasons such as manufacturing defects causing deviation from the confirmed design for the tunnel and ventilation shaft.
- Excessive vibration and air overpressure due to explosion within the tunnel during the transfer of explosives from the Access Point to the blast face.

The assessment results indicate that the Societal Risk fall into “Acceptable” region. The maximum Individual Risk is also acceptable since it is less than 1 x 10^{-5} per year. It is concluded that the construction of the Central Kowloon Route associated with the transport and use of explosives satisfies the Hong Kong Government risk criteria set out in Annex 4 of the TM-EIAO.

9.18 Recommendations

The following recommendations for further risk mitigations should be considered for the safe transport of explosives as “Good Practices”:

- Only the required quantity of explosives for a particular blast should be transported to avoid the return.
- The approved truck dedicated for transport of explosives should comply with the "Guidance Note on Requirements for Approval of an Explosives Delivery Vehicle" issued by CEDD Mines Division. The truck should be periodically inspected and properly maintained in good operation conditions. The fuel carried in the fuel tank should be minimized to reduce the duration of fire. Adequate fire-fighting equipment shall be provided, inspected and replaced periodically (e.g. fire extinguishers).
- The driver and his assistant should be physically healthy, experienced and have good safe driving records. The driver should hold a proper driving license for the approved transport truck. Dedicated training programme and regular road safety briefing sessions / workshops should be provided to enhance their safe driving attitude and practice. Smoking should be strictly prohibited.
- Emergency response plans in case of road accident should be prepared and implemented. The driver and his assistant should be familiar with the emergency procedures including evacuation, and proper communication / fire-fighting equipment should be provided to the driver and his assistant.
- Close liaison and communication among Mines Division, contractors for transport of explosives, and working staff of the tunnel blasting should be established. In case of any change of work schedule leading to cancellation or variation of explosives required, relevant parties should be informed in time to avoid unused explosives at the work sites.
- Close liaison and communication with Fire Services Department should be established to reduce the accidental detonation escalated from a fire. The contractors for transport of explosives should use the preferred transport routes as far as practicable.
- Contingency plan should be prepared for transport of explosives under severe weather conditions such as rainstorms and thunderstorms.
- For explosive transport, all packages of explosives on the truck should be properly stored in the truck compartment as required. Packaging of the explosives should remain intact (i.e. damage free) until they are transferred to the blasting site.
- Activities of transport of explosives should be supervised and audited by competent staff to ensure full compliance with the requirements.
- Availability of a parking space should be ensured before commencement of transport of explosives. Location for loading and unloading of explosives should be as close as possible to the shaft or the adit. No hot work should be performed in the vicinity during the time of loading and unloading.
- It is recommended to explore to minimize the use of the cartridged emulsion explosives and maximize the use of bulk emulsion explosive as far as practicable.

- It is recommended to explore to use smaller explosive charges such as 'cast boosters' or 'mini-cast booster' instead of cartridged emulsion as primers for bulk emulsion. This is option reduces the quantity of explosives required for transportation for the sections where bulk emulsion will be used.
- Instrumentation and monitoring plan should be submitted to all relevant stakeholders for agreement prior to the commencement of the tunnel blasing works. Such plan should be implemented during construction of CKR tunnels.
- Contingency plan should be submitted to all relevant stakeholders for agreement prior to the commencement of the tunnel blasting works.

The following recommendations for further risk mitigations should be considered for the safe use of explosives as "Good Practices":

- The blasting charge weight should not exceed the maximum MIC as specified for the tunnel section.
- Provision of blast doors or heavy duty blast curtains should be implemented at the shafts, adits and other suitable locations to prevent flyrock and control the air overpressure.
- Good communication and coordination should be performed for safe blasting of different chainage locations on the same day.
- Evacuation and secure refugee areas should be implemented / provided to the working staff.
- Healthy competent licensed shotfirers and blasting engineers should be employed to conduct the blasting work.
- Proper control measures should be enforced during explosive transport within the tunnel and charging the blast holes, such as speed limit for the truck, no hot work in the vicinity, etc.
- Ground vibrations of the blasting operation should be monitored and MICs should be adjusted according to the actual geotechnical features to ensure blasting vibrations within the specified PPV limit.
- For tunnel blasting near gas facilities, requirement of the "Gas Production and Supply Code of Practice - Avoiding Danger from Gas Pipes" should be respected. Close liaison and coordination with HKCG should be established to provide sufficient notice of the planned blasting activities in an appropriate format within a reasonable time period prior to blasting. Emergency response procedures should be prepared and implemented in case of gas leaks.
- For tunnel blasting near MTRC railway tunnels, close liaison and coordination with MTRC should be established to provide sufficient notice of the planned blasting activities in an appropriate format within a reasonable time period prior to blasting. Emergency response procedures should be prepared and implemented in case of any damage to the railway facilities.

- Blasting activities regarding use of explosives should be supervised and audited by competent site staff to ensure full compliance with the blasting permit conditions.
- The use of bulk emulsion where the maximum instant charge (MIC) envisaged for a particular blast is above 0.5kg. This prevents the occurrence of excessive vibrations due to potential bulk emulsion dosing inaccuracy in the case of low MIC. It is recommended to explore the bulk emulsion dosing technology so as to maximize the use of bulk emulsion explosive as far as practicable.

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