Chapter

Scaling Accident Coping Strategies and Testing Coping Capability

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Abstract

Accidents are events that we do not want to happen. But they do. And present-day stresses in our complex society can evolve into future accidents, and potential disasters. Root causes range from poor maintenance at nuclear facilities, to effects amplified by climate change. The traditional paradigm used to account for accidents is made up of three parts. The first is to assess the risk of occurrence, then to judge if the assessed risks are acceptable compared to society's benefit, and ultimately to provide a generalised emergency service that will try to mitigate the consequential impact. Taking a more holistic and critical approach is to question and test if the preparedness, response and recovery capability is adequate. This represents a new paradigm for accident management, involving the need to quantitatively scale our accident and disaster coping strategies and capability. The scaling analysis needs to account for magnitude, time, rate and space.

Keywords: accident, disaster, society, risk, holistic, scaling, test, coping strategy, coping capability, preparedness, response, recovery

1. Introduction

The logic in this chapter began as a very rudimentary concept in the author's mind, a short time after the nuclear power plant accident at Fukushima Daiichi, on the north east coast of Japan in March 2011 [1]. I felt that we had to fundamentally improve not only the measures we apply to prevent severe man-made accidents, but to also question how we may improve our coping capability [2–16]. The aim being to wisely determine if a given coping strategy and civil emergency response strategy was actually sound and credibly doable [17–22]. If not, then to establish a more systematic [23, 24] and consistent process [25–27] for modelling civil emergency response that would identify practical improvements when and where needed, specifically in terms of the emergency preparedness, response and recovery tasks; progressing through civil emergency, see **Figure 1**.

Going back some 34 years to 1975, Harold C. Cochrane at the University of Colorado, produced a ground breaking study in the USA, looking at 'Natural Hazards and their Distributive Effects' [11]. Cochrane's work was also done in cooperation with Gilbert F. White and J. Eugene Haas [10]. More than any other, when I first read this work by Cochrane, it helped to formulate a more systematic and holistic approach for modelling civil emergency response [16, 23]. When I was descending into New York's JFK in 2014, I happened to have been reading Cochrane's paper, as well as the studies by White and J. Eugene Haas [10, 11]. As I looked out of the window, I saw the absolutely enormous expanse of man-made sprawl across

New York's urban region. At that split second—some might say a *light-bulb moment*, having read Cochrane's work during my flight, then seeing the massive system of buildings and infrastructure, the distributive effect of a low pressure storm surge amplified by climate change resonated with me, see **Figures 2** and **3**.

For a particular dangerous hazard-shock scenario, the tasks to be carried out by the emergency service organisations (that is, society's civil protection personnel who have a duty to protect the public) may be assimilated with the effectiveness and ultimate success of their preparedness, response and recovery tasks and activities. From a modelling perspective—before, during and after the hazard-shock scenario, see **Figure 4**. In summary, I have tried to outline in this chapter the basis

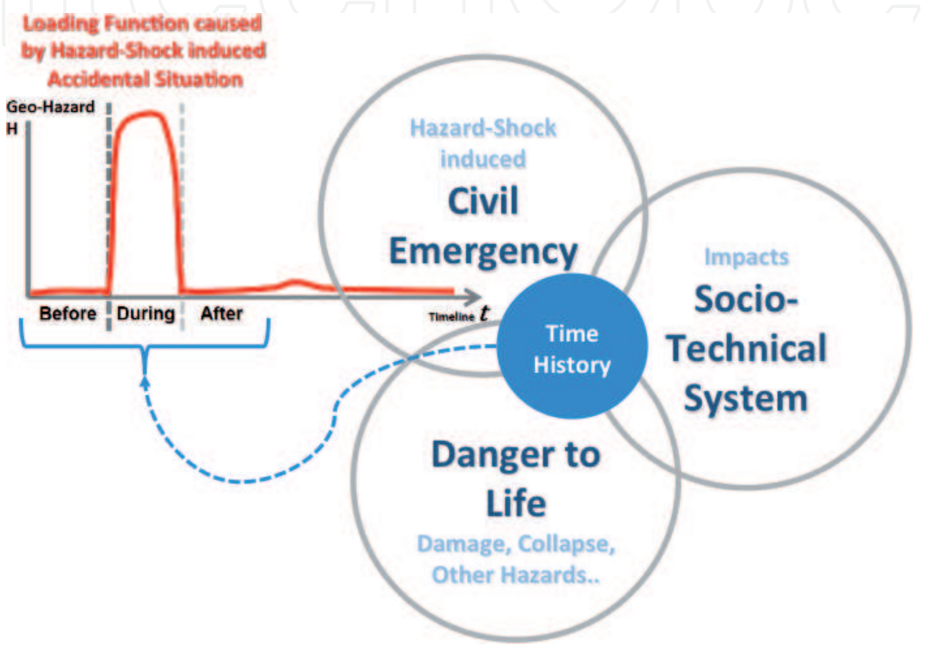


Figure 1.
Concept for temporal time history through a civil emergency.

Figure 2.
A modern-day urban city being a dense socio-technical system.

Figure 3.
Future global sea rise set to increase distributed scale of storms.

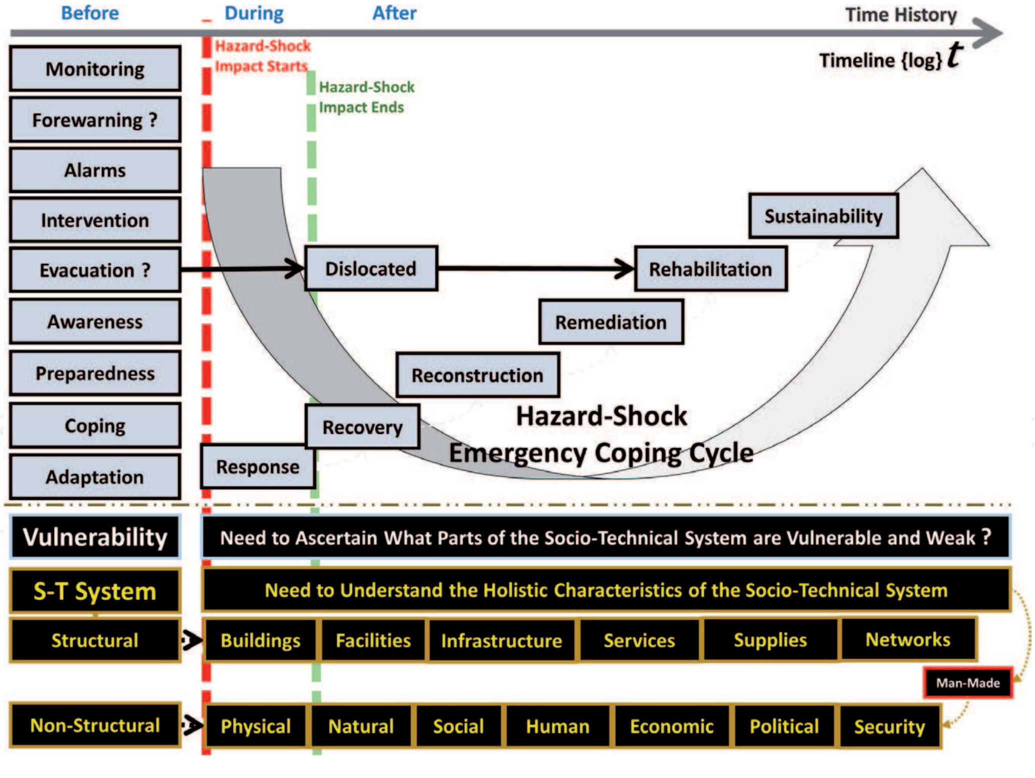


Figure 4.
Simple basis of emergency coping cycle in event of hazard-shock.

for a systematic and consistent process for modelling civil emergency response. The framework of this process encompasses:

- A background to survival and coping with future hazard-shock scenarios;

- Introducing seven types of generic hazard-shock scenarios for modelling;
- The duty for response to civil emergencies, including accidents and disasters;
- Subjective review of civil emergency coping capability;
- How to know the robustness of our socio-technical infrastructure;
- A new objective approach to quantify coping capability; and,
- The implications of climate change.

Applying this systematic process should help civil emergency duty organisations to verify and validate their accident and disaster coping strategies. The hierarchy of the process discussed in this chapter also enables a graded approach to be applied, from subjective qualification to a more rigorous objective quantification which uses a temporal coping capability analysis model.

2. Understanding the background

Accidents and disasters come in many forms. Conflicts of war, unintentional man-made accidents and natural disasters destroy the peace and regular stable order of society. Since the start of the new century at the 2000th year millennium, an upsurge of international terrorism became a harbinger of fear and anger (that still exists today), hurting innocent people and causing mass exodus of refugees.

Another profound problem has evolved as a stress on society since the industrial revolution; the release of gaseous carbon into the atmosphere by burning fossil fuels has given us global warming [13]. Now the impact of global warming has become a stark reality, whether experienced by extremely dangerous storm winds, flood inundation and rapid wildfires. Global warming can exacerbate accidents and disasters [5, 13, 15, 18]. During and after such dangerous scenarios, we all must try to cope and survive. We shall have to be prepared for more extreme magnitude and longer period hazard-shock scenarios, amplified by climate change. The future aftermath consequences initiated by seemingly 'natural' hazards will see larger areas affected, more severe to extreme forces, causing many lives to be lost, subsequently having increased government spending and insurance claims [10, 11]. It is therefore important to understand the severity of the hazard-shock scenario's time history and theoretically simulate what could happen and how, see **Figure 1**. In addition, we need to distinguish between the scientific basis of hazard-shock scenarios, compared to the practical demand placed on the civil emergency response duty organisation, as well as the strain taken by the response personnel and other volunteers *on-the-ground*.

When a major accident or disaster occurs, the public look to the duty emergency services, volunteer bodies, and government officials to take care of things. The presumption being that the relevant regional and national authorities will duly respond and cope with the dangerous situation. From a local community viewpoint, and those who live in the affected region, the public would normally wait until the emergency services arrive, telling them either to stay indoors, or to evacuate. But local communities may well have to cope by themselves without any additional help immediately forthcoming; into the future such a situation is likely to become a common practice with climate change.

In **Table 1** we introduce the concept for categorising the form of the hazard-shock scenario that the civil emergency responder's must face. In simple terms, seven types of generic hazard-shock scenario may be identified (**Table 1**):

- Regular;
- Serious;
- Overwhelming;
- Unpredictable;
- Sudden;
- Rapid; and,
- Disastrous.

In the United Kingdom a statutory Act of Parliament has been in place since 2004 which requires Category 1 responders to attend to civil emergencies under the Civil Contingencies Act (CCA) [7], and its regulations [8]. It is a requirement under the CCA to periodically assess the risk of emergencies occurring which affect or may affect a regional area. Reviewing and assuring the validity of a Category 1 responder's risk assessment should take place as often as is necessary to ensure that the preparedness for incident and emergency response is reasonably sound and will

Regular	Regular exposure from severe shock scenarios that necessitate mobilisation of coping strategies with response, and possibly recovery plans; the effect of the shock that exercises some of the coping strategies, response and possible recovery capability.
Serious	Serious exposure from severe to extreme shock scenarios that necessitate mobilisation of coping strategies with both response and recovery plans; the effect of the shock stressing the coping strategies, response and recovery capability.
Overwhelming	Overwhelming exposure from extreme to catastrophic shock scenarios that necessitate mobilisation of coping strategies with both response and recovery plans, but the effect of the shock is overwhelming, making coping success very poor.
Unpredictable	Unpredictable exposure from severe to possibly overwhelming shock scenarios that necessitate mobilisation of coping strategies with both response and recovery plans, the effect of the shock stressing the coping strategies, and may be overwhelming, making coping success range from probable to very poor.
Sudden	Sudden exposure from shock scenarios when forewarning is not possible, fundamentally limiting the effectiveness of coping strategies with both response and recovery plans due an inability to be forewarned, prepared and to mitigate the possible consequences.
Rapid	Rapid exposure from shock scenarios when the onset of the shock is so quick as to fundamentally limit the effectiveness of coping strategies with both response and recovery plans due an inability to have time for preparation and mitigation of the possible consequences.
Disastrous	Disastrous exposure from shock scenarios giving catastrophic effects of mass destruction, loss of life and/or environmental devastation, far beyond what is possible to respond to or recover from, whatever coping strategies and capability may be available.

Table 1.
Generic categories of societal hazard-shock scenarios.

be essentially successful against its business continuity plans, as well as complying with CCA duties described in the Act and Regulations [7, 8].

It is generally accepted that responders will need to adopt a structured and systematic risk assessment process that guides the requirements for incident and emergency response. The intention being to achieve a sound and well organised response in the event accidents and disasters jeopardise the safety and well-being of the public. The risk from civil emergencies is usually assessed by standardised risk assessment [28], merged with long standing experience of responding to accidents and disasters [10, 11, 16–18, 21, 22, 29], as summarised below:

- **Contextualisation.** Identify stakeholders, process evaluation criteria and the principles to be used during the risk identification. Describe and understand the characteristics of the area (e.g. social, environmental, infrastructure and hazardous-substance sites).

- **Identification of the hazards.** For the range of hazard-shocks identified, to apply an allocation scheme for mobilisation across the Category 1 responders and their particular operational remit in the regional areas.

- **Risk analysis.** The principal responders for each hazard-shock should consider the risk likelihood, but also the time and spatial conditions of the hazard-shock's impact relative to the public at risk.

- **Risk evaluation.** The collective risk profile needs to be collated in terms of the likelihood and impact assessments for each hazard-shock, encompassing the range of hazard-shock scenarios that are believed to be of concern. Evaluating the significance of the hazard's impact is important in terms of the necessary preparedness and resources that will be needed to successfully respond and cope with any unfolding accidents or disaster.

- **Risk treatment.** Responding to hazard-shocks needs to be prioritised for action with the necessary risk reduction measures. This also means that there should be an awareness of the potential limitations and gaps in responder's coping capability and capacity. The awareness should be realistic and practical as to what can, and cannot be done.

- **Monitor and review.** Irrespective of the commitment and effort afforded to incident and emergency response plans, the analyses and modelling work done to direct the plans will retain some degree of theoretical simplifications and assumptions. Surveillance and monitoring of actual hands-on exercises provides insight and practical awareness that can then be used for continuous improvement, adjusting for incorrect initial assumptions, together with limited or inadequate coping capability issues.

The basic risk assessment approach [28] amounts to a pragmatic methodology that mates probability and consequence of an accident or disaster to gauge the imperative for defensive measures. Civil contingency responders are familiar with this approach, while unquestionably useful for immediate decision making at the time of initial attendance as well. However, previously derived regional and national risk registers can become outdated and invalid as time goes by, and this will likely be a significant issue with fast rate climate change on our socio-technical system.

In addition, basic risk assessment does not readily allow for verification or validation of preparedness, response, recovery and coping strategy plans. In order to further understand the coping demand and manning burden placed on the emergency services and their response management, it is advised that a broader holistic approach should be considered; as introduced in this chapter. It is also important to account for the temporal time history of the accident/disaster scenario, encompassing the period before, during and after the hazard-shock scenario has impacted the exposed region.

The generic risk from hazard-shocks, as well as accounting for underlying regional stresses and vulnerabilities, should therefore be holistically considered from a socio-technical system perspective and accounting for the temporal characteristics of the hazard-shock scenarios, as identified in **Table 1**. It will be important to model the stress and shock incubation period, on-set and rate of impact, including the form of the response needed and subsequent recovery from the aftermath. Other key factors to be considered are:

- The initiating events may be man-made, natural, or a mixed combination;
- Severe to extreme initiating events are intrinsically varied and difficult to exactly define;
- Apply a more holistic mindset for analysis of hazard-shocks impacting a socio-technical system that is sensitive to long-term stresses;
- Initiating events, hazards, threats, stresses or shocks—all can progress and eventually escalate to dangerous risk and the necessity for attendance of the emergency services as first responders; and,
- To wisely discriminate between safety and security issues that can arise.

It is important to apply a wider holistic thought process that is able to model the time-history response that tries to mitigate the consequential risk, while better define the temporal progression through a hazard-shock scenario. Independent of the actual technical form of the hazard-shock scenario, it is important to characterise the type and degree of burden that will be made on the Category 1 and 2 responders, commensurate with the UK's Civil Contingencies obligation in the UK [7, 8].

The spectrum of hazard-shock scenarios identified in **Table 1** may be used as a generic basis for periodic review, testing, assessment and possibly in-depth analysis of coping capability. In addition, it should be helpful to better understand the future demand that is likely to be placed on the civil emergency management and their response manning burden. Irrespective of whether the hazard-shock is caused by events like earthquake, wind, flood, etc. from the emergency responder's viewpoint there will generally be certain hazard-shock characteristics that will impose varying scales of demand on the emergency facilities and their manning, together with the speed of mobilisation and distances to be travelled by the responders. To holistically assess our society's socio-technical vulnerability, accounting for impact scenarios that will risk [7, 8, 21, 22], the following key factors should be considered:

- Human habitation and its demographics;
- Community health and welfare;
- Social stability and resilience;

- Protection of the environment;
- Damage, failure and inundation of infrastructure;
- Disruption and loss of critical supply chains, and,
- Loss of economic fluidity.

The engineered fabric that is intrinsic of our urban and rural infrastructure also has the potential to be vulnerable and trigger yet greater danger as a forcing hazard-shock scenario gets more severe and distributed across a broader area. Emergent and additional dangers shall arise when the region exposed has co-located industrial, petro-chemical and nuclear plants. In this circumstance, what might be judged as just a regular or serious hazard-shock scenario, could readily escalate to a more onerous overwhelming and unpredictable situation, as indicated in **Table 1**, simply because of the emergence of other man-made dangers. Like what happened at Fukushima Daiichi in 2011 [1]. With the more onerous hazard-shock scenarios, cascade and domino failures will occur, thereby increasing the scale of demand on the civil emergency response, as accidents occur and the expanding disaster escalates.

In the UK, another set of regulations applies to major industrial and petro-chemical plants, being the Control of Major Accident Hazards Regulations (or COMAH) [6]. This regulation aims to prevent major accidents involving dangerous substances and limit the consequences of incidents to people and the environment. The COMAH regulations are overseen by the UK's Health and Safety Executive (HSE) and the Environment Agency (EA) and apply to organisations or sites such as chemical production facilities, warehouses or distribution centres that handle or store large quantities of hazardous substances.

For large COMAH sites, known as top-tier sites, the regulations stipulate the need for Public Information Zones (or PIZs) around the facility and its site. This is because public communities will exist in the region of the COMAH site, whether by coincidental residences, or personnel and their families that depend on jobs working at the sites. The owner organisations that operate the facilities are obligated under COMAH to provide information about:

- The potentially dangerous substances and how they may affect the adjacent community in the event of a major accident at the facility;
- The policy and strategy for protecting the public, together with the particular safety measures that are established;
- How the public shall be warned and kept informed about a major incident and escalating accident situation; and,
- The recommended protective actions that the public and the local community should carry out to remain safe.

During an incident that requires the mobilisation of the emergency services and other civil contingency agencies, then it becomes imperative that the relevant COMAH owner-operators are also part of the response and recovery planning. In addition, the local/regional government, together with the wider residential public and local community volunteers must be engaged and coordinated with in order to successfully cope with every unfolding danger. The possible consequences for poor coping could be:

- Death and serious harm;
- The need for mass evacuation;
- Damage and collapse of property and buildings;
- Chemo-toxic pollution of the environment and water courses;
- Disruption and curtailment of business and economic prosperity; and,
- Possible collateral and cascading danger to other facilities and critical infrastructure beyond the original response zone.

Development of coping strategies with preparedness plans that form the basis for the coping strategy will also need to consider evolving stresses that will amplify a risk's consequence, including generic stress problems like:

- Increased population density;
- Challenges to economic prosperity;
- Uncontrolled pollution and waste;
- Lessening natural resources;
- Climate change effects and amplification of consequences;
- Reduced land caused by global sea rise;
- More devastating natural storms;
- Aggravated man-made threats—criminal and terrorist;
- Human conflict and wars;
- Public unrest, fear & mistrust; and,
- Lack of government and political clarity without a will to be proactive.

3. Subjective review of civil emergency coping capability

Here we will introduce a pragmatic civil emergency response review process that tests if the coping strategy and preparedness plan is realistic and viable. The intent of this coping review process is to subjectively assess an emergency response organisation's ability to cope with a wide range of future hazard-shock scenarios, impacting the socio-technical system and potentially causing a danger to life, see **Figure 1**. The range of generic societal hazard-shock scenarios advocated in this review process are introduced in **Table 1**, encompassing Regular, Serious, Overwhelming, Unpredictable, Sudden, Rapid and Disastrous; as introduced earlier in this chapter.

Broken out into three parts as a staged pathway, the review process is framed on three hierarchy levels—representing (i) generic, (ii) specific and (iii) regional investigation. This subjective approach is essentially an expert qualification of the overall coping capability through the complete civil emergency coping cycle (as depicted in **Figure 4**). The skeletal basis of the coping capability review and assessment process is provided here, setting out a benchmark template for staged discussion, involving particular review of stakeholder agreements and practical readiness for implementation.

It is likely that emergency responders should be able to assimilate their own past experience and future concerns for particular hazard-shocks that should fairly correlate with each generic category of the hazard-shock scenarios identified in **Table 1**. The key objective here is being to better understand what the responders can, and cannot do realistically, then to establish improvements with supplemental countermeasures.

3.1 Generic coping capability review mindset and scope

- This generic coping capability review should be of benefit to national governments, national medical organisations, leaders of the civil emergency services, insurance and tort liability-legal groups.

- Firstly, benchmark the basis of the coping capability review for the emergency response organisation by accounting for the complete range of generic categories of societal hazard-shock scenarios, as identified in **Table 1**. Effectively to 'stretch' the civil emergency coping strategy with its preparedness, response and recovery planning.

- The full scope of the coping capability review should investigate each category of societal hazard-shock scenario, one by one, starting from the 'Regular' (or normal) state, and then progressively investigating each category of societal hazard-shock scenarios, benchmarked with **Table 1**.

- Define the key review outputs needed to determine the organisation's overall coping capability for each societal hazard-shock scenario category from **Table 1**.

- Check that the review's resulting conclusions conform and comply with governmental and legal obligations, like with the UK's CCA and COMAH obligations [6–8] {while other countries will have similar civil emergency obligations}.

- Identify and include in the review process all relevant corporate and regional emergency response expertise.

- Identify and agree important interfaces between organisations and particular responder roles to participate in the coping capability review process.

- Agree other parties judged to be relevant for the benchmark hazard-shock scenarios who need to participate in the review process.

- Ensure the key stakeholders are engaged in the review process, while recognising direct and indirect organisations that will be part of the coping strategy and its preparedness (before), response(during) and recovery (after) the hazard-shock events.

- Formulate the benchmark hazard-shock scenarios that need to be progressed in the coping capability review, guided by **Table 1**.

- Clearly define the hazard-shock scenario time-history predictions to be appraised during the review, accounting for forcing magnitude, time of activities, rate of impact and sensitivity, and the spatial distribution across the affected area.

- Capture and document the generic review results of the civil emergency coping strategy, then preparedness, response and recovery plans.

- Review and consider the effectiveness and efficiency of the civil emergency coping strategy, preparedness, response and recovery plans to an exposed region.

- Establish the temporal hazard-shock scenario time-history demand placed on responders, starting from initial warning alarm, response mobilisation, through to final stand-down, while accounting for manning fatigue, tiredness and even mental post-event disorders.

- Provide prior coping capability review documentation packs to all participating groups and parties.

- Carry out the coping capability review by officially documenting all inputs and outputs, while making sure that no security protocols are undermined or bypassed.

3.2 Specific coping capability assessment and scope

- This specific coping capability review should be of benefit to local government, councils, police, fire service, ambulance, hospitals, critical infrastructure owner-operators, and the principal service and supply sector organisations—see **Figure 5**.

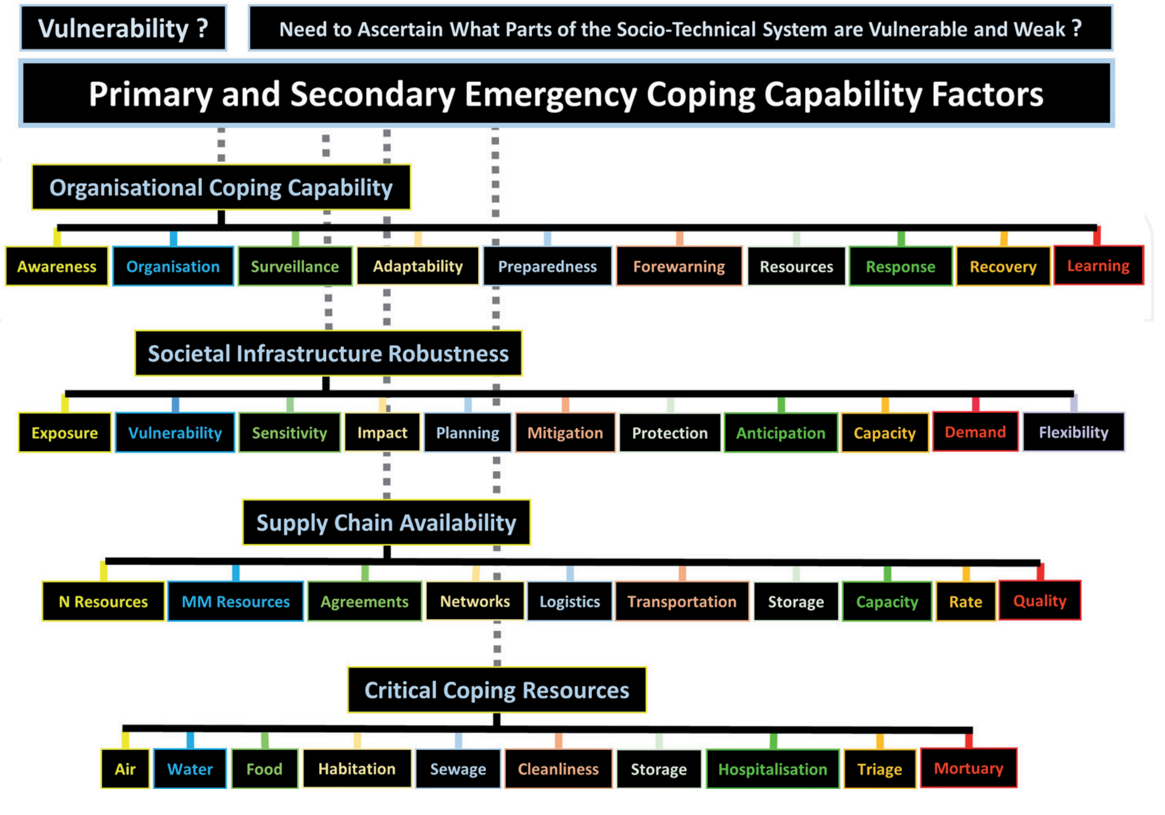


Figure 5.
Identifying important emergency coping capability factors.

- Establishing the key inputs and outputs that enable the specific coping capability assessment, and in readiness for validation of the regional response plans.
- Capture the basic holistic picture of the socio-technical components, including the structural and non-structural parts, including:
  - Physical fabric;
  - Buildings;
  - Facilities;
  - Infrastructure;
  - Networks;
  - Services;
  - Human demography;
  - Social structure;
  - Natural resources;
  - Economic and business-jobs; and,
  - Safety and security measures.
- Ensure the specific coping capability assessment process to take key account of impact the particular loss / emergent danger consequences, including:
  - Human life;
  - Community health and welfare;
  - Presence of industrial, petro-chemical and nuclear sites;
    i. Accounting for their respective dangerous substances, release and pathways;
  - Chemo-toxic releases;
  - Public evacuation;
  - Safe havens;
  - Societal reconstruction;
  - Contaminated land;
  - Remediation actions;

- ○ Rehabilitation practicalities;
- ○ Future sustainability (especially considering climate change and populous growth);
- ○ Social stability and resilience;
- ○ Protection of the environment;
- ○ Damage, failure and inundation of infrastructure;
- ○ Disruption and loss of critical supply chains; and,
- ○ Loss of economic fluidity.

- Establish specific definitions and criteria for regional socio-technical vulnerability, weaknesses, failure and loss parameters.
- Simplify shock/hazard/threat incident response coping capability into four mobilisation sectors, in order to cross-reference the fundamental organisational and socio-technical system, while the preliminary focus points (**Figures 5** and **6**) are advised to look at the:
  - ○ Organisational coping capability;
  - ○ Societal infrastructure robustness;

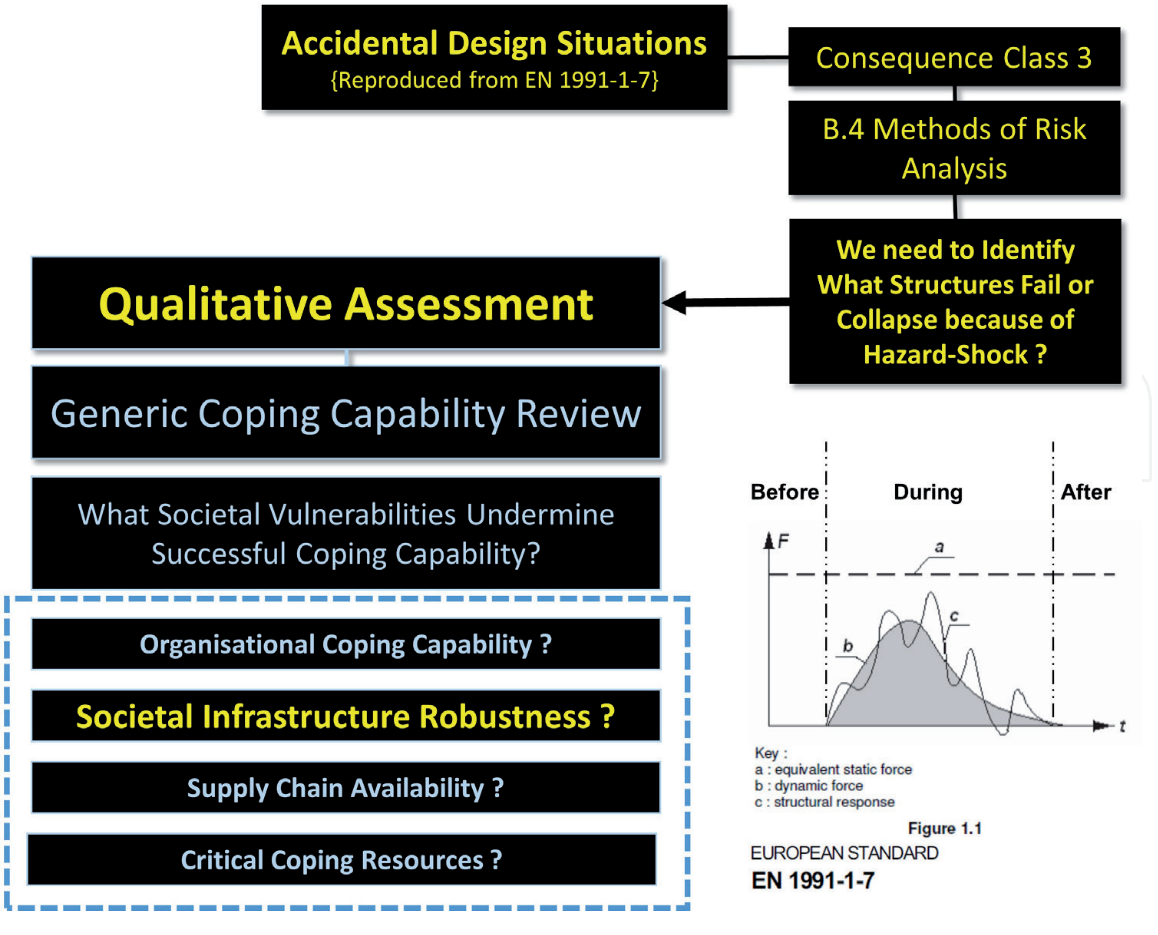


Figure 6.
Using existing structural (EN) standard to assess risk vulnerability.

  - Supply chain availability; and,
  - Civil contingency preparedness, response and recovery plans with the coping objectives.

- Progress through the temporal hazard-shock scenario timeline in terms of the emergency organisation's coping capability to perform and succeed with their civil contingency plans and objectives.

- To tally and interrelate the four fundamental organisational and socio-technical provision of the infrastructure, supply chains and critical coping resources needed for civil contingency preparedness, response and recovery plans/coping strategies, see **Figures 4** and **5**.

- Consider goodness of the specific coping capability, set against the specific standards and requirements that need to be achieved.

3.3 Regional (and local) validation of the coping capability

- This regional validation is essentially designed for actual 'hands-on' practice responders themselves, providing the benefit of their particular regional knowledge and expertise.

- Present to regional (and local) civil emergency response management and the official role holders the generic and specific coping capability assessment, referenced through the coping cycle in terms of the preparedness, response and recovery plans.

- Constructively engage with regional (and local) manager(s) and role holders, accounting for their regional (and local) feedback and advice, capturing any omissions, concerns or errors that may exist with the generic and specific coping strategy.

- Identify and collate recommended improvements to the emergency coping strategy and planning package, while also merging the regional feedback and advice—thereby gaining collective endorsement throughout the organisations and actors, at high generic level, specific technical and with the regional/local practitioners.

- Compile a Coping Capability Status Report for collective vision and feedback commentary.

- Revise the Coping Capability Status Report into a standardised report structure, including a live lessons learned section to enable future management improvement.

- Distribute the Coping Capability Status Report to all participants and indirect stakeholders.

- Regularly monitor and ascertain variations of significance that need to be addressed, while establishing a regular periodic review and Coping Capability Status Update.

4. Can the infrastructure stand up and functionally survive?

The scale of future hazard-shock born disasters is set to become much more onerous; in certain cases likely to be far beyond what our present existing fabric can tolerate and withstand. A region's basic resources must be adequate, fit for purpose and not diminish to zero during the hazard-shock's impact or its aftermath, otherwise the ability to cope be degraded and become ineffective. For example, it will be important to continue the provision of essential services and supplies in order to maintain the well-being and safety of the residents throughout the response and recovery phases, see **Figures 4** and **5**. Otherwise the residents shall have to be evacuated and relocated to a better position. However, evacuation may be extremely difficult to physically do, or not quick enough to accomplish within a safe time window, or simply impossible without clear and safe egress routes.

It is advised that a much more holistic approach is taken to analyse the significance of future emerging risks that can jeopardise our societal infrastructure, services, supplies and networks. Coping capability reviews are advised to consider the hazard-shock scenarios identified in **Table 1**. The coping capability review should encompass a much broader perspective of hazard-shock scenario consequences, including better understanding as to whether future hazard-shock scenarios cause cascade and domino failures of coping-critical buildings and infrastructure. In addition, there is a need to ascertain if safety-critical facilities and their adjacent emergency services can cope with ever larger scale distributed hazard-shocks amplified by climate change effects. The vulnerability of the socio-technical buildings and infrastructure needs to be better understood and recognised in the coping capability modelling, see **Figure 6**.

Different hazard-shock scenarios (as benchmarked in **Table 1**) will produce varying effects and consequences, dependent on the specific vulnerabilities that exist within the region's socio-technical system. Therefore, in the event that a severe to extreme natural hazard impacts a vulnerable region, exposing the societal fabric and residents to danger, the capability and capacity to (i) tolerate, (ii) withstand, (iii) absorb, or alternatively, (iv) break and fail to resist the hazard-shock's impact energy needs to be recognised, understood and assessed.

Let us now look for respected guidance that can help us to determine the robustness of our society's fabric and infrastructure. The European Standard EN 1991-1-7 becomes a useful guidance tool [30], see **Figure 6**. EN 1991-1-7 defines robustness as:

'*the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error, without being damaged to an extent disproportionate to the original cause*'.

As advocated in EN1991-1-7 [30], the basic types of 'accident situations' that buildings need to be robust against includes:

- Natural hazards;
- Fire;
- Explosion;
- Impacts;
- Rail;

- Aircraft (with helicopter);
- Criminality;
- Terrorist threat;
- Other types of shocks and threats; as well as,
- Accounting for Inadequacies in the design and construction processes.

A wide distributed disaster together with man-made emergent dangers can put enormous pressure and demand on the local civil emergency responders, while severely stretching the effectiveness and efficiency of their coping strategy. This problem exists in regions exposed to very severe hazard-shocks that may also have industrial, petro-chemical and nuclear facilities sited there.

The accident at the Fukushima Daiichi nuclear power plant, in March 2011, demonstrated the need to explore scenarios in which external hazards that far exceed the original design basis of our as-built infrastructure. It became painfully apparent on the 11th March 2011 that we do not necessarily recognise or model what can happen beyond the design basis of our man-made infrastructure.

The fundamental problem here is that we could be ill prepared and inefficient in our attempt to have in place the appropriate civil emergency arrangements, while ultimately running the risk of not being able to effectively mitigate the consequences, nor cope with the longer-term recovery from the accident's aftermath. Due to the accident at Fukushima Daiichi nuclear power plant [1], the International Atomic Energy Agency (IAEA) decided to revise their guidance for nuclear power plant hazard-shock assessment. As a result of this effort, in 2017, the IAEA published an updated methodology for the vulnerability assessment of nuclear operating facilities subject to extreme external hazard-shock events, [31].

The types of specific hazard-shocks that would usually be identified for vulnerability assessment of an individual operating nuclear power plant using the IAEA's approach [31], are:

- Earthquake;
- High winds;
- Tornado;
- Abrasive windstorm;
- Hail;
- Lightning;
- Flood;
- Civil-ground instability;
- Extreme temperature;
- Volcanism;
- External fire;

- Explosion;
- Aircraft crash;
- Ship/barge impact;
- Collisions;
- Electromagnetic interference;
- Chemo-toxic release; and,
- Extra-terrestrial impact.

The philosophy used in [31] is to determine the strength of the hazards that could compromise safety, while trying to identify points of weakness in the man-made engineering. This methodology is intended to be used for existing nuclear power plants in their 'as-is' condition around the world, while the logic of the approach may readily be extended to encompass the regional infrastructure that is important for coping capability, see **Figures 5** and **6**. The IAEA guidance therefore provides advice to nuclear operators to search out any cliff edge effects that could escalate into a disaster situation as a result of extreme hazard-shocks impacting the nuclear facility [31]. In addition, the IAEA guidance advises on assessing the time frame of a nuclear power plant response once extreme events cause the more vulnerable items to fail. This vulnerability assessment process advocated by the IAEA [31] was formulated to achieve consistent and reproducible results.

Vulnerability assessment should be performed for events that are physically possible, even if they are thought to be of a very low probability and would have previously been screened out of the assessment scope. The intent here is to eliminate the possibility of screening-out a hazard from the very beginning on the basis of a frequency of occurrence which has been obtained with a large uncertainty, or (unknowingly) from incomplete or outdated information.

Similar to the European Standard EN 1991-1-7 mentioned previously [30], the IAEA's assessment methodology [31], allows for evolution of a harmonised approach to better understand what vulnerabilities exist in the man-made parts of our socio-technical fabric. Resulting conclusions about the vulnerability of regional industrial, petro-chemical and nuclear facilities that can cause a cascade of numerous emergent dangers may then be investigated for sensitivity against the generic, specific and regional civil emergency arrangements, including the overall effectiveness and efficiency of the coping strategy.

5. Objective approach to quantify coping capability

From this discussion it becomes a reasonable argument that we need to ascertain if, and how our society will be able to cope with future hazard-shock scenarios of the types identified in **Table 1**, and the increasing threat that climate change amplification introduces to escalate the scale of destructive mass consequence. Of particular importance is the need to determine if regional/local civil emergency services can cope with larger scale distributed hazard-shock triggered events, having an ever increasing severity and consequence driven by climate change.

In concept there is a limiting threshold to the capability and success of civil emergency response; this being evident with massive wildfires across South

America and Australia linked with drought conditions and climate change in 2019. It is therefore suggested that quantifying the scale of future emergent hazard-shock scenarios against the available civil emergency response capability is becoming a crucial issue that needs to be addressed with urgency.

Let us now investigate a new way of how we can model and quantify hazard-shock scenarios in terms of coping capability. The logic applied here is referenced against the overall coping capability through the complete 'Hazard-Shock Emergency Coping Cycle', see **Figure 4**.

An objective analysis can be pursued by applying the particular quantitative criteria and parameters that use relevant technical dimensions and data that is able to scale the hazard-shock preparedness, response and recovery burden—before, during and after the hazard-shock event. The deterministic parameters applied in this coping capability model have intentionally been formulated in order to ascertain the scale of demand placed on the civil emergency response organisations as they carry out their response and recovery tasks. The model formulation generically accounts for the hazard-shock's impact effect in terms of particular quantities that relate to magnitude, time, rate and space values, now using quantitative criteria and modelling parameters, as opposed to requiring expert qualitative peer judgement.

This objective analysis approach uses a phased temporal equation, progressing before, during and after any civil emergency response for a particular hazard-shock scenario [25–27], described in summary by a temporal series model using three sequential data matrices, (see **Table 2**):

- **Before** the hazard-shock event—$[P_{rB}].[H_B].[E_P].[Z_P].[D_P].[F_O]$;
- **During** the hazard-shock event—$[P_{rD}].[H_D].[V_D].[T_D].[S_D].[R_D]$;
- **After** the hazard-shock event—$[P_{rA}].[H_A].[V_A].[T_A].[S_A].[R_A]$.

Two forms of criteria are included for objective modelling, encompassing both probabilistic and deterministic mindsets, thereby allowing for integration and correlation with recognised vulnerability and risk assessment methods [28–31].

A simple summary of the model is provided in **Table 2** that outlines the 'Emergency Coping Cycle Data Matrix with Criteria and Parameters'. An important point to raise is that the model is not meant to be an exactly rigid and solvable equation or algorithm, but has been developed to reflect an interrelated series of period-demarcated matrices that conceptually simulate the hazard-shock's progressive time-history (simply thought of as being before, during and after in **Figure 1**).

The Emergency Coping Cycle Data Matrix was simply derived by considering the actual temporal sequence of an extreme hazard-shock event, while investigating the impact it has on a community and the capability of the emergency response

Mobilised action	Cycle period	Coping cycle matrix data parameters
Preparedness	Before	$[P_{rB}]. [H_B]. [E_P]. [Z_P]. [D_P]. [F_O]$
Response	During	$[P_{rD}]. [H_D]. [V_D]. [T_D]. [S_D]. [R_D]$
Recovery	After	$[P_{rA}]. [H_A]. [V_A]. [T_A]. [S_A]. [R_A]$
Qualification by experience	Quantification by data matrices	

Table 2.
Emergency coping cycle modelling criteria and parameters.

and recovery organisations to successfully cope. Using this approach, we are able to follow the temporal time-history of a particular hazard-shock's impact against the socio-technical system. We gain insight on what loss and damage occurs, the dangers that the emergency services face, as well gaining insight on how well the emergency/disaster coping strategy and its planning performs—essentially being a predictive coping capability *stress-test*.

Tables 2–5 define how the Emergency Coping Cycle Data Matrix is quantitatively represented by a temporal series data matrix. It is not an exact numerical algorithm, nor was meant to be, yet provides a reasonably intuitive model idealisation that simulates the hazard-shock temporal cycle, while employing both deterministic and probabilistic mindsets. This modelling approach now enables us to utilise powerful computing platforms that are able crunch data with relative ease, making analysis of structured masses of data a reality. The Emergency Coping Cycle Data Matrix is essentially a pre-formed structure of data blocks that enable us to question and even test accident and disaster coping strategies and their more detailed planning, underpinned by data-modelling of the type proposed here. Of particular significance will be the ability to perform iterative sensitivity studies when the criteria and parameters are varied. This also gives us the ability to optimise the coping strategy for its effectiveness and efficiency, and indicating credible risk reduction measures throughout the coping cycle.

A natural hazard event can exert an enormous force causing destruction of the built infrastructure and the resident living beings. Be it the rumble of the lower earth we stand on, a torrent of unstoppable water, the caustic suffocation and incineration by volcanic pyroclastic flow, or the seemingly explosive effect caused

Parameter	Description
P_{rB}	This parameter has two states, being (i) from past records, and (ii) future prediction with factors like climate change amplification. State (i) is the historical frequency of the collective range of severe to extreme hazard-shocks that the socio-technical system has experienced over recorded time and with 'smoking-gun' evidence. State (ii) is the predicted future collective frequency taking account of climate change amplification effects. Effectively this P_{rB} value is indicating how many times the socio-technical system/region will be exposed to hazard-shocks when the emergency responders are mobilised per year, decade and century. {It is important to also realise that the value of PrB also correlates to how frequent the civil emergency strategies and plans shall likely be executed, then informing how much demand and manning burden needs to be catered for}.
H_B	Characterisation of the hazard-shocks in terms of technical specifiers including hazard-shock the magnitude energy, impact time, rate of onset and spatial distribution of the severe to extreme hazard-shocks scenarios. {Please also refer to **Table 1** that indicates the various 'Generic Categories of Societal Hazard-Shock Scenarios', thereby indicating the demand placed on civil emergency responders}.
E_P	Exposure potential of the socio-technical system in terms of location, geography, geomorphology, human demography, population density, medical wellbeing, economic worth, resilience and sustainability, etc. {effectively describes the regional community's exposure potential in terms of loss consequences}.
Z_P	Socio-technical fabric of the region in terms of buildings, facilities, infrastructure, services, supplies, networks, plants and processes; accounting for the age and condition of the fabric.
D_P	Potential for emergent dangers to life and environment that may be triggered by hazard-shock events, covering petro-chemical processes and storage, nuclear power plants, etc.
F_O	Account of whether forewarning that the hazard-shock event is to come and how much time is likely to be available for preparation, shelter, evacuations, etc.

Table 3.
Emergency preparedness coping cycle parameters before Hazard-shock starts.

Parameter	Description
P_{rD}	Probability of success that the emergency response organisation shall be able to perform their duties for a specific character of a hazard-shock, while maintaining a flexible and adaptive capacity.
H_D	Hazards that shall be experienced by the emergency response organisation and its personnel during the hazard-shock event (not the hazard-shock itself); therefore needing to consider HAZOP review and assessment to protect personnel and enhance success for coping.
V_D	Recognised vulnerability of the region's socio-technical system against the specific hazard-shock being assessed, accounting for the (i) socio-technical fabric (Z_P), and (ii) potential emergent dangers (D_P) that can make the emergency response difficult.
T_D	Period of time for which the emergency response organisation shall be mobilised and required to continue doing their response duties for the specific character of the hazard-shock.
S_D	Spatial area that the emergency response organisation shall be required to operate in order to do their response duties for the specific character of the hazard-shock being analysed.
R_D	Primary and secondary resources that the emergency response organisation shall likely need in order to be flexible and adaptive, while also being dependent on the vulnerability of the region's socio-technical system, accounting for the (i) socio-technical fabric (Z_P), and (ii) potential emergent dangers (D_P) that can make the emergency response difficult.

Table 4.
Emergency response coping cycle parameters during hazard-shock impact.

Parameter	Description
P_{rA}	Probability of success that the emergency recovery organisation shall be able to perform their duties after the hazard-shock has passed and in the aftermath period, while maintaining a flexible and adaptive capacity.
H_A	Hazards that shall be experienced by the emergency recovery organisation and its personnel after the hazard-shock has passed and in the aftermath period; therefore needing to consider HAZOP review and assessment to protect personnel and enhance success for coping.
V_A	Recognised vulnerability of the region's socio-technical system against the specific hazard-shock being assessed, accounting for the (i) socio-technical fabric (Z_P), and (ii) potential emergent dangers (D_P) that can make the emergency recovery difficult.
T_A	Period of time for which the emergency recovery organisation shall be mobilised and required to continue doing their recovery duties for the specific character of the hazard-shock and its resultant aftermath across the socio-technical system/region.
S_A	Spatial area that the emergency recovery organisation shall be required to operate in order to do their recovery duties for the specific character of the hazard-shock being analysed.
R_A	Primary and secondary resources that the emergency recovery organisation shall likely need in order to be flexible and adaptive, dependent on the conditional aftermath that is likely to exist, while also accounting remaining dangers that can make the emergency recovery difficult.

Table 5.
Emergency recovery coping cycle parameters after hazard-shock has passed.

by extreme velocity winds from a wide hurricane/typhoon and localised tornado. The energy from these kinds of natural hazard events is released suddenly and can be without forewarning, as in the case of slippage along a fault in the earth's crust, or slowly as in the case of land subsidence.

A significant consideration is that a concentrated amount of energy is impacted over a short-time duration, and can be distributed over a massive surface area of land that includes urban and rural regions. The difference in natural hazard energy impact rate and its relative magnitude characterises the degree of destruction and overall loss that can occur. The degree of danger is dictated by the amount of energy released at a particular rate and over the hazard's duration period of exposure against the socio-technical system.

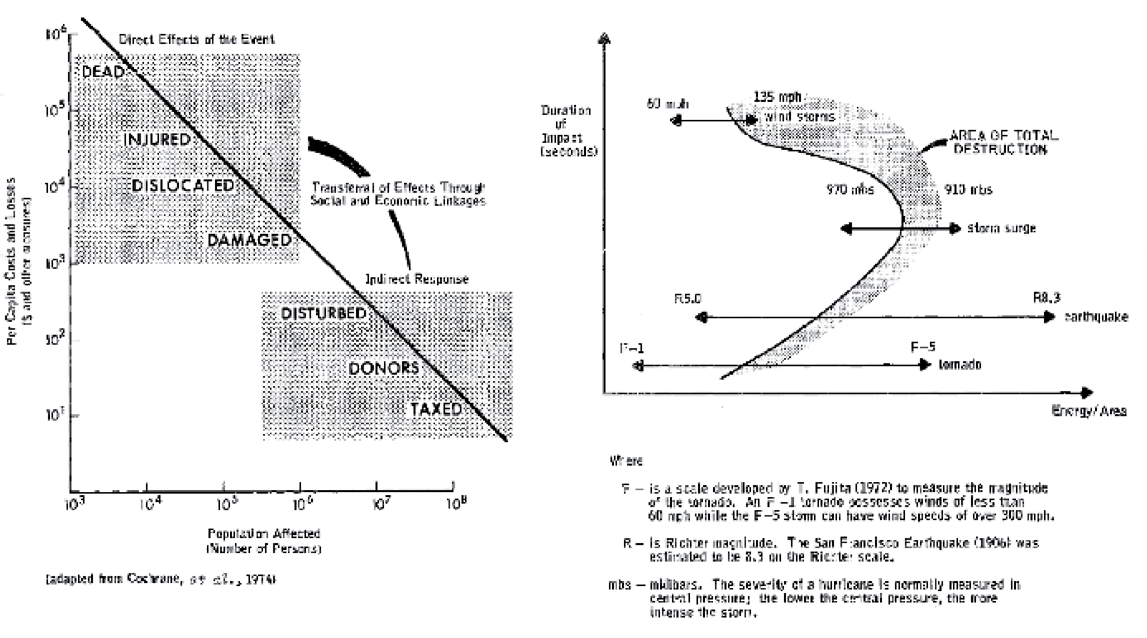
The relative robustness of the infrastructure's fabric as it is exposed to the impacting energy of the natural hazard determines whether buildings will survive or collapse, whether man's power networks keep people's homes supplied, if the road, rail and air routes can be used to supply products, and whether food supplies can get to supermarkets.

Now referring to **Tables 2–5**, the parameters 'H_D' and 'T_D', during the hazard's impact period was specifically developed in order to consider and account for the amount of hazard energy and its rate of impact. The collection of parameters grouped within the three phases of the hazard event scenario, (that is before, during and after), allow for finding characteristic relationships and trends that might otherwise be missed. For example, the ratio of $\{H_D/T_D\}$ gives us a resultant quantitative value to indicate that hazard's magnitude compared to the elapsed time period to cause damage, which may then be graphically plotted to ascertain the likely destructive potential and loss of life for a particular region and area of interest.

Looking at **Figure 7** {that is respectfully reproduced from Cochrane's work [11]}, and **Figures 8–10**, we see that Cochrane's 1975 modelling of 'Natural Hazards and their Distributive Effects', [11], may now be correlated with the present chapter's model for Emergency Coping Cycle Modelling Criteria and Parameters, **Tables 2–5**, first introduced by the author in 2016 [25–27].

The parameter Z_P that is integral of the preparedness criteria, before the hazard-shock event occurs, see **Tables 2** and **3**, is meant to represent the day to day demographic, economic and structural state of the region's socio-technical system; including recognition of the region's specific organisational readiness provided by the local civil contingency groups, whether professional or voluntary, which is of prime importance to the region's urban and rural resilience.

The generic breakdown of the components contained in the parameter Z_P, as identified in **Tables 2** and **3**, may be defined as follows:



Reproduced from "Natural Hazards and their Distributive Effects", by Harold C. Cochrane, Institute of Behavioral Science, The University of Colorado, 1975; [1].

Figure 7.
Early 1975 consequence study on the impact of natural hazards.

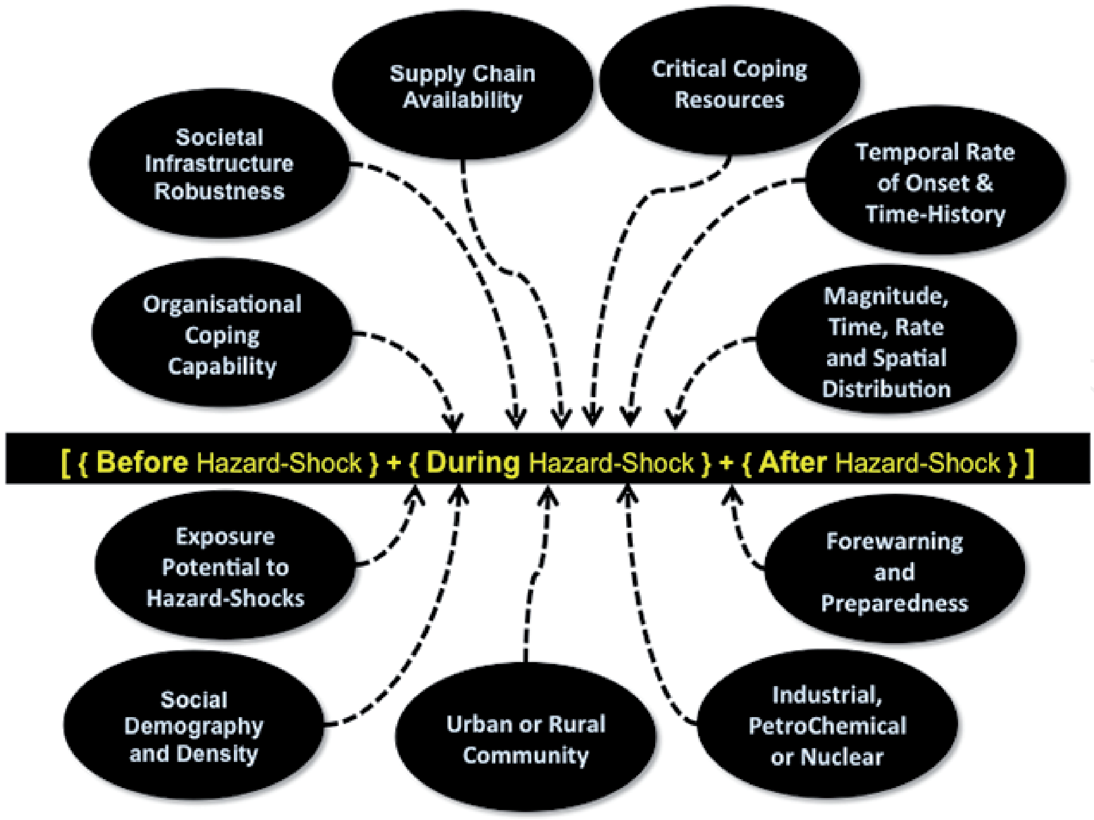


Figure 8.
Key information input data for analysis of emergency coping cycle.

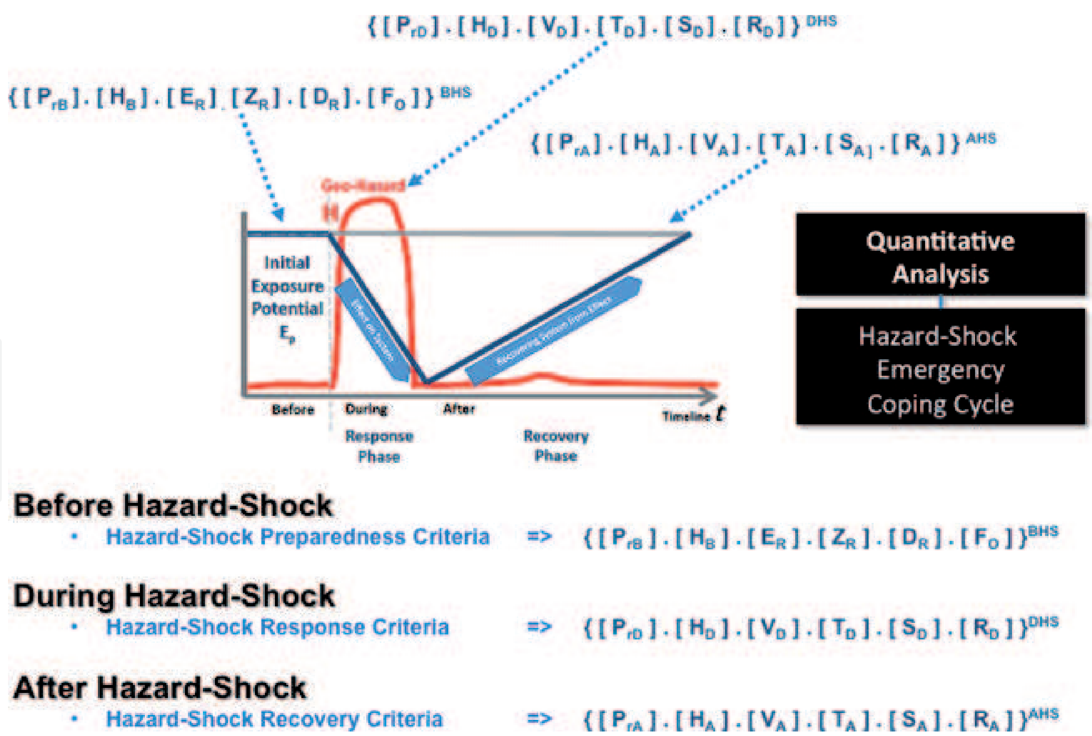


Figure 9.
Developmental basis of the emergency coping cycle data matrix.

- Organisational preparedness strategy and planning to achieve coping capability;
- Robustness of the buildings, communications, transport, networks and services;

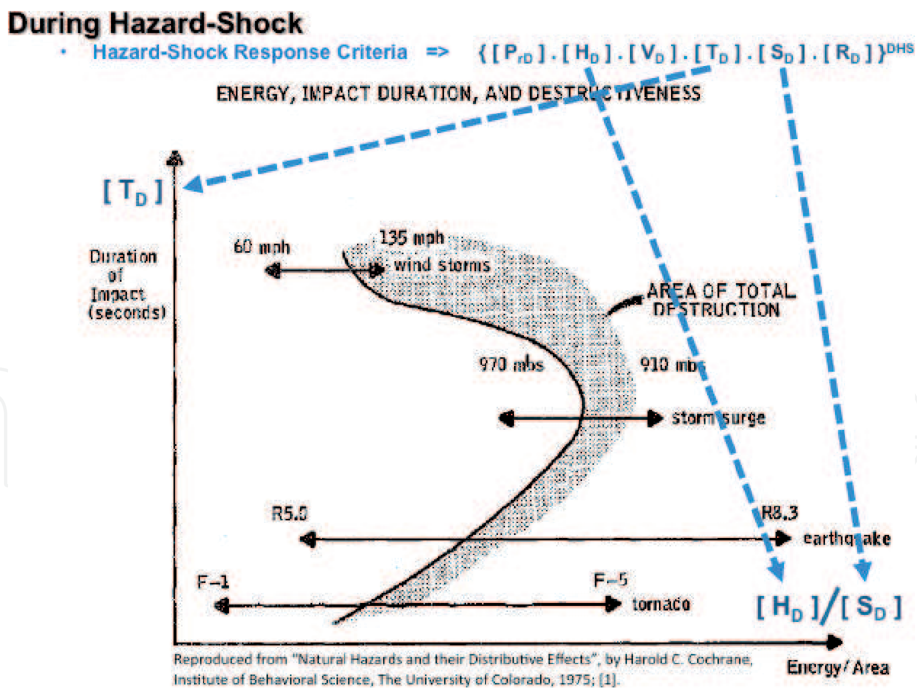


Figure 10.
Emergency coping cycle data matrix correlated with 1975 study [1].

- Availability of supply chains, especially those significant to resilience;
- Immediately ready and locally accessible critical coping resources;
- Urban and rural population densities and their spatial distribution;
- Integrity of governmental agreements, leading actors, policy makers and police.

In this instance the coping success probabilities indicated in **Table 2**, specifically P_{rD} (during the hazard-shock impact phase) and P_{rA} (after the hazard-shock impact and during the aftermath recovery phase), will result in a combined low probability of *coping success* by the civil emergency services. Hence, a probabilistic mindset for successfully coping is applied; the probabilities of P_{rD} and P_{rA} quantitatively indicate the likelihood of successfully performing the civil emergency coping activities at two periods in time:

- During the hazard-shock scenario; and,
- After the hazard-shock, with the consequential aftermath.

The similarity to hazard risk assessment [28] in terms of using the probabilistic mindset now becomes apparent, although the new Emergency Coping Cycle Data Matrix introduced in this chapter is focused on achieving *coping success*. The differentiator here being that we are trying to model the likelihood for successfully being able to cope with the impacting hazard-shock scenario. This approach enables a more rigorous appraisal of the effectiveness for coping with civil emergencies, while also being able to set objective success targets for the civil contingency management [7, 8, 13, 15, 25–27, 29] to defend society against severe and extreme hazard-shock scenarios scoped in **Table 1**.

The region's socio-technical system vulnerability allied with its organisational emergency strategy and planning is thereby being holistically tested in relation to the necessary temporal hazard-shock coping capability. And using the theoretical benchmark phases from before, to during, then after the hazard-shock impact time history, we may then (i) qualitatively assess and (ii) quantitatively analyse the success of being able to cope.

The means to provide better preparedness against hazard-shocks is initially reflected with the factor Z_P, see **Table 3**. Hence, the more likely will the success of coping be when the necessary resources during (R_D) and after (R_A) the impact event are conservatively adequate and fit for purpose, see **Tables 4** and **5**. If a preliminary coping success assessment or analysis of a region indicates that the holistic resilience of the socio-technical locality is poor, and that the required resources through the hazard-shock time history will not be available or effective, the coping capability shortfalls can be found and considered for improvement. This method should enhance coping capability and attain better risk reduction.

For 'Regular' shock scenarios advocated in **Table 1**, then the coping success probabilities of P_{rD} and P_{rA} should both be close or equal to 1. But when the shock is equivalent to an 'Overwhelming' scenario, then P_{rD} and P_{rA} will each be less—potentially below 50% chance of coping success; giving an overall product of P_{rD} times $P_{rA} = 0.5 \times 0.5 = 0.25$, or only 25% chance of coping success.

Worst of all, for a theoretical shock event that could equate to a 'Disastrous' scenario, both P_{rD} and P_{rA} will be very low indeed, no better than something like 10% for each factor; thereby resulting in an overall success for coping of the order P_{rD} times $P_{rA} = 0.1 \times 0.1 = 0.01$, or just 1% chance of coping success. [*Author's note—please keep in mind that these rough 'guestimates' are simply offered for clarification of the logic, as opposed to precise calculation that would need to be carried out in practice*].

Now let us consider the whole collection of factors that are introduced in **Table 1** from a deterministic perspective, encompassing the periods before, during and after the shock event. Starting with the factor Z_P, to the coping resources during the shock impact factored into R_D, and subsequently the resources needed to recover from the shock's aftermath with the factor R_A, are all key to gauging the complete scale of coping capability that is required for the preparedness, response and recovery activities.

We now realise that the actual real-world temporal relationship between the coping capability factors like Z_P, R_D and R_A are quite crucial in order to better understand how we might gain confidence that the organisational coping strategies and pre-plans are complete, suitable and sufficient. Essentially we can use this developmental model to test whether the emergency coping strategies and pre-plans are sound and reasonably efficient. And this form of coping capability test is flexible enough to allow for both deterministic and probabilistic viewpoints, as presented in **Tables 2–5**. Also, see **Figures 9** and **10** where we link with Cochrane's study of 1975 [11].

It is therefore advocated that the present coping capability modelling approach discussed here is amenable to further fruitful development by analysts, but here we shall concentrate purely on the logic and method of the Emergency Coping Cycle Data Matrix model. If this approach were found to be useful and of benefit to future socio-technical design and planning, in particular related to adaptation in the face of climate change effects, then the logic could be framed into a fairly simple best practice standard, similar in concept to the assessment process advocated by the subjective review of civil emergency protection earlier in Section 3. Such a standard 'template' could prove helpful in testing for consistency and continuity between different analysts, designers, planners and civil emergency services.

6. So what about climate change?

Even though James Hansen passionately appealed to the United States Senate in 1988 that global warming with resultant climate change was a distinct reality, evidenced by a sharp rise in global temperatures as a result of human activity, very little practical action has taken place to slow or correct this worrying trend in the last three decades. Global warming is now showing its *Disastrous* character (see **Table 1**) amplifying floods and wildfires as evidenced all across the world in 2019.

More recently, some scientists are becoming fearful that the usual expected hazards including earthquakes, tsunamis and volcanoes will also become more frequent with increased danger because of climate change effects. If such judgements turn out to be right, then it is expected that future natural hazards will become extremely destructive, including destruction of our built structures coinciding with mass fatality, to an extent our modern human society has not experienced in recorded times.

Our modern society uses ever greater power linked with population and industrial growth. Scientist's unofficially call this time the *Anthropocene Epoch*. We are set to have more massive and more powerful storms, greatly increased flooding, triggering major landslides, suffering with long droughts and spontaneous initiation of huge wildfires. Climate change is questioning our very survival, while civil emergency response organisations will likely have to cope with more demanding accidents and disasters.

Integral of a review and assessment process for civil contingency planning [7, 8] in the modern day is the need to properly account for an escalating stress due to climate change amplification. The stress from climate change is increasing the magnitude and frequency of natural hazard-shocks that the emergency responders will need to tackle, thereby implying that more regular periodic reviews shall be necessary to ensure that the national and regional civil contingency strategies are practicable and consistent with the range of generic societal hazard-shock scenarios.

This implies that weather born hazard-shocks which cause major impact damage with high consequence losses will be more frequent. In addition, emergency response organisations will be prone to a ratcheted rise in demand for their services, while also placing an ever-greater management and manning burden on the necessary scale and capacity to successfully respond. Therefore, if not appropriately scaled and timely to the task ahead of them, the emergency responder organisations will become less and less successful to perform their duty role.

Our society is now dense, complex and implicitly dependent on the structural fabric built up over the last few hundred years; especially in the more developed countries. And in many ways, a capitalist society also needs this type of tight interwoven society to be economically successful. The existing structural fabric was previously planned and evolved for basic function and efficiency, but without insight or account of the subsequent burden of industrialism to introduce global warming with deleterious climate change effects and dangers. In addition, if we consider the interconnected commodities trade and service networks that are used every day across the world to drive economic growth, it becomes apparent that our economy and society is potentially more vulnerable to shock-hazard scenarios that can cause massive-distributed consequences. Perrow recognised this problem of coupling and interaction of complex man-made systems allowing *normal accidents* to occur in 1984 [2].

It is therefore reasonable to judge that accidents will likely become more frequent and of greater consequential significance to disrupt the economy and to undermine the socio-technical system as a whole, in a world undergoing climate change. Our economy and wider society has an increased vulnerable to shock-hazard scenarios than ever before, resulting from denser populous, highly complex, interdependent fabric, then amplified by climate change effects.

Taking a very simple perspective, climate change causing global sea rise with additional flooding conditions will nullify and exceed past design margins of previously built defences, like with sea walls and levees. Future storms amplified by climate change are being projected to become so extreme and cause so much damage and destruction that communities and the societal infrastructure that provides service and supplies will need to recede back inland, see **Figures 2** and **3**. Dense populous merged with complex infrastructure at coastal-facing regions shall become extremely difficult to protect, **Figure 3**, even if forewarning of bad storm weather allows public evacuation.

A hot spell in the UK during February 2019, followed by a heatwave, contributed to almost 100 major wildfires, being the most ever recorded within a year. These wildfires occurred in Yorkshire, Cornwall, Dorset, Derbyshire, Northern Ireland, the Peak District, Rotherham, Wiltshire, Wales and the Highlands in Scotland. In the Autumn and early Winter of 2019, the UK experienced severe flooding events.

Our urban and rural society is becoming more vulnerable because of the conflicting stresses of our densely inter-dependent lifestyle and increasing climate change effects. A key lesson from the experience of Typhoon Hagibis that spread its fury over Japan in October 2019 was the unexpected cascading failure of Japan's seemingly modern infrastructure, services, supplies and networks. The resultant crisis was manifested by:

- Hospitals and medical care facilities being severely compromised;
- Petroleum and diesel fuel supply shortages;
- Inability to invoke emergency back-up power;
- Unavailability of water services;
- Transportation routes inhibited or just blocked;
- Supply chain distribution paralysis;
- Normal and even emergency communications network failure;
- Civil emergency services and volunteers being overwhelmed; and,
- Emergency services and other responders being overstretched and exhausted.

The scale of vulnerability is therefore sensitive to the dense coupling and interaction that is an intrinsic characteristic of our modern socio-technical society, first identified and questioned in 1984 by Charles Perrow [2], and having profound implications into the future with system failures, accidents, disasters and mass crises. More than 110,000 people were mobilised to perform search and rescue operations during and after Typhoon Hagibis. Australia is similarly experiencing a record heatwave with mammoth wildfire blazes in the latter part of 2019, scorching millions of hectares of land, over a thousand houses burnt down, numerous human fatalities, wildlife unable to survive and firefighters becoming exhausted without respite.

Governments and regional authorities will have to supplement standard risk assessment techniques with a wider consideration of societal resilience and infrastructure robustness. And this is becoming a tangible issue for not only lesser developed countries, but also for highly evolved countries like the UK. Protection against future accidents, and possible escalating disaster amplified by climate change effects, shall need to assess the risk, but also practically consider the adequacy of the emergency response coping capability, accounting for the overall temporal time of an accident or disaster—before, during and after. A much more efficient and effective civil emergency response capability is perceived to be of major imperative.

7. Why and what next?

None of us wish for accidents or disasters that evolve into crisis situations. None of us wish to die prematurely. None of us wish for our children, nor our children's children, to suffer because of our mistakes. Day to day in our normal, and usually happy lives, thinking about awful things is not nice. We all like to be content and free from danger. And businesses want to be positive, intrinsic of a growing and prosperous economy. In a responsible society, we try to instill a duty of care for ourselves and to others. We vote for our democratic governments in order for them to make decisions on our behalf, the public expectation being that governments shall maintain our well-being, safety and security now and into the future.

We do what we believe is right for the livelihood of our families, businesses account for things that can go wrong to affect their profitability, and governments are always looking towards the horizon for things that could happen to reduce their country's GDP, the signs of medical pandemics, together with unprovoked events like military and cyber-attack. The range of things that can go wrong are accounted for in a large company's risk register, and the CEO asks of their organisation and its management whether adequate protection and mitigation measures are in place.

But sometimes people take stark denial approaches to particular societal stresses, shocks and future emergent threats or hazards. If the public had their own risk register, what items would be mentioned? Premature death would most likely be the first priority mentioned, whether caused by a road accident or cancer, hence the need for a medical health service. The next item on the public risk register is likely to be unemployment that shall threaten their personal ability to pay the house bills and feed the family. Then a proportion of the public are going to indicate their concern for being flooded out of their homes, while the occurrence of fire is likely to be mentioned too. Hence the need for emergency services to quickly respond and protect the public in developed countries.

The practical reality is that different groups of people around the world will have a wide spectrum of risk concerns. People perceive and judge their own vulnerability in diverse and sometimes perplexing ways. Into the future we face the high probability (towards certainty) that we shall have to cope with the planet's usual natural hazards, combined with and amplified by, the increasing stress of global warming [18, 13–16].

Concerns for the earth's biosphere under the stress of human activity is not new. As early as the eighteenth century, Alexander Von Humboldt identified human kind's effect on the natural world [32], then George Perkins Marsh at the time of the American Civil War in 1863 [33] stated his concern. Other people—scientific researchers, public news outlets and even the youngest of our society, have consistently questioned the dilemma that exists with population growth, human consumption and a changing climate [10, 11, 13–16, 34].

A fundamental question facing human kind is whether our society will be able to cope with more onerous future stresses, shocks, hazards and threats into the future that can either cause accidents, or make them worse by amplifying the accident's effect and its aftermath consequences? This introduces the need to better model whether our existing preparedness, response and recovery plans and capability is in fact adequate against the hazard-shock scenarios that will impact us in the near future. The preparedness, response and recovery measures should therefore be properly modelled using quantitative criteria and parameters, specifically simulating hazard scenario's magnitude, time, rate and spatial dimensions.

Whatever the risk register may contain, the risk assessment methodology used to establish the risks does not indicate whether the emergency services with their duty responders will be able to do what is required, and whether they shall ultimately cope with the unravelling crisis. In essence, this chapter puts forward a means to objectively assess society's capability to cope when faced with major hazard-shock scenarios in the context of an uncertain and potentially more dangerous future. The basic premise applied here then is to ascertain the ability to cope throughout the period of the emergency scenario.

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