Towards a Holistic Assessment of Resilience Frameworks

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Abstract

The increasing rate of catastrophic events owing to climate change, pandemics, and significant changes in the international balance of power leading to armed conflicts have revealed disaster management weaknesses which need to be addressed as soon as possible so as to ensure the continued stability, safety and indeed existence of mankind. In this context, the concept of resilience framework has emerged; however, current such artefacts appear to be rather fragile, ambiguous, and difficult to use in practice in the face of said vulnerability and complexity. The question is: how can decision-makers ensure that a proposed resilience framework displays the necessary qualities and contains the required elements and guidance for the necessary local and cross-domain actions to increase resilience for their specific sector, organisation, or community? This paper attempts to define a multi-pronged approach to assess such artefacts in an integrated and holistic way so that the resilience frameworks are 'complete', understood, and actioned and thus effectively support disaster risk management.

Keywords: Resilience Framework, Disaster Risk Reduction, Defence, Information System, Architecture Frameworks, Enterprise Architecture

1. Introduction

A series of significant disruptors such as extreme climate events, pandemics involving new viruses such as COVID-19 and substantial changes in the international balance of power underlying present and potential military conflicts have emphasized shortcomings in dealing with adverse events and the imperative need to address them. Along these lines, the concept of *resilience* has been often defined as the capacity to adapt when faced with adversity, threats, or significant sources of stress. The main idea is to avoid hazards becoming *disasters*, i.e. interfering with people and things of value, and the impacts of such hazards exceeding the ability to avoid, cope or recover from them [1, 2].

Governments and organisations worldwide have considered ways to achieve and enhance resilience; unfortunately, this endeavour is typically hindered by the inherent complexity of the components and concepts involved and the lack of appropriate guidance in using them. The concept of *resilience framework* has been introduced in order to address these shortcomings; however, important questions arise: how suitable and 'complete' (for the envisaged purpose) are these frameworks for specific organisations and events? how should they be actually used at various levels; and, importantly, how can they promote the essential aspect of collaboration in disaster prevention? What are the desired properties of such frameworks? This paper proposes a way forward in assessing proposed resilience frameworks in view of the above questions, adopting a multi-pronged approach with emphasis on the Informational aspect of the entities involved.

2. Resilience

2.1. Definition, Important Aspects and Challenges

Current relevant research proposes a multitude of definitions of resilience, many coming from psychology [3]; a mainstream meaning of resilience is similar to that of Janas [4] who identifies it as the ability to bounce back from adversity, frustration and misfortune. In this paper, the authors have used a definition relevant to dealing with disaster risk management in a complex and systemic context. Along these lines, resilience is understood here as the capacity of a dynamic system to adapt successfully to changes in the environment; in other words, its *agility in the face of adverse changes in its environment.* Of course, the various Information Systems of the involved organisations must support this resilience by providing the necessary up-to-date information where and when required and importantly, by *being themselves resilient*.

Note that in this paper, the authors have chosen to start by focusing the examination of resilience structuring efforts on a specific geographic location, subsequently extended to a global context so as to support further research. The chosen initial location is Australia, owing to its typically high exposure to many types of natural and man-made hazards among which fire, floods, storms, and tsunamis feature prominently.

Thus, a resilience study performed by an Australian economic think tank [2] identifies three aspects that contribute to improving resilience: shared awareness, teaming and collaboration and preparedness, all of which must be supported by the relevant Information Systems. This highlights the importance of unambiguously representing the available information and achieving a common shareholder understanding of the current and future situations, of the relations between entities of interest and of proper and systemic life-long planning. In addition, an investigative commission in Australia has also found that, in examining resilience, one needs to look at the contributing factors such as hazards, exposure and vulnerability [5]; disaster risk can, therefore, be managed by focusing efforts toward each of these factors. Importantly, in the view of the authors, this endeavour should be accomplished *in all* of the 'before' (mitigate and prepare), 'during' (respond) and 'after'(recover) phases of disaster management - seen here as an ongoing incremental effort, containing various resilience emphasis (see Fig. 1).

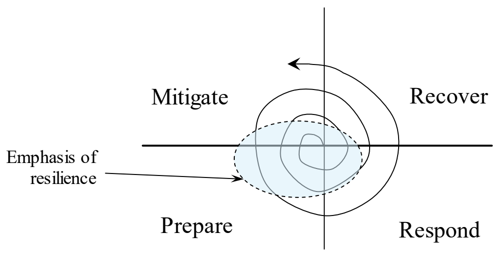


Fig. 1. Emphasis of Resilience within the (ongoing) Disaster Management Effort

This stance is supported by other research finding that the disaster management phases are in fact overlapping; for example, effective recovery is planned in advance and is embedded in the initial disaster response [6]. Thus, one needs to prepare and mitigate the effect of previous events and disasters, achieve as high degree of resilience as possible, respond when an event occurs then recover – followed by repeating the loop at a higher level, i.e. mitigating and preparing in the context of the knowledge gained from the last iteration. In this context, data and information play a paramount role. Along these lines, Management Information Systems (MIS) can provide the necessary intelligence as current and historical operational performance data, while Decision Support Systems (DSS) can assist decision makers in responding but also preparing for the next possible iteration of the specific disaster type. Importantly, it is to be noted that while gathering data has become increasingly easy, the amount of data and its proper interpretation continue to be a significant problem [7]. This makes the Information System aspect of resilience especially important and in need of proper modelling.

Another challenge is highlighted by The Global Facility for Disaster Reduction and Recovery report [8] which states that risk assessments need to move from a single point in the present towards a useful life-long approach that can continuously guide decision makers towards a resilient future. This supports the life cycle-centred approach proposed by the authors and further detailed in this paper.

Various studies have also looked at determinants and technologies that can enhance resilience (e.g. [3, 9]). One recurring theme was that the inherent complexity dictates a ‘divide and conquer’ approach, by selecting limited sets of aspects at any given time. These issues are further explored in this paper.

2.2. Resilience Frameworks

In order to properly structure the complexity of interrelated aspects and interactions making up the resilience concept there have been calls to create and adhere to resilience frameworks [10, 11]. Along these lines, the United Nations Office for Disaster Risk Reduction has overseen the creation of the Sendai Framework for Disaster Risk Reduction 2015 – 2030 [12], which aims to decrease disaster risk and losses.

In order to assess potential problems with the current resilience efforts, is important to review the various *meanings* given by such efforts to Sendai Framework’s targets and priorities for action to prevent new- and reduce existing disaster risks. In Australia, the initial definition of a Resilience Framework describes risk assessment as its primary function, followed by the call for a framework containing a guide to activities required in order to reduce the identified disaster risk. The same enquiry, as well as the previously mentioned think tank [2], have found that *vulnerability* is in fact created by humans and owes much to the potentially cascading and compounding character of such events [ibid.], with the current response being “too little, too late, and too short-sighted” [13].

The above analyses and conclusion reflect the lack of preparedness stemming from mis-understanding the seriousness of the current situation (be it a shortage of trusted supply chains, extremely limited domestic manufacturing, or inadequate energy security [14]) and the complexity of the often compounding and interacting disaster events [15, 16].

The National Disaster Risk Reduction Framework (NDRRF) [17] developed by the National Resilience Taskforce (NRTF) defines disaster risk as “a product of the effect of hazard […], impacting on (people and things) and the ability for those people and assets and systems to survive and adapt” [17].

2.3. Current Resilience Framework Issues

From the United Nations Office for Disaster Risk Reduction report [18] and a the review of current Resilience Frameworks the issues appear to be as follows:

- there is confusion as to what a resilience framework should actually be composed of;
- there is substantial theoretical background in respect to resilience, however lacking underlaying metamodels describing concept definitions such as viewpoints, levels of abstraction, hierarchies, and other important concepts such 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 their entire life;
- No reference to life cycle of the participant entities and no modelling of the human role;
- there seems to be no statement in relation to an explicit set of qualities expected from a resilience framework (e.g. reliability, maintainability, ease of use, adaptability etc);
- shared situational awareness, understood as a) the perception of environmental elements and events with respect to time or space, b) making sense of their meaning, and c) the projection of their future status [19], is not achieved due to issues similar to the problems encountered in Defence C2 failures [20], such as notably the lack of interoperability;
- in respect to the previous point, calls to learn lessons from similar, albeit more evolved Defence high-level requirement descriptions but no detail of how these concepts and capabilities may integrate into the resilience concept applied to generic disasters.

3. Proposed Assessment Framework

The authors propose an assessment framework composed of three main components: Non-Functional Requirements (NFR, or system qualities)-based evaluation (as per ISO/IEC 25010 [21], not covered here due to space limitations), Architecture evaluation and EA Modelling Framework-based evaluation, as shown in **Fig. 2**. The last step is the most comprehensive, allowing to model complex concepts and thus ensuring that the assessment procedure suitably evaluates the 'requisite variety' [22] of the resilience framework in respect to the complexity of its intended Universe of Discourse (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 real-world disaster situations.

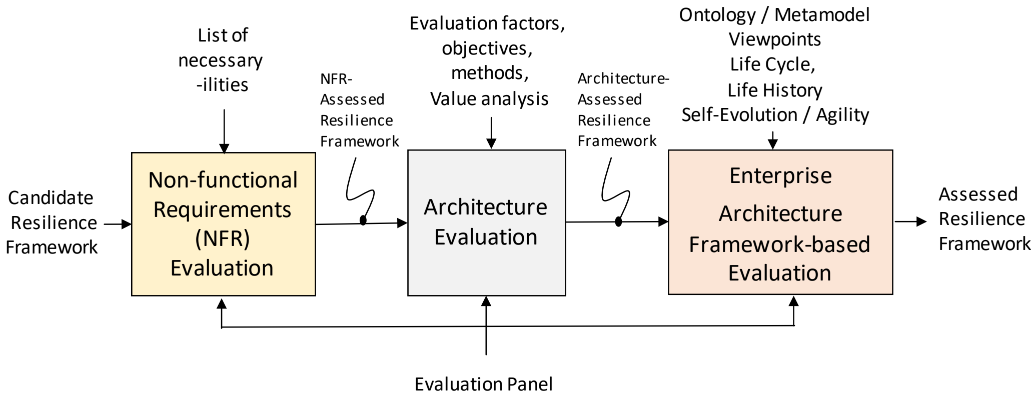


Fig. 2. The Assessment Framework Concept

3.1. Architecture Evaluation of the Resilience Frameworks

The variety of viewpoints and apparent lack of underlying guiding paradigm reflected in the reviewed risk reduction management documents brings in two questions: a) how does one know that all the *appropriate* aspects have been covered and b) how can it be ensured that the represented aspects have been structured in the most suitable way for the intended purpose? The first question is answered using an Enterprise Architecture Framework (EAF) (see Section 3.3 for details), while the second question can be dealt with through the use of *architecture evaluation* (see **Fig. 3**).

In regards to the second approach, the authors resort to the use of a generic architecture evaluation standard, namely ISO42030 [23], which aims to organize and record 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 (NFRs), and 2) compare candidate solutions using an *appropriate* decision-making method. Concerning 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 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 may include for example disaster risk mitigation, preparedness, response and recovery cost, schedule, quality and risk. Appropriate evaluation methods on this level typically include referring to existing analysis reports, or using expert panels.

Given the high complexity of the Disaster Risk management UoD, it may be sometimes necessary to establish whether the quality requirements are met, or whether there is a possible trade-off, or an opportunity to optimize; or the way architectural decisions contribute to the expected quality attributes (for example, 'will a federated-type resilience framework and associated information system improve its agility?').

If the desired measures are not readily available when inspecting the proposed architecture, then further *architectural analysis* may also be needed, requiring the development of e.g., simulation models usable for sensitivity analyses. It is to be noted that, as architecture analysis typically also explores alternatives [24], it is quite costly in resources and time and should only be used when absolutely necessary.

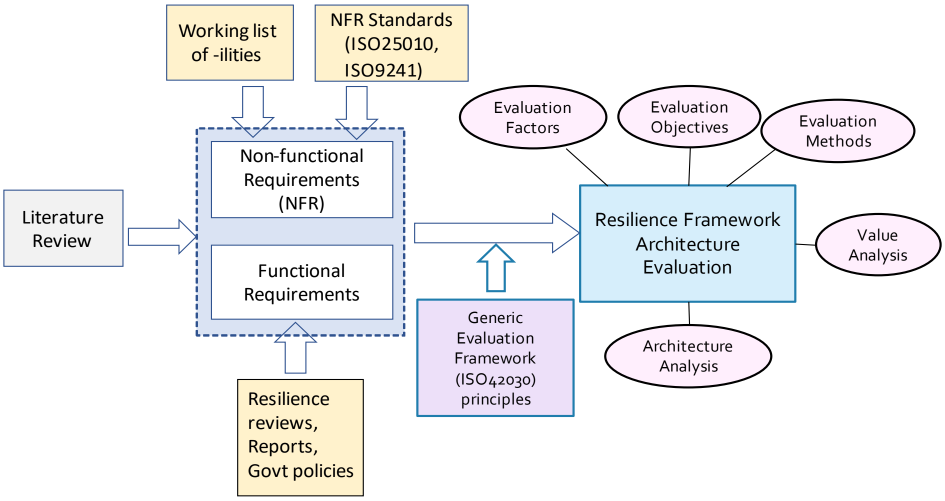


Fig. 3. Architecture Evaluation of Resilience Frameworks

3.2. Evaluation Using an Enterprise Architecture Framework

In order to manage complexity, a typical approach for assessing and enacting a Resilience Framework is to structure its concepts into various categories according to a classification schema, ideally supported by an underlying metamodel so as to maintain integrity and consistency of the classifications. Such categories would ideally be viewpoints reflecting main stakeholder group concerns expressed in the disaster risk reduction requirements.

One such classification structure comes from the domain of Enterprise Architecture, namely Annex B of ISO15704:2019, called the Generalised Enterprise Architecture and Methodology (GERAM) [25]. The authors have selected it for being the abstraction- and thus including the elements of several other mainstream EAFs. GERAM is an established and proven artefact, having been used in several projects within many domains, including Disaster Management [26]. The modelling framework (MF) of the Reference Architecture component of GERAM (called GERA) contains a rich set of viewpoints which can be used to structure proposed resilience frameworks, in order to assess their completeness for the envisaged purpose and also to enable a common stakeholder understanding of the present, future and necessary transition between these two states. This MF is represented in **Fig. 4**, together with an example of modelling construct creation by selecting focused combinations of dimensions.

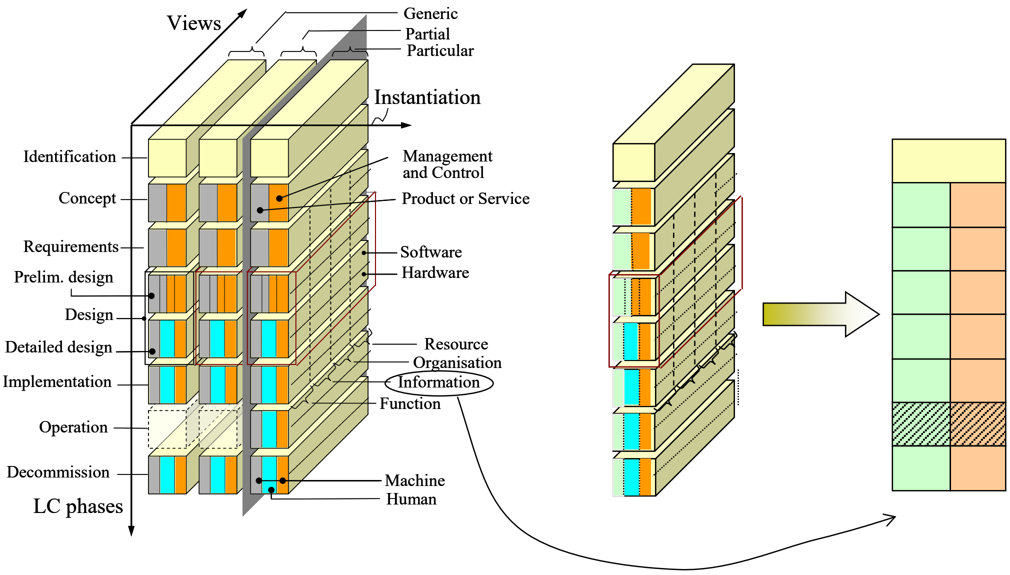


Fig. 4. GERA MF and example creation of a modelling construct for dynamic business models

Assessment of Viewpoints

In regard to the running example of the NDRRF from Section 2.2, one can identify several viewpoints from the perspective of the GERA MF:

- Understand Disaster Risk (equivalent to Sendai Framework Principle) maps on the Information Viewpoint of the GERA MF;
- Accountable Decisions (Sendai Framework Principles 1, 2 and 3), comprising processes and models for action, maps on the Function viewpoint;
- Policies, programs, standards, codes to reduce disaster risk may be represented through the Partial Model level in the GERA MF;
- Enhanced Investment in disaster reduction maps on Resources viewpoint of GERA MF;
- Governance, ownership, and responsibility may be mapped on the Organisation viewpoint of GERA MF (but also in dynamic business models showing relations between relevant entities, such as further shown in **Fig. 5**).

Life Cycle, Cooperation, Disaster Compounding and Interaction, Vulnerability

The life cycle context present as an orthogonal dimension in the proposed MF allows to satisfy the life-long modelling requirement established in Section 2.1. Further on, various modelling constructs focused on specific viewpoints allow filtering selected aspects in order to manage the inherent complexity of the UoD. For example, **Fig. 5** illustrates how the modelling construct obtained as shown in **Fig. 4** can represent the relations between entities relevant to disaster management together with the necessary collaboration and interoperability [27] of the participant entities, in a dynamic business model.

Thus, for example, in **Fig. 5** one can see the cooperation of the government (Govt), various disaster reduction-involved organisations (DRRO) and local communities (Com) working together to co-design and deliver risk reduction and management programs [6] (see arrows from these entities to the Disaster Management Project (DMP), Resilience Framework (RF) and Disaster Response Units (DRU)). Agility of relevant entities (e.g. the Resilience Framework, Special Disaster Operations SDO, etc.) is represented by arrows going from the 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 to some extent, which is specified in the figure.

Importantly, one can also use this model to analyse proposed future states, such as the current calls for Defence to create a Special Disaster Operations unit in order to better plan for- and execute disaster relief operations, for which it is increasingly called upon [28].

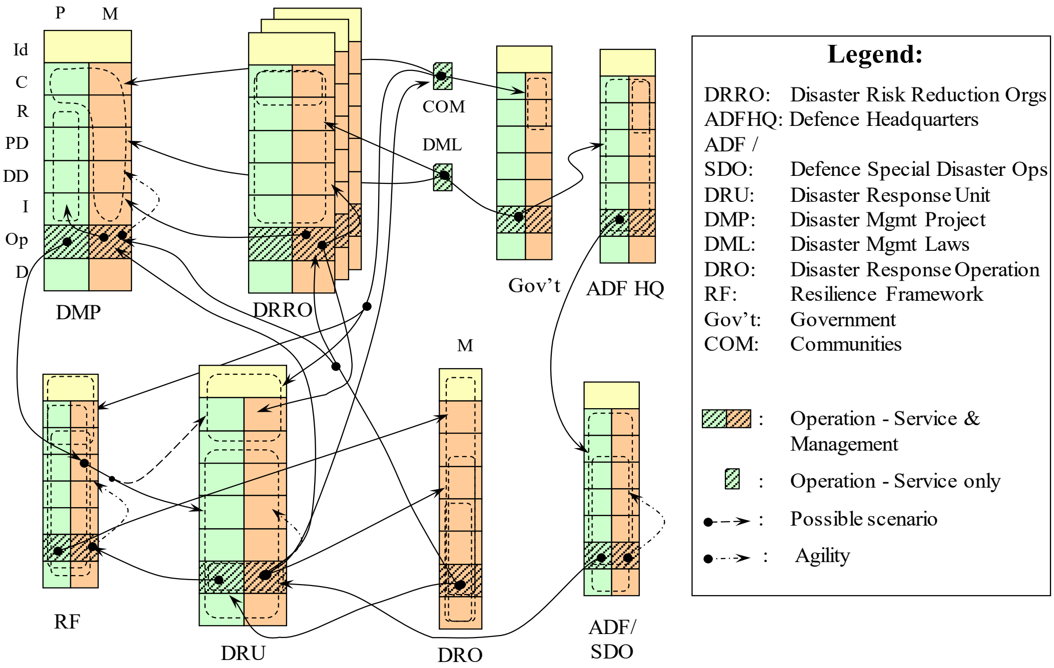
In the real world there are many other types of interconnected disasters [29] such as Earthquake / Tsunami [26], Fire-Clouds–Storm-Lightning–Fire [5]; this kind of inter-relation can also be modelled using the above-described approach by selecting appropriate viewpoints (see e.g. [26] for an example).

The Time Dimension

Time is not represented explicitly in the proposed MF for clarity purposes, although it is present in the form of a *life history* concept, which can be represented graphically by adding an orthogonal time dimension to the modelling constructs derived from the GERA MF. This has not been represented here due to space limitations.

Other Potential Assessments using the proposed MF

Further detail, important in assisting the current difficulties in the actual implementation of the Resilience Framework [18], can be provided by using the selected MF. Thus, Management *vs.* Service / Mission Accomplishment provides clarity for decision makers and operators. The Software *vs.* Hardware division allows to represent the implementation of required functions and their physical deployment. Automation extent shows e.g. what information and resources are required by- and what functions must be performed mostly by machines, so as to avoid putting human disaster response crews at risk. The available space does not allow giving additional explicit examples of these aspects' mappings here.



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

Fig. 5. Possible disaster management dynamic business model

4. Conclusions

This paper has adopted a holistic approach towards assessing candidate resilience frameworks in terms of their completeness and adequacy for their intended use. This may assist policy makers establish whether a proposed resilience framework is suitable for their purpose in regard to necessary qualities, suitable structure and applicable viewpoints and concepts, selected according to their intended domain, resources, etc.

The following key findings have also been made: i) The Disaster Risk Reduction and Management UoD is a *System of Systems,* which interact in intricate and often quasi-chaotic way; and ii) Considering this context, a resilience framework must remain *viable* on the long term but also display *agility*, i.e., be able to to promptly *evolve* without causing unacceptable disruption. In other words, *a resilience framework must be itself resilient*.

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