Function:	Track & Civil
Document Type:	Procedure

Performance and Risk-Based Fire Design of Bridges for Structural Collapse Prevention and Vulnerability Mitigation

ETP-09-06

Applicability

ARTC Network Wide

Publication Requirement

Internal / External

Primary Source

Document Status

Version #	Recommended Review Due	Prepared by	Owner	Endorser	Approver
1.0	01 Apr 2031	Engineering Services	Manager Engineering Services	Principal Structural Engineer	Manager Engineering Services 07/04/2026

Amendment Record

Amendment Version #	Date Reviewed	Clause	Description of Amendment
1.0	01 Apr 2026		First issue

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1 Introduction

1.1 Purpose

This procedure outlines ARTC requirements for the fire design of new bridges to prevent structural collapse and mitigate their vulnerability to fire.

The objective is to enhance the resilience of new bridges within ARTC railway corridors against collapse and to mitigate structural vulnerability during possible fire events. This is achieved by assigning each new bridge an appropriate classification based on its fire performance and associated fire risk, with each classification prescribing specific design requirements.

This procedure excludes explosion loads and the structural response to blast effects. It also excludes tunnel fire-safety requirements, which are addressed in other Australian Standards. Fire-safety requirements for miscellaneous structures (such as buildings, stations, platforms, cantilevers, portals, and towers) constructed over, under, or in the vicinity of existing railway tracks are likewise excluded.

Although this procedure applies only to new bridge designs, it may be used to assess any existing bridge or a bridge upgrade (e.g., a superstructure replacement) and implement the necessary fire measures if requested by ARTC.

1.2 Scope

This procedure utilises a mathematical performance- and risk-based Multi-Criteria Decision-Making (MCDM) framework to categorise new bridges into three Bridge Fire Design Categories (BFDCs, 1–3), each corresponding to specific fire design provisions.

Generally, the mechanical properties of concrete and steel degrade as temperature increases, regardless of whether a standard, external, hydrocarbon, or other types of fire (such as what may occur in an electric vehicle) cause the heating. Concrete begins to exhibit noticeable stiffness and strength reduction above approximately 300 °C, with more severe losses developing in the 500–600 °C range; spalling may occur under rapid heating or high-moisture conditions. Steel begins to lose stiffness and yield strength at approximately 250 °C, with accelerated degradation occurring above 400–500 °C. While these temperature-dependent behaviours are consistent across all fire types, hydrocarbon fires reach these critical temperatures far more rapidly, resulting in much earlier loss of structural capacity in unprotected members.

Road and rail vehicles are transporting increasingly larger volumes of hydrocarbon fuel. In contrast, the safety systems of large vehicles (such as fuel tankers and rail freight) and the design standards of the transport networks are gradually being improved.

Fire incidents have been shown to have the potential to cause severe structural damage, partial or total collapse, loss of life, network disruption, and significant economic loss, and shall therefore be appropriately recognised in new bridges.

At present, AS 5100 assigns responsibility for determining bridge fire design requirements to the relevant authority but prescribes specific fire-related provisions when such design is mandated. A clear understanding of structural performance in fire conditions, along with an assessment of fire-related risks, allows for a practical, consistent, and cost-effective bridge fire design. The identification of fire-risk classes and associated factors, rather than neglecting these elements, assists bridge designers in selecting appropriate and economical design parameters, thereby mitigating the risk of structural collapse during a possible fire event and enhancing bridge performance under fire exposure. Accordingly, a practical, performance- and risk-based MCDM framework is required to classify new bridges within ARTC railway corridors and to implement design provisions that enhance network resilience and mitigate structural vulnerability during and after possible fire events.

2 Fire Design

2.1 Bridge Fire Design Categories (BFDC)s

New bridge designs shall be classified into three Bridge Fire Design Categories (BFDC)s as follows:

- BFDC-3, high-performance- and risk-driven classification
- BFDC-2, medium-performance- and risk-driven classification
- BFDC-1, low-performance- and risk-driven classification

Table 1 lists the BFDC requirements for new bridge designs.

2.2 Bridge Fire Design Requirements

In summary, Fire Resistance Level (FRL) represents the graded Period of Structural Adequacy, PSA (in minutes) that a structural member must achieve under the standard fire test. It comprises three performance criteria: structural adequacy, integrity, and insulation, expressed as three numbers separated by slashes (e.g., 120/90/60). A dash (–) in the integrity or insulation rating indicates that no requirement applies for that specific criterion.

For ARTC bridges, all fatigue-critical detail categories of structural steel members, as well as the physical condition of all steel members, shall remain fully visible and accessible for inspection at any time. Fire protection materials or any form of encasement or cover that would obstruct inspection shall not be applied. Accordingly, for ARTC, the design of steel bridges (unprotected members as required in this procedure) for BFDC-2 and BFDC-3 classifications (see Table 1) should be considered impractical and uneconomical due to high thermal demands and the inherently higher Degrees of Freedom (DoF) of steel bridges.

For BFDC-2 and BFDC-3 classifications:

- Secondary structural members in ARTC bridges may be excluded from fire design following a detailed cost and risk assessment approved by ARTC, provided that they:
  - Do not compromise the overall structural stability or lead to bridge collapse
  - Do not overstress primary structural members as a result of high heat transfer, localised buckling, or localised failure; and
  - Do not prevent safe, practical, and economical repair or replacement following a fire event
- The bridge designer shall review and assess the behaviour and performance of all structural members of ARTC bridges during the design process to ensure that the omission of fire design provisions for certain members, as noted above, does not compromise the overall structural stability of the bridge under fire conditions, and that any associated cost implications remain within acceptable and manageable limits.
- In ARTC bridges, for structural members other than girders or beams (e.g., exposed slabs or floors to fire), where potential fire damage is deemed economically unjustifiable

or could compromise long-term performance, as reviewed and approved by ARTC, the fire design should incorporate protection measures providing not less than 30 minutes of integrity and insulation to ensure the bridge remains functional and maintainable following a fire event.

- Substructural members may be exempted from fire design where a risk assessment demonstrates that fire exposure on any side is unlikely to adversely affect their load-bearing capacity.

ARTC bridges with superstructure heights of 18 m or greater above the rail, road, ground, or water level may be classified as BFDC-1 without the need for further assessment.

The fire design load case shall be considered only under the Ultimate Limit State (ULS) load combination, incorporating Permanent Effects (PE) and the fire effects.

ARTC bridge design drawings shall indicate the adopted BFDC classification and fire design load case. The bridge design report shall include a detailed BFDC determination (refer to Appendix A) as calculated and filled in the BFDC Determination Form, ETP0906F-01, and, if required, associated cost and risk assessments, advanced computational fire modelling (e.g., fluid dynamics), or simplified fire calculations.

Table 1: Minimum Required BFDCs for New Bridge Designs

BFDC	DESCRIPTION	MINIMUM REQUIREMENTS
3	The superstructure of a rail bridge (ARTC/non-ARTC) over ARTC tracks	○ Design for an FRL of (120/–/–), hydrocarbon fire curve (RABT-ZTV, rail), unless a detailed risk assessment approved by ARTC confirms that hydrocarbon fire design is not required at the bridge location. Under no circumstances shall the design classification be lower than BFDC-2 (Note 1)
	The superstructure of a road bridge (overbridge) over ARTC tracks	
	The superstructure of a footbridge over ARTC tracks	
	The superstructure of ARTC underbridge over roadway	○ Design for an FRL of (120/–/–), hydrocarbon fire curve (RABT-ZTV, road/bus), unless a detailed risk assessment approved by ARTC confirms that hydrocarbon fire design is not required at the bridge location. Under no circumstances shall the design classification be lower than BFDC-2
	Other ARTC underbridges (e.g., over creeks, gullies, etc.)	○ Refer to BFDC-2
2	All above	○ Design for an FRL of (90/–/–) based on the standard cellulosic time–temperature fire curve in AS 1530.4. Simplified calculations may be carried out using recognised methods in AS 3600, AS 4100, or AS 2327.1 (as required in AS 5100) (Note 2)
1	All above	○ No fire design is required

Note 1 At this stage, AS 5100 does not fully provide material properties, including stress–strain relationships at elevated temperatures; accordingly, if required, other international standards may be used when designing members at elevated-temperature conditions.

Note 2 BFDC-2 does not necessarily indicate the absence of a hydrocarbon or other types of fire scenarios at the bridge site; rather, it represents a lower classification than BFDC-3, considering assessed structural performance and risk factors (refer to Section 3). This design level is intended to provide some structural robustness for possible fire scenarios. Although this classification only includes a standard cellulose-type fire curve with a lower FRL and does not represent the severity of hydrocarbon fire conditions, it provides a degree of structural resilience that helps limit damage and preserve partial stability under accidental hydrocarbon fire exposure.

3 Performance- and Risk-Based Multi-Criteria Decision-Making (MCDM) Fire Design Framework

The following equation shall be used to determine the Performance-Risk (PR) indicator, Ψ :

$$0.23 \leq \Psi = \sum_{i=1}^{n} \sum_{k=1}^{m_k} \alpha_{i,k} \left(\frac{\sum_{k=1}^{m_k} \omega_{i,k}}{\sum_{k=1}^{m_k} \omega_{i,k,max}} \right) \leq 1.0$$

Where; $\alpha_{i,k}$ is the subclass importance factor, $\omega_{i,k}$ is the weighting factor of the subclass $k = 1, \ldots, m_k$ in class $i = 1, \ldots, n$, and $\omega_{i,k,max}$ is the maximum weighting factor of the subclass $k = 1, \ldots, m_k$ in class $i = 1, \ldots, n$ (refer to Table 4).

A bridge includes different classes (i) as defined in Table 2.

Table 2: Bridge Classes and Their Characteristics

BRIDGE CLASS (i)	CLASS DESCRIPTION	CLASS NATURE (Performance, Risk, or Risk Response)	JUSTIFICATION
1	Bridge Geometry, Material, and Design Properties (Superstructure Only)	Performance	Represents the highest class because it is controllable through project and engineering design, and directly influences the bridge's inherent fire resilience, resistance, redundancy, and residual load-carrying capacity
2	Estimated Economic Impact (AUD)	Performance	Reflects the financial resilience and cost sensitivity of ARTC corridor and the bridge in the event of a possible fire. It represents a design-related consequence indicating the potential direct or indirect financial losses associated with a fire event to ARTC railway network. Bridges with higher economic exposure present greater risk significance than other bridges in the railway network
3	Bridge Location	Risk	Indicates the bridge's proximity to critical facilities, such as railway stations or platforms. The bridge's location near these facilities affects severity and hydrocarbon fire risk by influencing ignition potential and local fuel load density. These factors collectively shape the likelihood, nature, and potential consequences of a fire event
4	Human-Induced Fire	Risk	Introduces potential fire risks caused by human activity
5	Type of Track or Road	Risk	Includes track or road geometry, traffic composition, and the type of track and

			road, which are risk factors and impact the necessity for fire design
6	Natural (Environmental) Fire	Risk	Introduces potential natural fire risks
7	Fire Service Intervention Time (FSIT)	Risk Response	Represents a risk response to a possible fire event, defined as the estimated duration from ignition until the commencement of effective firefighting actions by emergency services. It accounts for detection, alarm transmission, dispatch, travel, and initial firefighting setup

Table 3 lists the required PR indicator, Ψ, range associated with each BFDC classification.

Table 4 lists the subclasses (k), weighting factors ($\omega_{i,k}$), and the subclass importance factors ($\alpha_{i,k}$) for each of the above bridge classes (i).

The aggregate subclass importance factors within each class ($\sum_{k=1}^{m_k} \alpha_{i,k}$) follows a power-law decay characterised by an exponent of 0.5 from class 1 to class 7.

In Table 4, the bridge classes (i), subclass importance factors ($\alpha_{i,k}$), aggregate subclass importance factors ($\sum_{k=1}^{m_k} \alpha_{i,k}$), or the subclass rankings or values within each class may be swapped, or either increased or decreased, by the bridge designer with prior approval from ARTC, provided that an appropriate technical and engineering justification is documented for the specific bridge design. However, the total aggregate subclass importance factor, $\sum_{i=1}^{n} \sum_{k=1}^{m_k} \alpha_{i,k} = 1$, and PR indicator ($\Psi$) ranges as specified in Tables 3 and 4 shall be maintained to ensure consistency across all new bridge designs.

Table 3: Required PR Indicator, Ψ , Range Associated with Each BFDC

BFDC	PR INDICATOR, Ψ , RANGE
3	$0.70 < \Psi \leq 1$
2	$0.50 < \Psi \leq 0.70$
1	$0.23 \leq \Psi \leq 0.50$

For new bridge designs, it shall be permissible to conduct sensitivity analyses to identify the optimal geometric, material, configuration, design, or other parameters that minimise the PR indicator (Ψ).

Appendix A represents some elaborative scenarios for calculating Ψ and defines the BFDC level for new bridge designs.

Table 4: Bridge Classes, Associated Subclasses, Weighting, and Importance Factors

BRIDGE CLASS (i)	SUBCLASS (k)	WEIGHTING FACTOR $(\omega_{i,k})$	MAXIMUN WEIGHTING FACTOR $(\omega_{i,k,max})$	SUBCLASS IMPORTANCE FACTOR $(\alpha_{i,k})$
Class 1: Bridge Geometry, Material, and Design Properties (Superstructure Only)				
Bridge material (Note 1)	Concrete	1	5	0.111
	Masonry/brick	2		
	Steel	3		
	Timber	4		
	Polymer-based	5		
Bridge type (Note 2)	Arch	1	6	0.060
	Slab	2		
	Elevated suspension/cable-stayed	3		
	Girder/Plank/Box	4		
	Half-through	5		
	Through/lattice truss	6		
Total span(s) length (m) (Note 3)	< 30	1	3	0.040
	30-60	2		
	> 60	3		
Span(s) type	Simply Supported	1	2	0.030
	Continuous	2		
$\sum_{k=1}^{4} \omega_{1,k,max}$			**16**	
Aggregate subclass importance factor for Class 1, $\sum_{k=1}^{4} \alpha_{1,k}$				**0.241**
Class 2: Estimated Economic Impact (AUD)				
Indirect: estimated track closure and/or other indirect costs (ARTC part only) in million	< 5	1	4	0.117
	5-10	2		
	10-20	3		
	> 20	4		
Direct: estimated bridge repair or replacement cost (ARTC part only) in million	< 5	1	4	0.080
	5-10	2		
	10-20	3		
	> 20	4		

$\sum_{k=1}^{2} \omega_{2,k,max}$			**8**	
Aggregate subclass importance factor for Class 2, $\sum_{k=1}^{2} \alpha_{2,k}$				**0.197**
Class 3: Bridge Location				
A bridge located within 20 m of a railway station or platform, where these facilities are situated above or below the bridge	No	1	5	0.161
	Yes (remote/rural station/platform with < 500 passengers/users per day)	2		
	Yes (local/small town station/platform with 500-2,000 passengers/users per day)	3		
	Yes (suburban/regional station/platform with 2,000-10,000 passengers/users per day)	4		
	Yes (capital city terminals/CBD interchange/station with > 10,000 passengers/users per day)	5		
$\sum_{k=1}^{1} \omega_{3,k,max}$			**5**	
Aggregate subclass importance factor for Class 3, $\sum_{k=1}^{1} \alpha_{3,k}$				**0.161**
Class 4: Human-Induced Fire				
Fire on track or road	An ARTC underbridge: no rail or road bridge under/over the bridge	1	9	0.112
	A footbridge: fire occurs under (in ARTC railway corridor) or over the bridge (on the footbridge)	2		
	An overbridge: fire occurs above the bridge (road is a prohibited or restricted route for Dangerous Goods, DG) (Note 4)	3		
	An ARTC underbridge: fire occurs under the bridge (road is a prohibited or restricted route for DG)	4		

	An overbridge: fire occurs above the bridge (road is not a prohibited or restricted route for DG)	5		
	An ARTC underbridge: fire occurs under the bridge (road is not a prohibited or restricted route for DG)	6		
	A rail bridge: fire occurs under/over the bridge (a railway corridor crossing under/over ARTC railway corridor)	7		
	Fire occurs in ARTC railway corridor transporting DG ≥ 20% but < 50% of Annual Gross Tonnage (AGT), where one or more of the above subclasses may also apply (Note 5)	8		
	Fire occurs in ARTC railway corridor transporting DG ≥ 50% of AGT	9		
Threat perception- deliberate, malicious, or undeliberate, including sabotage, terrorism, vandalism, homelessness/encampment activities, storage of DG beneath a bridge, and civil unrest such as riots or protests	No	1	2	0.020
	Yes	2		
$\sum_{k=1}^{2} \omega_{4,k,max}$			**11**	
Aggregate subclass importance factor for Class 4, $\sum_{k=1}^{2} \alpha_{4,k}$				**0.132**

Class 5: Type of Track or Road				
Horizontal curve radius (m) of track (under/over the bridge) (Note 6)	No track	1	3	0.024
	> 600	2		
	< 600	3		
Type of track (under/over the bridge) (Note 7)	No track	1	4	0.010
	Passenger only	2		
	Freight only	3		
	Freight and passenger (shared)	4		
Number of tracks (under) (Note 8)	0	1	4	0.010
	1	2		
	2	3		
	> 2	4		
Number of tracks (over)	0	1	4	0.010
	1	2		
	2	3		
	> 2	4		
Horizontal curve radius (m) of road (under/over the bridge)	No road	1	3	0.024
	> 300	2		
	< 300	3		
Type of road (under/over the bridge)	No road	1	6	0.010
	Local road providing access to properties and local destinations with an Annual Average Daily Traffic (AADT) of < 1,000 vehicles/day	2		
	Collector road collecting traffic from local streets and distributing it to arterials with an AADT of 1,000-5,000 vehicles/day	3		
	Sub-arterial road linking local roads to arterials, supporting moderate traffic volumes with an AADT of 5,000-10,000 vehicles/day	4		
	Arterial road connecting regions and facilitating large volumes of traffic with	5		

	an AADT of 10,000-40,000 vehicles/day			
	Freeway and high-capacity road, limited-access roads for long-distance traffic with an AADT of > 40,000 vehicles/day	6		
Number of lanes (under)	0	1	4	0.010
	1	2		
	2	3		
	> 2	4		
Number of lanes (over)	0	1	4	0.010
	1	2		
	2	3		
	> 2	4		
$\sum_{k=1}^{8} \omega_{5,k,max}$			**32**	
Aggregate subclass importance factor for Class 5, $\sum_{k=1}^{8} \alpha_{5,k}$				**0.108**
Class 6: Natural (Environmental) Fire				
Historical area vulnerability (number of historical natural fire events within 1,000 m)	0	1	4	0.020
	1	2		
	2-5	3		
	> 5	4		
Threat perception-environmental (bushfire-prone: bush, grassland, or trees within 100 m)	No	1	6	0.069
	Yes (rainforest/non-burnable vegetation, e.g., dense/moisture-rich vegetation with a low likelihood of ignition)	2		
	Yes (grassland, e.g., open grasses, pasture, or crop stubble)	3		
	Yes (shrubland, e.g., dense low shrubs with few or no tall trees)	4		
	Yes (woodland, e.g., widely spaced trees with grassy/shrubby understorey)	5		
	Yes (forest with steep slope, e.g., tall, dense	6		

	trees with a closed canopy and shrubs/litter)			
$\sum_{k=1}^{2} \omega_{6,k,max}$			**10**	
Aggregate subclass importance factor for Class 6, $\sum_{k=1}^{2} \alpha_{6,k}$				**0.089**
Class 7: Fire Service Intervention Time (FSIT)				
FSIT (minutes)	< 10	1	4	0.072
	10-20	2		
	20-30	3		
	> 30	4		
$\sum_{k=1}^{1} \omega_{7,k,max}$			**4**	
Aggregate subclass importance factor for Class 7, $\sum_{k=1}^{1} \alpha_{7,k}$				**0.072**
Total aggregate subclass importance factor, $\sum_{i=1}^{7} \sum_{k=1}^{m_k} \alpha_{i,k} = 1$				**1.000**

Note 1 Steel transom-top and steel-concrete composite bridges shall be taken as steel bridges (evaluate the primary member material in similar cases)

Note 2 For special bridge types other than the above-specified types, the closest subclass shall be assigned.

Note 3 Only bridge clear span(s) directly over or under the ARTC tracks within ARTC railway corridor shall be considered.

Note 4 The designation of prohibited or restricted routes for the transport of DG shall be confirmed with the relevant state or local transport or road authority.

Note 5 ARTC railway corridor transporting DG comprising < 20% of AGT shall be considered a non-dedicated DG corridor, with the applicable subclasses applied from 1 to 7. Designers should, where information is available, consider future AGTs of DG when determining the appropriate subclass. Also, for other cases not exactly mentioned in these subclasses, the closest subclass shall be assigned. For information regarding the AGTs of DG, contact ARTC.

Note 6 For information regarding the horizontal curve radius of track, contact ARTC.

Note 7 Freight or passenger-only bridges shall be assigned (4) if they also include a shared pedestrian path, but not if they only have a maintenance walkway.

Note 8 This includes the lanes or tracks of the bridge. In any subclasses, a separate footbridge or a shared-use path shall be treated as a lane or an additional lane.

3.1 Appendix A

Scenario 1

A straight, two-lane, steel–concrete composite box girder overbridge (owned by others) is proposed to function as a freeway carrying an AADT volume exceeding 40,000 vehicles per day, spanning over a straight (horizontal curve radius of tracks > 600 m) shared railway corridor in NSW. The underlying railway corridor accommodates four tracks shared between ARTC network and the passenger rail network. This ARTC railway corridor carries DG limited to ≤ 20% of the AGT.

The bridge is simply supported, with a span of 38 m. There are no stations or platforms located beneath or adjacent to the structure, and no shared-use pedestrian or cyclist path is provided on the bridge deck. This bridge is not a prohibited or restricted route for DG.

Historical data (e.g., from Fire and Rescue NSW) indicate three recorded bushfire incidents within a 1,000 m radius of the bridge. Apart from these natural fire events, no specific human-induced fire threats have been identified at this location. The surrounding environment within 100 m of the bridge consists of steep, forested terrain with tall, dense vegetation forming a closed canopy, understorey shrubs, and surface litter, classified as bushfire-prone. The estimated FSIT for the area is relatively high, ranging from 20 to 30 minutes.

As the bridge is not owned by ARTC, the potential combined direct and indirect losses for ARTC in the event of a fire incident above the road are assessed to be low, estimated at approximately AUD 5 million.

Table A1: Scenario 1

BRIDGE CLASS (i)	SUBCLASS (k)	WEIGHTING FACTOR ($\omega_{i,k}$)	MAXIMUM WEIGHTING FACTOR ($\omega_{i,k,max}$)	SUBCLASS IMPORTANCE FACTOR ($\alpha_{i,k}$)
Class 1: Bridge Geometry, Material, and Design Properties (Superstructure Only)				
Bridge material	Steel	3	5	0.111
Bridge type	Girder/Plank/Box	4	6	0.060
Total span(s) length (m)	30-60	2	3	0.040
Span(s) type	Simply Supported	1	2	0.030
$\sum_{k=1}^{4} \alpha_{1,k}$				**0.241**
$\sum_{k=1}^{4} \omega_{1,k}$		**10**		
$\sum_{k=1}^{4} \omega_{1,k,max}$			**16**	
$\sum_{k=1}^{4} \alpha_{1,k} \left(\frac{\sum_{k=1}^{4} \omega_{1,k}}{\sum_{k=1}^{4} \omega_{1,k,max}} \right)$			**0.241 × (10/16) = 0.151**	

Class 2: Estimated Economic Impact (AUD)				
Indirect: estimated track closure and/or other indirect costs (ARTC part only) in million	< 5	1	4	0.117
Direct: estimated bridge repair or replacement cost (ARTC part only) in million	< 5	1	4	0.080
$\sum_{k=1}^{2} \alpha_{2,k}$				**0.197**
$\sum_{k=1}^{2} \omega_{2,k}$		**2**		
$\sum_{k=1}^{2} \omega_{2,k,max}$			**8**	
$\sum_{k=1}^{2} \alpha_{2,k} (\frac{\sum_{k=1}^{2} \omega_{2,k}}{\sum_{k=1}^{2} \omega_{2,k,max}})$			**0.197 × (2/8) = 0.049**	
Class 3: Bridge Location				
A bridge located within 20 m of a railway station or platform, where these facilities are situated above or below the bridge	No	1	5	0.161
$\sum_{k=1}^{1} \alpha_{3,k}$				**0.161**
$\sum_{k=1}^{1} \omega_{3,k}$		**1**		
$\sum_{k=1}^{1} \omega_{3,k,max}$			**5**	
$\sum_{k=1}^{1} \alpha_{3,k} (\frac{\sum_{k=1}^{1} \omega_{3,k}}{\sum_{k=1}^{1} \omega_{3,k,max}})$			**0.161 × (1/5) = 0.032**	

Class 4: Human-Induced Fire				
Fire on track or road	An overbridge: fire occurs above the bridge (road is not a prohibited or restricted route for DG)	5	9	0.112
Threat perception- deliberate, malicious, or undeliberate, including sabotage, terrorism, vandalism, homelessness/encampment activities, storage of DG beneath a bridge, and civil unrest such as riots or protests	No	1	2	0.020
$\sum_{k=1}^{2} \alpha_{4,k}$				**0.132**
$\sum_{k=1}^{2} \omega_{4,k}$		**6**		
$\sum_{k=1}^{2} \omega_{4,k,max}$			**11**	
$\sum_{k=1}^{2} \alpha_{4,k} \left(\frac{\sum_{k=1}^{2} \omega_{4,k}}{\sum_{k=1}^{2} \omega_{4,k,max}}\right)$			**0.132 × (6/11) = 0.072**	
Class 5: Type of Track or Road				
Horizontal curve radius (m) of track (under/over the bridge)	> 600	2	3	0.024
Type of track (under/over the bridge)	Freight and passenger (shared)	4	4	0.010
Number of tracks (under)	> 2	4	4	0.010
Number of tracks (over)	0	1	4	0.010
Horizontal curve radius (m) of road (under/over the bridge)	> 300	2	3	0.024

Type of road (under/over the bridge)	Freeway and high-capacity road, limited-access roads for long-distance traffic with an AADT of > 40,000 vehicles/day	6	6	0.010
Number of lanes (under)	0	1	4	0.010
Number of lanes (over)	2	3	4	0.010
$\sum_{k=1}^{8} \alpha_{5,k}$				**0.108**
$\sum_{k=1}^{8} \omega_{5,k}$		**23**		
$\sum_{k=1}^{8} \omega_{5,k,max}$			**32**	
$\sum_{k=1}^{8} \alpha_{5,k} (\frac{\sum_{k=1}^{8} \omega_{5,k}}{\sum_{k=1}^{8} \omega_{5,k,max}})$			**0.108 × (23/32) = 0.078**	
Class 6: Natural (Environmental) Fire				
Historical area vulnerability (number of historical natural fire events within 1,000 m)	2-5	3	4	0.020
Threat perception-environmental (bushfire-prone: bush, grassland, or trees within 100 m)	Yes (forest with steep slope, e.g., tall, dense trees with a closed canopy and shrubs/litter)	6	6	0.069
$\sum_{k=1}^{2} \alpha_{6,k}$				**0.089**
$\sum_{k=1}^{2} \omega_{6,k}$		**9**		
$\sum_{k=1}^{2} \omega_{6,k,max}$			**10**	
$\sum_{k=1}^{2} \alpha_{6,k} (\frac{\sum_{k=1}^{2} \omega_{6,k}}{\sum_{k=1}^{2} \omega_{6,k,max}})$			**0.089 × (9/10) = 0.080**	

Class 7: Fire Service Intervention Time (FSIT)				
FSIT (minutes)	20-30	3	4	0.072
$\sum_{k=1}^{1} \alpha_{7,k}$				**0.072**
$\sum_{k=1}^{1} \omega_{7,k}$		**3**		
$\sum_{k=1}^{1} \omega_{7,k,max}$			**4**	
$\sum_{k=1}^{1} \alpha_{7,k} \left(\frac{\sum_{k=1}^{1} \omega_{7,k}}{\sum_{k=1}^{1} \omega_{7,k,max}}\right)$			**0.072 × (3/4) = 0.054**	
$\sum_{i=1}^{7} \sum_{k=1}^{m_k} \alpha_{i,k} \left(\frac{\sum_{k=1}^{m_k} \omega_{i,k}}{\sum_{k=1}^{m_k} \omega_{i,k,max}}\right)$			**0.151 + 0.049 + 0.032 + 0.072 + 0.078 + 0.080 + 0.054 = 0.516**	
PR indicator (Ψ)			**BFDC-2**	

In Scenario 1, an alternative superstructure material (concrete superstructure) reduces the material subclass within Class 1 from 3 to 1. This adjustment would decrease the PR indicator to 0.486, placing it within the BFDC-1 range. It should be noted that the selection of concrete over steel does not influence the risk of fire occurrence; however, concrete exhibits superior thermal stability and slower degradation of mechanical properties, thereby enhancing the structural performance of this bridge during fire exposure. In fact, verification of the revised concrete bridge for compliance with the BFDC-2 classification would also be economical, straightforward, and practical.

Scenario 2

A straight, single-track passenger railway bridge (owned by others) is proposed to be designed using prestressed concrete planks, spanning over a curved ARTC railway corridor with a horizontal track radius of 750 m. The underlying corridor accommodates two ARTC railway tracks, with the AGT of DG limited to ≤ 20% of the total AGT.

The bridge is simply supported, with a span of 19 m over ARTC railway corridor. No stations or platforms are located beneath or above the structure. The bridge deck includes a shared-use pedestrian path to facilitate local community access across the corridor.

Historical data indicate no recorded bushfire or comparable natural fire events within a 1,000 m radius of the site. Furthermore, no human-induced fire threats (e.g., deliberate, malicious, or accidental) have been identified at this location. The surrounding environment within 100 m of the bridge is classified as grassland, consisting primarily of open grass, pasture, or crop stubble. The estimated FSIT for this new bridge ranges from 10 to 20 minutes.

As the bridge is not owned by ARTC, the potential combined direct and indirect losses for ARTC in the event of a fire incident occurring above ARTC corridor are assessed to be low, estimated at approximately AUD 3 million.

Table A2: Scenario 2

BBRIDGE CLASS (i)	SUBCLASS (k)	WEIGHTING FACTOR ($\omega_{i,k}$)	MAXIMUM WEIGHTING FACTOR ($\omega_{i,k,max}$)	SUBCLASS IMPORTANCE FACTOR ($\alpha_{i,k}$)
Class 1: Bridge Geometry, Material, and Design Properties (Superstructure Only)				
Bridge material	Concrete	1	5	0.111
Bridge type	Girder/Plank/Box	4	6	0.060
Total span(s) length (m)	< 30	1	3	0.040
Span(s) type	Simply Supported	1	2	0.030
$\sum_{k=1}^{4} \alpha_{1,k}$				**0.241**
$\sum_{k=1}^{4} \omega_{1,k}$		**7**		
$\sum_{k=1}^{4} \omega_{1,k,max}$			**16**	
$\sum_{k=1}^{4} \alpha_{1,k}(\frac{\sum_{k=1}^{4} \omega_{1,k}}{\sum_{k=1}^{4} \omega_{1,k,max}})$			**0.241 × (7/16) = 0.105**	
Class 2: Estimated Economic Impact (AUD)				
Indirect: estimated track closure and/or other indirect costs (ARTC part only) in million	< 5	1	4	0.117
Direct: estimated bridge repair or replacement cost (ARTC part only) in million	< 5	1	4	0.080
$\sum_{k=1}^{2} \alpha_{2,k}$				**0.197**
$\sum_{k=1}^{2} \omega_{2,k}$		**2**		
$\sum_{k=1}^{2} \omega_{2,k,max}$			**8**	

$\sum_{k=1}^{2} \alpha_{2,k} (\frac{\sum_{k=1}^{2} \omega_{2,k}}{\sum_{k=1}^{2} \omega_{2,k,max}})$			**0.197 × (2/8) = 0.049**	
Class 3: Bridge Location				
A bridge located within 20 m of a railway station or platform, where these facilities are situated above or below the bridge	No	1	5	0.161
$\sum_{k=1}^{1} \alpha_{3,k}$				**0.161**
$\sum_{k=1}^{1} \omega_{3,k}$		**1**		
$\sum_{k=1}^{1} \omega_{3,k,max}$			**5**	
$\sum_{k=1}^{1} \alpha_{3,k} (\frac{\sum_{k=1}^{1} \omega_{3,k}}{\sum_{k=1}^{1} \omega_{3,k,max}})$			**0.161 × (1/5) = 0.032**	
Class 4: Human-Induced Fire				
Fire on track or road	A rail bridge: fire occurs under/over the bridge (a railway corridor crossing under/over ARTC railway corridor)	7	9	0.112
Threat perception-deliberate, malicious, or undeliberate, including sabotage, terrorism, vandalism, homelessness/encampment activities, storage of DG beneath a bridge, and civil unrest such as riots or protests	No	1	2	0.020
$\sum_{k=1}^{2} \alpha_{4,k}$				**0.132**
$\sum_{k=1}^{2} \omega_{4,k}$		**8**		

$\sum_{k=1}^{2} \omega_{4,k,max}$			**11**	
$\sum_{k=1}^{2} \alpha_{4,k} \left(\frac{\sum_{k=1}^{2} \omega_{4,k}}{\sum_{k=1}^{2} \omega_{4,k,max}}\right)$			**0.132 × (8/11) = 0.096**	
Class 5: Type of Track or Road				
Horizontal curve radius (m) of track (under/over the bridge)	> 600	2	3	0.024
Type of track (under/over the bridge)	Freight and passenger (shared)	4	4	0.010
Number of tracks (under)	2	3	4	0.010
Number of tracks (over)	1	2	4	0.010
Horizontal curve radius (m) of road (under/over the bridge)	No road	1	3	0.024
Type of road (under/over the bridge)	No road	1	6	0.010
Number of lanes (under)	0	1	4	0.010
Number of lanes (over)	1	2	4	0.010
$\sum_{k=1}^{8} \alpha_{5,k}$				**0.108**
$\sum_{k=1}^{8} \omega_{5,k}$		**16**		
$\sum_{k=1}^{8} \omega_{5,k,max}$			**32**	
$\sum_{k=1}^{8} \alpha_{5,k} \left(\frac{\sum_{k=1}^{8} \omega_{5,k}}{\sum_{k=1}^{8} \omega_{5,k,max}}\right)$			**0.108 × (16/32) = 0.054**	
Class 6: Natural (Environmental) Fire				
Historical area vulnerability (number of historical natural fire events within 1,000 m)	0	1	4	0.020

Threat perception-environmental (bushfire-prone: bush, grassland, or trees within 100 m)	Yes (grassland, e.g., open grasses, pasture, or crop stubble)	3	6	0.069
$\sum_{k=1}^{2} \alpha_{6,k}$				**0.089**
$\sum_{k=1}^{2} \omega_{6,k}$		**4**		
$\sum_{k=1}^{2} \omega_{6,k,max}$			**10**	
$\sum_{k=1}^{2} \alpha_{6,k} (\frac{\sum_{k=1}^{2} \omega_{6,k}}{\sum_{k=1}^{2} \omega_{6,k,max}})$			**0.089 × (4/10) = 0.036**	
Class 7: Fire Service Intervention Time (FSIT)				
FSIT (minutes)	10-20	2	4	0.072
$\sum_{k=1}^{1} \alpha_{7,k}$				**0.072**
$\sum_{k=1}^{1} \omega_{7,k}$		**2**		
$\sum_{k=1}^{1} \omega_{7,k,max}$			**4**	
$\sum_{k=1}^{1} \alpha_{7,k} (\frac{\sum_{k=1}^{1} \omega_{7,k}}{\sum_{k=1}^{1} \omega_{7,k,max}})$			**0.072 × (2/4) = 0.036**	
$\sum_{i=1}^{7} \sum_{k=1}^{m_k} \alpha_{i,k} (\frac{\sum_{k=1}^{m_k} \omega_{i,k}}{\sum_{k=1}^{m_k} \omega_{i,k,max}})$			**0.105 + 0.049 + 0.032 + 0.096 + 0.054 + 0.036 + 0.036 = 0.408**	
PR indicator (Ψ)			**BFDC-1**	

In Scenario 2, the bridge designer does not need to design the bridge for a fire event.

Scenario 3

A double-track freight underbridge (owned by ARTC) is proposed to be designed as a new single-span, ballasted steel truss bridge located on a straight railway corridor crossing over a major curved eight-lane freeway with a horizontal curve radius of 500 m and an AADT exceeding 40,000 vehicles. The freeway is not a prohibited or restricted route for the transport of DG. ARTC railway corridor accommodates two tracks, with the AGT of DG limited to ≤ 20% of the total line AGT.

The bridge is simply supported with a span length of 54 m. No stations or platforms are located in proximity to the structure, and the deck includes only a maintenance walkway, with no shared-use pedestrian path provided.

Although historical records show no bushfire or natural fire events within a 1,000 m radius of the site, several deliberate protest-related and arson fires have been reported in the surrounding area, contributing to a human-induced perception of fire risk. The area within 100 m of the bridge is classified as rainforest or non-burnable vegetation, characterised by dense, moisture-rich flora with a low ignition likelihood.

The FSIT for this location is high, estimated to exceed 30 minutes, primarily due to the distance from the nearest fire station and potential traffic congestion on the freeway. In the event of a fire, the combined direct and indirect economic loss is considered high, estimated at approximately AUD 30 million, reflecting the strategic importance of the corridor and bridge location.

Table A3: Scenario 3

BRIDGE CLASS (i)	SUBCLASS (k)	WEIGHTING FACTOR ($\omega_{i,k}$)	MAXIMUM WEIGHTING FACTOR ($\omega_{i,k,max}$)	SUBCLASS IMPORTANCE FACTOR ($\alpha_{i,k}$)
Class 1: Bridge Geometry, Material, and Design Properties (Superstructure Only)				
Bridge material	Steel	3	5	0.111
Bridge type	Through/lattice truss	6	6	0.060
Total span(s) length (m)	30-60	2	3	0.040
Span(s) type	Simply Supported	1	2	0.030
$\sum_{k=1}^{4} \alpha_{1,k}$				**0.241**
$\sum_{k=1}^{4} \omega_{1,k}$		**12**		
$\sum_{k=1}^{4} \omega_{1,k,max}$			**16**	
$\sum_{k=1}^{4} \alpha_{1,k} \left(\frac{\sum_{k=1}^{4} \omega_{1,k}}{\sum_{k=1}^{4} \omega_{1,k,max}}\right)$			**0.241 × (12/16) = 0.181**	
Class 2: Estimated Economic Impact (AUD)				
Indirect: estimated track closure and/or other indirect costs (ARTC part only) in million	10-20	3	4	0.117
Direct: estimated bridge repair or replacement cost (ARTC part only) in million	10-20	3	4	0.080

$\sum_{k=1}^{2} \alpha_{2,k}$				**0.197**
$\sum_{k=1}^{2} \omega_{2,k}$		**6**		
$\sum_{k=1}^{2} \omega_{2,k,max}$			**8**	
$\sum_{k=1}^{2} \alpha_{2,k} (\frac{\sum_{k=1}^{2} \omega_{2,k}}{\sum_{k=1}^{2} \omega_{2,k,max}})$			**0.197 × (6/8) = 0.148**	
Class 3: Bridge Location				
A bridge located within 20 m of a railway station or platform, where these facilities are situated above or below the bridge	No	1	5	0.161
$\sum_{k=1}^{1} \alpha_{3,k}$				**0.161**
$\sum_{k=1}^{1} \omega_{3,k}$		**1**		
$\sum_{k=1}^{1} \omega_{3,k,max}$			**5**	
$\sum_{k=1}^{1} \alpha_{3,k} (\frac{\sum_{k=1}^{1} \omega_{3,k}}{\sum_{k=1}^{1} \omega_{3,k,max}})$			**0.161 × (1/5) = 0.032**	
Class 4: Human-Induced Fire				
Fire on track or road	An ARTC underbridge: fire occurs under the bridge (road is not a prohibited or restricted route for DG)	6	9	0.112
Threat perception-deliberate, malicious, or undeliberate, including sabotage, terrorism, vandalism, homelessness/encampment activities, storage of DG beneath a bridge, and civil	Yes	2	2	0.020

unrest such as riots or protests				
$\sum_{k=1}^{2} \alpha_{4,k}$				**0.132**
$\sum_{k=1}^{2} \omega_{4,k}$		**8**		
$\sum_{k=1}^{2} \omega_{4,k,max}$			**11**	
$\sum_{k=1}^{2} \alpha_{4,k}(\frac{\sum_{k=1}^{2} \omega_{4,k}}{\sum_{k=1}^{2} \omega_{4,k,max}})$			**0.132 × (8/11) = 0.096**	
Class 5: Type of Track or Road				
Horizontal curve radius (m) of track (under/over the bridge)	> 600	2	3	0.024
Type of track (under/over the bridge)	Freight only	3	4	0.010
Number of tracks (under)	0	1	4	0.010
Number of tracks (over)	2	3	4	0.010
Horizontal curve radius (m) of road (under/over the bridge)	> 300	2	3	0.024
Type of road (under/over the bridge)	Freeway and high-capacity road, limited-access roads for long-distance traffic with an AADT of > 40,000 vehicles/day	6	6	0.010
Number of lanes (under)	> 2	4	4	0.010
Number of lanes (over)	0	1	4	0.010
$\sum_{k=1}^{8} \alpha_{5,k}$				**0.108**
$\sum_{k=1}^{8} \omega_{5,k}$		**22**		

$\sum_{k=1}^{8} \omega_{5,k,max}$			**32**	
$\sum_{k=1}^{8} \alpha_{5,k} \left(\frac{\sum_{k=1}^{8} \omega_{5,k}}{\sum_{k=1}^{8} \omega_{5,k,max}}\right)$			**0.108 × (22/32) = 0.074**	
Class 6: Natural (Environmental) Fire				
Historical area vulnerability (number of historical natural fire events within 1,000 m)	0	1	4	0.020
Threat perception-environmental (bushfire-prone: bush, grassland, or trees within 100 m)	Yes (rainforest/non-burnable vegetation, e.g., dense/moisture-rich vegetation with a low likelihood of ignition)	2	6	0.069
$\sum_{k=1}^{2} \alpha_{6,k}$				**0.089**
$\sum_{k=1}^{2} \omega_{6,k}$		**3**		
$\sum_{k=1}^{2} \omega_{6,k,max}$			**10**	
$\sum_{k=1}^{2} \alpha_{6,k} \left(\frac{\sum_{k=1}^{2} \omega_{6,k}}{\sum_{k=1}^{2} \omega_{6,k,max}}\right)$			**0.089 × (3/10) = 0.027**	
Class 7: Fire Service Intervention Time (FSIT)				
FSIT (minutes)	> 30	4	4	0.072
$\sum_{k=1}^{1} \alpha_{7,k}$				**0.072**
$\sum_{k=1}^{1} \omega_{7,k}$		**4**		
$\sum_{k=1}^{1} \omega_{7,k,max}$			**4**	
$\sum_{k=1}^{1} \alpha_{7,k} \left(\frac{\sum_{k=1}^{1} \omega_{7,k}}{\sum_{k=1}^{1} \omega_{7,k,max}}\right)$			**0.072 × (4/4) = 0.072**	
$\sum_{i=1}^{7} \sum_{k=1}^{m_k} \alpha_{i,k} \left(\frac{\sum_{k=1}^{m_k} \omega_{i,k}}{\sum_{k=1}^{m_k} \omega_{i,k,max}}\right)$			**0.181 + 0.148 + 0.032 + 0.096 + 0.074 + 0.027 + 0.072 = 0.630**	
	PR indicator (Ψ)		**BFDC-2**	

In Scenario 3, the bridge shall be designed to a minimum BFDC-2. Adopting an alternative superstructure material or bridge type (such as a concrete box girder) reduces the PR indicator and may also lower the estimated economic loss; however, the PR indicator is still expected to remain above 0.50.

In this scenario, a concrete superstructure should be adopted for ARTC bridge at this location instead of a steel bridge to achieve optimised and economical cross-sections for fire design purposes while also satisfying fatigue performance requirements.

Overall, considering the high weighting factors associated with the busy non-restricted/prohibited route for DG beneath the superstructure, together with the identified threat perception and high FSIT, this bridge is assessed to require design in accordance with BFDC-2.

Scenario 4

A new iconic, simply supported 32 m long Fibre Reinforced Polymer (FRP) truss footbridge (owned by others) is proposed to be constructed over a busy CBD terminal station accommodating more than 10,000 passengers per day, spanning over a straight railway corridor. The underlying corridor comprises two tracks shared between ARTC network and the passenger rail network. ARTC railway corridor carries DG, accounting for more than 20% but less than 50% of the total AGT.

Historical data indicate no recorded bushfire or natural fire events within a 1,000 m radius of the bridge site (predominantly urban environment), and no human-induced fire threats have been identified. The surrounding area within 100 m is primarily urban, with minimal vegetation and negligible bushfire risk.

The FSIT for this location is low, estimated at less than 10 minutes. Owing to the footbridge's critical CBD location and the contractual arrangements between ARTC and the passenger rail network, the estimated combined direct and indirect loss to ARTC in the event of a fire incident is assessed to be approximately AUD 30 million.

Table A4: Scenario 4

BRIDGE CLASS (i)	SUBCLASS (k)	WEIGHTING FACTOR ($\omega_{i,k}$)	MAXIMUM WEIGHTING FACTOR ($\omega_{i,k,max}$)	SUBCLASS IMPORTANCE FACTOR ($\alpha_{i,k}$)
Class 1: Bridge Geometry, Material, and Design Properties (Superstructure Only)				
Bridge material	Polymer-based	5	5	0.111
Bridge type	Through/lattice truss	6	6	0.060
Total span(s) length (m)	30-60	2	3	0.040
Span(s) type	Simply Supported	1	2	0.030
$\sum_{k=1}^{4} \alpha_{1,k}$				**0.241**
$\sum_{k=1}^{4} \omega_{1,k}$		**14**		

$\sum_{k=1}^{4} \omega_{1,k,max}$			**16**	
$\sum_{k=1}^{4} \alpha_{1,k} (\frac{\sum_{k=1}^{4} \omega_{1,k}}{\sum_{k=1}^{4} \omega_{1,k,max}})$			**0.241 × (14/16) = 0.211**	
Class 2: Estimated Economic Impact (AUD)				
Indirect: estimated track closure and/or other indirect costs (ARTC part only) in million	10-20	3	4	0.117
Direct: estimated bridge repair or replacement cost (ARTC part only) in million	10-20	3	4	0.080
$\sum_{k=1}^{2} \alpha_{2,k}$				**0.197**
$\sum_{k=1}^{2} \omega_{2,k}$		**6**		
$\sum_{k=1}^{2} \omega_{2,k,max}$			**8**	
$\sum_{k=1}^{2} \alpha_{2,k} (\frac{\sum_{k=1}^{2} \omega_{2,k}}{\sum_{k=1}^{2} \omega_{2,k,max}})$			**0.197 × (6/8) = 0.148**	
Class 3: Bridge Location				
A bridge located within 20 m of a railway station or platform, where these facilities are situated above or below the bridge	Yes (capital city terminals/CBD interchange/station with > 10,000 passengers/users per day)	5	5	0.161
$\sum_{k=1}^{1} \alpha_{3,k}$				**0.161**
$\sum_{k=1}^{1} \omega_{3,k}$		**5**		

$\sum_{k=1}^{1} \omega_{3,k,max}$			**5**	
$\sum_{k=1}^{1} \alpha_{3,k} \left(\frac{\sum_{k=1}^{1} \omega_{3,k}}{\sum_{k=1}^{1} \omega_{3,k,max}}\right)$				**0.161 × (5/5) = 0.161**
Class 4: Human-Induced Fire				
Fire on track or road	Fire occurs in ARTC railway corridor transporting DG ≥ 20% but < 50% of Annual Gross Tonnage (AGT), where one or more of the above subclasses may also apply	8	9	0.112
Threat perception-deliberate, malicious, or undeliberate, including sabotage, terrorism, vandalism, homelessness/encampment activities, storage of DG beneath a bridge, and civil unrest such as riots or protests	No	1	2	0.020
$\sum_{k=1}^{2} \alpha_{4,k}$				**0.132**
$\sum_{k=1}^{2} \omega_{4,k}$		**9**		
$\sum_{k=1}^{2} \omega_{4,k,max}$			**11**	
$\sum_{k=1}^{2} \alpha_{4,k} \left(\frac{\sum_{k=1}^{2} \omega_{4,k}}{\sum_{k=1}^{2} \omega_{4,k,max}}\right)$				**0.132 × (9/11) = 0.108**
Class 5: Type of Track or Road				
Horizontal curve radius (m) of track (under/over the bridge)	> 600	2	3	0.024
Type of track (under/over the bridge)	Freight and passenger (shared)	4	4	0.010

Number of tracks (under)	2	3	4	0.010
Number of tracks (over)	0	1	4	0.010
Horizontal curve radius (m) of road (under/over the bridge)	No road	1	3	0.024
Type of road (under/over the bridge)	No road	1	6	0.010
Number of lanes (under)	0	1	4	0.010
Number of lanes (over)	1	2	4	0.010
$\sum_{k=1}^{8} \alpha_{5,k}$				**0.108**
$\sum_{k=1}^{8} \omega_{5,k}$		**15**		
$\sum_{k=1}^{8} \omega_{5,k,max}$			**32**	
$\sum_{k=1}^{8} \alpha_{5,k}\left(\frac{\sum_{k=1}^{8} \omega_{5,k}}{\sum_{k=1}^{8} \omega_{5,k,max}}\right)$			**0.108 × (15/32) = 0.051**	
Class 6: Natural (Environmental) Fire				
Historical area vulnerability (number of historical natural fire events within 1,000 m)	0	1	4	0.020
Threat perception-environmental (bushfire-prone: bush, grassland, or trees within 100 m)	No	1	6	0.069
$\sum_{k=1}^{2} \alpha_{6,k}$				**0.089**
$\sum_{k=1}^{2} \omega_{6,k}$		**2**		

$\sum_{k=1}^{2} \omega_{6,k,max}$			**10**	
$\sum_{k=1}^{2} \alpha_{6,k} (\frac{\sum_{k=1}^{2} \omega_{6,k}}{\sum_{k=1}^{2} \omega_{6,k,max}})$			**0.089 × (2/10) = 0.018**	
Class 7: Fire Service Intervention Time (FSIT)				
FSIT (minutes)	< 10	1	4	0.072
$\sum_{k=1}^{1} \alpha_{7,k}$				**0.072**
$\sum_{k=1}^{1} \omega_{7,k}$		**1**		
$\sum_{k=1}^{1} \omega_{7,k,max}$			**4**	
$\sum_{k=1}^{1} \alpha_{7,k} (\frac{\sum_{k=1}^{1} \omega_{7,k}}{\sum_{k=1}^{1} \omega_{7,k,max}})$			**0.072 × (1/4) = 0.018**	
$\sum_{i=1}^{7} \sum_{k=1}^{m_k} \alpha_{i,k} (\frac{\sum_{k=1}^{m_k} \omega_{i,k}}{\sum_{k=1}^{m_k} \omega_{i,k,max}})$			**0.211 + 0.148 + 0.161 + 0.108 + 0.051 + 0.018 + 0.018 = 0.714**	
PR indicator (Ψ)			**BFDC-3**	

In Scenario 4, this footbridge shall be designed to a minimum BFDC-3, unless a detailed risk assessment approved by ARTC confirms that hydrocarbon fire design is not required at the bridge location. If this risk assessment confirms that hydrocarbon fire design is not required, the footbridge shall be designed to a minimum BFDC-2.

As with the other scenarios, replacing only the bridge material from FRP to steel would reduce the PR indicator to 0.684. Practically, if a concrete bridge is designed at this location, the PR indicator would be further reduced to 0.654 (both BFDC-2). Modifying the bridge type or configuration at this location would also improve the bridge's post-fire resilience and may reduce the estimated economic loss.

3.2 References

AS 5100 Bridge Design

AS 3600 Concrete Structures

AS 4100 Steel Structures

AS 2327.1 Composite structures Simply supported beams

AS 1530.4 Methods for fire tests on building materials, components and structures

Part 4: Fire-resistance tests for elements of construction

3.3 Definitions

Requirements are mandatory to follow to claim full compliance with this procedure. Requirements are identified within the text by the term "shall'.

Recommendations do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term "should".

Permissions are neither requirements nor recommendations but give options. Permissions are identified within the text by the term "may".

The following terms and acronyms are used within this document:

Term or acronym	Description
ARTC	Australian Rail Track Corporation Ltd.
AADT	Annual Average Daily Traffic
AGT	Annual Gross Tonnage
BFDC	Bridge Fire Design Category
DG	Dangerous Goods
DoF	Degree of Freedom
FRL	Fire Resistance Level
FRP	Fibre Reinforced Polymer
FSIT	Fire Service Intervention Time
MCDM	Multi-Criteria Decision-Making
PE	Permanent Effect
PR	Performance-Risk
PSA	Period for Structural Adequacy
ULS	Ultimate Limit State