Safety Review of Dangerous Goods Vehicles Traffic under proposed Land Bridge in Cockle Bay, NSW

For DPT Operator Pty Ltd

11 April 2025

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Revision: 1

Risk Engineering Solutions

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SUMMARY

The proposed Cockle Bay Park (CBP) development by DPT Operator Pty Ltd and DPPT Operator Pty Ltd (DPT) includes a landbridge over the Western Distributor to create an area of publicly accessible open space. There had been ongoing consultations with regulatory agencies in NSW as part of the development application (DA) assessment process. A number of safety studies involving Dangerous Goods (DG) transport have been undertaken for the landbridge.

Based on changes to design, FRNSW has determined that the development over the Western Distributor does not perform like a tunnel and is therefore **not** a tunnel under AS 4825-2011, and is considered a "Landbridge" [1]. SafeWork has some concerns over Class 1 and Class 5.1 DGs being transported under the landbridge.

This review and hazard assessment by Arriscar Pty Ltd (Arriscar) addresses the issues raised in the Joint Agency Letter to the Department of Planning, Housing and Infrastructure (DPHI) [2], subsequent concerns of SafeWork NSW [3], and identified gaps in the previous reports.

The present study has not attempted to repeat the work done in previous studies, but enables the regulator to obtain a more complete picture of the safety and risk issues.

The following findings were made in this review:

There is no statistically significant data on dangerous goods vehicle (DGV) accident frequency on Western Distributor (WD). Frequency of leak from bulk tankers carrying DGs from international data, calculated for the traffic under the landbridge are 1.6E-04 p.a. for petrol tankers and 1.4E-05 p.a. for LPG tankers. The frequency derived from tunnel fires in Australia is 2.96E-05 p.a.

- Release scenarios considered credible were modelled using the software PHAST 9.0. There is potential for injury/ fatality to road users in the event of loss of containment of LPG or gasoline from bulk tankers, or a toxic gas release.
- A semi-quantitative risk assessment using the TfNSW risk matrix [4] was carried out using the quantitative data on consequence and frequency estimated in this report as input for ranking the event within a cell in the risk matrix.
- There were no events identified in the "Very High Risk" category. There was one event in the "High Risk" category. There were four (4) events identified in the 'Medium" risk category and five (5) in the "Low" risk category.
- The Medium risk events are considered tolerable if it can be demonstrated that they can be managed at a level considered DFAIRP (So Far As Is Reasonably Practicable). The Low risk events are broadly acceptable.

A SFAIRP methodology is described in this report and demonstration of SFAIRP using the well-established "bow-tie" methodology. It was found that the proposed development would satisfy the SFAIRP criteria.

The present report completes the gaps in the previous studies and addresses the issues raised in the Joint Agency letter [2], and summarised in Section 2 of this report.

Recommendations have been made to DPT to ensure that the landbridge is designed and operated safely.

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NOTATION

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AN	Ammonium Nitrate
ANSTO	Australian Nuclear Science and Technology Organisation
AQIS	Australian Quarantine Inspection Service
AS	Australian Standard
ASET	Available Safe Egress Time
CBP	Cockle Bay Park
CFD	Computational Fluid Dynamics
Cl_2	Chlorine
CO_2	Carbon Dioxide
DG	Dangerous Goods
DGV	Dangerous Goods Vehicle
DPHI	Department of Planning, Housing and Infrastructure
DPT	DPT Operator Pty Ltd and DPPT Operator Pty Ltd
EPA	Environment Protection Authority NSW
FDS	Fire Dynamics Simulator
FEB	Fire Engineering Brief
FER	Fire Engineering Report
FRNSW	Fire & Rescue NSW
HAZMAT	Hazardous Materials
IBC	Intermediate Bulk Container
IOGP	International Oil and Gas Producers Association
kg	Kilograms
kg/s	Kilograms per second
kPa	kilopascals
kW/m^2	Kilowatts per square metre
L	Litres

Abbreviation	Description
LPG	Liquefied Petroleum Gas
m	metres
m/s	Metres per second
MAE	Major Accident Event
MHF	Major Hazard Facility
min	Minutes
mm	Millimetres
MW	Megawatts
N_2	Nitrogen
O_2	Oxygen
RSET	Required Safe Egress Time
SFAIRP	So Far As Is Reasonably Practicable
TfNSW	Transport for NSW
TNT	Tri-nitro Toluene
VCE	Vapour Cloud Explosion
WD	Western Distributor

1 INTRODUCTION

1.1 Background

DPT Operator Pty Ltd and DPPT Operator Pty Ltd (DPT) had submitted a State Significant Development Application (SSDA) and an Environmental Impact Statement (EIS) proposing a redevelopment of the Cockle Bay Wharf Building and surrounding areas to create a new open space and a commercial, retail and tourist precinct, referred to as Cockle Bay Park (CBP).

The development comprises of the following:

- A landbridge over the Western Distributor to create an area of publicly accessible open space
- Retail outlets, including new food and beverage destinations and
- Commercial office tower adjacent to the Western Distributor.

There had been ongoing consultations with NSW Department of Planning Housing and Infrastructure (DPHI), NSW Environment Protection Authority (EPA), Transport for NSW (TfNSW), Fire & Rescue NSW (FRNSW) and SafeWork NSW. There were initial concerns that the proposed landbridge could constitute a "tunnel" under AS 4825-2011 [5]. If the definition of tunnel applies, then, under the Government policy, placarded dangerous goods vehicles (DGV) may not be permitted to use the roadway.

A number of safety studies involving DG transport have been undertaken for the landbridge [6], [7], [8], [9], [10], [11] and additional consultations have been undertaken.

Based on changes to design, FRNSW has determined that the development over the Western Distributor does not perform like a tunnel and is therefore **not** a tunnel under AS 4825-2011, and is considered a "Land Bridge" [1]. SafeWork has some concerns over Class 1 and Class 5.1 DGs being transported under the landbridge [3].

DPT has commissioned Arriscar Pty Ltd (Arriscar) to undertake a safety review of DG transport under the landbridge addressing the issues raised in the Joint Agency Letter to DPHI [2], subsequent concerns of SafeWork NSW [3], and identified gaps in the previous reports.

Arriscar prepared a safety review report addressing the gap issues to provide a more complete picture of the risks associated with DGV transport under the landbridge [12].

The Arriscar report [12] was submitted to DPHI in December 2024. DPHI had commissioned GHD Pty Ltd to conduct a peer review of the Arriscar report. The GHD peer review [13] identified additional information requirements. This information was requested from DPT Operator by DPHI [14].

The present report is an update of the Arriscar safety review report [12], incorporating the responses to issues raised in the GHD review [13] and request for information by DPHI [14].

1.2 Scope of the Review

The present study scope consists of the following:

- Address the issues raised in the Joint Agency Letter to DPHI [2] that has not been fully addressed in previous studies.
- Address the remaining concerns of SafeWork NSW [3] regarding Class 1 and Class 5.1 DG transport.
- Identify gaps in the previous reports and address the gaps.

- Assess the safety measures and controls provided to maintain the risks at a level considered SFAIRP (So Far As Is Reasonably Practicable)

The present study has not attempted to repeat the work done in previous studies, but enables the regulator to obtain a more complete picture of the safety and risk issues.

In the risk assessment of DG transport, the consequences and frequencies are separately reported.

2 Issues Raised by Regulatory Agencies

2.1 Government Agencies involved

The agencies involved in the assessment of the proposal were:

1. Department of Planning, Housing and Infrastructure, NSW (DPHI)
2. Transport for NSW (TfNSW)
3. Fire and Rescue NSW (FRNSW)
4. Environment Protection Authority of NSW (EPA)
5. SafeWork NSW

The positions taken by the agencies are summarised below:

2.1.1 NSW Department of Planning, Housing and Infrastructure

The DPHI is the consent authority and has coordinated responses from all other relevant agencies. The request for additional information [14] mainly covers the following:

- Response to comments on the findings of GHD peer review [13]
- Response to comments on the recommendations of GHD peer review [13]

2.1.2 Transport for NSW

TfNSW, in its response has stated:

> *"TfNSW has duly considered the supporting documentation in the assessment of the impacts of proposed landbridge on the Western Distributor, which includes a risk assessment based on ASA Standard T MU MD 20001 ST System Safety Standard for New or Altered Assets and fire safety study which considers AS 4825-211 Tunnel Fire Safety. TfNSW is satisfied that further restriction on the operation of DVG's travelling on Western Distributor would not be required following completion of the proposed landbridge, subject to implementation of the appropriate fire suppression systems and TfNSW safe systems requirements to ensure the ongoing safety of current and future users of the Western Distributor."*

Refs. [11] and the present study address the requirements of TfNSW.

2.1.3 Fire and Rescue NSW

There was a joint agency letter of FRNSW, EPA and SafeWork to DPHI on 22 December 2021 [2]. The initial position taken was that the proposed landbridge development constitutes a 'tunnel' in accordance with AS 4825-2011 [5], where placarded DG vehicles may not be permitted to travel.

Subsequently, after additional studies by DPT and consultation meetings, FRNSW had arrived at the following position on 17 November 2023 [1].

> *"FRNSW provide in-principle support that the structure proposed to be constructed over the existing Western Distributor be defined as a 'landbridge', and that the* ***space enclosed does not constitute a tunnel*** *as defined within AS 4825-2011 Tunnel fire safety.*
>
> *This in-principle support acknowledges that several design changes have been proposed since the original design submission in SSD-9978934 (FRNSW ref: D21/129156) such that the performance of the enclosed space exceeds that of a space that is not a tunnel, i.e., a*

substantially enclosed roadway that is less than 80m in length. These design changes have been supported by preliminary and detailed comparative and absolute analysis.

The detailed comparative and absolute assessments presented to FRNSW in the meeting on 26 October 2023, are to be documented in the Fire Engineering Brief (FEB) and Fire Engineering Report (FER) as part of a normal fire engineering process for FRNSW review and comment. This is to be done subsequent to the SSD approval, if granted".

2.1.4 NSW Environment Protection Authority

Vehicles and drivers transporting placarded loads of DGs on NSW roads are licensed by the EPA.

Originally, the EPA had taken the position with FRNSW and SafeWork that the proposed landbridge was a 'Tunnel' [2]. Subsequently, based on additional studies and FRNSW's acceptance that the landbridge is not a tunnel and considered a landbridge [1], the EPA has modified its position and has supported the FRNSW's latest position on the development [15].

"The EPA has joint responsibility with SafeWork NSW for the administration and enforcement of dangerous goods legislation in NSW. As such, the EPA acknowledges and supports Fire and Rescue NSW position on this matter outlined in the letter to TSA Management on 17 July 2023 (Attachment 1).

We have no further comment on this proposal."

2.1.5 SafeWork NSW

SafeWork NSW has commented in the joint agency letter on 22 December 2021 [2]. Subsequently, based on additional studies and consultations, SafeWork has commented that its main concerns are related to potential consequences of a DG vehicle accident and loss of containment, particularly explosions associated with ammonium nitrate (AN) and AN emulsions, and explosives that could result in undermining the structural integrity of the landbridge and cause harm to road users and public [3].

3 Gap Analysis of Existing Safety Studies

The safety studies conducted for the proposed landbridge project are summarised in Table 1.

Table 1: Safety Studies Conducted

No.	Study Name	Study by	Ref.
1	Dangerous Goods Vehicles Safety Risk Assessment	Aurecon	[11]
2	Bow-Tie analysis	Aurecon	[9]
3	Risk Register	Aurecon	[10]
4	CBP FDS results technical note	Arup	[7]
5	CBP Land Bridge DG blast assessment	Arup	[6]
6	CBP Landbridge over the Western Distributor - Fire Safety Study	Aurecon	[8]
7	CBP Traffic survey – truck size count	Aurecon	[16]
8	Safety Review of Dangerous Goods Vehicles Traffic under proposed Land Bridge in Cockle Bay	Arriscar	[12]

Table 2 lists the queries raised in the joint agency letter [2] that need to be addressed by DPT. Parts of these have been addressed in previous studies, and the present study complements these studies and addresses residual concerns.

The queries listed have been raised with reference to the Coffs Harbour bypass tunnel project, but some of them were considered relevant to the Cockle Bay landbridge project.

Table 2: Queries Raised in Joint Agency Letter

No.	Issue raised	Gaps in the previous studies	Reference to Sections of this report
1	Analysis covers road users, occupants of any buildings in the vicinity, the environment, emergency responders, assets and infrastructure, the functioning of the road network and the economic consequences of an incident under the landbridge.	Addressed in the EIS.	Covered in consultations
2	The degree of exposure to those people and assets affected, not just the number of persons, including road users, present in the adjacent area.	Consequences of fires and explosions studied in Refs. [7] and [6]. Exposures for loss of containment of different DG Classes need to be discussed further.	Section 7
3	The risks of confinement underneath the landbridge of any emergency incident, and the retention effects of pressure, smoke and heat, and potential failure of structural integrity.	Consequences of fires and explosions studied in Refs. [7] and [6] for liquid fuel fires and explosives. Need	Section 7

No.	Issue raised	Gaps in the previous studies	Reference to Sections of this report
		additional discussion on other DG Classes.	
4	The differences in evacuation from under the landbridge compared to surface environments.	Not discussed in previous studies.	Section 10.9
5	An assessment of the full and comprehensive range of dangerous goods transported across both short and longer terms, their classification, form, quantities and seasonality.	Not discussed fully in previous studies.	Sections 5 and 6
6	An assessment of the risks posed by the loss of containment of dangerous goods.	Needs additional discussion to those addressed in previous studies.	Section 9
7	Assessment across a full range of potential scenarios, including the impact of installed fire protection on dangerous goods that react dangerously with water	Needs additional discussion to those addressed in previous studies with consequence analysis.	Section 7
8	An assessment of the hazards of mixed loads	Needs to be addressed.	Section 7
9	A reliable assessment of vehicle crashes, including the accurate representation of frequency	Frequency quoted in Appendices of Ref. [11] refer to international truck accident frequency. Local data needs to be analysed.	Section 8
10	An assessment by a tool that is applicable to Australian conditions, underpinned by conclusions and assumptions directly related to local risks, conditions and regulations	The software tools used in previous studies are considered adequate. Additional analysis has been conducted in this study.	Software tool for consequences is PHAST 9.0 and CFD tools used by ARUP [6], [7]
11	Reliable forecasting of population and vehicle traffic growth over the life of the landbridge	Addressed in the EIS	Sections 4 and 5
12	Accurate calculation of fatality impact zones for emergencies, particularly explosions	Needs additional discussion to those addressed in previous studies.	Section 7
13	Realistic presentation of traffic flows, speeds and vehicle distances	Needs additional discussion to those addressed in previous studies.	Covered in Ref. [17]. Not repeated here.
14	Proper justification for any assumptions made	Need to develop an Assumptions Register.	Appendix A

4 UPDATES ADDRESSING GHD PEER REVIEW COMMENTS

The findings and recommendations giving rise to additional information generated in this study are summarised in Table 3.

Table 3: Comments made in GHD peer review

No.	Issues raised in GHD Review	Reference to additional information provided
1	Section 5 of Ref. [12]: *Table 4 is comprehensive, however, a conclusion at the end of this section (i.e. a column at the end of the table) would have been useful to demonstrate what dangerous goods data will be relevant moving forward. The table has provided the facts but has no indication of how these were interpreted. Whilst the summary indicates that some dangerous goods classes were not seen during the 7-day survey, they are assessed in later sections.* ***This inconsistency is a minor item in relation to the purpose of the peer review and some clarity is provided in later sections.***	The 7-day survey does not identify types of dangerous goods. The data is presented only to show the relative proportions of DGV against heavy vehicle traffic and total traffic volume.
2	Section 6 of Ref. [12]: *Table 6 provides a summary of the relevant scenarios to be considered for each class of dangerous good. A statement to this effect would have been useful prior to the commentary on the potential hazardous events (sections 6.4 to 6.14) as there is inconsistency within the descriptions regarding plausible scenarios (some have it and others do not).*	A statement has been included before Table 6. Missing descriptions of plausible scenarios are included.
3	Section 7 of Ref. [12]: *This scenario (MAE6) should be modelled; the model has been completed as a catastrophic rupture, which is not considered plausible (in a vehicle accident, it is more likely that a sharp object will puncture a drum with a hole size less than 50 mm). However, as this is considered a worst case scenario and the impacts are also worst case, the conclusions drawn from the model are still relevant (but are conservative).*	Since impact from a larger event (catastrophic rupture) has no adverse impact on the land bridge, modelling of a smaller event (50mm leak) was not considered necessary. This has been agreed to in the peer review.
4	Section 7 of Ref. [12]: *The decision to not consider this MAE (MAE 11) further is unexpected. Transportation of a large lithium-ion battery could result in radiant heat from thermal runaway, particularly if it is damaged in an accident. Modelling of a battery fire should be completed to show the impacts of a battery fire are expected to be less than that of a petrol fire. Again, the FFFS control is important to mitigate escalation.*	MAE11 has been modelled in this update, i.e. fire of a large Li-ion battery.
5	Section 9 of Ref. [12]: *Table 22 would have benefited from including details on the consequence category, e.g. service disruption or safety.*	Comments have been added before Table 24 (Updated Table number)
6	Section 9 of Ref. [12]: *Using a blanket L5 for all scenarios, however, is not typical, particularly for a bulk petrol release. Given the discussions around incident frequency in section 8 of the report (estimation of incident likelihood), a rating of L4 for scenario 5 (petrol tanker) should be considered. Leaving the remainder of the likelihood ratings at L5 would be suitable based on the information presented in section 8.* *Potential changes by peer review* *Using a L4 with C2 for scenario 5 changes the risk rating to a B, which*	Likelihood for scenario 5 has been further reviewed and SFAIRP justification has been revised in this review.

No.	Issues raised in GHD Review	Reference to additional information provided
	is high and would need a SFAIRP justification/demonstration.	
7	Section 10 of Ref. [12]: *Potential changes by peer review* *Based on experience, some of the effectiveness ratings appear overly optimistic and it is recommended that CCTV and drainage should be rated moderate, rather than high. The fire incident and fire safety operational data for major Australian road tunnels paper from AusRoads (reference 29 from Attachment 1) highlights the importance of the CCTV and could support leaving the rating at high. However, this would require the WD to be monitored 24/7, as is the case for the true tunnels considered in the paper. If this is not the case, the effectiveness of CCTV should reduce to moderate.* *A check on the bow-ties to consider the implications of changing this effectiveness shows this would influence the SFAIRP rating for some of the scenarios. Where the change is an asset damage impact, this is considered still acceptable (taking application of SFAIRP as per the rail industry where only safety impacts need a SFAIRP justification).* - *Changing the CCTV effectiveness rating to moderate would change the SFAIRP justification of the MAE for class 2.1 for asset damage only but would suggest this is acceptable (as done in the rail industry).* - *Changing the CCTV effectiveness rating to moderate would not change the SFAIRP justification of the MAE for class 2.3 but does mean that there is no high or very high rated barrier on the right side of the bow-tie. This makes the inclusion of an in-vehicle communication method critical.* - *Changing the CCTV and drainage effectiveness ratings to moderate would not change the SFAIRP justification of MAE for class 3 bulk and packages for asset damage.* - *Bow-ties for class 3 bulk include a design element (as a high effectiveness), which has little influence on the impact (potential fatality) as the consequence modelling that was used to determine the impact was already restricted. However, including a design element associated with structural reinforcement of the land bridge roof beams/concrete planks (as noted in reference 6 of Attachment 2) would provide a high effectiveness design mitigation control.* - *Changing the CCTV effectiveness rating to moderate would not change the SFAIRP justification of MAE for class 3 bulk for safety. High effectiveness of controls is needed for bulk, as the peer review suggests that the risk rating be reassessed to a "B", meaning it is only acceptable if it is at SFAIRP.* - *Changing the CCTV effectiveness rating to moderate would change the SFAIRP justification of MAE for class 3 packages for safety. This makes the inclusion of an in-vehicle communication method critical.* -	Table 23 of Ref. [12] has been reviewed for CCTV and Drainage and bow ties have been revised where applicable, including in-vehicle communications requirement.
8	Section 12 & Section 13 of Ref. [12]: *The recommendations reflect the contents of the report. However, the following control should be included (based on the Attachment 2 reports):* *Inclusion of structural reinforcement of the land bridge roof beams/concrete planks.*	The recommendations have been reviewed and updated.

No.	Issues raised in GHD Review	Reference to additional information provided
9	Appendix A of Ref: [12]: *It is unclear what the relevance of assumption No. 5 is to this report. This is the first reference to "pipelines" and the "Melrose Park precinct master plan layout".* *Assumption No. 7 contradicts earlier statements that indicated it was class 1.1 and 1.2 that were prohibited, and that 1.3 and 1.4 were possible. Doesn't change the modelling outcome.*	Assumption 5 has been marked as "Not Used". Typo in Assumption no.7 regarding transportation prohibition. Wording has been corrected in this update.
10	Appendix B of Ref: [12]: *The bow-ties in this Appendix are not in the same order as the list in Table 25 which makes it difficult to follow and can confuse the reader. Table 25 is incorrect for the class 3 MAE bow-ties (No. 4 is actually No. 5 and vice versa).*	The error has been corrected in this update.

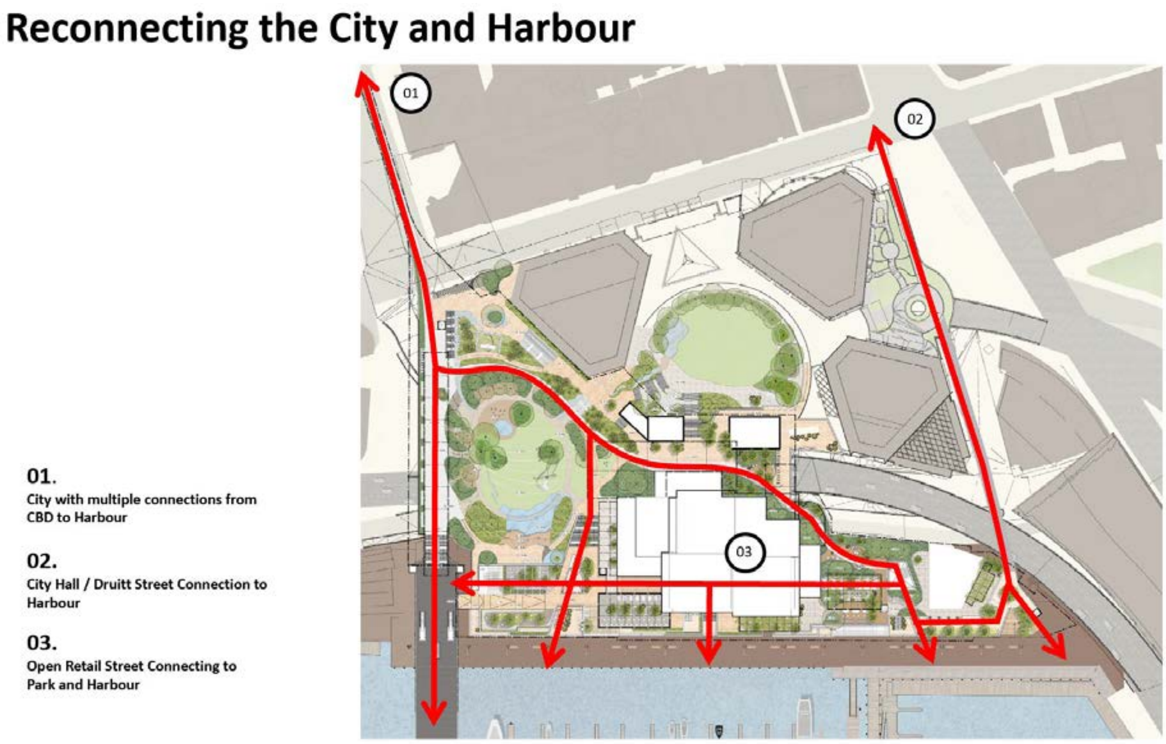
5 BRIEF DESCRIPTION OF PROPOSED LAND BRIDGE

5.1 Land Bridge Development

The overall Cockle Bay Park redevelopment includes a landbridge across the WD connecting the City on the East to Sydney Harbour on the West. The landbridge will provide a direct link between Pyrmont Bridge and Market Street across the WD and Harbour Street, and create significant new public open space and parkland.

A plan view of the roads around the proposed landbridge is shown in Figure 1.

Figure 1: Road Network around the proposed Landbridge on Western Distributor



A concept view of the landbridge is shown in Figure 2 and Figure 3 [18]. A plan of the area under the landbridge is shown in Figure 4.

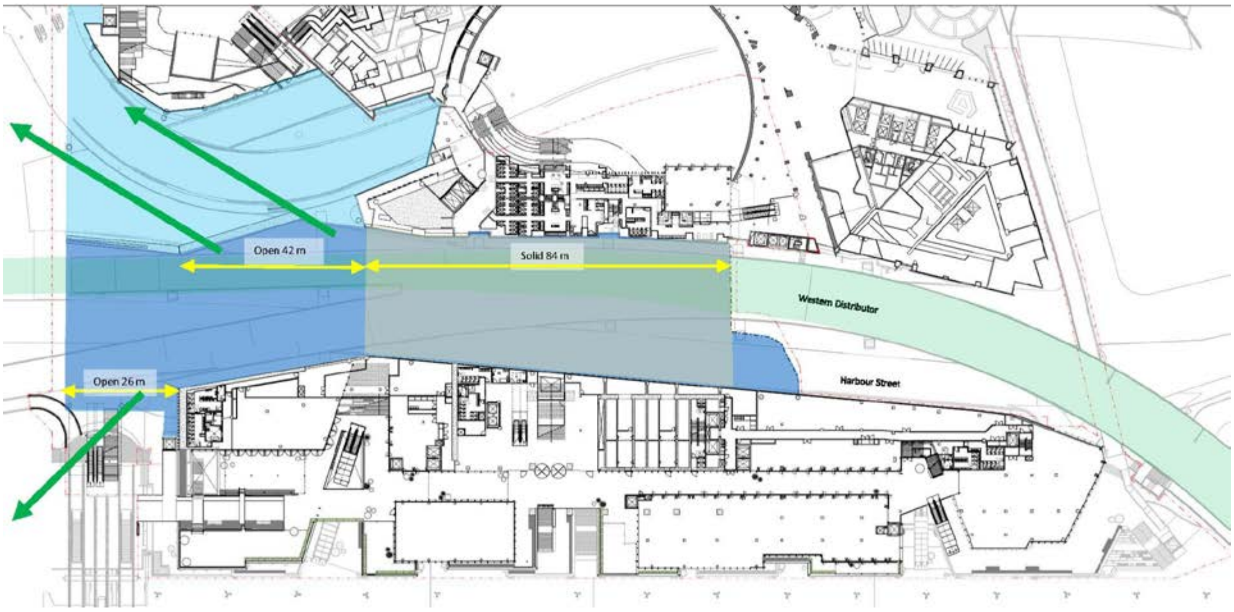
The landbridge will generally have the following dimensions:

Total Length:	110m (approx.)
Length of enclosed section:	84m
Width:	32.5m
Clearance from road:	15m

Figure 2: Concept View of Land Bridge over Western Distributor (1)

Figure 3: Concept View of Land Bridge over Western Distributor (2)

Figure 4: View of Area under the Proposed Landbridge over Western Distributor



5.2 General Traffic

There are no statistically significant traffic data available for the Western Distributor traffic. Different estimates have been made.

The traffic in the Western Distributor has been stated as approximately 6 million vehicles per year in 2017 [11]. This amounts to 16500 vehicles per day on average in both directions. This is significantly less than the estimate from TfNSW of 120,000 vehicles per day using the Western Distributor [19].

Vehicle traffic survey on Western Distributor was collected by Matrix Transport and Traffic Data Pty Ltd on 6th June 2017 [20]. A summary is provided in Table 4.

Table 4: Summary of Western Distributor Traffic Data

Vehicle type/day	North bound	South bound	Total
Cars	16,585	27,202	43,787
Rigid trucks	514	733	1,247
Semi-Trailers	53	93	146
B-Doubles and large trucks	3	34	37
Buses	205	263	468
Total	17,360	28,325	45,685
Total heavy vehicles	775	1123	1898
Heavy vehicles % of total	4.46%	3.96%	4.15%
DG traffic (7 day count) [16]	309	180	499

The data is based on a single day's survey. However, it gives an approximate value for the traffic volume on the Western Distributor of approximately 46,000 per day in 2017.

A conservative estimate of 50,000 vehicles per day on the Western Distributor has been assumed for the present review. Nearly 96% of the traffic consists of cars. It is split into 40% north bound and 60% south bound.

Because of the limited statistical data in heavy vehicles volume, this review has focused on evaluating the assessed loss of containment frequency for ascribing a likelihood rating on a risk matrix, rather than a full quantitative risk assessment.

5.3 Heavy Vehicle Traffic

Heavy vehicle traffic including buses constitutes 4.2% of the total.

Based on the assumption of 50,000 vehicles per day, the truck traffic is 2075 per day or 830/day northbound and 1245/day southbound.

Not all the heavy vehicle traffic consist of dangerous goods. The DGV traffic is discussed in Section 5.4.

5.4 Dangerous Goods Traffic

A traffic survey was undertaken by Aurecon on behalf of DPT [16] to survey the dangerous goods truck movement on the Western Distributor.

On average a total of 499 DGVs per day were counted in the survey over 7 days. It gives an approximate value for the DG traffic volume on WD of 13069 DGVs/ year covering both directions.

Details of types of DG Class transported through the Western Distributor is shown in Section 5.

The DG traffic volume constitutes 26.3% of total heavy vehicle traffic on the Western Distributor (499/1898) calculated from Table 4. For the sample period, the DGV traffic is only 0.078% of the total traffic flow on WD.

Because of the limited statistical data in DG traffic volume, this review has focused on evaluating the assessed loss of containment frequency for ascribing a likelihood rating on a risk matrix, rather than a full quantitative risk assessment.

6 DANGEROUS GOODS TRANSPORTED

This section describes the dangerous goods transported through the Western Distributor. Most of them consist of Classes 2.1 and 3 (fuels). The peak body representing the industry (AEISG) has advised that no Class 5.1 goods are transported [21]. A full list is provided to ensure that all classes of DGs are assessed for consequence impacts in the event of transport and loss of containment on the land bridge.

6.1 Dangerous Goods Classes

Not all the Classes of DGs are transported through the Western Distributor of Sydney. The dangerous goods and their classes are summarised with comments on transport with respect to the Western Distributor are listed in [11].

Table 5: Dangerous Goods Classes and Road Transport

DG Class	Description	Type	Examples	Consequences	Relevance to Western Distributor
1	Explosives	1.1 High energy explosives 1.2 Explosive projectiles 1.3 Low energy explosives 1.4 Minor explosion hazard	Ammunition, explosives Ammunition with projectile effect Fire works Air bags, toy explosives	Major blast Blast with projectiles Minor explosion, fire Low impact	Class 1.1 and 1.2 goods Transport banned in Sydney CBD Small quantities may be transported infrequently for special occasions Placarded quantities are unlikely to be transported
2	Compressed gases	2.1 Flammable 2.2 Non-flammable 2.3 Toxic	LPG bulk tanker and LPG, acetylene in cylinders on trucks Air, N_2, O_2, cryogenic liquids (N_2, O_2, CO_2) Chlorine, ammonia	Fire, explosion Minor impact Toxic impact on exposure	Transported. Ban on placarded load during peak periods. Liquid oxygen may be transported to hospitals. Chlorine in cylinders may be transported occasionally. Traffic survey has indicated mainly LPG tankers and flat top trucks of LPG cylinders.
3	Flammable liquids	Low flash point liquids	Gasoline, solvents (tankers, drums or IBCs)	Fire, smoke	Gasoline transported routinely as indicated by survey [16]. Ban on placarded load during peak periods.
4	Flammable solids	4.1 Flammable solids 4.2 Spontaneously combustible 4.3 Dangerous when wet	Metal powder, sulphur. Alkali metals Alkali metals, calcium carbide	Fire Fire Fire, explosion as hydrogen is	These materials are intermediates or raw materials used in manufacture. Industries using them are located mainly in the west and south of Sydney and there is no need to transport them

DG Class	Description	Type	Examples	Consequences	Relevance to Western Distributor
				generated in the reaction	via Western Distributor. Survey indicated no Class 4 goods [16].
5	Oxidising agents	5.1 Oxidising substances 5.2 Organic peroxides	AN, AN emulsion, Calcium hypochlorite, pool chemicals Used as an initiator in polymer/ resin manufacture.	Fire, explosion Evolves Cl_2 gas in fire Fire	Concern raised by SafeWork [3]. AEISG has indicated that AN is not transported across the harbour bridge [21]. Industries using these materials are located only in the West and South of Sydney.
6	Toxic or infectious substances	6.1 Toxic substances 6.2 Infectious substances	Toxic liquids, pesticides, herbicides etc Clinical and biological wastes, quarantine materials	Injury, harm on exposure. Non-volatile liquids. Potential for disease on contact.	Any transport would only involve pesticides in packaged aerosols for retail markets. Infrequent transport of possible clinical/ hospital waste to approved disposal facility.
7	Radioactive	Small quantities of low level radiation	Radio-isotopes	If exposed, may need to decontaminate.	May be transported to hospitals for diagnostic imaging. Highly infrequent.
8	Corrosive	Acids, alkalis	Caustic soda, sodium hypochlorite (pool chemical), paint strippers.	Skin injury if exposed. Non-volatile.	Mainly in packaged containers for retail. Bulk transport is rare.
9	Miscellaneous	Does not come under above Classes	Lithium-ion batteries, aerosol cans with non-flammable propellants	Battery fire	Need an external fire to start a battery fire as higher temperatures are necessary to start runaway reaction.
	Mixed loads	More than one DG Class in the same DGV	-	Potential for reaction between different Classes of DGs	Packages segregated in accordance with ADG Code Edition 7.6, Chapter 9.1 [22]

6.2 Types of Dangerous Goods Transported through Western Distributor

Not all classes of DGs are transported through the Western Distributor as most of the industries using the DGs and storage and distribution facilities are located in the west of Sydney, and directly transported from Port Botany.

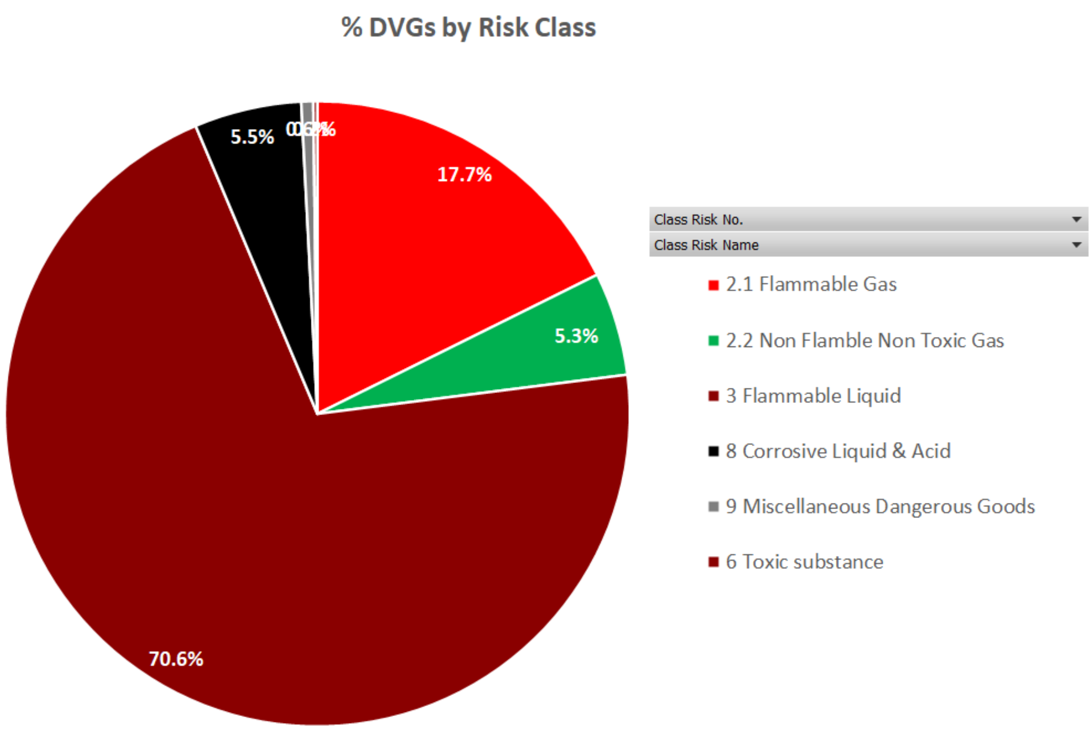
A traffic survey was undertaken by Aurecon on behalf of DPT [16] to survey the dangerous goods truck movement on the Western Distributor. The survey was conducted between 18/06/2022 to

22/06/2022. Even though the survey duration is short, the data reflects the type of dangerous goods carried on the Western Distributor. Table 6 and Figure 5 summarise the survey data.

Table 6: Summary of DG Traffic Survey on Western Distributor

DG Class	No. of vehicles/ day	%
1	0	0
2.1	86	17.7%
2.2	26	5.3%
2.3	0	0
3	344	70.6%
4	0	0
5	0	0
6	1	0.21%
7	0	0
8	27	5.5%
9	3	0.62%
Total	**427**	**100%**

Figure 5: DG Traffic on Western Distributor by Class



It is seen that petrol and LPG tankers constitute 88.3% of the total, and Class 4 and 5 goods are totally absent. While the data may not be statistically representative (short duration), it can be said with reasonable certainty that Class 3 liquids and next Class 2.1 gases dominate the DG traffic.

NSW Road Rules [23] state the following on prohibited areas for placarded DGV traffic:

> *"Bradfield Highway between the hours of 7 am and 9.30 am Monday to Saturday both days inclusive and between the hours of 4 pm and 6.30 pm Monday to Friday both days inclusive."*

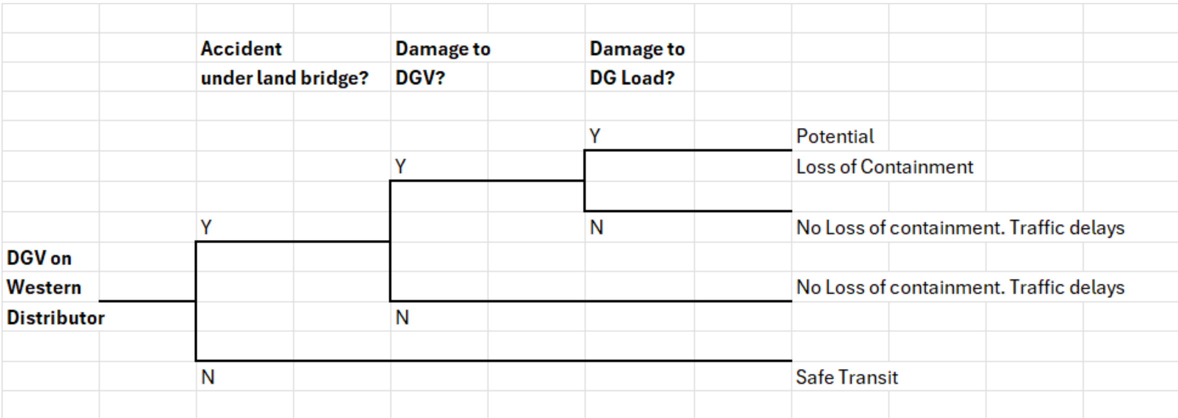
7 HAZARDOUS SCENARIOS AND SAFEGUARDS

7.1 Introduction

In normal circumstances, no loss of containment is expected when a DGV traverses the Western Distributor. A loss of containment may occur only in the event of a vehicle accident and damage to the vessel in the case of bulk tanker or damage to the truck and the DG load.

An event tree illustrates the sequence in Figure 6.

Figure 6: Event Tree for DGV Loss of Containment



7.2 Loss of Containment

Not all accident events would result in a loss of containment (LOC). Events causing loss of containment of dangerous goods on the Western Distributor, adapted from Ref. [24] are:

1. Collisions between vehicles (vehicle changing lanes and driver error), with impact energy exceeding the energy to damage the package. There is no oncoming traffic.
2. Accident as single vehicle accident collision (with landbridge wall, overturning). This could happen if the DGV driver lost control in a 4-lane section of the WD.
3. Technical failures (on the vehicle; on the package, tank truck, tank container).

Dangerous goods carriage by road must be compliant with the ADG Code [22], and EPA licencing conditions. These include:

- Inspection and maintenance of DGVs
- Driver accreditation after the driver undergoes approved training
- Approved packaging of DGs must pass specific stress test (e.g. drop test, leak test, internal pressure test, stacking test) as described in the ADG Code [22].

There are too many variables involved and it is not possible to estimate a probability of loss of containment following an accident. A value of 10% is generally used as being conservative in the Intermodal Study [11].

7.3 Incident Prevention Safeguards

The following safeguards exist to prevent an accident involving DGs in the Western Distributor and under the proposed landbridge:

- Divided lanes (no oncoming traffic)

- Placarded DGVs prohibited on Harbour Bridge between the hours of 7 am and 9.30 am Monday to Saturday both days inclusive and between the hours of 4 pm and 6.30 pm Monday to Friday both days inclusive.
- DGVs are inspected and licensed by NSW EPA
- DGV drivers have to undergo special training from an authorised trainer and receive a DG driver licence from NSW EPA
- Multiple lanes on Western distributor
- Enclosed area under the landbridge will be well lit for visibility
- Fluorescent lane marking on the road under the landbridge (recommended)

The above safeguards are common to all classes of DGVs.

Additional prevention/ mitigation safeguards for each Class of materials are described in Table 7.

Comments on the potential hazardous events involving different classes of DGs are proved below.

7.4 Class 1 Materials

Class 1.1 and 1.2 materials are prohibited in the CBD and not transported. Class 1.3 and 1.4 material may be occasionally transported (e.g. fireworks for celebratory occasions in local government areas on the north of City).

According to the ADG Code [22], Class 1.3 materials are low energy explosives and may result in a fire or minor blasts in succession with projectiles. These may cause damage to the vehicles of other road users in the immediate vicinity.

Similarly, the ADG Code states that

"Class 1.4 goods present only a small hazard in the event of ignition or initiation during transport. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire will not cause virtually instantaneous explosion of almost the entire contents of the package" [22].

7.5 Class 2.1 Goods

Class 2.1 materials consist of LPG tanker (bulk) and Flammable gas cylinders on a flat top open truck. They consist of 18% of DG traffic, the majority being LPG.

The potential scenarios are:

1. Release of LPG from a valve gland of LPG tanker and fire. Potential explosion if vapours accumulate.
2. Release of LPG from a damaged valve on an LPG cylinder on a flat top truck
3. Release of flammable gas (e.g. methane) from a damaged valve on a cylinder

Aerosol cans with butane propellant come under Class 2.1. These may be transported as packages for distribution to retail stores. The packages are securely stored on the covered trucks.

7.6 Class 2.3 Goods

Class 2.3 goods consist of:

- Anhydrous ammonia tankers, portable tanks and cylinders

- Chlorine gas tankers and cylinders (in liquid state)
- Compressed toxic gases used in instrument calibration

Of the above, there is very little need for an anhydrous ammonia tanker using the Western Distributor. The facility manufacturing anhydrous ammonia is in Newcastle (Kooragang Island).

Anhydrous ammonia cylinders may be transported to industrial gases distributors and to frozen food manufacturers using ammonia as a refrigerant. Should there be a loss of containment, toxic impact (injury/ fatality) is possible. Such transport, however, is expected to be infrequent.

Bulk chlorine may be transported from Botany Industrial Park to Prospect water treatment plant and there is no need to use the Western Distributor.

Chlorine cylinders may be used for dosing swimming pools in aquatic centres. Recent practice has been to substitute them for dilute sodium hypochlorite without having to use liquid chlorine.

7.7 Class 3 Goods

Class 3 goods are transported in the following forms:

- Road tankers with refined petroleum products (e.g. gasoline) distributing fuel to retail dispensers.
- Road trucks carrying flammable liquids in 205L drums
- Road trucks carrying smaller packages of flammable liquids for delivery to retailers (generally maximum 20L cartons or less)

The majority of DGVs using the Western Distributor are gasoline road tankers (about 70% of DGVs) [16].

The loss of containment scenario is:

- Damage to road tanker in accident and leak of flammable liquid and ignition. There is potential for incident escalation.

7.8 Class 4.3 Goods

Class 4.3 goods evolve flammable gases on contact with water. Examples are calcium carbide which used in the manufacture of acetylene, and some metal powders. These materials are packaged in a double layered package with an inner layer impervious to water.

The Class 4.3 goods are imported into Port Botany in containers and may be transported to chemical storage warehouse by intermodal companies storing and delivering on behalf of the users. The users are located in the western suburbs of Sydney and there is very low likelihood for Class 4.3 goods transport through the Western Distributor. The sprinklers are thermally activated and would not operate unless there is a fire.

A spill of Class 4.3 goods alone would not cause a hazardous incident unless there is a vehicle fire and sprinklers operate, when flammable gas would be generated with potential explosion. In the event of a spill, the HAZMAT unit of FRNSW would not apply water based on the placard information.

7.9 Class 5.1 Goods

A spill of Class 5.1 goods alone would not cause a fire or explosion. In the event of an external fire, the material would heat up and release toxic gases and oxygen. The oxygen would promote a self-sustaining combustion. If AN is involved in a fire in a confined space, an explosion could occur.

The main materials of concern are:

- AN or AN emulsion (toxic gases and potential explosion)
- Calcium hypochlorite (bleach/ pool chemical). Can generate toxic chlorine gas in a fire.

An explosion involving ammonium nitrate can result in structural damage.

AN is used as a bulk fertiliser in rural farming areas and ammonium nitrate emulsion is used for making explosives in situ in the mining industry. None of them are used in urban areas.

The AN that used to be imported in Port Botany has been largely shifted to the Port of Newcastle to supply the mining industry in the Hunter Valley and western districts of NSW, and very low quantities (if any) are imported into Port Botany.

The Australasian Explosives Industry Safety Group (AEISG) has informed TSA Management that AEISG members do not transport, nor have an intention of transporting ammonium nitrate or ammonium nitrate emulsion along the Western Distributor [21].

Calcium hypochlorite is transported as bleaching powder (35% calcium hypochlorite) in small containers to retailers (e.g. hardware stores). It is in plastic containers or in double layered bags. It is not flammable, and needs an external fire for decomposition. The transport is also infrequent.

7.10 Class 5.2 Goods

The Class 5.2 materials are organic peroxides, used as initiators in the manufacture of polymers and in making speciality chemicals (e.g. resins) as a curing agent.

A spill of organic peroxide in itself may not result in an incident. If the material is involved in a fire, it can sustain a mechanism known as “self-accelerating decomposition” through the evolution of oxygen as a decomposition product that sustains the fire. An explosion is likely in a confined area.

The organic peroxides are always transported in small quantities, sometimes in refrigerated trucks (if required). The users of these goods are located in Botany and some Western suburbs of Sydney and there is no need for transport of Class 5.2 goods through the Western Distributor.

7.11 Class 6 Goods

Class 6.1 goods are toxic liquids and generally non-volatile. They are used as intermediates in the manufacture of other chemicals/ products. Transport is by drums on pallets, secured in the trucks.

Should a loss of containment occur, a maximum of 205L from a drum may leak out and a form a pool on the ground. So long as inhalation and skin contact is avoided, it would not cause injury.

The major Class 6.2 material transported are clinical waste by authorised waste transporters to an approved disposal facility, and quarantine material. The waste material is in special sealed containers and secured in the trucks. Quarantine material is isolated at the Port in a secure area until cleared by Australian Quarantine Inspection Service (AQIS).

It is unlikely that other road users would come into contact with the goods. The DGV driver is licensed and carries spill kit and will contact the emergency services hazmat unit in the event of a spill.

There could be interruptions to traffic, but no injury or structural damage.

Class 6 materials has not been raised as a concern by any of the regulatory agencies.

7.12 Class 7 Goods

Most radioactive materials transported in Sydney are used in nuclear medicine in diagnostic imaging and hospitals and transported from ANSTO in Lucas heights, south of Sydney.

Special packaging applies to prevent exposure. Further, there is no exposure to other road users as those already under the landbridge can use other lanes to move out of the area.

Class 7 materials has not been raised as a concern by any of the regulatory agencies.

7.13 Class 8 Goods

Class 8 goods are corrosive substances (acids or alkalis). These are transported as:

- Bulk liquids in a chemical tanker
- In 205L plastic drums (non-corrosive) on pallets
- Small packages (plastic containers of 500 mL to 1-2 Lites) for delivery to retailers.

The material is not flammable and there is no fire hazard. They are non-volatile. Skin contact must be avoided.

An accidental release may cause traffic interruptions, but unlikely to result in exposures to other road users who do not need to get of their vehicles.

Class 8 materials has not been raised as a concern by any of the regulatory agencies.

7.14 Class 9 Goods

Class 9 goods cover a wide range of materials such as:

- Lithium-ion batteries
- Aerosol cans

The batteries pose a fire hazard, but need an external heat source to raise the temperature of the battery to start a battery fire. In the absence of battery charging, transport of batteries in approved packages at ambient temperature is unlikely to cause a fire.

Battery fire scenario is modelled in Section 8.11.

Table 7: Prevention and Protection Safeguards for DGV Incidents under Land Bridge

DG Class	Description	Hazardous Scenario	Additional Prevention Safeguards*	Mitigation Safeguards
1.3/1.4	Mild explosives	Fire/ explosion	• Goods packaged in approved packages and placed within cartons in the truck. • Explosives and detonators are not to be transported in the same vehicle by Regulations.	• Sprinkler system in landbridge enclosure • Landbridge structure can withstand explosions of 45 kg TNT equivalent without structural damage [6] • Emergency response procedure
2.1	Flammable gases (bulk)	Fire/ explosion/ smoke in enclosed area	• Steel frame on the chassis around the tanker itself carrying hose and pump and protecting the tanker from direct impact • A pneumatically actuated internal self-closing (ISC) valve on LPG tanker is kept closed during transport (primary isolation) • Manual valves on liquid and vapour outlets are kept closed during transport (secondary isolation) • Caps protecting the nozzle on the valves • All fittings protected by an iron barrier during transport. The barrier must be in place to move the tanker as the brakes would be engaged otherwise.	• Gases odorised for detection • Sprinkler system in landbridge enclosure • Emergency response procedure Recommendations: 1. Sprinkler system to be designed to the requirements of High Hazard in accordance with AS 2118-2017

DG Class	Description	Hazardous Scenario	Additional Prevention Safeguards*	Mitigation Safeguards
			• Robust certified pressure vessel design for the tanker	
2.1	Flammable gases (cylinders)	Fire. Explosion on accumulation of unignited gas.	• Cylinders secured in cages • LPG cylinders have a collar protecting the nozzle from damage • Cylinders designed and tested to pressure vessel standards	• Sprinkler system in landbridge enclosure • Emergency response procedure
3	Flammable liquids	Fire	• Steel frame on the chassis around the tanker itself carrying hose and other equipment can offer some protection from direct impact	• Sprinkler system in landbridge enclosure • Emergency response procedure
5.1	Oxidising agents	Fire/ explosion	• AN will not be transported on harbour bridge [21] • Any other Class 5.1 material (e.g. bleach) are not explosion hazards.	• Sprinkler system in landbridge enclosure
5.2	Organic peroxides	Fire	Not expected to be carried in WD, if any.	
6.1	Toxic liquids	Toxic exposure	Drums designed to ADG requirements, drop tested [22]. Drums secured on pallets.	• Emergency response procedure (calls for Hazmat unit) • Spill kit carried in truck
6.2	Infectious materials	Exposure	• Licensed waste trucks and transport company	• Emergency response procedure

DG Class	Description	Hazardous Scenario	Additional Prevention Safeguards*	Mitigation Safeguards
			• Compliance with ADG Code [22] requirements for packing and transporting UN3291 clinical waste. These requirements allow for the use of portable bins (20 L to 80 L capacity) and mobile bins (50 L to over 600 L capacity). • Transport companies follow SafeWork NSW advisory document for transport of clinical wastes [25].	• Driver trained to isolate the area until emergency services in protective clothing arrive for cleanup.
8	Corrosives	Injury	Drums designed to ADG requirements, drop tested [22]. Drums secured on pallets.	• Emergency response procedure (calls for Hazmat unit) • Spill kit carried in truck
9	Miscellaneous (Li-ion batteries)	Fire	Goods packaged to ADG Code requirements [22] No charging of batteries in carriage No ignition sources in the package storage area.	• Sprinkler system in landbridge enclosure • Emergency response procedure

*Safeguards are in addition to the accident prevention safeguards described in Section 6.2.

8 HAZARD CONSEQUENCE ANALYSIS

8.1 Summary of Hazardous Scenarios

The hazardous scenarios considered in this review are summarised in Table 8. The scenarios are referred to in this report as Major Accident Events (MAEs).

Table 8: MAEs Assessed for the Landbridge

No.	DG Class	MAE Description	Consequences of LOC	Modelled?
1	1.3, 1.4	Damaged package	Fire, minor low energy explosions. Potential damage to vehicles of other road users.	45 kg TNT equivalent blast modelled in Ref. [6]
2	2.1	LPG release from gas cylinder on flat top truck	Jet fire on immediate ignition. Flashfire on delayed ignition Localised impact. Unlikely to affect other road users in the vehicles.	Yes. Modelled in this study.
3	2.1	LPG release from road tanker	Jet fire on immediate ignition. Flashfire/ VCE on delayed ignition Potential injury/ fatality to other road users Structural damage potential	Yes. Modelled in this study. Also addressed in Ref. [6]
4	2.3	Toxic gas release from cylinder	Injury/ fatality on inhalation	No. Qualitative assessment.
5	3	Petrol release from road tanker compartment	Pool fire, smoke generation Potential for injury, fatality	Modelled in Ref. [7]
6	3	Flammable liquid release from drum (205L)	Pool fire, smoke generation Localised impact. Injury potential.	Yes. Modelled in this study.
7	5.1	Ammonium nitrate loss of containment	Explosion. Potential injury/ fatality to other road users Structural damage potential	No. Not transported.
8	6.1	Toxic spill	Potential exposure and injury	No. Qualitative assessment.
9	6.2	Clinical waste spill	Potential for infection on exposure	No. Qualitative assessment.

No.	DG Class	MAE Description	Consequences of LOC	Modelled?
10	8	Corrosive liquid spill	Potential for in jury	No. Qualitative assessment.
11	9	Li-ion battery fire	Fire, toxic fumes, injury potential	No. Qualitative assessment.

Where modelled in this study, the well-accepted software PHAST 9.0 was used. The consequence results are discussed in the following Sections.

8.2 MAE 1 – Class 1 Goods

The consequences of ignition of Class 1.3 or 1.4 goods may result in fires and low energy explosions. Potential for damage to vehicles of other road users in the vicinity of the DGV.

Major consequences are not expected. These goods were not modelled in Ref. [6]. A blast assessment using a CFD model was carried out by ARUP [6] using a 45 kg equivalent TNT explosion. This assessment was undertaken for a Class 3 petrol tanker.

The study found that the columns supporting the landbridge would not be impaired by an explosion of magnitude 45 kg TNT.

There could be damage to other road user vehicles in the vicinity with potential injuries and fatality.

8.3 MAE 2 – LPG Cylinder Leak

A road accident under the landbridge is unlikely to cause an LPG cylinder failure. The cylinder is a pressure vessel, and can withstand damage if dropped from the flat top truck.

A possible release source is a valve damage and release of cylinder contents. The capacity of the cylinder is typically 15-18 kg (forklift cylinders) or 4.5-9 kg (household use). The valves are protected by a collar and hence even if a leak occurred, the release would impinge on the collar and lose momentum. The gas released would stay close to ground and slowly disperse.

The modelling results are summarised in Table 9 and Figure 7.

Table 9: LPG Cylinder Leak and Ignition Consequences

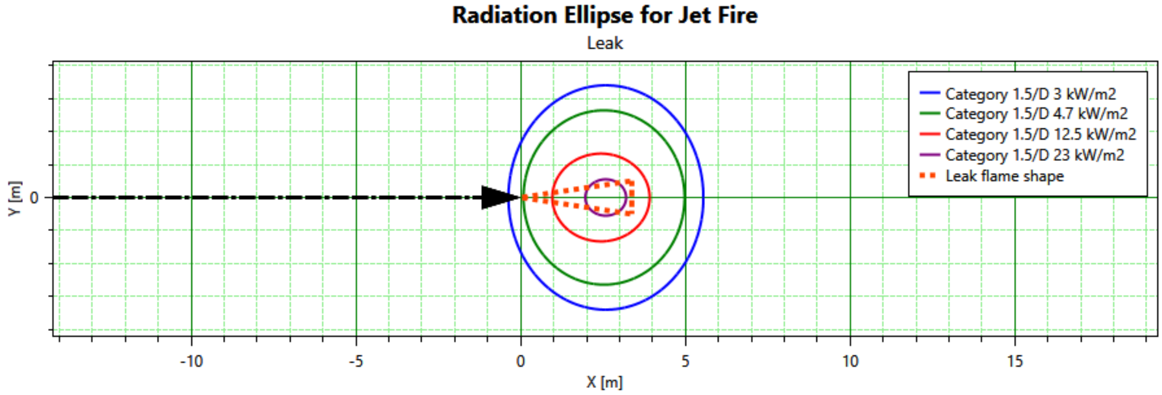
Parameter	Value
Material	Propane
Leak size, mm	1.6
Release rate, kg/s	0.033
Jet Flame Length, m	3.4 (will not reach roof)
Fire duration	<10min

The thermal radiation distances are shown in Table 10.

Table 10: Fire Radiation Distances for LPG Cylinder Leak and Fire

Distance to Heat radiation, kW/m²				
3	4.7	12.5	23	35
6m	5m	4m	3m	Not Reached

Figure 7: Thermal Radiation from LPG Cylinder Fire



The distance to lower flammability limit is confined to the vicinity of the leak with very low probability of ignition. The driver response in this instance is to stop the traffic and call emergency services.

PHAST 9.0 modelling indicated that an explosion overpressure would not result. The values were calculated using the TNO multi-energy model and a blast strength given by Curve No.5 (small cloud).

Because of the protected collar at the nozzle, the potential for flame impingement on adjacent cylinders is low. They could be heated by radiant heat and release LPG through the pressure safety valve (PSV) which could also ignite and prolong the fire.

There is adequate time for evacuation of the area before any escalation to a cylinder BLEVE (Boiling Liquid Expanding Vapour Explosion) could occur. Further, potential for escalation is minimised by water spray application from the sprinkler system.

The consequences of this event are possible injury to a few in the immediate vicinity, but the likelihood a fatality is low.

8.4 MAE 3 – LPG Bulk Tanker Leak

A road accident involving an LPG tanker on the Western Distributor is not expected to result in a tanker failure. The tanker is a pressure vessel and the impact energy from an accident must exceed the pressure vessel strength. This could occur if the LPG B-Double were to jack knife and there is tank collision with another vehicle. A lane change accident alone would only result in a side on impact with the tanker support structure without directly impacting on the tanker.

A leak from fittings may occur, but a pre-existing condition must be present for this to occur. It is the failure of the ISC valve to close after tanker filling when the pneumatic air supply to open the valve for loading is disconnected prior to drive off. With this condition, the manual valve and its cap must be damaged in the accident.

Should a leak occur at the fittings, the rate of release is small (estimated as approximately 10-20mm). Larger leaks would be isolated by the excess flow valve which is internal to the tanker.

The perception and postulate that a road tanker accident on the WD would automatically result in a major LPG leak from a tanker failure is not considered credible.

The release from a 13mm hole at the fittings was modelled in PHAST 9.0. The modelling results are summarised in Table 11, Figure 8 and Figure 9.

Table 11: LPG Tanker 13mm Liquid Leak and Ignition Consequences

Parameter	Value
Material	Propane
Leak size, mm	13
Release rate	2.22
Jet Flame Length, m	21.3 (will reach roof and set off the sprinkler system)
Surface emissive power, kW/m^2	133
Fire duration	>2 hours

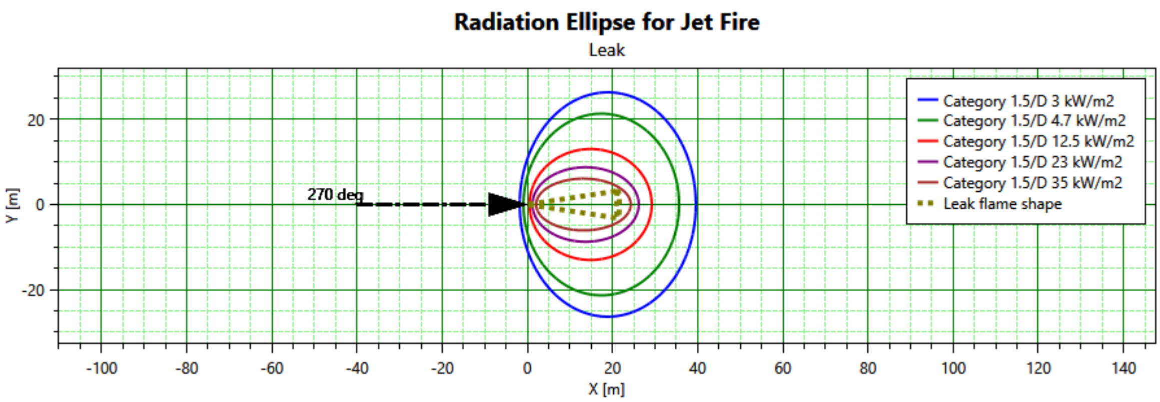
The thermal radiation distances are shown in Table 12.

Table 12: Fire Radiation Distances for 13mm LPG Liquid Leak and Fire

Distance to Heat radiation, kW/m^2				
3	4.7	12.5	23	35
40m	36m	29m	26m	24m

The values given in the Tables above are approximate in that PHAST 9.0 can only model fires in the open. The heat absorbed and reflected from the walls has not been considered.

Figure 8: Thermal Radiation from LPG Tanker 13mm Liquid Leak



The vehicles in front of the DGV can drive out from under the landbridge. For vehicles stopped behind the DGV, those within 25m-30m can sustain damage. Since the fire can last a long time, road users in their vehicles will suffer harm from injury to fatality, if not evacuated from the area.

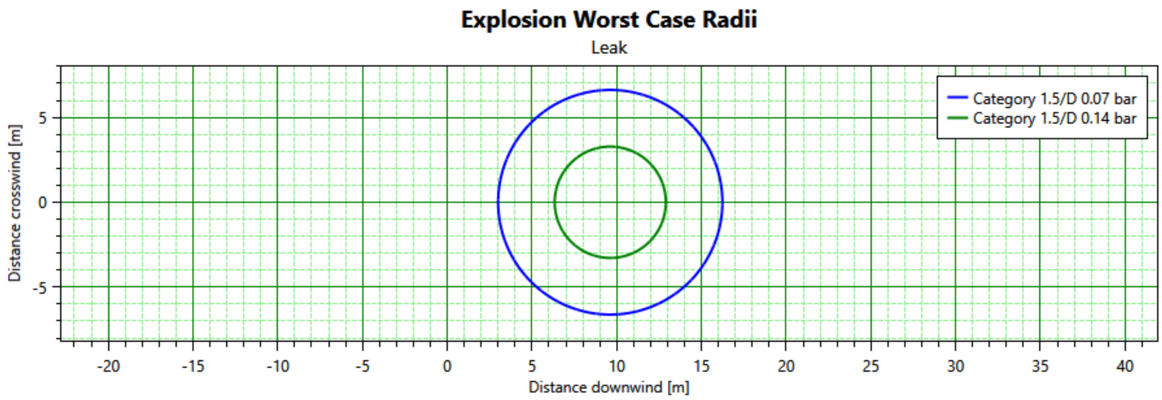
The explosion overpressure distances are listed in Table 13. The values were calculated using the TNO multi-energy model and a blast strength given by Curve No.5 (small cloud).

Table 13: VCE Overpressure Distances for LPG Leak and Ignition

Distance to Side-on Overpressure, kPa			
7	**14**	**21**	**35**
16m	13m	NR	NR

Note: NR – Not reachable

Figure 9: VCE from LPG Tanker 13mm Liquid Leak



The vapour cloud explosion overpressures calculated are approximate as the road under the landbridge is confined and a 3D CFD model is required to simulate more accurate explosion results. The indications are that cars in the immediate vicinity behind the LPG truck could be damaged with potential injury to road users.

An LPG release from a road tanker and ignition underneath the landbridge is considered a serious event. The event can be equally serious under the current conditions.

The likelihood of occurrence is very low as discussed in Section 8.

8.5 MAE 4 – Toxic Gas from Cylinder Leak

Chlorine gas cylinders have a cap on the valve assembly, protecting them from damage during transport and handling. Therefore, in the case of a road accident on a flat top truck carrying chlorine cylinder, no damage to the valve and hence no release is expected.

Chlorine cylinders, similar to LPG cylinders, are pressure vessels and inspected and pressure tested at statutory intervals.

Should a release occur under the road bridge, there could be potential fatality from the gas being drawn into stopped vehicles through the air-conditioning system. This scenario is not significantly different to an accident on the WD under existing conditions, as chlorine gas is heavier than air and stay close to ground.

The likelihood of transport of Class 2.3 cylinders on WD is very low. This scenario was not quantified further, but considered qualitatively in the bow-tie analysis in Section 10.

8.6 MAE 5 – Gasoline release from Bulk Tanker Compartment

A six-axle petrol tanker typically would contain 6 compartments, each with a capacity of 9000L. Most tankers have 5 compartments. For the type of accidents envisaged in the WD, maximum release is likely to be from 1 or 2 compartments. Not all the compartments may contain flammable liquid, some may contain diesel. The tanker is not a pressure vessel and therefore the impact resistance is low.

The main protection for the tanker is the supporting chassis extending on the sides, which would take the first impact of an accident.

A fuel release from a bulk tanker is the worst credible accident event in an enclosed stretch of road. The release is not expected to be instantaneous release of full tanker compartment contents, but a hole in the tanker compartment (say 50mm) and liquid leak through the hole.

Consequences of such a release, taking n-heptane as the representative material for gasoline (see Assumptions Register in Appendix A), PHAST modelling results are shown in Table 14, Table 15 and Figure 10.

Table 14: Petrol Tanker Compartment 50mm Leak and Ignition Consequences

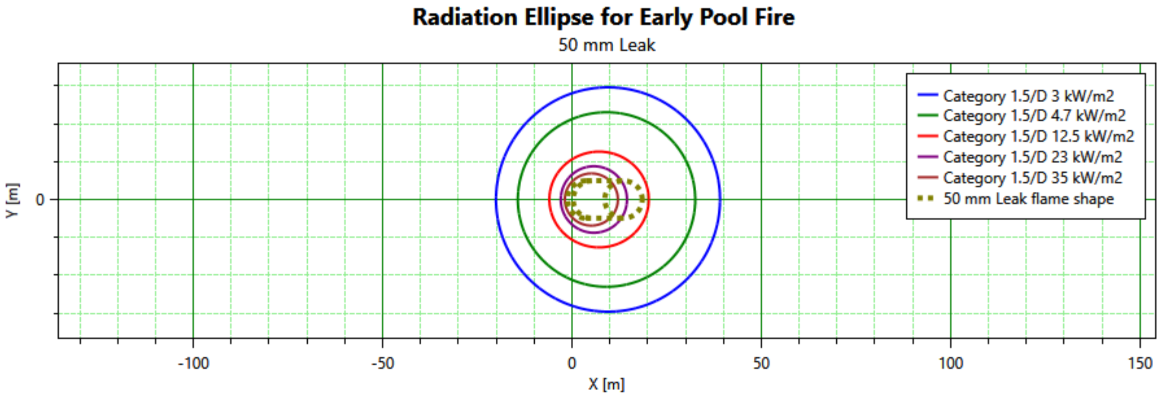
Parameter	Value
Material	n-Heptane
Mass in Storge compartment, kg	6172
Hole size, mm	50
Release rate, kg/s	6.62
Pool diameter, m	9.9
Flame height, m	20.6 (will reach roof and set off the sprinkler system)
Surface emissive power. kW/m^2	50 (84% smoky flame)
Fire duration	16 minutes

The thermal radiation distances are shown in Table 16.

Table 15: Fire Radiation Distances for Petrol Tanker 50mm Leak and Fire

Distance to Heat radiation, kW/m^2				
3	4.7	12.5	23	35
39m	33m	20m	15m	12m

Figure 10: Thermal Radiation from Petrol Tanker Compartment 50mm Leak



The 50mm gasoline leak did not result in a vapour cloud explosion.

The distance to 23 kW/m^2 (escalation threshold) is 15m. Vehicles within this radius could be subject to significant damage with injury, fatality potential. This thermal radiation consequence is the same for a potential fire occurring on open road.

8.6.1 Smoke generation from Petrol tanker Fires

The heat output (total combustion) from the release of a 50mm leak (6.62 kg/s) is 290 MJ [26]. ARUP has modelled the smoke generation under the landbridge from a gasoline tanker leak at 250 MW [7]. This is more conservative than a value of 100 MW for petrol tankers recommended in NFPA 204 [27].

Smoke modelling was carried out using the CFD software FDS. The following conclusions were reached [7]:

The Required Safe Egress Time (RSET) was estimated as 300s. The Available Safe Egress Time (ASET) was calculated as 450s, indicating that there is adequate time available for evacuation of the landbridge area while keeping the smoke exposure within the tolerability criteria.

The modelling was based on smoke venting through one end of the landbridge, depending on the wind direction. Based on the study in Ref. [7], it may be concluded that additional ventilation would not be required.

The study was presented to FRNSW by Arup, TSA Management and DPT on 31 January 2023 [17].

8.7 MAE 6 – Flammable Liquid Release from 205L Drum

The scenario involves a spill of two (2) drums of 200L capacity of flammable liquid (taken as n-heptane) on the road forming a pool and draining away. If ignited, a pool fire would result.

The drums are packaged for transport in accordance with ADG Code [22]. This requires that the drums are tested for strength by a drop test and a leak proof test by the manufacturer. The drums are secured on pallets.

Even in the event of an accident, drum failure is unlikely in the absence of a sharp object penetrating the drums. On a consequence basis alone, fire calculations carried out in PHAST 9.0 are summarised in and Figure 11.

Table 16: Flammable Liquid Drum Leak and Fire Consequences

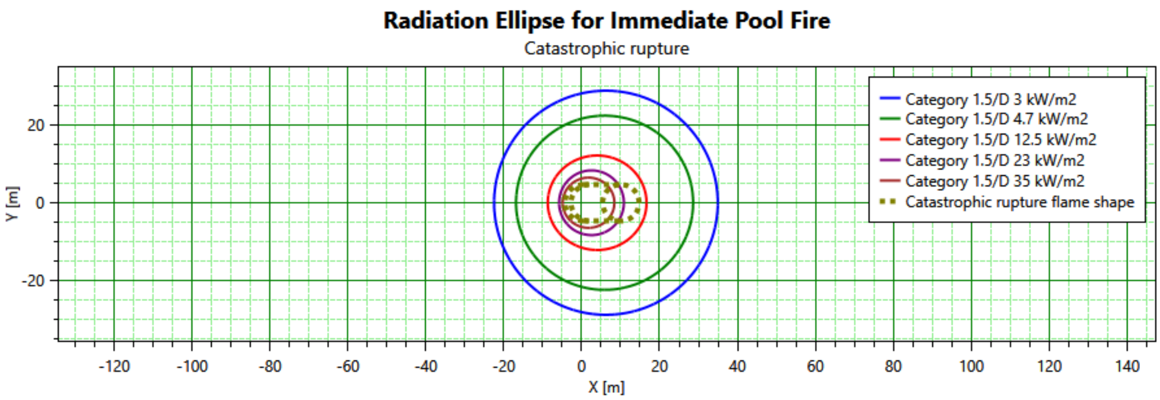
Parameter	Value
Material	n-Heptane
Mass released, kg	274 (two drum)
Pool diameter, m	10.1
Flame height, m	(will reach roof and set off the sprinkler system)
Surface emissive power. kW/m^2	69 (83% smoky flame)
Fire duration	< 1 minute

The thermal radiation distances are shown in Table 16.

Table 17: Fire Radiation Distances for Flammable Liquid Drum Spill and Fire

Distance to Heat radiation, kW/m^2				
3	4.7	12.5	23	35
36m	29m	17m	11m	9m

Figure 11: Thermal Radiation from Flammable Liquid Drum Leak



The vehicles in front of the DGV can drive out of landbridge. For vehicles stopped behind the DGV, those within 15m-20m can sustain some damage. Since the fire duration is less than 1 minute (not allowing for drainage), road users in their vehicles will suffer no or minimum harm.

8.8 MAE 7 – Toxic Liquid Spill from 205L Drum

The toxic liquids are harmful if inhaled, ingested or comes into skin contact. The liquids in the main are non-flammable and non-volatile.

There will be no contact of the liquid with other road users in their vehicles. The DGV carries a spill kit and the driver is trained in its use as part of the training for licensing. As part of the DGV carrier's emergency response procedures emergency services hazmat unit will be contacted.

There would be short term interruptions to traffic, but no harm to people is expected.

8.9 MAE 8 – Clinical Waste Spill

The clinical wastes are packaged in accordance with ADG Code [22] prior to loading on truck. The portable or mobile bin must comply with each of the following minimum requirements:

- Rigid construction with a lid that is identifiable by its colour and able to be secured during transport.
- Strong enough to withstand manual or mechanical handling and shocks and loadings normally encountered during transport.
- Able to retain liquid under normal conditions of transport.
- There are additional requirements for bins that are intended to contain sharp objects such as broken glass and needles.

There will be no contact of the waste with other road users in their vehicles. As part of the waste truck's emergency response procedures emergency services hazmat unit will be contacted. The response includes removal of the waste in approved containers wearing protective clothing against infection, and disinfecting the area prior to resumption of normal traffic.

No harm to people in their respective vehicles is expected.

8.10 MAE 10 – Corrosive Liquid Spill from 205L Drum

A corrosive liquid spill scenario is similar to a Class 6.1 liquid scenario. It is harmful if comes into contact with skin. The liquids are non-volatile and non-flammable. Some acids such as hydrochloric acid may emit fumes and harmful if inhaled.

There will be no contact of the liquid with other road users in their vehicles. The DGV carries a spill kit, full face mask to protect the driver (first responder). The driver is trained in its use them as part of the training for licensing. As part of the DGV carrier's emergency response procedures emergency services hazmat unit will be contacted.

8.11 MAE 11 – Li-ion Battery Fire

There are special requirements for Li-ion battery packaging for transport. Each battery must be individually packaged in non-metallic packaging made of cushioning material that is non-combustible, non-conductive and absorbent. The individual packaging must then be enclosed in outer packaging [22].

Therefore, the potential for exposing a battery package in the event of a road accident is very low.

One mechanism by which a battery fire can occur is from an external fire and heating of the battery. Overheating of Li-ion battery can result in a self-accelerating reaction called thermal runaway, where internal temperature and pressure rise at a quicker rate than can be dissipated. Subsequently, a cell produces significant amounts of heat, off-gassing, smoke generation, and can ignite, causing vigorous flames. Cells may explode violently as part of the combustion process [28].

A scenario was postulated for battery fire. This consists of packaged Li-ion battery transported and subject to a fire from other cargo in the truck, heating the battery. While the likelihood of the event is low, the consequence analysis is undertaken for completeness.

Li-ion batteries come in various shapes and sizes, depending on applications. For the present study, an Electric Vehicle (EV) battery cargo is modelled. The battery capacity is expressed as kilo-Watt hours (kWh), ranging from 64 kWh to 100 kWh, depending on the EV application. An alternative way of expressing capacity is in Ampere-hours (Ah).

Ah = kWh/ V where V is the voltage, generally 12 or 24 volts.

When a Li-ion battery cargo is subject to external heat, the following occurs:

(a) Local heating and generation of gases containing significant flammables.

(b) In an enclosed area, ignition of the flammables could result in an explosion, following by fire.

(c) The fire further heats the batteries in the cargo and generates more gases to sustain the fire, spreading to the entire cargo.

(d) The battery materials such as plastics also get involved in the fire, as the fire spreads.

The fire can last for many hours. High volumes of water is required to cool the fire. In some instances, the firefighters may decide to let the unit burn out and protect surrounding exposures. The road will have to be closed for many hours, and people in cars must be evacuated, if they cannot drive away.

Experimental data has shown that Li-ion battery fires at the source can reach temperatures of up to 480^{O}C [29]. Sandia laboratories has undertaken experiments with Li-ion battery fires and has shown the following [30]:

- EV and PHEV battery packs are much higher energy (15-50 kWh)
- A 50 kWh battery can have up to 7000 cells
- Surface heat flux in a fire can be up to 70 kW/m^2
- Not all cells/ adjacent batteries would go on fire at the same time (escalation and fire propagation effect)

For this study, the battery fire was modelled as a planar fire of size equal to the surface area of the container side panel, with surface heat flux of 70 kW/m^2, radiating heat to surrounds.

Surface area of side of 20 ft container = 5.9m (L) x 2.35m (W) = 13,87 m^2.

For a surface (target) facing the plan 1m^2 in surface area, the following distances to various thermal radiation levels are calculated using view factors, ignoring any attenuation from humidity. Results are shown in Table 18.

Table 18: Battery Fire Thermal radiation Distances

Thermal Radiation Level kW/m^2	Distance to Radiation Level, m
70	Fire surface
35	0.8
23	1.0
12.6	1.3
4.7	2.2
3	2.7
1.6	3.7

The thermal radiation impact is entirely localised. Vehicles immediately adjacent to battery fire could be affected, but escalation to other vehicles is not expected, and the people in other vehicles can safely escape away from the fire. Any structural impact is not expected.

The overhead sprinkler system can assist in keeping the batteries from overheating in the event of an external fire.

9 ESTIMATION OF INCIDENT LIKELIHOOD

9.1 Introduction

In a previous study for the proposed development [11], the frequency of DGV accidents has not been quantified. Instead, the following approach was adopted:

1. Use of existing intermodal studies on DGV road transport in Sydney metropolitan area for benchmarking
2. Discussion as to the acceptability of DGV traffic under the landbridge since the frequency is likely to be less than those used in the intermodal study.

The Joint Agency letter [2] has asked for a quantitative estimate of risk under the landbridge where possible.

Since there are significant differences between an intermodal study with DGVs on open roads, and high volume of DGVs from manufacturing and import areas, the benchmarking alone does not address the issue raised in the Joint Agency letter.

In this section, the frequency of a DGV accident under the proposed landbridge has been estimated. Comparison with international data indicates significant range and uncertainty. Therefore a quantitative assessment of fatality risk is not undertaken in this report. The frequency analysis is used as an input to the semi-quantitative risk assessment.

9.2 Heavy Vehicles Accidents in Western Distributor

TfNSW has collected traffic accident data on Western Distributor for the period 1 October 2014 to 30 September 2019 (5 years) [31]. Data for the landbridge section was extracted from the detailed crash report. Associated with the detailed crash report is a summary crash report published by TfNSW [32].

Based on the TfNSW data [32], there have been only 2 accidents involving trucks on the relevant section of Western Distributor in the 5 years of data collected. None of them involved a DG vehicle.

9.3 Estimation of DGV Accident Frequency

An estimate of frequency of a DGV accident under the landbridge has been made using 4 different methods, as there is no direct data available, and there has been no DGV accident reported on Western Distributor in the 5 years of crash data published by TfNSW [31], [32]. The data covers the period Oct 2014-Sep 2019.

There is no statistically significant truck accident data for the Western Distributor and therefore available national data on tunnel fires and international data are referred to in this report.

9.3.1 IOGP Generic data

The International Oil & Gas Producers Association (IOGP) has published a generic statistic on releases from flammable liquid road tankers [33].

The reported release frequency of Class 3 liquid from bulk tanker is 6.3E-08 per truck-km.

Number of Class 3 bulk tanker movements = 17937 p.a.

Applying the Western Distributor DGV data (actual) for the above frequency, we can estimate a petrol tanker accident frequency under the landbridge as:

Petrol tanker leak frequency = 6.0E-08/ truck-km x 0.15 km (landbridge length) x 17937 truck/year

= 1.60E-04 p.a. or 0.016% chance of occurring in any given year.

Similar data has been published by IOGP [33] for Class 2.1 bulk tankers.

The reported release frequency of Class 2.1 liquid from bulk tanker is 2.06E-08 per truck-km.

Number of Class 2.1 bulk tanker movements = 4484 p.a.

Applying the Western Distributor DGV data (actual) for the above frequency, we can estimate an LPG tanker leak frequency under the landbridge as:

LPG Tanker leak frequency = 2.06E-08/ truck-km x 0.15 km (landbridge length) x 4484 truck/year

= 1.39E-05 p.a. or 0.003% chance of occurring in any given year.

9.3.2 Fire in Australian Tunnels

Austroads commissioned a study to collect statistics of fires in Australian road tunnels covering all capital cities [34], [35]. The data is shown in Table 19.

Table 19: Frequency of Fires in Major Australian Road Tunnels

Parameter	Metric
No. of Fires	78
Vehicle Kilometres Travelled	10,338,000,000
Fire Frequency/ vehicle-km	7.58E-09

Applying the above frequency to the landbridge (highly conservative), we have:

Fire frequency under landbridge = 7.58E-09 /vehicle km x 0.15 km x 26019 DG vehicles/year

= 2.96E-05 DG vehicle fires p.a., or 0.003% chance of occurring in any given year.

33,783 per year.

It is not known from the Austroads data [34] if any of the tunnel fires involved dangerous goods. The fire frequency estimated above can be considered to be conservative by an order of magnitude.

9.3.3 Benchmarking Data

Enfield Intermodal Study

The study for the Enfield Intermodal Terminal reports the following data [11]:

Release from DGV accidents (except Class 3 bulk tankers): 5.94E-09/ vehicle-km

Release from Class 3 DGV bulk tanker accidents : 2.71E-06 / vehicle-km

DGV traffic volume in the Western Distributor is 26019/year with 70% Class 3 bulk tankers and 30% the rest (from Table 6). Thus,

Class 3 liquid release frequency = 2.71E-06x 0.15 x 26019 x 0.7 = 7.4E-03 p.a.

Other DG release frequency = 5.94E-09 x 0.15 x 26019 x 0.3 = 6.95E-06 p.a.

Denison Street Transport Study

Ref. [11] does not report accident frequencies extracted from this study. It is expected to be similar to the Intermodal study in terms of accident rate/ vehicle-km.

9.3.4 Other International Data

Truck accident rates from the UK and the Netherlands have been reported in Ref. [11]. A summary of these data is given below:

UK truck accident frequency: 4.7E-07 per vehicle-km. Not all of these are DGVs.

The Netherlands DGV accident frequency is reported in the TNO Purple Book [36].

- Cylinder trucks: 3.5E-09/ vehicle-km
- Trucks carrying drums: 1.2E-08 /vehicle-km

9.4 Conclusions on DG Accident Rate Estimate under Landbridge

A summary of DG vehicles accident rates estimated by different methods is listed in Table 20.

Table 20: Summary of DGV Accident Rates Estimated

No.	Data Source	Vehicle accident frequency	Accident Frequency in Western Distributor		Ref.
			DGV Accident	Product Release	
1	IOGP data based (Release frequency Class 3 bulk)	6.0E-08/ truck-km (product release)	-	1.60E-04 p.a.	[33]
2	IOGP data based (Release frequency Class 2.1 bulk)	2.06E-08/ truck-km (product release)	-	1.39E-05 p.a.	[33]
3	Australian tunnels fires data based	-	-	2.96E-05 p.a. (fires)	[35]
4	Enfield Intermodal Study	5.94E-09/ truck-km (all except Class 3 bulk tanker) 2.71E-06/ truck-km Class 3 bulk tanker		Class 3 bulk tanker 7.4E-03 p.a. Others: 9.5E-06 p.a.	[11]
5	UK data	4.7E-07/ truck-km	4.82E-04 p.a.	-	[11]
6	TNO Purple Book	Cylinder trucks: 3.5E-09/ truck-km Drums carrying trucks: 1.2E-08/ truck-km	Difficult to separate the truck volume in each category	-	[37]

Note 1: The release frequency is expected to be at least one to two orders of magnitude less than the accident frequency as not all accidents would result in a leak or loss of containment.

The following observations can be made from Table 20:

- The DG truck accident frequencies reported vary within one to two orders of magnitude, increasing the uncertainty in numerical risk assessment.
- The estimated DG truck accident frequency on WD falls within the same range as reported international data, and therefore considered credible within the band of uncertainty.
- The uncertainty also makes a societal risk assessment using F-N curves difficult, in the absence of statistically significant local data.
- It was decided to use a qualitative risk assessment using the risk matrix, but using the quantitative data on consequence and frequency as input for ranking the event within a cell in the risk matrix.
- The approach taken in this study answers the query raised in the Joint Agency Letter [2], but has not made the risk assessment entirely quantitative due to uncertainties in the data.
- The assessment of consequences and likelihood separately without combining them into a risk value is still sufficient to draw conclusions on the level of risk.

10 RISK ASSESSMENT

10.1 Introduction

The System Safety Standard for New or Altered Assets by TfNSW [38] requires a risk assessment to be undertaken in accordance with “Risk Criteria for Use by Organisations Providing Engineering Services” [4].

10.2 Qualitative vs. Quantitative Assessment

Risk assessment and evaluation of a facility is often based on a qualitative or quantitative assessment of risk of fatality to exposed people (employees, public).

A qualitative assessment uses a risk matrix of severity and likelihood and calibrates the matrix based on adopted rule sets and assesses the risk.

In a quantitative assessment referred to as a Quantitative Safety and Risk Assessment (QSRA), the risk is estimated by determining the severity of an incident that could cause fatality, and numerically estimating the likelihood of occurrence of the incident (i.e. frequency) and combining the two.

In this study, a quantitative risk assessment of fatality risk has not been undertaken as it is difficult to postulate the number of road users under the landbridge who could be affected by a DG release incident, and there are significant uncertainties in a numerical estimation of the frequency. Further, a number of assumptions may have to be made which would be hard to justify.

Therefore, the QSRA has followed the following methodology:

- Assess the consequences of postulate DG loss of containment incidents (see Section 7).
- Estimate the frequency of loss of containment of DG under the landbridge (see Section 8).
- Estimate the risk of occurrence of a DG loss of containment event using the TfNSW risk matrix in Ref. [4].

The above approach satisfies the requirements of FRNSW who have asked for a quantitative estimate of risk in the Joint Agency Letter [2], and the System safety Standard of TfNSW [38], at the same time minimising the uncertainty in the assessment.

The quantification also helps to demonstrate SFAIRP (So Far As Is Reasonably Practicable) with a bow-tie analysis.

10.3 Risk Criteria

The TfNSW risk matrix is shown in Figure 12.

The columns of the matrix cover the range of consequences from “Insignificant” to “Catastrophic”. The criteria for ranking the consequence of an incident have several categories such as Safety, Environment, People, Assets, Reputation, Service delivery etc. The categories of interest in this instance are Safety, Environment and Interruptions to Service Delivery (interpreted as incidents causing traffic interruptions including those resulting from asset damage).

The rows of the matrix rank the likelihood of occurrence of the stated consequence, ranging from “Almost Certain” to “Almost Unprecedented”. Both qualitative and quantitative criteria have been specified for ranking the likelihood.

Figure 12: Transport NSW Risk Matrix

			Consequence					
	Description		Insignificant C6	Minor C5	Moderate C4	Major C3	Severe C2	Catastrophic C1
Likelihood	Almost certain	L1	D	C	B	A	A	A
	Very likely	L2	D	C	B	B	A	A
	Likely	L3	D	C	C	B	B	A
	Unlikely	L4	D	D	C	C	B	B
	Very unlikely	L5	D	D	D	C	C	B
	Almost unprecedented	L6	D	D	D	D	C	C

The criteria description have been simplified to suit the land bridge development safety review, and listed in Table 21 and Table 22.

Table 21: Criteria for Consequence Ranking

C6 Insignificant	C5 Minor	C4 Moderate	C3 Major	C2 Severe	C1 Catastrophic
Category: Safety					
Incident and/or injury to road user not requiring first aid or medical treatment	Injury or illness to road user, requiring first aid or medical treatment (non-hospitalisation)	Minor injuries or illnesses to road user requiring hospitalisation	1 to 10 serious injuries to road user, hospitalisation, potential disability Coordinated emergency response	Single fatality and/or 10 to 20 serious injuries to road users Coordinated emergency response required	Multiple fatalities and/or more than 20 serious injuries to road users Coordinated emergency response
Category: Everyday Service delivery					
Minor traffic incident resulting in minor delays	Partial or full closure of road resulting in minor to moderate delays	Incident requiring investigation by statutory authorities	Road closure for > 1hour, fire. Evacuation caused by fire, smoke, or hazardous substance spill.		Multiple injuries or fatality to road user
Category: Environment					
No appreciable changes to environment	Rectified in <1 day	Short-term impact (<1 year) Minor remedial actions	Short to medium term impact (1 -5 years). Remedial actions probable.	Medium-term impact (>5 years) Extensive remedial actions probable.	Long-term extensive impact (>10 years). Extensive remedial actions probably required

Table 22: Criteria for Likelihood Ranking

L6 Almost unprecedented	L5 Very Unlikely	L4 Unlikely	L3 Likely	L2 Very Likely	L1 Almost Certain
Category: Qualitative Expectation					
Not expected to ever occur during time of the structure	Only an unusual chance of this risk occurring based on historical data	Chance of this risk occurring, but not very often, based on historical data	Likely chance of this risk occurring during the structure lifetime	Expected to occur occasionally during lifetime of structure	Expected to occur frequently during structure lifetime
Category: Quantitative Frequency					
Once every 50 years < 2% probability of occurrence in the next 12 months	Once every 25 years 2 - 4% probability of occurrence in the next 12 months	Once every 10 years 4-10% probability of occurrence in the next 12 months	Once every year 10-50% probability of occurrence in the next 12 months	2-10 times per year 50-80% probability of occurrence in the next 12 months	> 10 times every year > 80% probability of occurrence within the next 12 months

The risk levels are categorised A to D as shown in the risk matrix. The following tolerance criteria apply to the risk level with appropriate responses required.

Table 23: Risk Tolerance and Responses

Risk rating	Response	Risk frequency
Very High 'A'	Intolerable and should be avoided except in extraordinary circumstances. An alternative solution shall be found and all necessary steps shall be taken to reduce the risk below this level without delay.	Monthly update of risk register by the risk owner
High 'B'	Undesirable. They can only be tolerated if it is not reasonably practicable to reduce the risk further. Shall be given immediate priority.	Monthly update of risk register by the risk owner
Medium 'C'	'Medium' risks are generally tolerable if it is not reasonably practicable to reduce the risk further. SFAIRP demonstration required.	Two monthly update of risk register by the risk owner
Low 'D'	Low risks are considered to be broadly acceptable. If options for further risk reduction exist and costs are proportionate to the benefit, then implementation of such measure should be considered.	Quarterly update of risk register by the risk owner

10.4 Risk Evaluation

Based on the consequence analysis in Section 7 and likelihood assessment in Section 8, the hazardous scenarios were placed in the TfNSW risk matrix. The assessment and ranking is summarised in Table 24.

All incidents on the land bridge would involve service disruption on the eastbound or westbound traffic. A DGV accident may require closure of WD in both directions until HAZMAT emergency crew allows traffic to resume. Service interruption risk is not assessed in Table 24.

Table 24: Ranking of Risk Parameters for the MAEs

No.	DG Class	MAE Description	Consequence	Likelihood	Risk (Safety)	Comments
1	1.3, 1.4	Damaged package and fire	C2	L5	C	Injuries, potential fatalities
2	2.1	LPG release from gas cylinder on truck	C4	L5	D	Injuries
3	2.1	LPG release from road tanker	C2	L5	C	Injuries, potential fatalities
4	2.3	Toxic gas release from cylinder	C2	L5	C	Injuries, potential fatalities
5	3	Petrol release from road tanker compartment	C2	L4	B	Injuries, potential fatalities
6	3	Flammable liquid release from drum	C3	L5	C	Injuries
7	5.1	Ammonium nitrate loss of containment	Not transported [21]			
8	6.1	Toxic spill	C5	L5	D	Minor
9	6.2	Clinical waste release	C5	L5	D	Minor
10	8	Corrosive liquid spill	C5	L5	D	Minor
11	9	Li-ion battery fire	C4	L5	D	Injury to people in adjacent vehicles

The following observations are made from the risk ranking:

- There are no Very High risk events.
- There is one (1) event with High risk (B). This involves Class 3 petrol tanker loss of containment and fire, based on high volume of bulk tanker traffic.
- There are four (4) MAEs with Medium risk ranking (C)
- There are five (5) MAEs with Low risk ranking (D)
- The High risk event has been further evaluated in SFAIRP assessment in Section 11.

- The Medium ranked risks are tolerable with assessment of SFAIRP (see Table 25). SFAIRP assessment is provided in Section 11.
- The Low ranked risks are broadly acceptable.

The Aurecon risk assessment report [11] has used the Austroads risk matrix [39] as being more suitable for low likelihood events. An assessment using the Austroads matrix indicated that the evaluated risks are not different from the TfNSW risk matrix.

11 SFAIRP ASSESSMENT

The concept of 'reasonably practicable' plays a key role in SFAIRP demonstration. The bottom line reached when any further expenditure on risk reduction measures is demonstrated to be 'grossly disproportionate' to the risk reduction achieved (i.e. reduction in incident frequency).

11.1 SFAIRP Demonstration Methods

There are no formally established regulatory criteria for SFAIRP, and it is also acknowledged by TfNSW [4]. The criteria selected in this study is based on Arriscar's experience in demonstrating SFAIRP under SafeWork's Major Hazard Facilities (MHF) Regulation, adapted suitably to the present context.

There are several methods of demonstrating SFAIRP. The generally accepted definition by regulators in their assessments of MHFs in Australia has been:

- Residual risk is balanced against the cost of averting or mitigation;
- Further risk reduction measures are technically feasible and effective i.e. practicable;
- However, if cost of further risk reduction is grossly disproportionate to the benefits, the occupier "discharges the burden of proving that compliance is not reasonably practicable" [40].

11.2 Adopted Method for SFAIRP Demonstration

The following method has been adopted for the Cockle Bay project, for demonstration of SFAIRP. It broadly consists of four components.

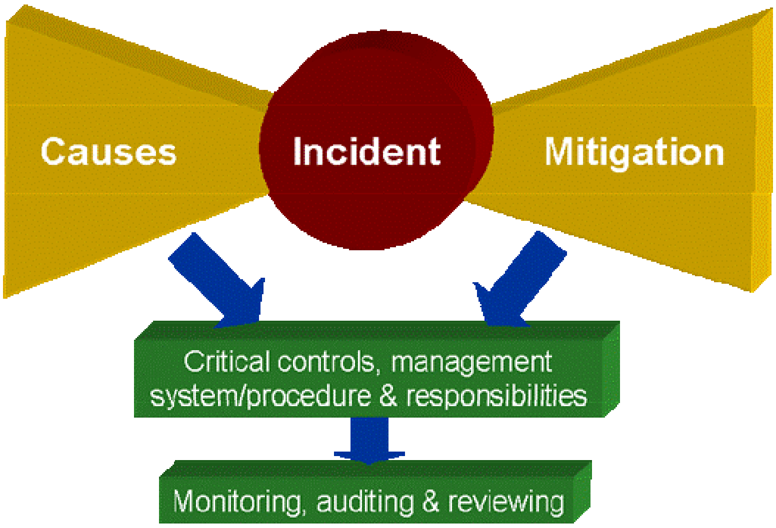
1. Compliance with Regulations and Guidelines
   - Compliance of the DG transporters with relevant Codes specified in NSW Road Rules Regulations ([41], [23]) on the restrictions of placarded load on the harbour bridge.
   - Compliance with relevant codes and standards and independent certification of the landbridge design and supports.
   - Assessment of risk and evaluation against TfNSW risk criteria [4].

   Regulatory compliance alone is not sufficient for SFAIRP demonstration.
2. Identification of safety critical elements (hardware and procedural) for hazard prevention and mitigation, and evaluation of their adequacy. This can be done with either a bow-tie analysis approach or Layers of Protection Analysis. This study has utilised a bow-tie analysis approach.
3. An effective Safety Management System (SMS) to maintain the integrity of the Safety Critical Elements.
   - Compile a list of Safety Critical Elements (includes both hardware and Safety Critical Activities)
   - Link Safety Critical Control Measures maintenance to specific SMS element/ procedure

4. Identification of additional practicable safety measures, and an assessment of whether the cost of the additional safety measures would be grossly disproportionate to the benefits gained.

Steps 2 and 3 are illustrated in Figure 13.

Figure 13: Linkage of Safety Critical Controls to Safety Management System



11.3 SFAIRP Demonstration Criteria

SFAIRP is said to be achieved when:

1) The design of the landbridge meets the requirements of established codes and standards. This will be part of construction approval at a later stage.
2) The facility maintained and operated to good industry practice.
3) The assessed risk to road users from DG vehicle incidents under the landbridge is in line with available TfNSW risk criteria [4].
4) Adequate and effective layers of protection for incident prevention and consequence mitigation are in place (appropriate signs, lighting, fire protection, lane marking, communication system) (Bow-tie analysis)
5) People in vehicles under the landbridge can escape safely in an emergency, and access for emergency services (an emergency response plan will be prepared in consultation with FRNSW and TfNSW).
6) There is an effective maintenance scheme for the safety critical elements (maintenance of road markings, lighting under the landbridge, sign postings if any, and firewater system)
7) Where additional capital expenditure on risk reduction measures is required, where possible, demonstrate that the cost of additional risk reduction is grossly disproportional to the benefits in terms of risk reduction. Otherwise include the additional safety measures.

11.4 Parameters Affecting Performance

In order to evaluate the barriers and mitigation measures in terms of their suitability to control the MAEs, a control hierarchy is given below:

a. Elimination
b. Prevention
c. Detection
d. Isolation
e. Protection of people
f. Fire protection

Effectiveness is defined as the probability that the control measure will perform its designed function to control the threat or consequence, taking into account the hierarchical role listed above

11.5 The Bow-Tie Model

The technical analysis was based on the Bow-Tie" model. A brief description of the model is given below.

Each MAE is the result of realisation of inherent hazards associated with a hazardous material, or activity associated with the material (storage, distribution, processing, operations, maintenance, etc.). As such, each MAE has a set of antecedent causes. These causes may be single-point causes (e.g. loss of containment from corrosion of equipment or pipework), or a complex combination of causes that involve equipment or control system failure and human error. For the purposes of this model, a cause is defined as a threat that places a demand on a control measure to act.

The control measures that eliminate or prevent the MAE from occurring (e.g. loss of containment) are referred to as 'barriers', and these are proactive controls.

Should one or more of the barriers fail, then the MAE (loss of containment) could occur. This does not, however, mean that there would be immediate escalation, or harm to personnel.

There are a number of reactive control measures such as detection of loss of containment and isolation (manual or automatic), consequence mitigation measures such as ignition control, fire protection, emergency preparedness and response. Depending on the degree of success of these reactive controls, a variety of outcomes is possible, ranging from control of the incident without escalation, to the other extreme of escalation and a large section of the facility being involved in the MAE.

Thus, the proactive control of causes ("threats"), and reactive control of the consequences or outcomes ("mitigation measures"), using a range of barriers and control measures constitute the model for control of hazards.

11.6 Bow-Ties

The bow-ties for the MAEs are shown in Appendix B.

The following rule applies for the bow-ties:

- The barriers for the threats (left side) and the mitigation control measures for the consequences (right side) of the bow-tie must be independent, i.e. failure of one-barrier must not disable another simultaneously.

11.7 Effectiveness of Barriers and Control Measures

The barriers and control measures must be rated for their effectiveness. This is done as a qualitative measure:

- Very High >90%
- High 70-90%
- Moderate 50-70%
- Low <50%

The rated effectiveness for barriers are listed in with comments on their selection. Some of the effectiveness selection is subjective.

Many of the barriers are maintained by the DG transport company and the DGV driver over which DPT has no control, and the barriers are imposed by EPA licensing regulations.

The WD maintenance falls under the responsibility of TfNSW. This also includes land marking and fire protection system maintenance under the landbridge, and emergency response plan implementation.

TfNSW has suggested that as part of conditions of consent, an agreement between TfNSW and DPT would need to be made regarding DPT's contributions to TfNSW for WD maintenance under the landbridge [42].

Table 25: Barrier Effectiveness

No.	Barriers/ Control	Responsibility	Effectiveness	Comments
1	Landbridge maintenance	TFNSW	High	Planned inspection and maintenance
2	DG road rules	DG Carrier	Moderate	There is evidence from road survey that not all DGV drivers follow the rule [16]
3	DGV inspection/ licensing	DG Carrier	High	Statutory requirement enforced by the EPA
4	Road tanker valves/ fittings protected	DG Carrier	High	By design
5	Landbridge lighting	TFNSW	Moderate	Lighting alone does not influence road user behaviour
6	DGV driver licensing	DG Carrier	High	Statutory requirement enforced by the EPA
7	Post-loading inspections of tankers/ cylinders	DGV Driver	Moderate	Routine activity by tanker driver
8	Isolation redundancy in tankers	DG Carrier	Very High	By design

No.	Barriers/ Control	Responsibility	Effectiveness	Comments
9	Secure packaging of DGs	DG Terminal Operator	High	Historically incidents have occurred from poor securing
10	Segregation of mixed loads	DG Terminal Operator	High	Human error on the part of DG operator
11	Gas cylinder inspections and valve replacement	Gas supplier	Very High	AS 4332 requirement
12	CCTV	TFNSW	Moderate	Monitored by TfNSW. The monitoring may not be on a 24/7 basis unlike the Sydney Harbour tunnel and hence ranked moderate.
13	Landbridge sprinkler system	TFNSW	High	Maintained by TfNSW through an authorised fire services contractor
14	Natural ventilation	TFNSW	Moderate to High	Based on ARUP's FDS study [7]
15	Spill kit and driver training	DG Carrier	High	DGVs carrying Class 6.1 and 8 goods must have chemical spill handling PPE for driver
16	Emergency Response Procedure	TFNSW/ DGV driver	Moderate to High	Driver training for licensing DGV Carrier's training for drivers HAZMAT unit in attends in an emergency
17	Drainage	TFNSW	High for small leaks. Moderate for large leaks as it would take some time for the spill to drain.	For Class 3 bulk tanker release, drainage would remove released liquid, limiting the inventory in a fire. Overall rating of Moderate has been adopted.
18	Structural reinforcement of land bridge roof beams/concrete planks	DPT Operator	High	Structure can withstand blasts of 45 kg TNT equivalent
19	In-vehicle communication system	TFNSW	High	Recommended in this study

11.8 Evaluation of Adequacy of Control Measures

The following rule set was adopted for SFAIRP:

1. Of the barriers on the left-side of the bow-tie, there must be a *minimum* of *two* barriers with High or Very High Effectiveness rating.
2. Of the barriers on the right-side of the bow-tie, there must be a *minimum* of *two* barriers with High or Very High Effectiveness rating, not including emergency response.

The barrier count and effectiveness for the various MAEs from the bow-ties in Appendix B and from Table 25 are summarised in Table 26 and Table 27.

Table 26: Summary of Barriers Effectiveness

No.	DG Class	MAE Description	Threat	Effectiveness of Barriers				SFAIRP rule set satisfied?
				Very High	High	Moderate	Low	
1	2.1	LPG release from gas cylinder on truck	Gas cylinder failure	0	2	1	0	Yes
			Tanker accident	0	4	2	0	Yes
			Truck fire	0	2	0	0	Yes
2	2.1	LPG release from road tanker	Tanker failure	1	2	1	0	Yes
			Tanker accident	0	4	2	0	Yes
			Truck fire	0	2	0	0	Yes
3	2.3	Toxic gas release from cylinder	Gas cylinder failure	0	2	1	0	Yes
			Tanker accident	0	4	2	0	Yes
			Truck fire	0	2	0	0	Yes
4	3	Petrol release from road tanker compartment	Tanker failure	1	2	1	0	Yes
			Tanker accident	0	4	2	0	Yes
			Truck fire	0	2	0	0	Yes
5	3	Flammable liquid release from package	Damaged package	0	2	1	0	Yes
			Vehicle accident	0	4	2	0	Yes
			Truck fire	0	2	0	0	Yes

For all threats for the MAEs, the prevention barriers have adequate effectiveness to satisfy selected SFAIRP criteria.

Table 27: Summary of Mitigation Controls Effectiveness

No.	DG Class	MAE Description	Consequence	Effectiveness of Barriers				SFAIRP rule set satisfied?
				Very High	High	Moderate	Low	
1	2.1	LPG release from gas cylinder on truck	Safety	0	4	2	0	Yes
			Asset Damage	0	3	2	0	Yes
2	2.1	LPG release from road tanker	Safety	0	4	2	0	Yes
			Asset Damage	0	3	2	0	Yes
3	2.3	Toxic gas release from cylinder	Safety	0	2	2	0	Yes
4	3	Petrol release from road tanker compartment	Safety	0	3	2	0	Yes
			Asset Damage	0	2	2	0	Yes
			Environment	0	2	1	0	Yes
5	3	Flammable liquid release from package	Safety	0	4	2	0	Yes
			Asset Damage	0	3	2	0	Yes
			Environment	0	2	1	0	Yes

For all consequences for the MAEs, the mitigation controls have adequate effectiveness to satisfy selected SFAIRP criteria. The exposure minimisation measures and emergency response have been given an adequacy rating of “Moderate”. The emergency response should address communicating to road users who have stopped in an emergency to raise the vehicle windows and place the circulation on ‘internal’ until further instructions from emergency services This has been included as a barrier for SFAIRP assessment and given a rating of ‘High’, as this system has worked successfully in road tunnels in Sydney.

There should also be a means of communication for the DGV driver to DPT monitoring room.

11.9 Landbridge Evacuation

In the event of accident under the landbridge, other road users who have stopped the vehicles under the landbridge would need to be evacuated.

There is a difference between surface evacuation and evacuation from enclosed road sections. In longer tunnels such as the WestConnex, emergency egress is provided at 120m intervals [43]. In the current context, the enclosed section is approximately 150m, with fully enclosed section of 84m. Therefore, evacuation must be conducted through the portals of the landbridge.

Road users must stay in their vehicles with windows raised until instructed to drive on or evacuate. They would follow the instructions of the emergency services who will decide which portal would be used for the evacuation, depending on the nature of the emergency.

Once out of the landbridge, the evacuees would assemble in a nominated area in the open where traffic flow has stopped. The assembly area needs to be decided during detailed design.

12 SAFETY CRITICAL ACTIVITIES

Safety critical activities (SCA) involve maintaining the integrity of the barriers and control measures in the bow-ties that ensure safety of the infrastructure and operations. In the current context, there are a few key stakeholders responsible for the SCAs associated with the landbridge operation.

- TfNSW for maintenance of WD infrastructure
- DG Carrier companies (including their drivers)
- NSW EPA (DGVs and driver licensing)
- Designer of CBP landbridge (compliance with codes and standards and certification of design)
- Designer of CBP landbridge (structural reinforcement of landbridge roof beams/concrete planks.

This section addresses the SCAs that are under the control of TfNSW for maintenance of the landbridge infrastructure.

The SCAs are:

1. Landbridge structure maintenance
2. Landbridge section lighting and maintenance
3. CCTV installation and maintenance
4. Upkeep of drainage underneath landbridge (free of blockages)
5. Development of emergency response procedure in consultation with stakeholders (DPT, TfNSW and FRNSW)
6. Communication system for road users who may have to stop under the landbridge in the event of an emergency, extended to the open space above the land bridge to enable targeted evacuation.

As conditions of development consent, TfNSW has recommended to DPHI that a formal negotiated agreement between TfNSW and DPT will be entered into, for the upkeep and maintenance of the landbridge infrastructure and associated SCAs above [42].

13 CONCLUSIONS

The following conclusions were reached in this review:

- The main DGVs using the WD are Class 3 bulk tankers (petrol tankers) and Class 2.1 bulk tankers (LPG tankers). These constitute approximately 70% of total DG traffic.
- A traffic survey has identified that approximately 70-75 DGVs use the WD per day, including both directions.
- Both qualitative and quantitative consequence assessment have been carried out using representative DGs from all Classes.
- The CFD studies by ARUP has shown that an explosion of 45kg equivalent TNT would not impair the supporting columns for the landbridge.
- The FDS studies by ARUP has shown that the RSET for landbridge evacuation is less than the AEST for a 250 MW heat output and smoke generation (typical of a petrol tanker 50mm leak).
- Risk evaluation using the TfNSW matrix has shown that there are no Very High events and a single High risk event associated with DG transport on the Western Distributor.
- The AEISG has confirmed that among its members, there is no intention of transporting ammonium nitrate on the WD. This addresses the concerns raised by SafeWork NSW.
- Road rules are in force to prohibit movement of placarded DGVs on the harbour bridge during peak traffic hours.
- A SFAIRP assessment has been carried out by proposing an assessment methodology and criteria, using bow-tie analysis technique. The assessment indicated that SFAIRP can be achieved by the proposed landbridge development.
- The review has addressed the queries raised in the Joint Agency Letter to DPHI, as part of assessment of the proposed development.
- The present updated report has addressed the comments raised in the GHD peer review report [13].

14 RECOMMENDATIONS

The following recommendations are made to DPT as a result of the present review:

1. Provide a sprinkler system to "High Hazard" deluge density underneath the landbridge in accordance with AS 2118.1- 2017.
2. Update the fire safety study in Ref. [8] based on the final design of the landbridge structure.
3. Develop safety management procedures manual addressing the following safety critical activities:
   - Landbridge infrastructure inspection and maintenance
   - Landbridge lighting maintenance
   - Lane marking maintenance with reflective paint for easy visibility
   - CCTV maintenance
   - Maintenance of drainage
   - Evacuation of road users from the landbridge and nominate assembly area (approximately 180 persons) [7].
4. Develop a communication method for the road users stopped under the road bridge in the event of an emergency.
5. Extend the in-vehicle communication system to the open space above the land bridge to enable targeted evacuation.
6. Implement the structural reinforcement of the land bridge roof beams/concrete planks referred to in the ARUP report [6].

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Appendices

Appendix A Assumptions

It is necessary to make technical assumptions during a risk analysis. These assumptions typically relate to specific data inputs (e.g. material properties, equipment failure rates, etc.) and modelling assumptions (e.g. release orientations, impairment criteria, etc.).

Details of the key assumptions adopted for the risk analysis are provided in this Appendix.

Each assumption is numbered and detailed separately. The basis for each assumption is explained together with its potential impact on the risk results. Key references are also listed for each assumption, where relevant.

It is important that the assumptions be supported by:

- Data in the literature, where available;
- engineering judgement of the analyst.

The main objectives are to minimise uncertainty in the risk estimate as far as is possible, and to ensure that the assumptions result in a 'conservative best estimate' of the risk. Such an approach is consistent with the following extract from Section 5 of HIPAP No. 6 [44]: "*In the consequence analysis and throughout the hazard analysis, the analyst must be conscious of the uncertainties associated with the assumptions made. Assumptions should usually be made on a 'conservative best estimate' basis. That is, wherever possible the assumptions should closely reflect reality. However, where there is a substantial degree of uncertainty, assumptions should be made which err on the side of conservatism.*"

Assumption No. 1: Traffic Volumes in Western Distributor
Assumption/s: • All traffic volumes used in the risk assessment are as outlined in Sections 4 and 5. The data collected is limited and should be treated as indicative. An incremental increase to 2024 has been assumed, resulting in a 20% increase in traffic flow. • The Dangerous Goods traffic on the Harbour Bridge was based on a week's traffic survey and count described in Section 5.
Justification and Impact/s of Assumption/s: • The traffic survey conducted by Matrix Transport and Traffic Data [20] in 2017 was used. This is the only surveyed data available reflecting local conditions. • The DG traffic survey was based on 7 days' traffic count of DG traffic by Aurecon [16]. The data is limited, but provides a good indication of the types and volume of DGs transported. • The uncertainties associated with limited data available can be taken into account by treating the calculated risk as indicative of the order of magnitude for risk assessment, rather than an actual measurement of risk. • Because of the limited statistical data in heavy vehicles and DG traffic volume, this review has focused on evaluating the assessed loss of containment frequency for ascribing a likelihood rating on a risk matrix, rather than a full quantitative risk assessment.
MAE/s Affected: • All.
Reference/s: • Matrix Transport and Traffic Data Ref. [20] • Aurecon survey of dangerous goods traffic on Sydney Harbour Bridge Ref. [16]

Assumption No. 2: NSW Road Rules
Assumption/s: • The NSW Road Rules regarding the prohibition of placarded DG traffic on the Sydney harbour bridge during specified peak hours is followed by transport operators.
Justification and Impact/s of Assumption/s: • The NSW Road Rule states: *During peak periods, all placard loads are prohibited from the Sydney Harbour Bridge. (7am to 930am Monday to Saturday, and 4pm to 630pm Monday to Friday)* The above prohibition is taken as a 'barrier' in the prevention of road accidents on the Western Distributor in bow-tie analysis. It is possible that some drivers may not be aware of or ignore this rule. The current analysis does not account for such breaches as the survey data indicates that almost all DG traffic on the Sydney Harbour Bridge occurs outside the 'peak' hours.
MAE/s Affected: • All.
Reference/s: • NSW Road Rules Ref. [23], [41] • Aurecon survey of dangerous goods traffic on Sydney Harbour Bridge Ref. [16]

Assumption No. 3: Representative Wind Speeds, Wind Directions and Stability Classes
Assumption/s: • Consequence modelling in PHAST 9.0 was based on a Stability condition D and wind speed of 1.5m/s (D1.5).
Justification and Impact/s of Assumption/s: • The landbridge encloses the traffic flow beneath it and hence there is no room for an inversion layer formation. Therefore Pasquil stability D (Neutral) is considered appropriate. • se the 'tilting' of the flame from a pool fire. An allowance for flame tilt is included in PHAST. • Wind speeds between 1m/s and 9m/s are covered in an 'open air' incident risk assessment. For the enclosure under the landbridge, a low wind velocity of 1.5m/s has been adopted. • Wind speed typically has minimal impact on jet fires due to momentum jet effects of a sonic release. High wind speeds may cause flame tilt in pool fires.
MAE/s Affected: • All.
Reference/s: • None. Assumption based on engineering judgement.

Assumption No. 4: Road User Population Underneath Landbridge
Assumption/s: • The road user population was not included in the risk assessment
Justification and Impact/s of Assumption/s: • It is difficult to estimate the road user population impacted by an incident since the incident hazard zone varies for different incidents. Even if the distance is known, assumptions have to made on the type of vehicle, number of passengers per vehicle and distance between vehicles, and any results derived have significant uncertainties. • The quantitative risk assessment carried out uses the risk criteria based on the Transport Assets Standard Authority's risk matrix, and estimates the likelihood of a loss of containment incident and does not calculate potential number of fatalities. It is sufficient for risk evaluation purposes if there would be a single or multiple injuries or fatalities.
MAE/s Affected: • None. The road user population is only required for the calculation of societal risk, which has not been carried out in this study.
Reference/s: • Transport Assets Standard Authority risk matrix in Ref. [4]

Assumption No. 5: Not Used
Subject:
Assumption/s: •
Justification and Impact/s of Assumption/s: •
MAE/s Affected: •
Reference/s: •

Assumption No. 6: Representative Materials
Assumption/s: • A Class 2.1 gas is modelled as LPG (propane) • A Class 3 liquid is modelled as gasoline (major component n-Heptane). • Class 2.3,4,5,6 and 8 materials were not modelled for consequences
Justification and Impact/s of Assumption/s: • The composition and materials used affect the magnitude of the consequences. Materials containing multiple components are simplified for modelling purposes by choosing a representative component to best approximate the variable composition. Modelling a representative material rather than a multi-component material reduces complexity, limits the potential for inconsistencies and ultimately has a minimal effect on the results. • The Class 2.1 cylinders may include acetylene cylinders used as a welding gas, but not transported as a placarded load. A trades utility vehicle may carry one or two cylinders. LPG is more representative as the cylinders are distributed to retail outlets (e.g. petrol stations). • Class 3 bulk tankers generally carry a mixed load of gasoline and diesel in different compartments. Gasoline was selected for the risk analysis as it is the most flammable product transferred in bulk. • Class 3 packaged load would normally contain flammable solvents in 205L drums or smaller packages. A release is modelled in the same way as gasoline. This assumption is conservative. • Placarded Class 4 package are rarely transported. • Ammonium nitrate (AN) (Class 5.1) has been discussed in previous consultations as a material of concern. The AEISG has confirmed that there is no intention of the Group's members transporting AN across the Sydney harbour bridge. • Class 6 and 8 materials are non-volatile. Some Class 6 goods may be combustible, but need an external fire to ignite them. Class 8 goods are non-combustible. A spill would be localised and road users in cars are unlikely to be affected. • Bow-tie analysis has considered all classes, in a qualitative assessment.
MAE/s Affected: • All.
Reference/s: • AEISG Ref. [21] • Assumptions based on engineering judgement

Assumption No. 7: Landbridge Blast Assessment
Assumption/s: • Impact of an explosion underneath the landbridge has been taken from the ARUP report [6], and not repeated in this study.
Justification and Impact/s of Assumption/s: • A blast in the enclosed area can occur from the transport of Class 1.4 goods (e.g. Fireworks). Transport of Class 1.1 and 1.2 goods is prohibited in Sydney CBD. • Modelling structural impact of blast requires a Computational Fluid Dynamics (CFD) software. The ARUP report [6] has used the Viper: Blast CFD software to analyse the overpressure effects of an explosion, by considering a TNT equivalent of 45 kg.
MAE/s Affected: • All.
Reference/s: • ARUP Australasia Pty Ltd, Ref. [6]

Assumption No. 8: Representative Hole Diameters for Release Modelling

Assumption/s:

Consequence modelling is based on the following representative hole diameters. These hose sizes are typical of release sizes assumed in risk assessments as 'credible' accident events.

Table 28: Representative Hole Diameters Selected for Consequence Analysis

Release Source	Material/s	Hole size, mm	Comments
Class 2.1 Cylinder	LPG (Propane)	1.6	Cylinder valve leak
Class 2.1 Bulk	LPG (Propane)	13	Valve gland leak
Class 3 (Package)	n-Heptane	200L	Drum contents
Class 3 (Petrol tanker)	n-Heptane	50	One compartment (9000L)

Justification and Impact/s of Assumption/s:

- Gas cylinders are unlikely to fail (pressure vessel design, secured in cages) unless penetrated with high velocity by sharp object such as fork lift tines. Sharp objects are not present in the type of accident envisaged on WD.
- Bulk LPG tanker is unlikely to rupture for the same reasons unless a B-Double jack-knife occurs. There is insufficient room on WD for such an event. The valve is isolated with a cap. A gland leak is postulated on the assumption that the ISC valve within the tanker had failed to close. Multiple barriers should fail for the event to occur.
- Packaged Class 3 liquids are assumed to consist of 205L drums or smaller containers. These are not pressure vessels and failure of a drum by fall may result in spill of its contents.
- Petrol tanker consists of 5 or 6 compartments each 9000L capacity. A catastrophic failure with all compartments failing and 54000L release is considered extremely unlikely. An initial fire from a leak (50mm) and loss of one compartment content is postulated. The fire may escalate and result in the failure of other compartments, and mitigation measures such as the sprinkler system to cool the other compartments are provided.

MAE/s Affected:

All.

Reference/s:

-

Appendix B Bow-Ties

The bow-ties developed for loss of containment of various classes of dangerous goods under the proposed bridge are included in this Appendix.

The hazard prevention barriers and the mitigation controls are used for evaluation of adequacy as part of SFAIRP discussion in Section 11.

Figure 14: Bow-Tie for Class 2.1 Goods (Gas Cylinders)

Hazard	Top event
Class 2.1 Cylinders	Loss of Containment

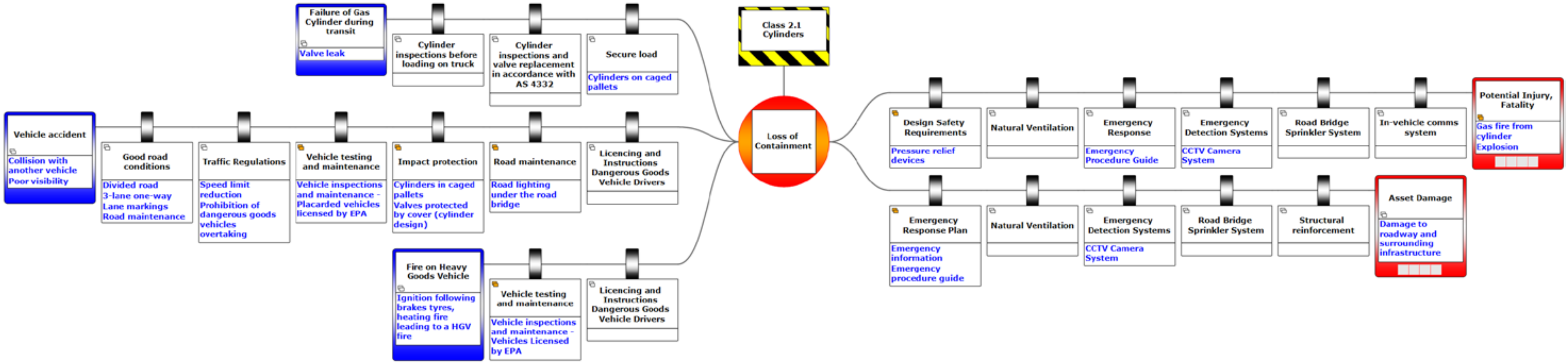

Figure 15: Bow-Tie for Class 2.1 Goods (Bulk LPG Road Tanker)

Hazard	Top event
Class 2.1 Bulk LPG Tanker	Loss of Containment

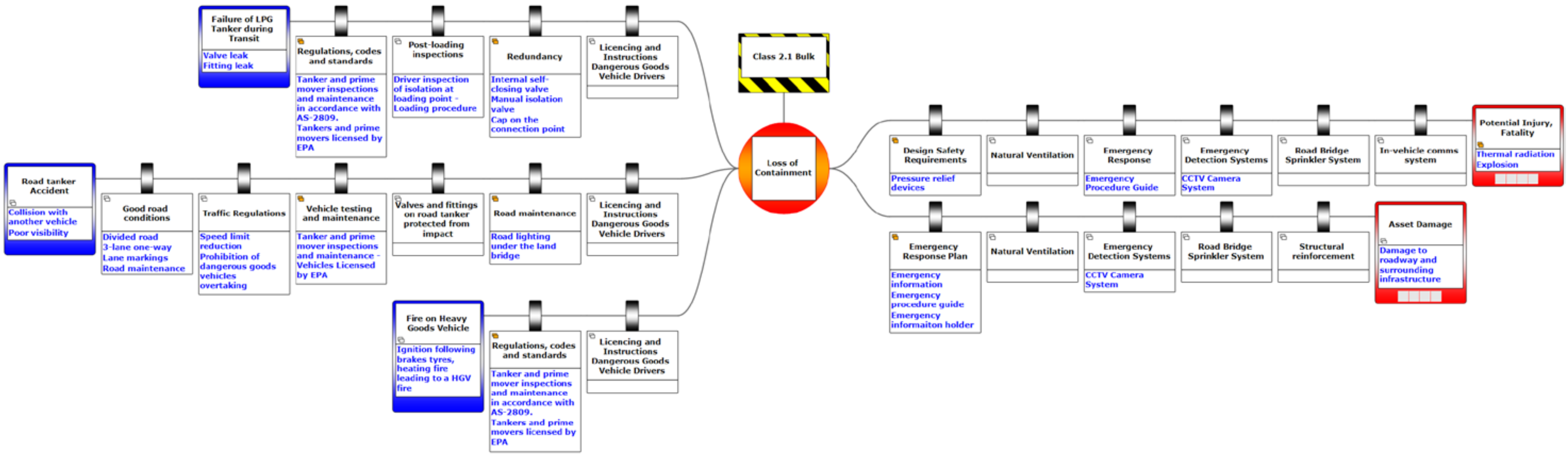

Figure 16: Bow-Tie for Class 2.3 Goods (Gas Cylinders)

Hazard	Top event
Class 2.3 Cylinders	Loss of Containment

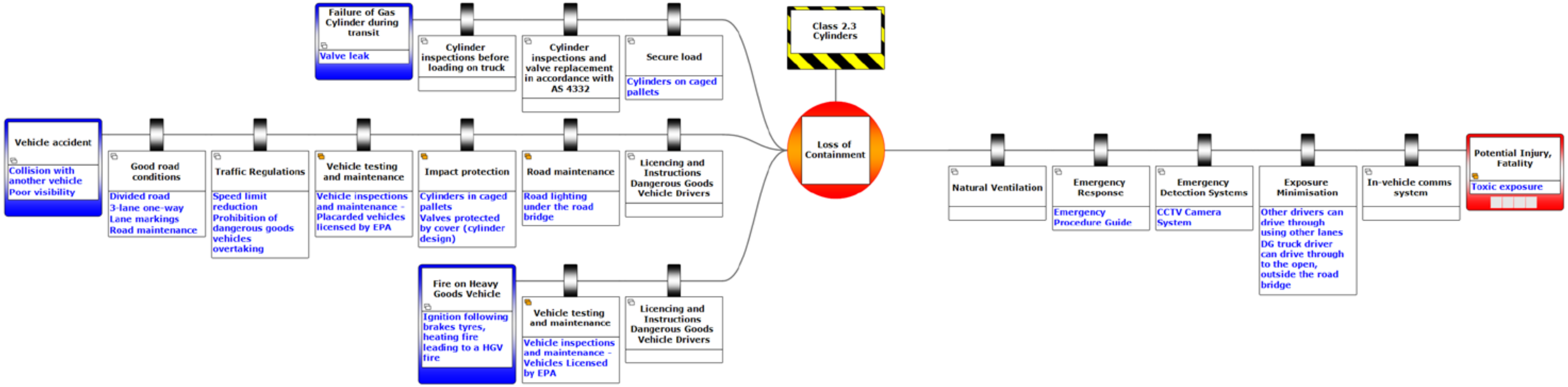

Figure 17: Bow-Tie for Class 3 Goods (Bulk Petrol Tanker)

Hazard	Top event
Class 3 Bulk	Loss of Containment

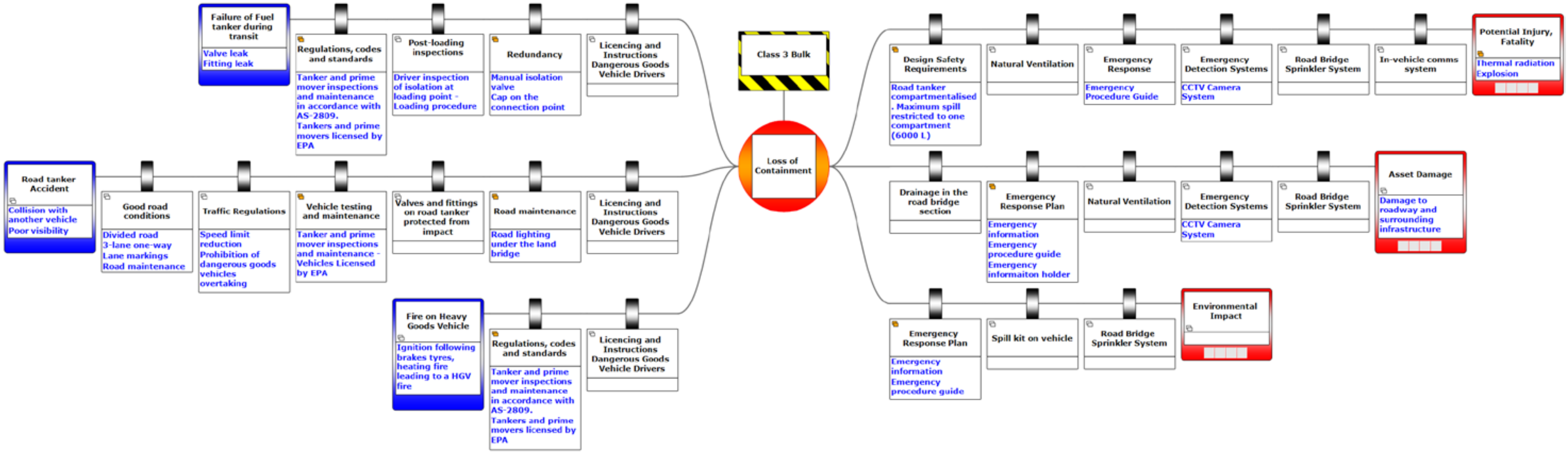

Figure 18: Bow-Tie for Class 3 Goods (Packaged)

Hazard	**Top event**
Class 3 Package	Loss of Containment