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Increasing communities' resilience to disasters: An impact-based approach

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ABSTRACT

The conventional processes of science, and the incorporation of science into policy and practice, appear not to be resulting in improved disaster reduction solutions for communities, despite intense research into hazards and risk. Resilience to disasters is increased when the societal impacts of disasters are reduced. On this basis, the contribution that Disaster *Risk* Reduction (DRR) can make to Disaster *Impact* Reduction (DIR) is assessed, and it is demonstrated that reducing event risk by reducing event probability only reliably reduces community disaster impacts for events that occur frequently. Such events do not fit the UNISDR definition of a disaster. Therefore, DRR cannot reliably improve DIR. Instead, DIR can be addressed directly by way of community adaptation, based on carefully selected impact scenarios derived by community-expert-official collaborations considering a broad range of event and asset damage scenarios. Probabilistic risk is a useful tool in insurance and re-insurance, and possibly in national policy-making, but such national policies are likely to be undermined by inevitable failures of risk-based approaches at the local level. This work clarifies the common usage of "risk" as meaning either impact, or impact x probability.

1. Introduction

Well into the 21st century, society is still attempting to come to grips with its ever-increasing vulnerability to extreme events resulting from the natural processes of planet Earth. This vulnerability has recently been demonstrated by extreme naturally-triggered disasters such as the 2004 Indian Ocean tsunami (e.g. [3]), the 2011 Tohoku earthquake-tsunami (e.g. [22]) and hurricane Harvey in 2017 (e.g. [27]).

Over the last few decades, the global policy and research community has come together several times to progress the task of reducing the impacts of disasters on society. This challenge was first taken up at the 2005 UN World Conference on Disaster Reduction (WCDR) in Kobe, Japan, only days after the 2004 Indian Ocean tsunami. International agencies and national governments then began to move toward setting clear targets and commitments for disaster reduction. The first step in this process was the formal approval, at the World Conference on Disaster Reduction, of the Hyogo Framework for Action (HFA: 2005–2015). The World Conference on Disaster Risk Reduction held on March 14–18, 2015, in the Japanese city of Sendai, adopted the successor accord to the Hyogo Framework. It is known as the Sendai Framework for Disaster Risk Reduction (2015–2030; https://www.unisdr.org/we/coordinate/sendai-framework). The global policy and research area by means of which nations are attempting to reduce vulnerability is thus "Disaster Risk Reduction" (DRR: e.g. [1]).

While less prominent in the official rhetoric, *resilience* has become a key concept in promulgating vulnerability reduction worldwide during the present century (e.g. [23]). Compared to DRR, the term resilience conveys better to non-experts the concept that they can be less affected by future disasters if they can become "resilient". The term conveys a sense of merit in the context of disasters, in much the same way that "sustainability" implies environmental merit.

Accordingly, a number of research and operational initiatives worldwide presently focus on resilience to disasters: for example, the New Zealand National Science Challenge "Resilience to Nature's Challenges"; the establishment of Durham University (UK)'s Institute for Hazard, Risk and Resilience; the National Disaster Resilience Strategy under development by the Ministry of Civil Defence and Emergency Management, New Zealand (Ministry of Civil Defence and Emergency management, 2018); the Queensland Strategy for Disaster Resilience, Australia (Queensland Government, 2014); and the Los Angeles County Community Disaster Resilience Project, USA (Rand Corporation,2018).

The substantial effort among global agencies to try to mitigate disaster effects has been matched by plentiful academic discussions and analyses of both "DRR" and "resilience". While DRR appears to be the better defined and understood term, perhaps because of its relationship with the well-established discipline of Risk Management (e.g. [30,15,18]), clarity in the usage and meaning of "resilience" is less

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evident. The ongoing detailed academic debate and discussion are not currently showing clear signs of converging to an agreed set of concepts usable in practice. Meanwhile, naturally-triggered disasters are exacting ever-increasing societal costs (https://www.preventionweb.net/risk/trends, Accessed 19 May 2018).

The purpose of the present work is, therefore, to propose some pragmatic short-cuts through these detailed academic considerations and, recognising from an operational perspective the need for urgency in community planning to reduce the effects of future disasters, to develop a set of feasible activities that can begin to improve communities' resilience to these events. Real-life disaster situations involve intricate and complex societal and political factors that may substantially affect the processes we suggest below. However, we do not believe that these complexities invalidate our analysis or suggestions.

First, we present the global high-level definitions relating to DRR and resilience. Second, we make the case that, however it is defined, resilience is increased if the impacts of future disaster events on society are reduced (Disaster Impact Reduction, DIR). On this basis, we show that DRR only increases resilience for events that occur many times in the planning timeframe of a community. These frequent events do not fit the UNISDR definition of a disaster. For events that match definitions of disasters (occurring very few times in a planning timeframe), DRR does not reliably lead to DIR, and therefore does not reliably lead to increased resilience.

Acknowledging that DRR does not necessarily lead to DIR, we consider DIR itself as the basis of increasing resilience as an alternative - or complement - to DRR. We suggest ways communities can identify and undertake adaptations that will result in reduction of the impacts of future disasters. These involve the use of disaster impact scenarios, rather than (or as a complement to) the annualised damage cost and net benefit estimates that often underpin risk-based decision support tools.

2. Terminology

Since the following discussion examines the relationships between DRR and resilience, we now summarise the definitions of these terms, as promulgated by UNISDR [34]; (italics added for emphasis).

2.1. Disaster

A *serious* disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Annotations: The effect of the disaster can be immediate and localised, but it often widespread and could last for a long period of time. *The effect may test or exceed the capacity of a community or society to cope using its own resources*, and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels.

2.2. Disaster risk

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, *determined probabilistically* as a function of hazard, exposure, vulnerability and capacity.

2.3. Disaster risk reduction

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, *all of which contribute to strengthening resilience* and therefore to the achievement of sustainable development

2.4. Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the *effects of a hazard* in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions *through risk management.*

The italicised phrases in these definitions correspondingly imply:

(a) that a disaster is unlikely to result from an event that happens more frequently than once every ten to twenty years, simply because the affected community will remember the recurrence of such events and will adapt (plan for them) so as to be less affected by them, in the knowledge that they will recur in the future; therefore, they are unlikely to be serious.
(b) That risk is determined probabilistically, meaning that risk of event = probability of event x consequence of event,
(c) that risk reduction results in resilience, and
(d) that resilience is achieved through risk reduction (management).

It is important to recognise that there are numerous definitions of these terms within the wider literature; the UNISDR definitions are not ubiquitous. This piece focusses on the terms "disaster" and "resilience". Therefore, further definitions of these terms are provided and discussed below.

2.5. Other definitions

Other definitions of "disaster" (cited by [16]) include:

- EMA [9]. "A serious disruption to community life which threatens or causes death or injury in that community and/or damage to property which is beyond the day-today capacity of the prescribed statutory authorities and which requires special mobilisation and organisation of resources other than those normally available to those authorities."
- FEMA, 2004 "An occurrence of a natural catastrophe, technological accident, or human caused event that has resulted in severe property damage, deaths, and/or multiple injuries." http://www.fema.gov/pdf/rrr/glo.pdf on 8 July 2004.
- ReliefWeb [26] "A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources."
- UN DHA [32] "A serious disruption of the functioning of society, causing widespread human, material or environmental losses which exceed the ability of affected society to cope using only its own resources. Disasters are often classified according to their cause (natural or manmade)."

From these additional definitions, it is clear that a common concept within definitions of "disaster" is the inability of the local community to manage the event using its own resources. This signifies the severity required to term an event a disaster and also implies the relatively infrequent occurrence of such events in a given locality.

Examples of other "resilience" definitions include (italics added for emphasis):

- IPCC [14]: "The ability of a system and its component parts to anticipate, absorb, accommodate, or recover *from the effects of a hazardous event* in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions."
- DFID [8]: "the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – *such as earthquakes, drought or violent*

conflict – without compromising their long term prospects.”

The above definitions thus unequivocally imply that *resilience to disasters can be achieved by risk reduction*. This implication is examined more closely herein.

3. Disasters

Genuine disaster events are, as defined above (Section 2), rare in any specific location, and often (in fact, usually; [7]) unexpected. Less frequent events are less likely to be present in societal memory, so are less expected, and pre-adaptation to their impacts is less likely. Definitions commonly imply that a disaster is unlikely to result from an event that happens more frequently than once every ten to twenty years, simply because the affected part of society will remember the recurrence of such events and will adapt (plan for them) so as to be less affected by them, in the knowledge that they will recur in the future. Therefore, events that occur at a range of frequencies, but are common enough to be expected, do not fit definitions of a disaster.

4. Resilience

In the disaster context, the term “resilience” first came into use in the 1950s (one article reported in *Scopus*); by 1990, seven articles were reported; by 2000, 40; by 2010, 770; and by 2018, almost 5000. This rapid growth in usage has been accompanied by a plethora of definitions of the term – *Scopus* currently reports 151 articles including the terms “disaster resilience” and “definition”. This suggests that the term “disaster resilience” is widely used for a range of concepts, which in turn makes it difficult to operationalise in practice. How does one develop strategies that will lead to resilience when controversy (if not confusion) exists over its meaning? This is particularly difficult when working with communities whose members are unlikely to be familiar with any technical interpretation of the word.

Here, we adopt the UNISDR [34] interpretation of resilience quoted above (Section 2), excluding the final phrase; we question both the UNISDR [34] and IPCC [14] definitions for their emphasis on “the preservation and restoration of… essential basic structures and functions” and “ensuring the preservation of basic structures and functions” when these very structures and functions may cause vulnerability. Instead, we interpret these definitions as supporting the societal preference for business as usual (especially given the IPCC definition also notes the option of improving structures and functions). Somewhat similarly, the DFID (2012) definition focuses on “maintaining or transforming living standards” in the face of disaster; when it is appreciated that a large proportion of Earth's population suffer poor living standards and struggle to “maintain or transform” them in the absence of disasters, this appears optimistic.

The objective of the present work is to propose a set of strategies that will realise “disaster resilience” for a community (in the present context, a self-identifying spatially-localised group of people; e.g. a town, or village, or region). Why would a community want to achieve resilience to disasters? Often, because many people in the community are aware that disasters can befall them in the future, and they want a plan that will enable the community to survive these disasters and redevelop prosperity afterwards; the alternative is to ignore the prospective disasters and accept the greater costs that will result. While some community members may be psychologically inclined to the alternative way of thinking (able to put the potential catastrophes out of mind while hoping that no disaster will occur in their lifetime), other community members will be inclined to the former, and their lives would be substantially improved if there were a plan that enabled them to see confidently past a disaster to a future with a good quality of life. More pragmatically, external organisations will be much more likely to invest in a community that plans for future disasters than in one that does not.

4.1. Achieve resilience or increase resilience?

Most of the definitions referred to above see resilience as something that can be achieved if the right things are done. However, it is difficult to ascertain whether or not anything is resilient until it is clear what it needs to be resilient to. In the disaster context, this is obviously disasters – but which disasters? Disasters come in a wide range of types and intensities; it is clearly unrealistic to achieve complete resilience to all of them, so in reality a community has to make a choice about *how* resilient it wishes to become – and to *which* disasters. This clarifies the issue somewhat; there are degrees of resilience, it is not a binary quality. Hence, resilience can perhaps better be seen as *a direction that will lead towards improved* “ability… to resist, absorb, accommodate…” ([34], Section 2d) and so on, rather than as a well-defined state which can be achieved once and for all. This view accords with that of Manyena [19], who argues strongly “… for a process-oriented definition of resilience, saying that [t]he danger of viewing disaster resilience as an outcome is the tendency to reinforce the traditional practice of disaster management, which takes a reactive stance.” [11]. In a similar vein, Pelling [25] approaches resilience (to climate change) as an outcome of the processes of adaptation and transformation that derive from identification of the basic causes of vulnerability as consequences of dominant development policies.

4.2. More resilient to what?

This is the other key question. The crucial phrase in the UNISDR definition (Section 2d) is “*effects* of a hazard” (emphasis added); this is what the achievement of resilience will reduce, and this is what the community needs to achieve resilience to. A community may be vulnerable to a range of potential disasters, such as earthquakes, landslides, flooding, etc., all of which behave differently, some of which can be forecast shortly in advance and some of which cannot. However, it is not the event itself to which the community needs to become more resilient; it is the “effects” (Section 2d) or *impacts* of the event on the community's ability to go about its normal business. These impacts involve damage to assets (houses, commercial premises, critical infrastructure, lifelines), damage to people (deaths and injuries) and interruption of services (food and fuel supply, health and welfare provision, civil order). Whichever kind of event hits the community, these are the impacts to which improved resilience is required. Every community will be uniquely vulnerable to these impacts because of its unique combination of sociocultural and socioeconomic make-up and physical location.

A community will evidently be more resilient to the impacts of any given hazard event if those impacts can be reduced; thus, a direct route to improved resilience to disasters is by way of measures to reduce the impacts of disasters on the community. Many years of experience have demonstrated that attempts to modify or prevent the hazard itself are unreliable, and can make impacts worse (e.g. [4,28,21]); hence the measures required to reduce impacts need to look at modifying society and its behaviour, to increase resilience to disaster events.

4.3. Costs of resilience

Resilience to disasters is not a free good, because investment in disaster resilience means less investment somewhere else. Every community has a range of vulnerabilities; for example, to everyday commercial competition as well as to natural events, and to occasional hazard impacts as well as genuine disasters (Section 3). Increased investment in resilience to disaster impacts may evidently reduce investment in everyday commerce and in protection against occasional hazard events [31]. Thus, any decision to prioritise investment in disaster resilience over other vulnerabilities to any given degree has to be taken by the community itself, as it is the body that is vulnerable, that has a clear picture of its desired future and has to pay for disaster resilience [24]. Here, we are focussed on reducing impacts of *future* hazard events which, if occurred today, would be disastrous. Therefore, this ignores the reality that reactional response to, and recovery from, any serious disaster are likely to be government-funded, because such retrospective assistance is known to be less effective and less beneficial for the community than pre-planned disaster resilience [33].

4.4. Resilience in a nutshell

From the above, we conceptualise "disaster resilience" for present purposes as: *societal adaptation designed to reduce the impacts of future disaster events on the everyday life of the community to an extent commensurate with the wishes of the community*. Note that this definition is not exclusive; other measures, such as preparation for disaster response and recovery, which do not directly reduce impacts, also lead to increased resilience. Nevertheless, even these measures indirectly reduce impacts because they speed the achievement of post-disaster conditions.

5. Planning timeframe

It is important to consider the future time period for which the community can sensibly plan, for two main reasons:

1. The farther into the future we try to plan, the more difficult it is to imagine how the community will have altered due to societal changes. For example, if we contemplate planning for 100 years into the future, we need to be able to visualise what 22nd century society will be like; this depends on many poorly-known factors such as how much sea level rise will have occurred and the impact this will have had on global society, the number and nature of wars that may have occurred, the nature of technology, global population and so on. For comparison, imagine someone in 1918 trying to plan for the world in 2018.
2. The longer in the future we plan for, the greater the number of hazard events that will affect the community in that time, on average. Curiously, as we shall see, the greater the number of hazard events we are concerned with, the greater is the reliability with which we can predict their future occurrence.

The second factor suggests that considering a long future planning period is advantageous, but the first obviously limits the feasibility of long-term planning. Since, in Western society at least, we can realistically assume that:

- adult individuals' serious interest in the future of the community they currently live in likely extends at most to 50 years (perhaps increased to 100 if they expect their children and grandchildren to stay in the same community);
- political planning and policy horizons rarely extend beyond 10–20 years;
- buildings and infrastructure rarely have expected lives greater than 50–100 years; and that
- plans are superseded on a rolling basis and thus evolve with time,

then planning is realistically limited to 50 – 100 years, at most. In the present work we take 100 years as the future period of interest, both for simplicity and to acknowledge that, although a shorter period may be more realistic, planning horizons lack clarity.

Further, acknowledging that any disaster will, by definition, have serious impacts on a community, it is reasonable to infer that the way a community redevelops after a disaster will result in significant changes to the pre-disaster situation. The nature of these changes is extremely difficult to anticipate, so the impacts of a further disaster on the changed community cannot be foreseen. Thus, after a disaster, the resilience plan will need to be revisited to take account of these changes.

Hence the relevant and realistic planning time frame for a community is either until the next disaster, or for 100 years, whichever is the shorter.

6. To what extent does DRR imply DIR?

As noted above (Section 2ii), risk is defined as the product of event probability and event consequence. For present purposes, consequence is equated with impact (i.e. risk is defined as the product of event probability and event *impact*); that is, consequence and impact both describe the costs to the community of the event resulting from damage to assets, lifelines, infrastructure, deaths and injuries, together with the consequential short-and long-term societal and commercial disruption.

Given a planning timeframe of a century (Section 5), the total impact on the community of specific future disaster events is the number of events that occur in that time multiplied by the average cost per event. The number of events in a century is 100 times the annual event probability, so on this basis, measures that reduce risks by reducing probability will indeed reduce the total impacts of those events by reducing the number of events that occur.

This assumes, however, that the number of events that will occur in any given 100-year period is accurately represented by the event probability. This is not necessarily – or even usually – the case. For example, if the annual event probability is 0.500, then the number of events in any given 100 years will theoretically be exactly 50, but in reality will be *roughly* 50 – it is likely to be within the range of 40–60 or so, but in terms of assessing costs 50 is close enough, especially considering that these are relatively low-impact events.

Considering rarer, more intense events, however – say with an annual probability of 0.05 – then the number of events in the next 100 years may realistically be 3, or 4, or 5, or 6, or 7, compared with the theoretical number of 5. In this case it makes a large difference to total impacts if 3 events occur or 7 events occur (Fig. 1).

Further, using an example that the probability of such events is reduced from 0.050 to 0.030 through hazard mitigation, while the event impacts stay the same; now the number of events may be 1, or 2, or 3, or 4, or 5. Hence, although the risk has been reduced by 40%, and the total impact may indeed be reduced, it may not – there is a 30% chance it will the same or greater. Thus, although reducing the risk by

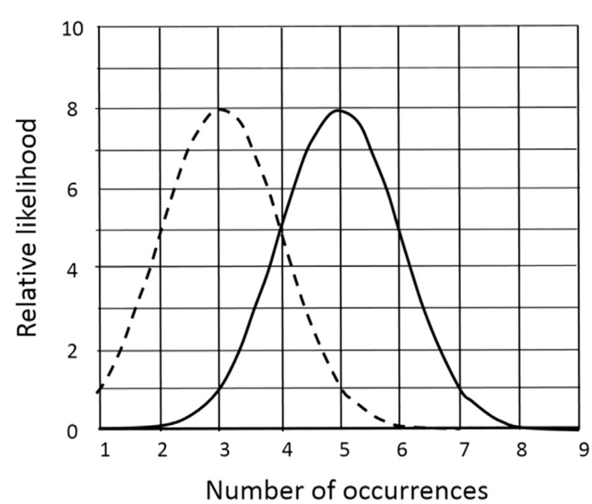

Fig. 1. Normal distribution showing the number of times (3 – 7) an event with an annual exceedence probability of 0.050 occurs in 100 years (full line) and their likelihoods; for example, 5 events are 8 times as likely as 3 or 7 events. If the annual exceedence probability is reduced to 0.030 the number of occurrences (1 – 5) and their likelihoods are shown by the dashed line. Thus, if the annual probability is 0.030 rather than 0.050, then 30% of the time there will be the same or more occurrences in 100 years – meaning no or negative impact reduction.

40% may reduce the number of occurrences, there is no guarantee of this. This means that, in general, there is no guarantee that reducing risk by reducing probability will in fact reduce total impact (Fig. 1).

With even rarer (and even more intense) events, whose annual probabilities are even lower, the situation is worse still. Say we reduce the annual probability of an event from 0.005 to 0.003; then the likely number of occurrences in any given 100 years, which was originally 0 or 1, remains 0 or 1, and the reduction of risk has no effect whatsoever on actual impact.

DRR thus leads reliably to impact reduction, over a chosen time period, *only for events that occur frequently during that time*. These are necessarily smaller, less intense events than those that occur more rarely, and their impacts will therefore be less. As noted in Section 3 above, the term "disaster" should be restricted to rare events. There is thus an irony in that *disaster* risk reduction only leads to resilience (impact reduction) for events that cannot be classed as disasters.

7. Disaster impact reduction

Since DRR does not reliably reduce the impacts of disasters, we are forced to look elsewhere for a basis for increasing resilience to disasters. The obvious place to look is towards directly reducing the impacts of future severe events, without considering their risk or probability (Disaster Impact Reduction, DIR). If this can be achieved, and adaptations developed so that the impacts of future events are reduced, then increased resilience is achieved. (So, incidentally, is reduced risk). Therefore, knowledge of the nature and magnitude of the community impacts that will result from the occurrence of severe hazard events during the next 100 years or so needs to be established.

Recalling that there is no way to reliably predict what type of hazard the next event will be, the event severity, or when the event will happen, this seems to be a tall order. Certainly, for a specified location, hazard science can constrain the type of event that can occur; it can also constrain the maximum credible severity of the event (bearing in mind, however, that several major earthquakes during the last two decades have exceeded their scientifically-determined maximum credible magnitude; [7]). For some types of event, the occurrence can be forecast to give days (storms and floods), weeks or even months (volcanic eruptions) of warning, with varying degrees of reliability. However, no warning greater than a matter of seconds is presently feasible for earthquakes, and hence very little for the hazard cascades they can initiate (tsunami; landslide – damming – dambreak flooding - river aggradation – flooding; landslide-tsunami).

This difficulty, however, reduces considerably when it is appreciated that communities do not need to be resilient to earthquakes, or eruptions, or storms. According to the present definition, they need to be resilient to their *impacts*. This can be taken further; resilience does not take the form of coping with specific assets being damaged, it takes the form of being less impacted by the societal consequences of any asset damage. For example, a community does not need to be resilient to a particular bridge collapsing, it needs to be resilient to the loss of services (transport, power, communications) resulting from that collapse.

This situation is simplified even further when it is recalled that the particular disaster a community needs to be most resilient is the next one to affect it. Thus, the community as it is at present needs to be resilient only to the impacts of the next disaster.

The situations that affect a community as a consequence of *any* disaster fall into a small number of categories, such as:

- deaths and injuries,
- loss of supplies (food, fuel, goods),
- loss of communications,
- loss of power,
- loss of water services (fresh water, storm water, waste water),
- loss of social services (finance, care, medical),
- loss of business,
- loss of societal structures and functions.

Thus, if a community can adapt so that it is better able to maintain its existence in the face of these losses, it becomes more resilient to future disasters *of any type*. This is equivalent to what Helm [13] calls "intrinsic resilience". If these losses can be reduced by pre-event adaptations, the community is better able to continue to function through and beyond the disaster. Some adaptation strategies to this end are now obvious, such as stockpiling of emergency food, fuel and medical supplies, satellite phones and stand-by generators. Reducing vulnerability to loss of power, water supplies and/or transport is more difficult, involving perhaps installation of a backup water, or power and fuel supply, or constructing alternative road access – here redundancy implies improved resilience, but at a considerable cost; this can, however, be spread over considerable time, because although the next disaster can in principle occur at any time, there may be several years or decades before it does occur. Again, as noted in 3.3 above, the immediacy of investment in disaster resilience is for the community to decide.

The preceding discussion has deliberately been framed in general terms, in order to preserve clarity of the fundamental concepts of resilience, however, we recognise that this clarity is to some extent artificial, in that it glosses over the many social and political factors that in reality contribute to the vulnerability and resilience of communities. For example, a community may be vulnerable to disaster impact because dwellings are sited close to a river, but the obvious strategy of relocation may be unworkable for numerous reasons. The riverside location may be a major source of revenue for the town, for example through tourism (e.g. [10]). Moreover, Tierney [29] explores the contribution of social inequality to disaster impacts; the community may not have adequate resources or alternative sites for the dwellings, nor the political influence to remedy these needs. Social inequality may be able to be offset, however, by recognition of and utilisation of the community's social capital – its resources of connectedness, linkages memory and networks (e.g. [2]).

8. Increasing community resilience: the scenario approach

While Section 7 emphasises that increasing community resilience has much more to do with the impacts that hazard events have on community services than with specific hazard events themselves, a clear idea of the types of threat that the community faces from hazard events is nevertheless a useful starting point for improvement of community resilience. This is because the decisions that are made about community adaptability to hazard impacts depend critically on the way of life and aspirations of the community, and thus must be made by the community itself (Section 4.3).

To make these decisions, the community needs to understand

1. the "hazard-scape" (the range of types and magnitudes of hazards that can affect the community; derived by hazards scientists in consultation with the community), and
2. the "asset damage-scape" (similarly, the types and intensities of asset damages that can occur; derived by engineers in consultation with the community), so that these drivers can be integrated with
3. the "community-scape" (the ways in which the community functions as a social, cultural and commercial entity; known intuitively by the community), to derive
4. the full "impacts-scape" (as outlined in Section 7) – to which resilience is required by way of adaptation.

A potential way of making relevant information available to the community is by way of three sets of scenarios:

1. Hazard event scenarios,

2. Asset damage scenarios, and
3. Community impact scenarios.

Hazard event scenarios represent the range of hazard events that the community can experience, limited by its geological and geomorphic setting. The chosen event intensities need to be at the upper end of what is likely (Section 6), but the exact choice of hazard and intensity needs to be made by the community in discussion with hazard scientists and officials, because the community has a clear picture of its desired future and what it is willing to pay for disaster resilience (Section 4.3).

Damage scenarios are developed from the hazard event scenarios, by the community in discussion with hazard scientists, engineers and officials; through these discussions the community becomes aware of the full range of likely direct hazard event effects. In this phase it is important to consider regional infrastructure damage too, because this may seriously impact the functioning of the community even if direct community impacts are moderate, or even zero.

The community impact scenarios are developed by the community (who possess expert local knowledge in this topic) in discussion with local authorities and infrastructure providers, for example to estimate how long it will take to improve and restore regional critical infrastructure levels of service [35].

These scenarios will also be influenced by increasing knowledge of hazard events in other places – for example, the 2016 M_w7.8 Kaikōura earthquake in New Zealand did not involve rupture of a single major fault, but involved rupture of about 20 minor faults, many previously unknown [12]. Hence major earthquakes are not limited to major faults, as has previously been assumed worldwide, implying that major earthquakes might occur almost anywhere that there are many minor faults. The Kaikōura earthquake also informed impact assessments and expected recovery trajectories for infrastructure stakeholders, particularly following damages to road and rail networks. These are already being used by infrastructure stakeholders including the national road and rail operators and Civil Defence Emergency Management within New Zealand to plan for other hazards elsewhere in the country [5].

It is important to realise that here, the scenarios facilitate collaboration with, as opposed to top-down education of, the community. For example, while the scientists and engineers are expected to provide greater levels of technical knowledge, the community may also be able to provide local knowledge which may alter the scientific and engineering knowledge. No group knows everything, and each will learn from others through the scenarios. This is possible because accurate communication of scenario information is much easier than accurate communication of technical scientific information (such as probabilistic risk) and technical engineering information. The scenario information is about hazard events, asset damage, and the impacts of asset damage on community life – which all parties are familiar with by experience, even if at much lower severities, or by knowing about impacts on other communities. All of these can be conveyed comprehensibly in everyday terms, and indeed the community can contribute substantially to their development. Not only can scenario information be more easily understood by all involved, but this also means that no-one is in a position of privileged knowledge, and thus of power, by virtue of profession or position. Everyone involved in scenario discussions has all the relevant information available to them and equally comprehensible by them. This is extremely important in enabling trust among the participants, which is itself a pre-requisite for open communication.

Once the full set of scenarios has been developed, and community members have an understanding of the nature, intensity and duration of the service losses they can expect to suffer under these scenarios, development of adaptation strategies can begin.

9. Selection of impacts scenario

In the present context, an impact scenario describes only one of the many possible sets of impacts that can affect the community as a result of the next disaster. Any chosen scenario is very likely to differ from the set of impacts that will in fact occur, but, given that the full range of impacts of all these sets (although able to be envisioned) is probably too broad to serve as a sensible target for adaptation, a specific set needs to be chosen for consideration. For example, a chosen scenario may assume that specific buildings and sections of infrastructure are damaged. In the next disaster, these exact buildings and sections of infrastructure are unlikely to all be impacted, or to be the only ones impacted. However, all buildings within the community may have been strengthened as a result of the scenario, so those that are impacted in the event are damaged less. The more severe is the chosen scenario, the greater the confidence the community can have that its chosen adaptations will allow it to survive and prosper through and beyond the event; but, as noted above (Section 4.3), more serious adaptations to disaster scenarios will incur greater costs and therefore leave less resource to devote to resilience to lesser threats. Hence, again, the choice of scenario must be made by the community according to its own degree of risk acceptance or aversion and its own vision of the future. Nevertheless, even if an event occurs that exceeds the chosen scenario, the adaptations to lesser scenarios will reduce impacts to some degree. So, the choice of scenario is not simple, but is important.

The choice of scenario is also important because a common criticism of the scenario approach, particularly the use of hazard event scenarios, is that it only deals with one of the many situations that may occur in the future and ignores all others – so it is a random shot in the dark with no certainty of usefully representing the next event. By contrast, the risk approach deals with the full range of known events and integrates their effects into the risk distribution, and an optimised solution can be derived by probabilistically optimising the countermeasures. Besides the intrinsic unreliability of the risk approach outlined above (Section 6), this objection mostly focusses only on impacts scenarios, whose possible range is qualitatively much smaller than that of the events scenarios. The remaining objections, which relate to the apparently random selection of an impacts scenario as a basis for planning, disappear when, as a result of considering the full range of likely impacts scenarios up to and including a maximum credible impacts scenario, the community chooses the scenario(s) it wants to use for planning. In fact, careful selection of an impacts scenario as the basis for resilience planning is potentially far more reliable than any probabilistically-derived “optimal” decision. In addition, adaptation to the wrong event still has benefits when a different event occurs, because adaptation is to impacts, not events (Section 7).

An excellent example of the benefits of pre-adaptation to the wrong scenario is given by the experience of an electricity utility in the 2010–2011 Christchurch earthquake sequence. Following the publication of knowledge about the magnitude and probability of a rupture on the plate-boundary Alpine Fault, and its likely effects on Christchurch although about 150 km away [17], Orion carried out strengthening of their electricity supply infrastructure in anticipation of this event. The next event to affect the system, however, was the series of local earthquakes that devastated Christchurch starting in 2010; thanks to its upgrading in anticipation of the different event, the Orion network required less reinstatement work following these events than would otherwise have been the case [20].

Finally, it is important to recognise that the above processes of scenario development and choice, and planning, take place in an environment in which power structures and politics can play a major role. Particularly at the local level these factors have the potential to see vested interests override community welfare. Such influences are intrinsically difficult to counter, and indeed to discern, given the wide range of backgrounds and personalities present in any group grappling with community adaptation planning. In spite of these complications, however, there is accumulating evidence that scenario-based community resilience planning can lead to better decisions than traditional top-down governance [6].

10. Use of the term "risk"

The present work is based on UNISDR [34] definitions, particularly of "disaster risk", and the emphasis in that definition that *risk is determined probabilistically*. On that basis, it has been made clear that "risk management" cannot reliably result in increased resilience, and the present proposals may thus appear to be a substantial departure from current standard practice. However, in reality, many uses of the term "risk" in both technical and policy literature do not conform to the UNISDR definition. Many uses of "risk" in fact mean "impact", and indeed only make sense in that context. It is enlightening, when reading reports and attending seminars and other addresses, to mentally alter every use of "risk" to "impact"; very often the sense of meaning is clarified, while often the meaning does not change, and rarely is it distorted.

Thus, the present suggestions, while clarifying some potential strategies for approaching resilience, are less revolutionary than might appear at first sight. It is likely that professional risk managers will object to the side-lining of probabilistic risk suggested herein, and scientists dedicated to increasing the sophistication of event magnitude-frequency distributions in the pursuit of resilience may resist these suggestions. In response, it is emphasised that probabilistic risk reduction has its place in dealing with events that happen frequently in a realistic time-frame; further, these events are often sufficiently well-described that accurate probability distributions can be derived – which is certainly not the case for less frequent events. But they are not disasters.

Probabilistic risk is most reliable where very large numbers of events are involved; for example, in insurance and reinsurance. Here, the organisation involved is dealing with the full range of events of all types that occur over very wide areas of the planet, and the summed impacts of even major disaster events can be reliably predicted on a statistical basis for time periods as short as a year (most insurance premiums are adjusted annually). The same may apply, to some extent, to a national government developing policy for spatially-averaged "resilience" for a whole country; the drawback in this context is that individual communities will not be reliably served by this policy, so from the community perspective, the policy will be perceived to fail from time to time [7]. A democratically-elected government is vulnerable at the polls to such perceptions.

Finally, the present work is by no means merely a semantic argument. In discussions and planning for reducing disaster impacts, lack of clarity about the meanings of "risk" and "resilience" can at the very best result in considerable time being wasted, and at the worst in unreliable strategies being adopted at great cost that fail to reduce the impacts of the next disaster to befall a community. The internal inconsistencies that have been demonstrated in high-level official definitions foster this lack of clarity, and the confusion that results inhibits the development and implementation of effective measures to reduce disaster impacts.

11. Conclusions

11.1. UNISDR is the leading organisation globally coordinating, campaigning and advocating for disaster reduction; its by-line is "Connect and convince to reduce disaster impacts" (https://www.unisdr.org/). The organisation's terminology [34] unequivocally implies that resilience to disasters can be achieved by risk reduction. However, this implication is false. It is only valid for events that occur frequently in the time-frame of interest to an affected community, and such events cannot be "disasters", according to the terminology (Section 3). Instead, Disaster Risk Reduction is reliable when applied to ensembles of many events, when the occurrence of events is more likely to closely match their probabilities. Insurance and reinsurance are examples of such contexts.

11.2. Disaster impacts are the effects on society of the damage caused to community and regional assets by hazard events. These include deaths and injuries, loss of supplies (food, fuel, goods), loss of communications, loss of power, loss of water services (fresh water, storm water, waste water), loss of social services (finance, care, medical), loss of business and loss of societal structures and functions. Impacts are largely independent of the hazard type (Section 7).

11.3. Reduction of disaster impacts is equivalent to increasing disaster resilience; this cannot, however, be reliably achieved by Disaster Risk Reduction. By contrast, measures specifically designed to reduce the impacts of disasters lead reliably to increased resilience (Section 7).

11.4. Disaster Impact Reduction can be approached by community-based development of hazard, asset-damage and community-impact scenario sets, also involving officials and experts. The scenario approach critically facilitates collaboration, as opposed to top-down education of the community. This means the impact scenarios can form the basis for planning to reduce community impacts by adaptation measures (Section 8).

11.5. Scenarios and adaptation strategies can be selected by community-official-expert collaborations, based on the community's knowledge of its capabilities and its aspirations (Sections 4.3 and 8). While important, the criticality of scenario selection is moderated by the fact that adaptation to the wrong event will nevertheless result in reduced impacts, because of the general nature of the impacts (Section 7).

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