Towards a Better Evaluation of Disaster Management Solutions

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Abstract: Worldwide, disaster management endeavours are confronted with a rising number of calamitous events triggered by climate change, pandemics and armed conflicts. The increasing rate and complexity of such occurrences has determined governments worldwide to attempt improving the disaster management effort by adopting various specialised artefacts, among which disaster management frameworks feature prominently. It appears however, that such artefacts display shortcomings such as lack of directly applicable guidance, ambiguity and a lack of agility in the face of constant change inherent to disaster events. This situation poses a conundrum to disaster management decision-makers who need to select such frameworks in the knowledge that they have the necessary qualities, employ a suitable architecture and contain the required elements to effectively guide the typically trans-disciplinary and cross-organisational disaster management effort. This paper seeks to assist in this regard by providing a novel, multi-pronged appraisal approach for candidate disaster management frameworks.

1 INTRODUCTION

As disaster events worldwide appear to constantly increase in frequency and intensity, the procedures and policies historically put in place to prepare for, deal with and recover from such occurrences show signs of no longer being able to cope with the changed environment. Consequently, inherent hazards can evolve into *disasters* negatively impacting upon people and valuables, beyond the ability to avoid, cope and recover from them (Global Access Partners & Institute for Integrated Economic Research - Australia, 2021; Parliament of Australia, 2020b). For this reason, Governments and organisations have continuously sought ways to enhance disaster management-related artefacts so as to cope with the changed situation; however, significant obstacles are typically encountered having to do with the inevitable intricacy of the specific components and concepts involved and also with the absence of suitable assistance to employ them in practice. Attempts have also been made to tackle this complexity and bring structure by employing disaster management *frameworks*; however, questions still remain as to how suitable and adequate for specific organisations and events these frameworks are, how are they to be used in practice at various levels and how they can effectively underpin the essential need for adequate collaboration in this domain.

As such, decision makers need assistance in their effort to make sense of, select, structure and actually use the plethora of existing and emerging candidate artefacts (including frameworks) claiming relevance and efficiency. They also need to know if these constructs actually have the desired properties for the task at hand and especially, if- and how do they cope with the high complexity and chaotic characteristics of the environment they are intended to operate in.
The geographical focus of this paper is Australia, due to its high rate of many types of disaster events such as fire, floods, storms, and tsunamis. Therefore, this is considered a good starting point that provides the required variety of case studies and artefacts relevant to disaster management.

The rest of the paper is structured as follows: a brief description of relevant concepts and related challenges in disaster management is followed by an introduction to the artefacts and principles proposed

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to be used. Then, it is explained how these artefacts can assist in the assessment of the disaster management frameworks, illustrating with several examples and a preliminary framework assessment. The paper closes with conclusions and proposed further work.

2 DISASTER MANAGEMENT ARTEFACTS

2.1 Resilience: Aspects and Approaches

There is a multitude of definitions for resilience in the relevant literature, with the common *leitmotif* being the capacity to cope with, and recover from adverse events. Therefore, resilience appears particularly relevant to disaster management and as such it is briefly analysed in the present context.

A study performed by an Australian economic think tank (Global Access Partners & Institute for Integrated Economic Research - Australia, 2021) identifies several aspects that contribute to improving resilience: shared awareness, teaming and collaboration and preparedness. These translate into the need to clearly represent and thus achieve a common shareholder grasp of the current and future situations, of the relations between entities of interest and of adequate and systemic life-long planning. Further investigations by a Royal Commission in disaster management arrangements (Commonwealth of Australia, 2020) has also found *hazards*, *exposure* and *vulnerability* as relevant factors in determining resilience.

Moreover, a report by the Global Facility for Disaster Reduction and Recovery (2016) recommends that risk and resilience assessments need to shift from a snapshot approach towards a 'useful life'-long appraisal that can constantly guide decision makers in attaining a resilient future state.

Literature describing the elements and technologies that can enhance resilience has also been reviewed (e.g. (Bernus, Noran, & Goranson, 2020; Connor & Zhang, 2006; Southwick, Bonanno, Masten, Panter-Brick, & Yehuda, 2014)). The main pervading theme here was that tackling the resilience Universe of Discourse using sets of viewpoints is highly beneficial in coping with the complexity inherent to disaster management. These findings are incorporated in the proposed appraisal approach (see the Enterprise Architecture Framework Evaluation in Section 3.3).

2.2 Frameworks: Features and Requirements

The United Nations Office for Disaster Risk Reduction has supervised the creation of the Sendai Framework for Disaster Risk Reduction 2015 – 2030 (United Nations Office for Disaster Risk Reduction, 2015), which aims to 'decrease disaster risk and losses' (ibid.). This framework appears to be the precursor of- and inspiration for most of the other major efforts in establishing national and regional disaster management frameworks.

A review of such frameworks in Australia has found that they have been created for each major phase of disaster management. Thus, for Preparation and Mitigation there is a Risk Reduction Framework (Commonwealth of Australia, 2018) and a Disaster Preparedness Framework (Australian Government, 2018); for Response there is a Resilience Framework (Global Access Partners & Institute for Integrated Economic Research - Australia, 2021) and for Recovery there are also dedicated frameworks (e.g. the state-level Recovery Framework in Victoria (2020)). Reference models ('guides') also seem to have been developed in order to provide some high-level guidance for framework creation (see e.g. the Disaster Recovery Framework Guide (2020)).

After examining the various frameworks developed for the 'Before' (mitigate and prepare), 'During' (respond) and 'After' (recover) phases of disaster management, it has been concluded that, in fact, their components often extend into other disaster management phases. This reflects the fact that in reality, the various phases of disaster management are partly overlapping. As an example, one needs to Prepare to attain as high a degree of resilience as possible, Respond when an event occurs and then Recover; however, as recovery comparatively takes a longer period of time, it is highly likely to overlap with future iterations of disaster management efforts. Similarly, Preparation may occur while at the same time mitigating the effect/s of previous events and disasters and Response may also take place while a previous Recovery effort and other phases relevant to other (also possibly cascading) disaster events are still occurring (see Fig. 1). This cyclic approach is also *incremental* in nature, as every iteration must consider lessons learned from previous activities.

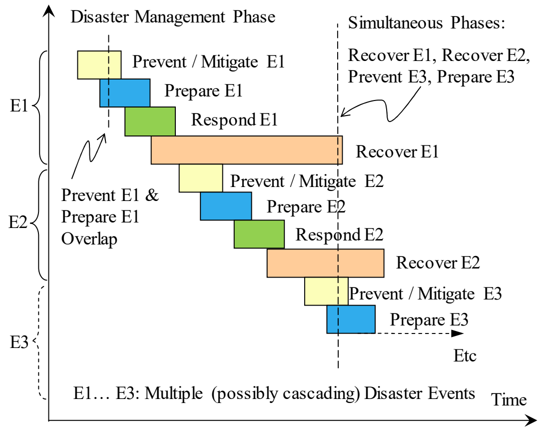


Figure 1: Possible Disaster Management Phase overlaps.

An effective disaster management framework should be able to represent, convey and facilitate this overlapping, iterative and incremental approach.

In Australia, a parliamentary enquiry (Parliament of Australia, 2020a) and think tank report (Global Access Partners & Institute for Integrated Economic Research - Australia, 2021), have found that vulnerability, a key term that defines the boundary between hazards and disasters, is inherently linked to the potentially cascading and compounding character of such events, such as "[…] pandemic with associated supply chain failures, or increasing frequency and severity of cyber-attacks" (ibid.), currently met with an inadequate response (Blackburn, Borzycki, & Jackson, 2021).

The above finding reflects the fact that the ability to adequately cope with one or more disaster events is closely linked to the proper understanding of the current situation (be it e.g. a lack of trusted supply chains, extremely limited domestic manufacturing, or inadequate energy security (Blackburn, 2018)) and the complexity of the often compounding and interacting disaster events (Gissing, Timms, Browning, Crompton, & McAneney, 2021; Pescaroli & Alexander, 2018). This again emphasizes the need for the supporting artefacts to adequately represent, help to understand, and address the current and future situations and compounded disasters. This important set of requirements is reflected further in the structure of the proposed framework assessment process.

2.3 Main Current Issues of Disaster Management Frameworks

In the international context, the main issues highlighted by the United Nations Office for Disaster Risk Reduction report (2014) are as follows:

- Information gathered via assessments is often not properly used also because policy makers do not know *how* to make sense of the large amount of data to obtain information (i.e. they are data rich, but information poor (Bernus & Noran, 2017));
- Future risks are being created in the present due to poor present and future states understanding;
- Lack of coordination between Disaster Risk Management and climate change policies due to poor constraint and mutual influence modelling;
- Insufficient Disaster Management funds due to improper Resource modelling;
- Incomplete vulnerability understanding due to low or non-existing human role modelling;
- Poor coordination between stakeholders, and a lack of information sharing due to improper modelling of the relations between stakeholders and other relevant entities, from several viewpoints;
- Improper Eco-system management – showing all relevant relations between entities, during their entire useful lives, not just at a point in time.

Compiling all the findings, the summary of main issues presented by the reviewed current Disaster Management Frameworks appear to be as follows:

- unclarity as to what a disaster management framework should actually contain;
- lack of proper disaster management framework theoretical background: for example, underlying metamodels describing concept definitions such as viewpoints, levels of abstraction, hierarchies, as life cycle and life history;
- confusion as to what stakeholders are to be involved and how do they relate to each other;
- inadequate representation of the relation between entities during the whole life of the involved entities, rather than in a snapshot manner;
- no reference to life cycle of the participant entities (including stakeholders) and no clear modelling of the human role;
- no explicit set of qualities expected from a disaster management-specific framework (e.g. reliability, maintainability, ease of use, adaptability etc);
- lack of shared situational awareness mainly due to interoperability issues;
- calls to learn lessons from analogous Defence Command and Control (C2) failures (Vassiliou, 2014) and high-level requirement descriptions, however, with no detail of exactly how these concepts and capabilities may integrate into the disaster management concept.

As current Disaster Management Framework (DMF) propositions will continuously evolve and new ones will be developed, the authors suggest an assessment structure intended to appraise candidate DMFs in line with the above issues and thus potentially also guide their further development.

3 PROPOSED ASSESSMENT STRATEGY

The assessment procedure proposed evaluates how the candidate artefact performs in structuring and assisting areas that are deemed essential for effective disaster management. The aspects assessed in each step have been determined according to the findings of Section 2 and are further explained in this section.

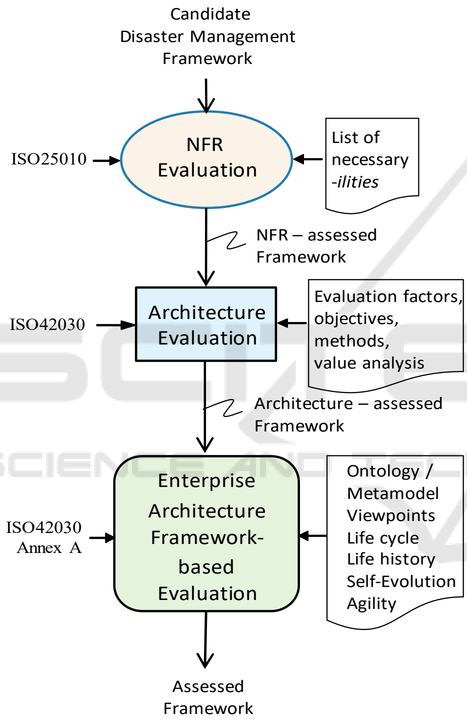


Figure 2: Proposed assessment strategy.

As can be seen in Figure 2., the first step looks for the presence of Non-Functional Requirements (NFRs) (also called '-ilities', or quality attributes) that are required to be present in the assessed artefact so that it adequately performs in supporting the disaster management Universe of Discourse (UoD). The second step evaluates the architecture of the artefact itself, in order to determine if it contains the required perspectives and aspects and also if it structures them in the most appropriate manner for the intended domain. The last step is the most comprehensive, allowing to assess more complex concepts and thus ensuring that the assessment procedure suitably evaluates the 'requisite variety' (Ashby, 1991) of the candidate framework in respect to the complexity of its intended UoD. More precisely, it evaluates whether the framework is able to guide Mitigation, Preparedness, Response and Recovery efforts matching the content and interactions' complexity of actual disaster situations.

Importantly, as depicted in Figure 2, each step is underpinned by internationally recognised and adopted standards. As one of the major identified problems is interoperability (see Section 2.3), the presence of said standards acts as a bridge towards common understanding, acceptance and agreement in respect to adopting a unified assessment procedure.

3.1 Quality Attributes of Disaster Management Frameworks as Systems-of-Systems

The Disaster Management Universe of Discourse can be considered a highly dynamic and complex *System of Systems* that interact in a complex manner (Commonwealth of Australia - Department of Home Affairs, 2018). Therefore, in its turn a Disaster Management Framework should be an *adaptable* system of systems whose complexity should match or exceed that of the Disaster Risk Management UoD (Ashby, 1991) and that should be continuously learning so as to maintain system qualities in the face of expected and unexpected changes.

The international Standard ISO 25010-2011 (ISO/IEC, 2011) gives guidance on quality attributes of systems and on additional attributes relevant to system use. Boehm et al. (2014) define an 'Initial Definition of an -ilities Ontology' based on value for the stakeholder, where the -ilities defined summarize the class hierarchy of the primary stakeholder -ilities classes of Mission Effectiveness, Resource Utilization, Dependability and Flexibility, joined by their primary means-ends subclasses, and the primary composite -ilities of Affordability and Resilience (ibid.). Based on the set of requirements in the Standard and on the above-mentioned hierarchy, previous efforts (Noran & Bernus, 2022) have produced an enhanced list of -ilities for assessment as shown in Table 1, featuring the addition of *ubiquity* (the capacity of being used irrespective of location), *evolvability* (understood as adaptive [self-]evolution (Brown, 2014)) and *viability* (i.e., the system's capability of long-term survival), all of which are very relevant in view of the rationale for the candidate DMFs targeted by the proposed evaluation process.

Table 1: Enhanced list of -ilities for Disaster Management Frameworks (additions in italics).

Individual -ilities
• Quality of Service: Performance, Accuracy, Usability, Scalability, Versatility • Resource Utilization: Cost, Duration, Personnel, Scarce Quantities (size, weight, energy, …) • Protection: Safety, Security, Privacy • Robustness: Reliability, Availability, *Maintainability* • Flexibility: Modifiability, Tailorability / Extendability, Adaptability • Composability: Interoperability/Portability, Openness/Standards Compliance, Service-Orientation • *Evolvability* • *Ubiquity*
Composite -ilities
• Comprehensiveness/Suitability: all of the above • Dependability: Quality of Service, Protection, Robustness • Resilience: Protection, Robustness, Flexibility • Affordability: Quality of Service, Resource Utilization • *Viability*

The following gives a short explanation as to how the -ilities in Table 1 may apply to an assessed candidate DMF. As some of the qualities are related, they will be treated as a group (or expanded upon only once) where relevant.

Thus, the DMF must eliminate ambiguity as all stakeholders should be able to understand and agree on the current and future situations and on the transition required; it should be usable by all the envisaged relevant stakeholders, and also be applicable to a range of scenario sizes irrespective of any major changes made to it by other entities. In other words, the framework must be able *to self-evolve* to a certain extent so as to adapt to changes in its environment (see Evolvability in Table 1, noting that the assessment of the self-evolution capability will also be analysed in Section 3.3). Where the necessary changes exceed the capacity of the framework to adapt itself, the controlling entities should be able to readily change it (see modifiability, tailorability and extendability in Table 1).

As resources are typically limited in crisis situations, the Framework in question should display an efficient use of resources – be it financial, human, time or energy. The use of the proposed Framework should allow modelling of the risks for response crews and should support security or privacy in all of the disaster management phases. The assessed Framework should be robust, i.e. it should be available when and where required (see Ubiquity in Table 1), should be consistent in its approaches and readily modifiable if so required. In order to maintain integrity, an underlying meta-model should be present to provide unambiguous terminology and underpin consistency following any changes. Interoperability, together with portability, openness and standards compliance should be present to ensure that the entities involved in disaster management planning, response and recovery can effectively work together, which is currently not a trivial aspect (Noran & Bernus, 2011). The framework's capacity of long-term survival (*viability in* Table 1) should also be present as it is essential in view of the incremental and evolutionary approaches taken to disaster management and of its typically overlapping phases (see Figure 1). This would ensure a unified and consistent approach using a single framework instead of a heterogeneous collection of paradigms promoted by the contributors to the various phases of disaster management efforts.

3.2 Architecture Evaluation of the Disaster Management Frameworks

The variety of viewpoints and apparent lack of underlying guiding paradigm reflected in the reviewed risk reduction management document raises two issues for the prospective users. Firstly, how can it be ensured that all the *appropriate* aspects have been covered in an appropriate manner? The answer to this issue is provided in this paper by using an Enterprise Architecture Framework-based assessment as shown in Section 3.3.

A second Issue relates to ensuring that the represented aspects have been organised in the most suitable way for the intended purpose. This matter is dealt with in this section by employing *architecture evaluation*. For this purpose, the authors resort to the use of a generic architecture evaluation standard, namely ISO42030 (ISO/IEC, 2019b), which aims to organize and document architecture evaluations for the enterprise, systems and software fields of application. According to this standard, the evaluation of alternatives should be performed in *two passes*: 1) eliminate proposals that do not satisfy mandatory non-functional requirements, and 2) compare candidate solutions using an *appropriate* decision- making method (see Figure 3).

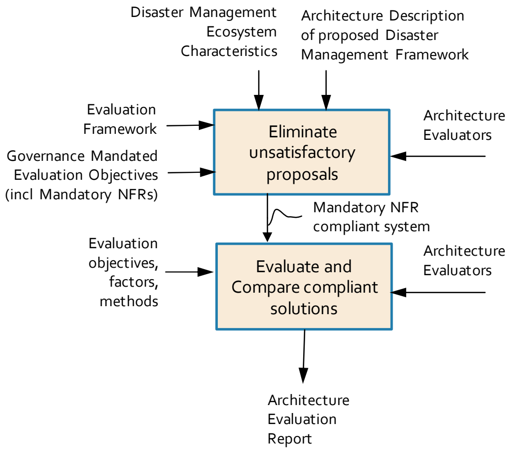


Figure 3: ISO42030-proposed evaluation process.

The first pass has been already dealt with in Section 3.1. In regards to the decision-making method specified in the second pass, ISO 42030 also requires that, based on business goals, architecture governance derives the *evaluation objectives,* specifying what kind of answers are expected from the architecture evaluation. Objectives can e.g., include determining if the solution will increase efficiency (and if so, then to what extent), or if it will improve current capabilities and / or services quality, or if it will promote new features (e.g., agility). The second pass is presented in more detail in Figure 4.

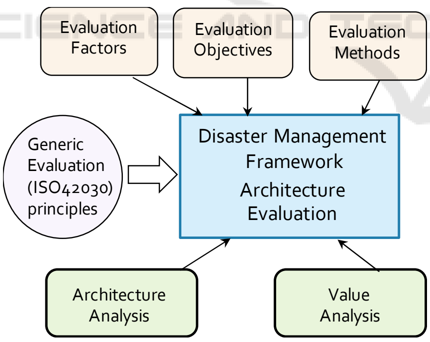


Figure 4: Proposed components for the Architecture Evaluation of Disaster Management Frameworks.

The comparison of potential solutions is to be performed by defining *evaluation factors* that influence the answers, and selecting methods known to deliver these answers. Such factors (which are normally derived from business drivers) may contain: disaster risk mitigation, preparedness, response and recovery cost, schedule and quality. Suitable *evaluation methods* here typically include the use of analysis reports or expert panels.

Due to the high complexity of the Disaster Management UoD, it may happen that he answers to the above evaluation are rather vague; therefore, to achieve a meaningful comparison of architectural solutions one must establish the *value* of a particular architecture (i.e., perform value analysis). Thus, it may be required to determine if the quality requirements are met, or whether there is a potential trade-off or optimisation possibility; there may also be a need to establish how architectural decisions contribute to the expected quality attributes (for example, 'will a *centralised*, or rather *federated* disaster management framework best underpin its agility?'). Note that this value assessment process must also include determining to what extent the chosen architecture supports achieving the business goals. The value of the chosen approach may be demonstrated using key performance indicators based on adequately selected metrics, e.g. disaster response promptness, extent, cost, etc.

Should the desired measures be not readily available when inspecting the proposed architecture, then *architectural analysis* may also be required, comprising the creation of e.g., simulation models that can be used for sensitivity analyses. It is to be noted that the cost of architecture analysis is typically high, as it needs to explore alternatives in detail (Martin, 2017); as such, it should only be used when absolutely necessary.

3.3 Evaluation using an Enterprise Architecture Framework

A typical approach in dealing with complexity is to structure the concepts into various categories according to a classification structure. This effort should be underpinned by a metamodel whose role is to uphold the integrity and consistency of this ordering. In this approach, the above-mentioned categories would become viewpoints exhibiting main stakeholder group concerns articulated in the various disaster management phase requirements. This approach is hereby proposed to be applied to candidate DMFs using a classification structure from the domain of Enterprise Architecture, namely ISO15704:2019 Annex A: Generalised Enterprise Architecture and Methodology (GERAM) (ISO/IEC, 2019a). This Enterprise Architecture Framework (EAF) has been selected for being the abstraction and synthesis of the elements of several other mainstream EAFs; GERAM is an established and proven artefact, having been used in several projects within many domains, which includes Disaster Management (Noran & Bernus, 2011). The modelling framework

(MF) of the Reference Architecture component of GERAM (called GERA) contains a set of viewpoints which can be employed to organise candidate frameworks so as to assess their completeness for the envisaged use and also to support a common stakeholder understanding of the present, future and necessary transition. The GERA MF is represented in Figure 5, together with an example of modelling construct obtained by selecting a specific set of dimensions.

The presence of (or need for) a metamodel and / or ontology underpinning the assessed framework can be modelled using the Generic Instantiation level, while the contents and appropriateness of potential templates and relevant standards can be represented using the Partial model level (see Figure 5 top).

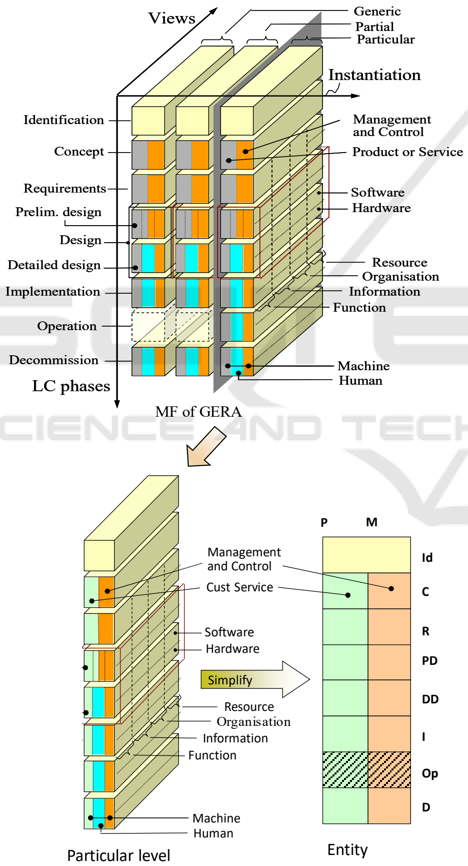


Figure 5: GERA MF and a sample creation of a modelling construct for dynamic business models.

3.3.1 Life Cycle, Vulnerability

The life cycle context present on the vertical axis in the proposed MF (see Figure 5 top) allows to meet the disaster event and management life-long modelling requirement established in Section 2.1. This is exemplified in Figure 6, where the typical phases of disaster management are mapped onto the GERA life cycle phases. In addition, it can be seen that the time-abstracting MF construct allows for selected modelled phases to be repeated as required. It should be noted that a representation considering time is also possible (exemplified later on in the paper).

Various other modelling constructs, focused on specific viewpoints, allow filtering selected aspects in order to manage the inherent UoD complexity (see Section 3.3.3 for more details).

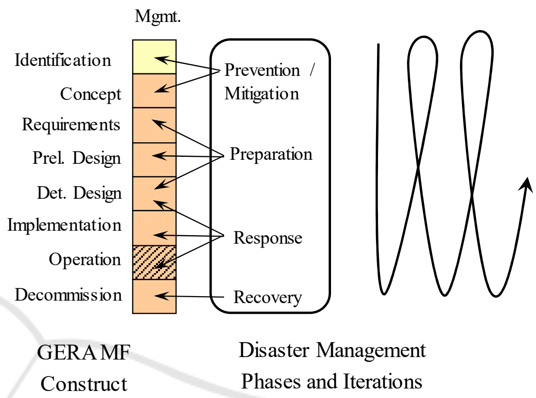
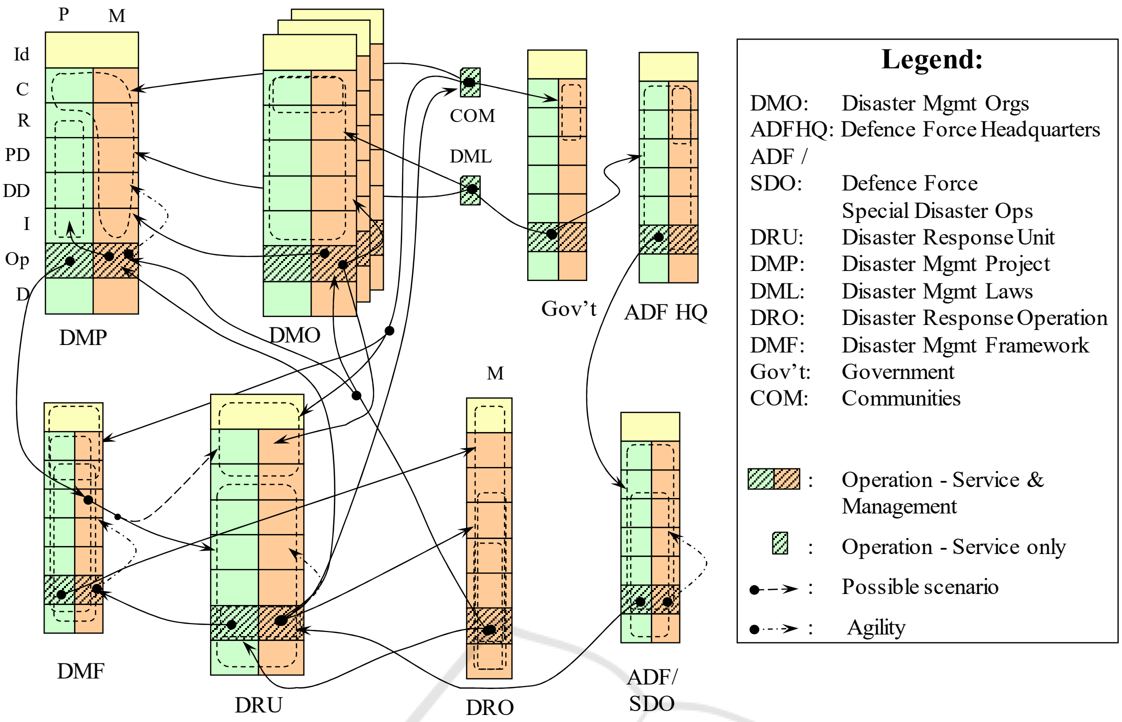


Figure 6: Disaster Management life cycle mapping on the GERA-derived construct.

In turn, Figure 7 illustrates a scenario of how the modelling constructs obtained (as shown in Figure 5) can be used to represent the relations between entities relevant to disaster management together with the necessary collaboration and interoperability (Noran, 2011) of the participant entities, in a so-called ‘dynamic business model’. Thus, for example, one can see the cooperation of the government (Govt), various disaster management organisations (DMO) and local communities (Com) working together to co-design and deliver risk reduction and management programs (Duckworth, 2021) (see arrows from these entities to the Disaster Management Project (DMP), Disaster Management Framework (DMF) and Disaster Response Units (DRU)).

The required agility of relevant entities (e.g. the Disaster Management Framework (DMF), Disaster Response Unit (DRU), etc.) is represented by arrows going from their Operation life cycle phase back to their own Architectural, Detailed Design and Implementation life cycle phases. This signifies that the entities can re-design themselves, as long as the extent of this re-organisation does not go over a set threshold, after which higher authority (typically, the designing entities) are invoked.



Life cycle phases: Id: Identification; C = concept; R = requirements, PD = preliminary design, DD = detailed design, I = implementation, Op = operation, D = decommissioning. *Other aspects:* P = Production / Service, M = management

Figure 7: Possible Disaster Management scenario (dynamic business model).

Importantly, one can also use this model to analyse proposed scenarios. Thus, one can investigate the possibility for the Defence Forces to create a Special Disaster Operations unit (ADF/SDO in the figure) in order to better prepare and execute disaster relief operations, as this seems to increasingly be the case (Jennings, 2020).

Vulnerability and related concepts derived from the reviewed documents (see Section 2.2) can also be analysed here, from the system-of-systems point of view modelled by the relevant entities in the context of their lifecycles and showing the automation extent. For this purpose, a suitable modelling construct showing human role (present in the structure shown in Figure 5 top) can be derived from the GERA MF.

3.3.2 Disaster Compounding

Concurrent and compounding disasters have been described in relevant literature, although mostly limited to one other factor only (i.e., societal pressure during other disasters (Gissing et al., 2021)). In the real world, however, there are many other types of interconnected disasters that need modelling; for example, Earthquake/ Tsunami (Noran & Bernus, 2011), or Fire-Clouds–Storm-Lightning–Fire (Commonwealth of Australia, 2020). This kind of inter-relation (initially shown using a simplified life-cycle focused representation in Figure 8) can also be further modelled using the above-described approach by selecting appropriate viewpoints to depict the required influences and necessary intervention by appropriate DRUs (see e.g. (Noran & Bernus, 2011)).

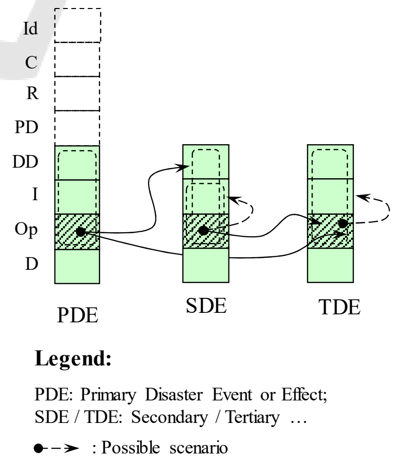


Figure 8: Disaster / effect compounding representation.

Note that this kind of mapping can also be performed for the interdependent *effects* of one or more disasters; for example, power interruption may impact on other services, then flowing into various other areas and communities.

To summarise, this approach allows to analyse patterns present in complex and highly dynamic systems interacting in a cascading fashion and to formulate suitable preparedness and response.

3.3.3 The Time Dimension: Life History

Time is not represented explicitly in the proposed MF, although it is present in the form of a *life history* concept, which can be depicted graphically by adding an orthogonal time dimension to the modelling constructs obtained from the GERA MF (see Figure 9); this can enable a more thorough analysis of the disaster management scenarios represented.
Such an approach may be required because, as shown in Figure 1, Section 2.2 and Figure 8, disaster events and disaster reduction, response and recovery actions may compound and overlay, augmenting the complexity of the situation and necessitating more detailed modelling. As an example, Figure 9 presents the scenario of setting up Disaster Response Organisations and Units, while also illustrating the overlap of Disaster Response Operations that they create and operate. Thus, the Government and Disaster Risk Task Force set up Disaster Risk Response Organisations, which then, with involvement from Community Organisations, set up Disaster Response Units and Operations. This representation is similar to that shown in Figure 7; however, due to the time dimension, it can give additional detail such as concurrency and succession. Note also the possibility to represent both management and mission fulfilment of the involved entities aspects, as necessary.
Importantly, this enriched model provides additional information as to 'who does what' - but also 'when'.

3.3.4 Additional Potential Assessments

Further assessments may assist with the current difficulties in the actual implementation of the proposed Frameworks as described by the United Nations Office for Disaster Risk Reduction (2014). These can be performed by creating constructs using various combinations of aspects contained by the above-described GERA MF. Thus, Management *vs.* Service / Mission Accomplishment provides clarity in regards to task allocation for decision makers and operators. The Software *vs.* Hardware division allows to represent the implementation of required functions

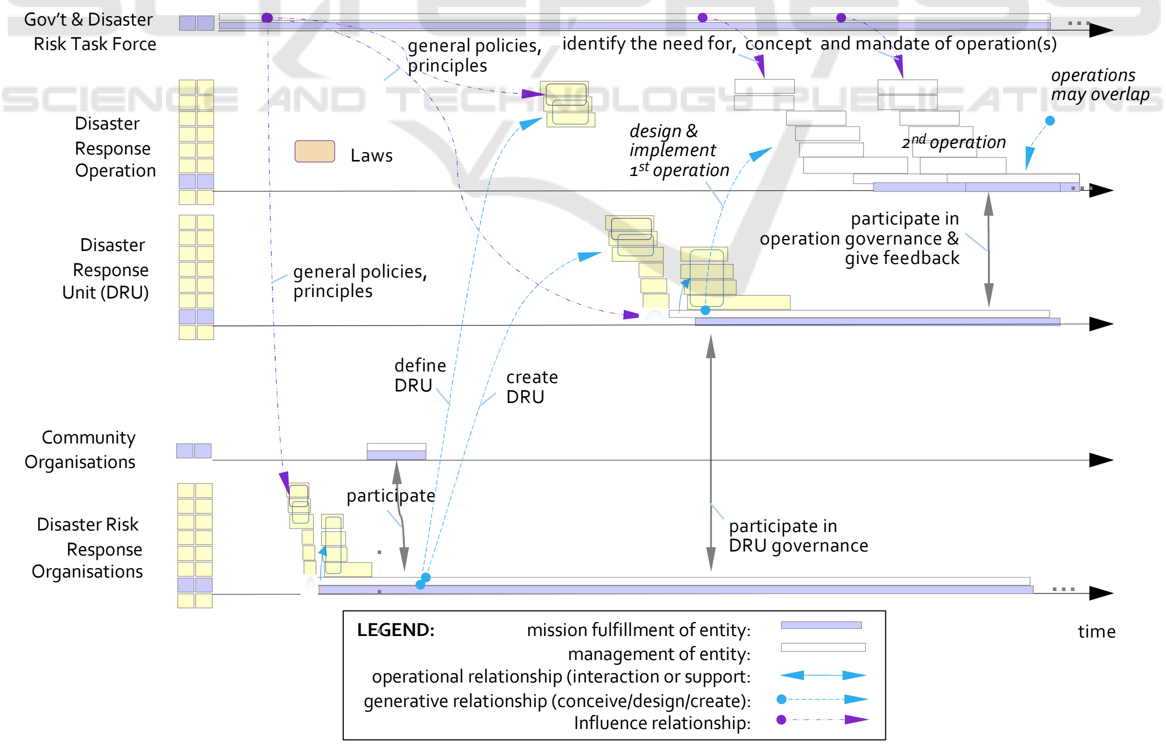


Figure 9: Life histories of entities relevant to the disaster management scenario.

and their physical deployment. Automation extent shows e.g. what information and resources are necessary to, and what functions can be performed by machines rather than humans, so as to avoid putting disaster response crews at unnecessary risk; this also aids in mitigating vulnerability.

Data and properly derived information (Bernus & Noran, 2017) that is adequate in quantity and quality and is delivered when and where required can significantly help all phases of the disaster management. This aspect can be modelled using the Information viewpoint of the GERA MF.

The way the candidate DMFs are actioned in all disaster management phases can be modelled using the Function viewpoint of GERA MF.

The essential aspect of organisational cooperation, which has proven to be a weak point in many disaster relief operations (Paturas, Smith, Albanese, & Waite, 2016), can be modelled in the Organisation viewpoint.

Finally, the paramount aspect of resourcing featuring prominently in disaster management (Chang, Wilkinson, Seville, & Potangaroa, 2010) can be modelled through the Resource viewpoint.

Explicit examples of these aspects' mappings are not possible here due to available space and will be disseminated separately.

4 CASE STUDY

The following will attempt to illustrate the use of the proposed assessment procedure by evaluating a DMF, namely the Australian Disaster Preparedness Framework (ADPF, see Figure 10, right) (Australian Government, 2018). Note that this represents only a preliminary evaluation, to be followed by more comprehensive efforts in future work.

4.1 Non-Functional Requirements

The first step of this assessment is limited to the NFRs deemed most important, i.e. adaptability, ubiquity, evolvability and viability (or possible synonyms present in the target document).

Adaptability: the ADPF states that national preparedness needs to be adaptable as part of the preparedness principles. However, there is no mention as to how this will be achieved.

Ubiquity: the ADPF mentions the need for national preparedness to be linked to foreign governments and international agencies. This is the only possible mention of ubiquity present in the document, however once again no details (even high level) are given of how this could be achieved.

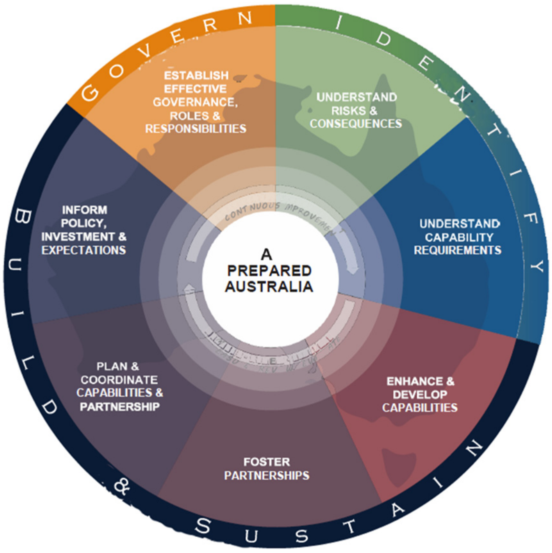


Figure 10: Australian Disaster Prevention Framework.

Evolvability: the document mentions the need to be 'adaptable' to changes in the nature of disasters and context of application. The only other potential mention of evolvability is 'continuous improvement'.

Viability: there is no mention of this NFR or of a similar term throughout the document.

Recommendation: the framework should give more attention and at least high-level guidance to the NFR-linked aspects, besides a mere mention in the document. NFRs such as viability should be included.

4.2 Architecture Evaluation

Evaluation Objectives for this framework may include whether the ADPF increases efficiency, improves current capabilities or quality, or if it promotes agility.

Efficiency is mentioned in the document in terms of the management of disasters along their entire lifecycle. However, the ADPF appears to give no details as to *how* this will be achieved. *Capabilities* appear to have received more attention within the Govern area of the framework; however, *Agility* is only mentioned under the form of adaptability.

In terms of the Evaluation Factors, such as disaster risk mitigation, preparedness, response and recovery cost, schedule and quality, the ADPF appears to only cover *Preparedness*. As the scope of the document appears to be limited to this phase (although sometimes also touching on the Recovery phase), this may be sufficient.

Recommendation: the ADPF should provide more guidance on streamlining the disaster management efforts and on the adaptability of the framework.

4.3 Enterprise Architecture Framework-based Evaluation

From the point of view of the disaster management life cycle, it appears that the ADPF only covers the Mitigate/ Prepare phases (see Fig. 6), which may be appropriate in view of its name ('Preparedness') although as mentioned references to other phases exist (e.g. Recovery).

The ADPF claims to aim to promote collaboration although this is not detailed in the document, even at high level (it could be achieved e.g. via a *Functional* viewpoint). The importance of *data* is stated in the document; however, once again there is no detail given on how this may be used to underpin an effective preparation effort; moreover, there appears to be no distinction between data and the *Information* derived from it. The *Organisation* and *Resources* viewpoints get mentioned in the document however no details (even high level) are provided as to how collaboration will happen, authorities will be allocated and resources will be shared and managed.

A minimal guide for the use of the framework is provided, although it does not follow a consistent approach (various concept categories are mixed in the same diagram) and in the absence of details, it is not very useful. Moreover, there is no sample scenario illustrating at least one of the proposed steps.

Recommendations: 1) The ADPF will need to be complemented with other frameworks covering Response and Recovery. 2) Information, Functional, Organisation and Resources viewpoints are highly recommended at least as high-level guidance for the use of the framework. 3) Generally, at least one example of each aspect covered should be provided. 4) Sample scenario/s should be provided, even at generic level to clarify the application of the framework for disaster management decision makers.

5 CONCLUSIONS AND FURTHER WORK

This paper has adopted a novel, holistic approach towards clarifying the still evolving concept of disaster management framework and assessing such candidate artefacts for their qualities, architecture, and completeness of their viewpoints in the context of their intended use. This work may assist policy makers establish whether a proposed disaster management framework is suitable for their purpose in regard to necessary qualities, suitable structure and applicable viewpoints and concepts, selected according to their intended domain, geographical location, as well as available and required resources.

Future research will extend the preliminary assessment to include all required elements and perform the appraisal of other proposed disaster management frameworks in order to validate and further refine the proposed assessment approach.

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