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IL4 Special Study Step One: Critical Success Factors

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Abstract

The Importance Level 4 Special Study introduced with AS 1170.4:2007 receives great variability of consideration throughout Australia. The 2024 update AS 1170.4 reinforces the applicability of the IL4 Special Study and the requirement for such a facility to remain 'Operational' and has been reinforced through previous AEES conference papers.

This paper expands upon McBean (2021) '*Step One: Establish the post-disaster operational requirements.* It explores the 'all-hazards' for consideration, minimum business continuity objectives to maintain operations, threat assessments currently being utilised, disaster management stages, and the benefit of establishing *Critical Success Factors* for a facility during the concept stage to embed for facility design and delivery.

Keywords: IL4 Special study, seismic design, resilience, vulnerability, business continuity planning, critical success factors, natural hazards, consequence, post-disaster, critical infrastructure.

1 Introduction

Importance Level 4 (IL4) facilities are critical for ensuring post-disaster functionality, either by supporting societal recovery or protecting communities and occupants from hazardous materials. The National Construction Code (NCC) mandates compliance with AS1170.4, which requires IL4 facilities to remain serviceable for immediate use following a 500-year earthquake event (an IL2 ULS design event).

McBean (2021) outlined a structured approach for conducting an IL4 Special Study, drawing on insights from the complex design process of the new Royal Adelaide Hospital (McBean, 2015).

However, Bartlett (2023) highlighted several challenges in adhering (properly designed) to IL4 design standards, including:

- IL4 Special Studies often being limited to the Concept or Design phase, with no enforcement through project delivery or verification upon completion.
- Misalignment between IL4 Special Studies and the intent of AS1170.4.
- Absence of an IL4 Special Study altogether.
- Downgrading facilities to IL3 or lower without robust justification.

This paper focuses on expanding McBean's (2021) *Step 1: Establishing the post-disaster operational requirements* (Step 1) to help organisations embed resilience into the design and construction process for IL4 facilities. This paper holds critical significance as it addresses persistent gaps in the application and enforcement of IL4 design principles, offering a practical framework to align facility design with the resilience objectives outlined in AS1170.4. By expanding on McBean's foundational steps, it provides a structured approach to embedding post-disaster operational requirements into the design and construction process, ensuring IL4 facilities can fulfill their intended role in societal recovery and safety. As such, this paper serves as a key reference for future design processes, equipping engineers, architects, and project stakeholders with the tools to enhance compliance, accountability, and performance in IL4 facility development. Its contribution is poised to advance the resilience of critical infrastructure and set a new benchmark for sustainable, disaster-ready design practices.

1.1 Step 1 Sub-stages

Step 1 will be broken into 3 sub-stages:

a. The natural hazard events to consider – *When it is needed?*

b. The identification of Minimum Business Continuity Objectives (MBCOs) for the given facility – *What is needed?*

c. Timeframes for continued operation – *When, and for how long, is it required to operate post-disruption?*

The intended outcome of this process is to support McBean's Step 2 (Determine structural performance targets and design criteria). Thus, the Step 1 process can enable the Design Team to address and embed these performance requirements for the procurement, build, and post-construction verification processes.

1.2 Disruption and Revival

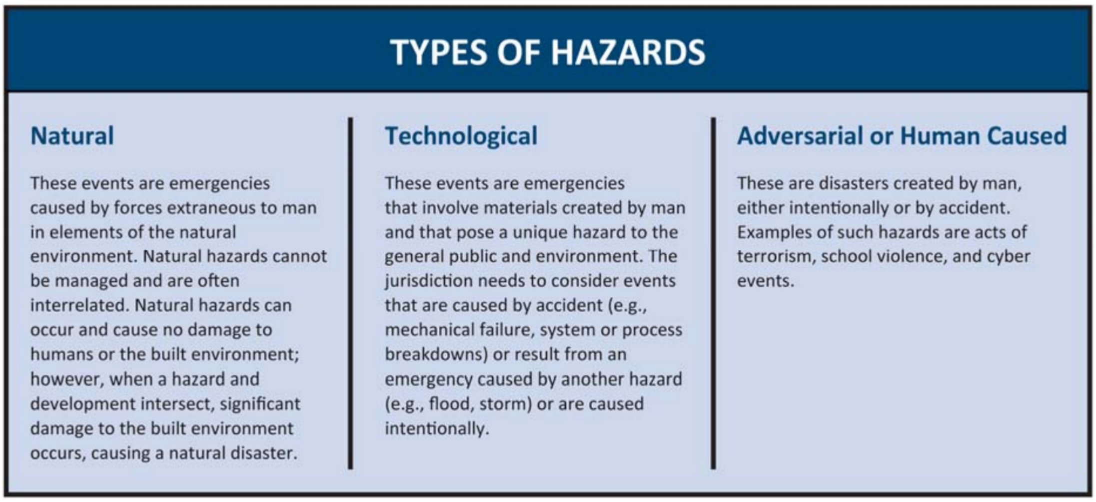
Critical infrastructure such as post-disaster facilities enable a society to recover sooner through effective response and early recovery. The longer the disruption, the greater the economic disruption and reduced spring-back for the society.

2 Hazards – General

Earthquakes are a prominent example of natural hazard events, but facilities are often exposed to a broader spectrum of hazards that may be overlooked by local building codes, designers, or even the facility's intended occupants. These hazards can include natural events such as floods, cyclones, and bushfires, as well as human-made risks like industrial accidents or hazardous material spills. While some hazards are explicitly addressed within regulatory frameworks, others may be dismissed as low priority or inadequately assessed, leaving facilities vulnerable to unexpected events. Recognising and accounting for this wider range of potential hazards is essential for designing resilient infrastructure capable of withstanding diverse challenges and maintaining operational continuity in the face of adversity. These are discussed below.

2.1 Hazard categorisation

The FEMA (2010) *'Types of Hazard'* (*Figure 1*) provides categorisation of hazards that may assist when considering the facility specific vulnerabilities.


TYPES OF HAZARDS

Natural

These events are emergencies caused by forces extraneous to man in elements of the natural environment. Natural hazards cannot be managed and are often interrelated. Natural hazards can occur and cause no damage to humans or the built environment; however, when a hazard and development intersect, significant damage to the built environment occurs, causing a natural disaster.

Technological

These events are emergencies that involve materials created by man and that pose a unique hazard to the general public and environment. The jurisdiction needs to consider events that are caused by accident (e.g., mechanical failure, system or process breakdowns) or result from an emergency caused by another hazard (e.g., flood, storm) or are caused intentionally.

Adversarial or Human Caused

These are disasters created by man, either intentionally or by accident. Examples of such hazards are acts of terrorism, school violence, and cyber events.

Figure 1 FEMA 'Types of Hazards' (CPG 101 v2)

Examples of such hazard categorisation is provided in *Figure 2* from FEMA (2018). An example worth including for Australian conditions is Bushfire, although considering recent wildfire events in North America this may be included in future revisions of this table.

Table 1: Example threats and hazards by category.

Natural	Technological	Human-caused
Avalanche	Dam failure	Active shooter incident
Drought	Hazardous materials release	Armed assault
Earthquake	Industrial accident	Biological attack
Epidemic	Levee failure	Chemical attack
Flood	Mine accident	Cyber-attack against data
Hurricane/Typhoon	Pipeline explosion	Cyber-attack against infrastructure
Space weather	Radiological release	Explosives attack
Tornado	Train derailment	Improvised nuclear attack
Tsunami	Transportation accident	Nuclear terrorism attack
Volcanic eruption	Urban conflagration	Radiological attack
Winter storm	Utility disruption	

Figure 2 FEMA (2018) 'Example threats and hazards by category (CPG 201, 3rd Edition)

2.1.1 Natural Hazards

In Australia, the NCC requirements for natural hazards result in:

a. Structural design for wind (including cyclone), snow (winter) and earthquake forces.
b. Flood: although minimal (shortfalls further explained in Bartlett 2023).
c. Bushfire, although only for threat to facility with a minor (non-evident) stay in place IL4 requirement for some facilities (see Bartlett 2023).

The IL4 Special Study picks up the resilience requirements for earthquake, although multiple other hazard events may also be deemed relevant for post-disaster function by the occupant of the building and can be integrated into this resilience report. Inclusion of other natural hazard events in the IL4 Special Study can:

a. Enable early identification of facility vulnerabilities.
b. Foster innovation for early intervention.
c. Eliminate duplication of hazard controls.

2.1.2 Technological hazards

The Technological Hazards generally addressed in facility design are *Utility Disruption*, although generally limited to power supply (electrical), and possibly communications redundancy (where relevant), although it's worth extending these considerations to potable water and sewer capacity alternatives.

As earthquake events have the potential *Utility disruption*, the *IL4 Special Study* is likely considering all of these in consultation with the building services design team.

2.1.3 Human-caused hazards

Human-caused hazards are generally only considered where prescribed by:

a. A government requirement for government entities or other critical infrastructure.
b. An organisation's own risk due diligence.

Where explosive attack (blast) is being considered, there are relevant structure design considerations to ensure these align with the earthquake and wind design outcomes. Furthermore, the location of essential services for post-disaster are likely to have similar security ratings, and any variation (gap) here should be verified.

2.2 Special Study – expansion for other natural hazards

An IL4 facility requires design consideration for:

- Wind events (under NCC referenced AS/NZS1170.2).
- Bushfire events (under NCC Section G5).

Due to the post-disaster function of IL4 facilities, and the severe consequence of hazardous facility failure, it is highly recommended that an IL4 Special Study should be expanded to consider other natural hazards.

2.3 Hazard event timeframe

Emergency response agencies and business continuity professionals commonly utilise the *Disaster Management Cycle* featuring:

- Mitigation.
- Planning & Preparedness.
- Response.
- Recovery.

There are multiple augmentations of this cycle with additional stages (5+) and an external ring expanding each of the 4 stages. IL4 facilities form part of this cycle, although the author questions how often this cycle is applied to the business case and translated into resilience outcomes from the concept design through to the final commissioned facility.

For the purposes of scenario testing, the author has found that the DRR Components *(Figure 3)* from the United Nations Disaster office for Disaster Risk Reduction (UNDRR) to provide greater insight for exploration of anticipated facility performance prior and during a disruptive event.

Facility *Business as Usual* generally relates to the Planning and Preparedness stages (***Error! Reference source not found.***), although the following DRR Components stages provide opportunity to deep dive into the anticipated performance of the facility during:

1. Anticipatory/Early Action
2. Disaster (onset)
3. Response
4. Early Recovery
5. Recovery

Reconstruction will not be covered in this paper as it is highly varied by event and severity.

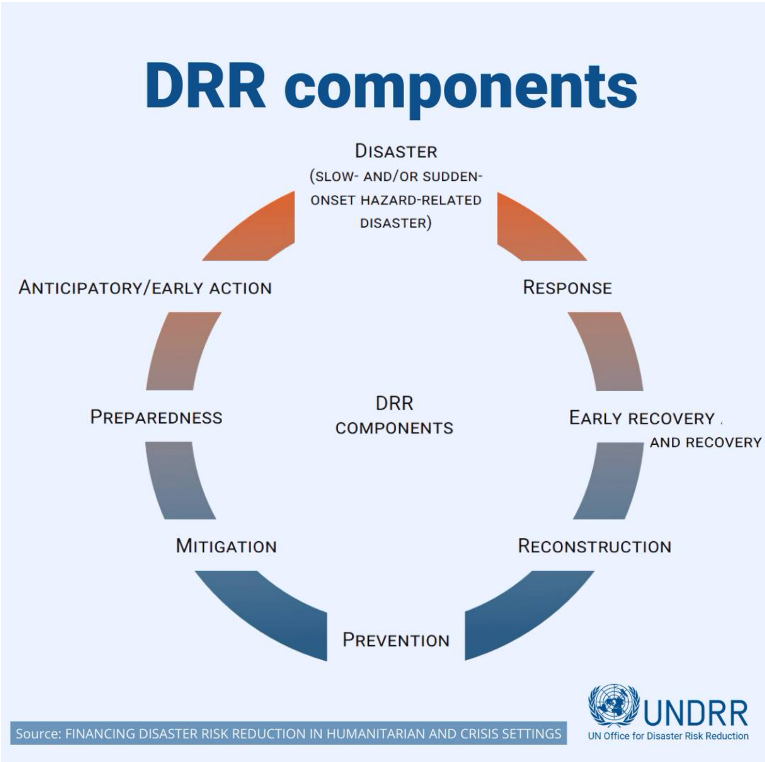


Figure 3 DRR Components (UNDRR)

2.3.1 Anticipatory/Early Action

It is recognised that earthquake events are sudden onset hazard events and 'no notice' is anticipated, although this timing allows for exploration of the *Administrative Controls* required for the facility to remain prepared.

For many other natural hazard events such as wind, flood and bushfire events, early action is generally possible, and design teams would benefit from the occupant's knowledge and guidance in this area.

2.3.2 Disaster (onset)

This is where the general earthquake design requirements come into play:

- protecting the occupants from building collapse (all buildings to varying degrees)
- protecting the occupants from falling non-structural elements (all buildings to varying degrees)

- specific building displacement limitation to reduce damage to openings and essential systems (generally IL4, and special IL3 facilities).

There are multiple factors that can influence the resilience of the systems and gaining stakeholder guidance on the elements of greatest importance for protection provides clarity for the design decisions.

2.3.3 Response

Response to a hazard event begins with a Situation Report, or Rapid Assessment of occupant wellbeing, the facilities safety, and identifying whether:

a. The building should be occupied, with evacuation possibly the initial action.
b. Identifying immediate actions within the facility to maintain safe occupation and operation.
c. Determining which essential systems are operational or can be re-established through alternate systems (redundancy).

2.3.4 Early Recover

Early recovery is re-establishing the post-disaster functions of the facility:

a. What is required to be operational?
b. What is not required and can be delayed?

Early Recovery could begin within minutes of the event, or hours later, and run for hours or days without external support. Some questions for the stakeholders:

- What is acceptable outage timeframe?
- How long should the facility remain operational without external support?
- Would the facility be prioritised by local authorities or service providers when there is resource scarcity?

In the authors experience, every critical infrastructure facility manager believes their facility is essential to the region and that they would be prioritised for resources. However, if they have already experienced a major disruption, and they've experienced a resources prioritisation system, they will usually have a different perspective and understanding of where they sit in the priority list.

2.3.5 Recovery

This is the long-term recovery process where the facility is anticipated to have been provided with external support to maintain essential services without disruption and possibly re-establish non-essential services.

3 Relevant Data

Effective hazard mitigation and resilient facility design rely heavily on the collection, analysis, and application of relevant data. Data serves as the foundation for informed decision-making, enabling designers, engineers, and stakeholders to assess risks, evaluate potential impacts, and develop strategies tailored to the specific operational and environmental needs of a facility. Robust data analysis ensures that assumptions about hazards are evidence-based, reducing the likelihood of vulnerabilities arising from incomplete or inaccurate information. In the context of IL4 facilities, leveraging high-quality data is crucial to align design processes with regulatory requirements and achieve the resilience objectives outlined in AS1170.4. This section explores the types of data necessary for comprehensive hazard assessment and highlights their role in guiding the design and construction of facilities capable of withstanding extreme events.

3.1 Business continuity

Organisations are complex systems exposed to a range of macro and micro environmental factors with the potential to cause great disruption to their ongoing performance and existence.

Resultingly, organisations establish *Business Continuity Plans* (BCPs) to embed resilience strategies to maintain *Business as Usual* (BAU), or restoration of critical success factors *as soon as possible* (ASAP).

In the author's experience, organisational BCPs:

a. Mainly focus upon people, equipment, processes, but not facilities.

b. Rely upon a backup facility:

    a. within the same region (within 10km).

    b. not being affected by the same disruption event (unlikely for some disruption events).

    c. That is not designed for IL4 ULS events and have no IL4 Special Study.

c. Rarely address natural hazard events; unless the organisation has experienced such a disruptive event previously, or witnessed other similar organisations impacted by them.

d. Do not trigger (initial or periodical) vulnerability assessments of existing assets to natural events.

e. Are not part of the Concept/Design Phase of new facilities. Facility resilience therefore relies heavily upon being a high priority for the design team engagement process and a strong knowledge by the stakeholder representatives present.

Resultantly:

- New facilities and their business case are frequently proposed without BCP consideration.
- Concept and Design Stages are often limited by business case budgets.
- Facility BCPs are generally written in the final months of construction or just prior to handover and occupation.
- Any shortfalls in the facility resilience are then assigned a low order risk mitigation.

3.1.1 The facility resilience gap

From a Special Study perspective, the author often experiences a natural hazard consequence gap. Facility occupiers see Strengths and Opportunity in designing and building a new facility but assume the NCC has resilience efforts equal to their own organisational needs. Other assumptions made illustrate bias such as:

a. Natural hazard events that disrupt BAU are:

    a. Rare, and therefore unlikely due to a reliance upon a risk matrix and lighter colours not requiring attention (fallacy).

    b. Inevitable, with consequences where blame can't be placed upon members of the organisation.

    c. Covered by insurance, and any extra expense now is wasted.

b. The NCC covers everything Australia needs because it:

    a. Is a dangerous place with a great deal of experience with natural hazards.

    b. Has the highest standards in the world (sic).

    c. Learns from the mistakes of others.

Unfortunately, bias and assumptions don't help to maintain functional performance and result in facilities with multiple points of failure that could have been eliminated or addressed through elimination or engineering controls.

3.1.2 Legislation by disaster

The COVID-19 crisis highlighted the critical role some organizations play in maintaining essential services during disruptive events. Often referred to as "Lifelines," these organizations are vital to societal continuity before, during, and after potential disasters. Many of them are subject to obligations under federal or state frameworks, such as the State Emergency Management Plan (SEMP) or the Security of Critical Infrastructure Act 2018.

Despite these classifications, there is no guarantee that Lifeline organizations' Business Continuity Plans (BCPs) are considered by design teams. The National Construction Code of Australia (NCC) does not currently mandate an all-hazard resilience approach for new facilities. Instead, it often defaults to siloed design practices and minimum compliance standards, such as deemed-to-satisfy solutions or structural engineering requirements.

As Bartlett (2023) notes, changes to the NCC can take years to implement. Even then, lessons learned are often diluted by expert bias and competing agendas, delaying the adoption of necessary resilience measures.

3.2 Value-adds, but address vulnerabilities.

New facilities are generally built out of a need; a gap between organisations present facilities capability and their present and future operating needs. To meet this need, an opportunity arises to bring value to the organisation that will strengthen the organisation's capacity and/or improve performance, and presumedly reduce their weaknesses.

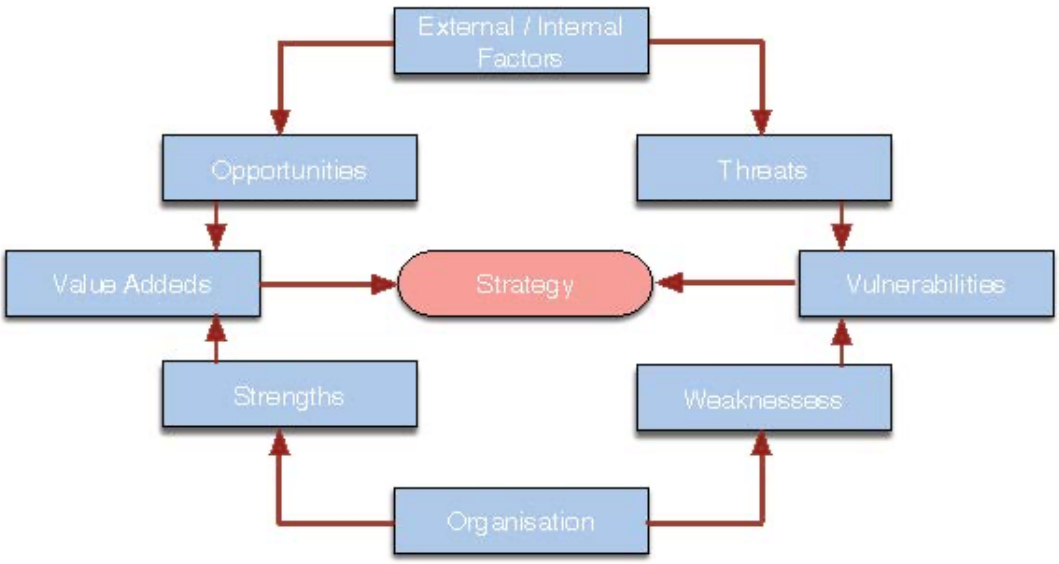


Figure 4 Augmented SWOT Process (Robinson & Francis 2019) – reproduced with permission.

4 Facility Objectives

The following framework is designed to support Design Consultants in effectively engaging with stakeholders to define and achieve comprehensive facility resilience objectives. It provides a structured approach to addressing critical considerations, including the classification of the facility, the types of activities and occupants it will accommodate, and the prioritization of essential functions during periods of disruption. By prompting targeted discussions around these key aspects, the framework ensures that resilience outcomes are thoughtfully integrated into the design process, aligning with both stakeholder expectations and the broader objectives of operational continuity and disaster readiness.

4.1 What is the facility?

Importance Levels definitions in the NCC Volume 1 (2022) are extremely light in detail, the examples in the Guide to the NCC Volume 1 (online only) provide some improvement, although they are far from expansive.

Bartlett (2023) *Figures 1 & 2* provided guidance for Importance Level determination, especially Importance Level 4 Case by Case Basis to enable downgrade to IL3 where appropriate. Further expansion of this approach is anticipated to be published in future, especially the establishment of organisational facility hierarchies to illustrate post-disaster performance, resilience timeframes and levels of uptime (redundancy) of systems.

4.2 What will the facility it house?

Are the contents unique/valuable?

Are the contents vulnerable to environmental changes?

Are the contents dangerous to the people/place/environment?

What will public/industry opinion be of the failure of the facility to protect the contents?

What will be the political fallout for the organisation or government agency if the contents or service fails to be protected?

4.3 What functions should be prioritised during disruption?

Which functions of the facility are critical immediately, essential post-disaster and discretionary (non-essential) during facility disruption.

Figure 5 (below) was created to provide categorisation by stakeholders of their minimum business continuity objectives.

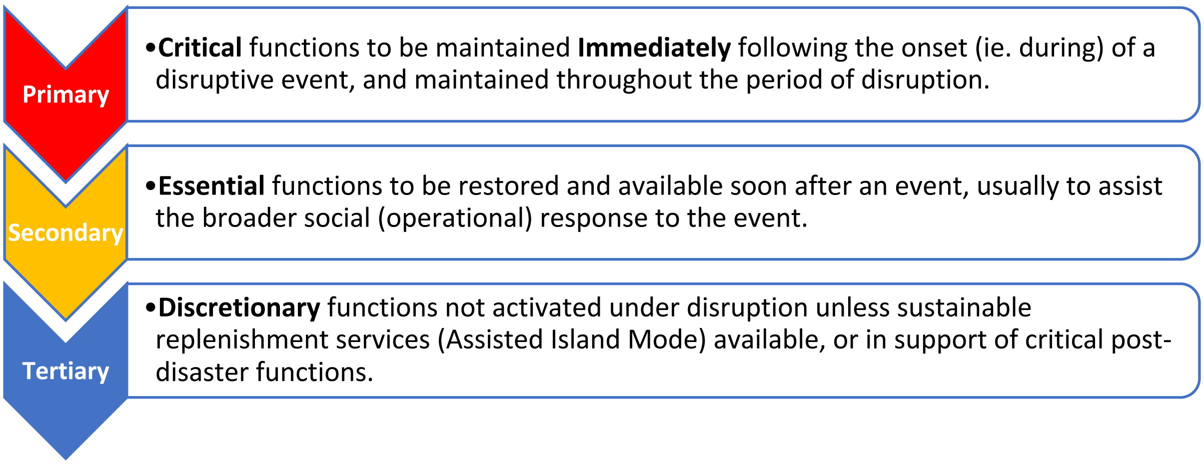


Figure 5 Minimum Business Continuity Objective (MBCO) categories and definitions (Bartlett 2024)

Once this data is agreed, this information can be expanded to establish the:

a. Performance requirements
b. Timeframes for re-establishment (Maximum allowable outages (MAO) & Maximum Tolerable Periods of Disruption (MTPD))
c. Levels of redundancy for systems

5 Timeframe (Island modes)

McBean 2021 Special Study process suggested a need for stakeholder to identify whether the structure or facility is required to be self-sufficient and function unsupported in “island mode” for a certain period.

Following a disruptive earthquake event, it is anticipated that utilities (such as potable water, power, sewer, communications) will be disrupted. Koschatzky *et al* (2017) suggested that for a magnitude 6 earthquake event in Melbourne could result in disruptions of:

- Electricity for approximately 2 months.
- Potable water 40 days.
- Sewer up to 150 days.

5.1 Island Mode (stand-alone)

Resultantly, it is considered due diligence for stakeholders and design consultants to establish acceptable periods of island mode operation and the functions of the facility to be maintained during this period.

It is worth noting that island mode resources will need constant monitoring during disruptive events to enable to prolong the facilities operations with modification for the dynamic environment created by the disruption. If fuel supplies are not anticipated to be replenished in the given timeframe, a facility may reduce the loads across the facility to extend the operating period for those higher priority functions.

Alternatively, it is also worth noting that generators and other equipment may have minimum loads to maintain safe operation and avoid premature damage to the backup systems.

5.2 Assisted Island Mode

Assisted Island Mode is a new term introduced by the author. It could possibly be improved upon and has also been referred to as a Hybrid Island Mode. The intent is that a facility begins to be replenished as scarce resources are allocated to the facility to continue operations.

*Figure 6****Error! Reference source not found.*** illustrates that Critical and Essential Functions are covered by Island Mode, whereas under Assisted Island Mode, the facility:

a. Continues Critical and Essential functions.
b. Replenishes the Island Mode capacity.
c. Re-introduces Discretionary Objectives.

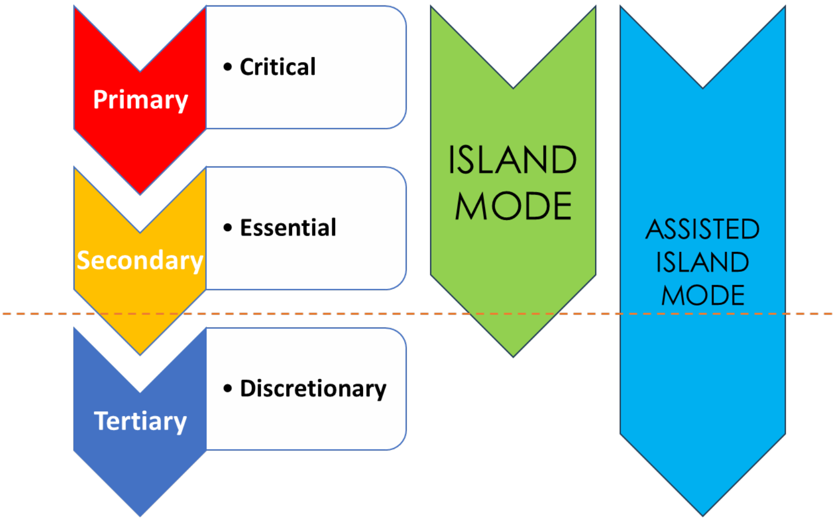


Figure 6 Objectives supported by Island Modes (Bartlett 2024)

6 Redundancy

Redundancy of equipment is typically addressed within the scope of the building services engineering team. While redundancy is essential for ensuring reliability and resilience, it comes with significant costs and must be critically evaluated to avoid reliance on the same single points of failure within the systems it is meant to support. Effective redundancy design should not only consider the duplication of critical components but also assess the independence and separation of systems to prevent cascading failures during disruptions.

Although the author does not have the expertise to provide detailed technical guidance in this area, valuable insights can be drawn from the Tier 1 to Tier 4 typology used in the data centre industry. This classification system outlines progressive levels of redundancy and resilience, with Tier 4 representing the highest standard of fault tolerance. By studying these established benchmarks and adapting similar principles, design teams can develop more robust redundancy strategies tailored to the specific needs and risks of their facilities. This approach ensures that resilience objectives are met without incurring unnecessary costs or introducing hidden vulnerabilities.

7 Process in practice: Combining the Components

Figure 7 was created to illustrate the:

- Disaster Stages (DRR Components)
- Minimum Business Continuity Objectives (MBCOs)
- Power resilience for 2 generators full facility operational load and 48hrs of diesel

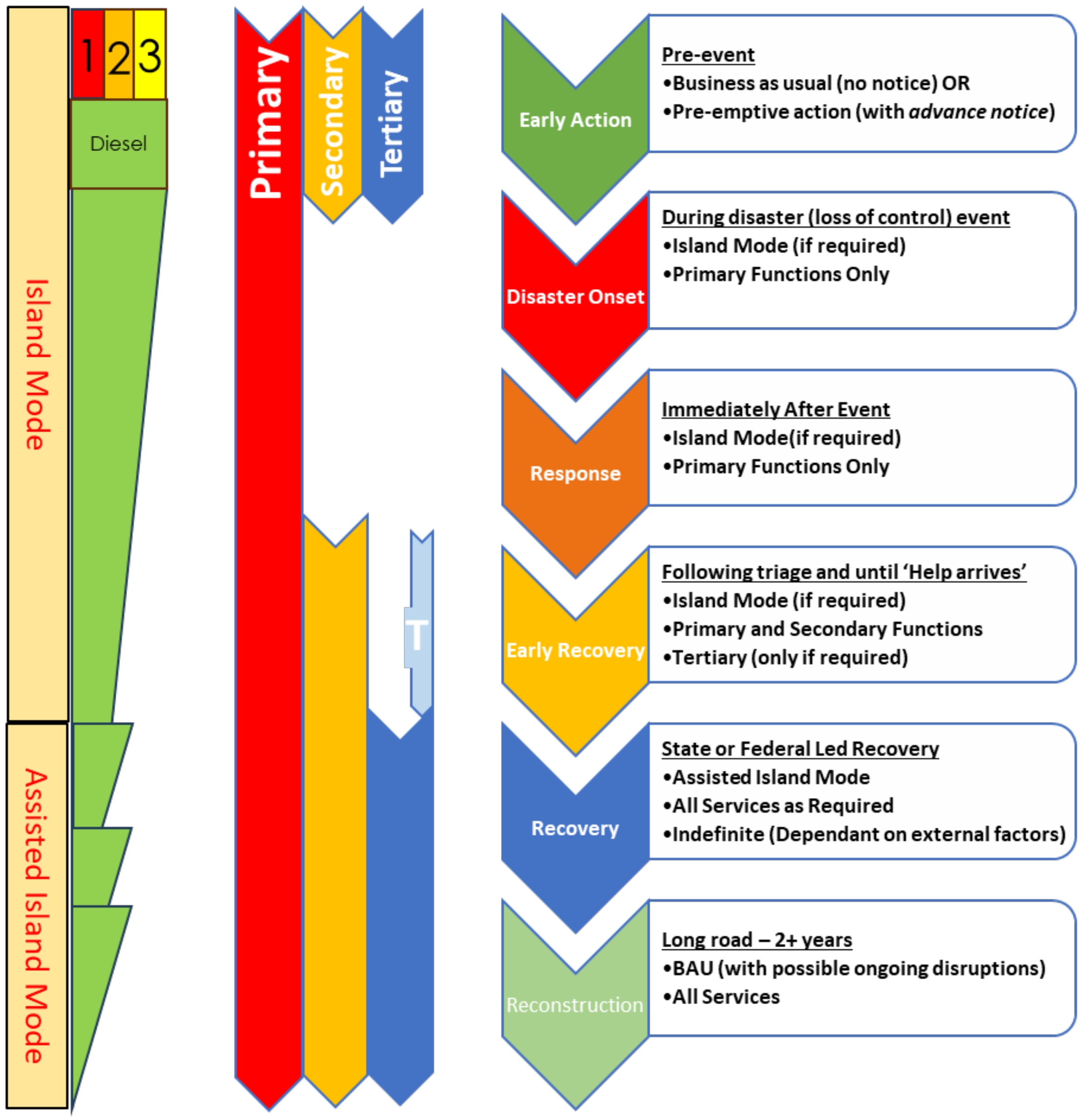


Figure 7 Functions v Disruption v Redundancy (Bartlett 2024)

7.1 Disaster Stages & MBCO's

Under each stage is relevant timeframes, government intervention considerations and the suggested objectives.

It's worth noting that a Discretionary (Tertiary) Objective can be re-established during the post-disaster function, although this is likely to accelerate the resource depletion and shorten the island mode capacity.

7.2 Power resilience & Redundancy

Extending upon the power resilience:

a. There are 3 generators to Normal load plus one unit (N+1) for redundancy (in case one fails).
b. 48 hrs of diesel full load operation, or an extended period (possibly 3 or 4 days) based upon reduced loads.
c. Assisted mode replenishing the fuel increases the period of operation and enables other functions.

With reliable external support (fuel deliveries), Assisted Island Mode could be established for long-term operation of the facility throughout the Early and Long-term recovery stages of the DRR.

8 Conclusions and recommendations

McBean's (2021) introduction of the 7-step IL4 Special Study process addressed a critical gap in guiding stakeholders toward the delivery of resilient facilities. Building on this foundation, this paper has expanded Step 1 to provide a more detailed framework for integrating stakeholder insights into the design and construction process.

Stakeholders possess invaluable knowledge about their post-disaster roles, processes, and operational needs. This paper emphasises the importance of systematically capturing and translating this knowledge into actionable design and construction outcomes, ensuring alignment with the remaining steps of the IL4 Special Study process. By enhancing the exploration of stakeholder needs, the sub-steps proposed in this paper aim to bridge the gap between operational objectives and built environment resilience.

Ultimately, this paper aspires to advance the design community's ability to deliver IL4 facilities that are not only compliant with AS1170.4 but also capable of fulfilling their critical roles during and after disaster events. By fostering collaboration and promoting a holistic approach to resilience, it sets the stage for more robust, sustainable, and disaster-ready infrastructure.

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