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Constructing a Holistic Approach to Disaster Risk Reduction: Significance of Focusing on Vulnerability Reduction

With the increase of natural disaster losses, policy makers, practitioners and the research community all around the world are seeking effective and efficient means of overcoming or minimising such losses. Although various theoretical constructs are beneficial to understanding the disaster phenomenon and the means of minimising losses, the disaster risk management process becomes less effective if the theory and practice are set apart from each other. Therefore, this paper seeks to establish the relationship between two theoretical constructs called 'disaster risk reduction' and 'vulnerability reduction'. It will construct a holistic approach to disaster risk reduction and improve its applicability in a practical settings. The paper is based on a literature review and an overall understanding gained through a doctoral study. The doctoral study was based on two case studies conducted in post-disaster infrastructure reconstruction projects in Sri Lanka and three expert interviews in the United Kingdom and Sri Lanka. As findings, the paper produces an effective classification of disaster risk reduction strategies and a theoretical framework on the influence of disaster risk reduction strategies on vulnerability reduction.

Keywords: Disaster risk reduction, vulnerability, vulnerability reduction, Holistic approach to disaster risk reduction

1. Introduction

1.1 Background

The functions of everyday life can stall due to disasters, irrespective of where the disasters take place, causing a wide range of consequences in a wide range of areas such as, human, economic, social, political, psychological and environmental concerns for communities. Disaster losses cannot be measured simply in monetary terms as the loss of lives is immeasurable and the impact on communities is either direct or

indirect in nature. Disaster losses occur at all levels, from individual household losses to national and international level losses resulting from exceptional catastrophic events (UNDP, 2004).

With the increase in natural and man-made disaster losses, policy makers, practitioners and the research community all over the world are seeking effective and efficient means of overcoming or minimising such losses. This has resulted in various theoretical constructs being introduced related to the disaster risk management domain. Although many of these theoretical constructs such as ‘disaster risk’, ‘susceptibility’, ‘resilience’, ‘resistant’, ‘disaster risk reduction’, ‘vulnerability reduction’, and ‘hazard mitigation’ have been advantageous for disaster management scholarship, they have failed to sufficiently address the triggering agents, functional areas, actors, variables, and disciplines pertaining to disaster events (McEntire *et al.*, 2002).

1.2 Aim of the paper

‘Disaster risk reduction’ and ‘vulnerability reduction’ are commonly discussed topics in the current disaster management domain. They are used interchangeably to mean ways of overcoming and minimising disaster losses. In this context, this paper focuses on establishing a relationship between these two theoretical constructs to develop a holistic approach to disaster risk reduction with particular reference to improving its applicability in practical settings.

1.3 Research methodology

This paper is based on a literature review and an overall understanding gained through two case studies conducted on post-disaster infrastructure reconstruction projects in Sri Lanka and three expert interviews in the United Kingdom and Sri Lanka. The literature review and the empirical research explored ‘the influence of integration of disaster risk reduction into infrastructure reconstruction on socio-economic development’. Both qualitative and quantitative data were collected and analysed to investigate the influence of integration of disaster risk reduction into infrastructure reconstruction on projects’ and communities’ vulnerability reduction. Two case studies were conducted within a water supply and sanitation reconstruction project and a road reconstruction project following the tsunami of 2004. The case studies consisted of a series of semi-structured interviews and a questionnaire survey. The questionnaire survey was mainly conducted to triangulate the data gathered from the semi-structured interviews. It added depth to the study by using

multiple sources of evidence. While the semi-structured interviews were analysed using NVivo (version 8) software, the questionnaires were analysed using descriptive statistics techniques. The expert interviews were conducted in Sri Lanka and the United Kingdom to overcome the difficulty that use of case study approach would have on generalising the findings to a wider population. The findings of expert interviews are not context specific and therefore the overall study ensured its ability to generalise to suitable domains. Thus both the literature review and the empirical study helped to establish a novel argument about the relationship between the two concepts and the understanding of the applicability of their theoretical meanings in practical settings.

2. Current understanding of risk of natural disasters

McEntire (2001) explains disasters as the disruptive and/or deadly and destructive outcomes of triggering agent(s) when they interact with, and are exacerbated by, various forms of vulnerability. DFID (2005a) also describes disaster risk as resulting from a combination of hazards (in other words, triggering agents) and people's vulnerability to those hazards. While triggering agent(s) stand as the independent component of a disaster that may originate from the natural environment, human activity, or a combination of the two, vulnerability is considered to be the dependant component that is determined by the degree of risk, susceptibility, resistance and resilience (McEntire, 2001).

A disaster is a function of the risk process (UN/ISDR, 2004a: p.16). Thus, 'disaster risk' is defined as "*the probability of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions*" (UN/ISDR, 2004b). Earthquakes, storms and torrential rains, are some natural phenomena we refer to as 'hazards' and are not considered to be disasters in themselves. For example, an earthquake that occurs on a desert island does not trigger a disaster because there is no existing population or property to be affected (ADRC, 2005). In addition to a hazard, some 'vulnerability' to the natural phenomenon must be present for an event to constitute a natural disaster.

Conventionally, risk is expressed by the equation:

$$Risk = Hazard \text{ (frequency and severity)} \times Vulnerability \text{ (exposure/capacity)}$$

(Source: UN/ISDR, 2004a)

According to the above equation, vulnerability is seen as a function of exposure and capacity. However, ADRC (2005) sees disaster risk as a function of the hazard, exposure and vulnerability, which is interpreted as follows:

$$\text{Disaster Risk} = \text{Function} (\text{hazard}, \text{exposure}, \text{vulnerability})$$

The ADRC (2005) definition of disaster risk can be interpreted as shown in Figure 1. According to this definition, exposure is defined outside the term vulnerability. However, when existing literature in this domain was critically reviewed, it was realised that both exposure and capacity can be considered as aspects of vulnerability and this is discussed in following sections of this paper.

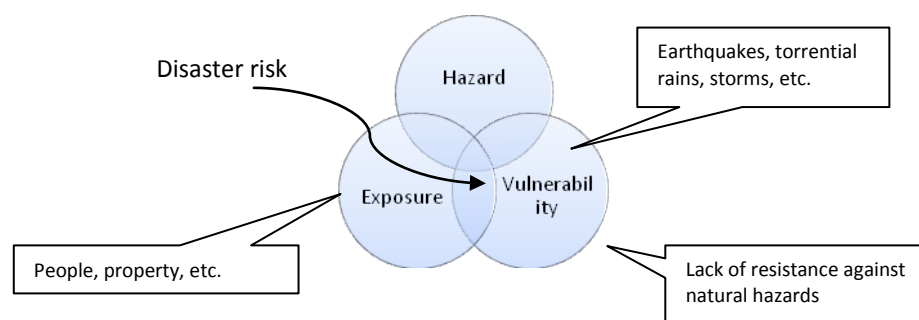


Figure 1: Mechanism behind the emergence of natural disasters (Source: ADRC, 2005)

1.4 Hazards

UN/ISDR (2004a: p.16; 2004b) describes hazard as a “*potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation*”. Hazards can have different origins: they may be natural or man-made (UN/ISDR, 2004b). Natural hazards are caused because of natural phenomena, such as events with a meteorological, geological, or even biological origin. Examples of natural hazards are cyclones, tsunamis, earthquakes and volcanic eruptions that are exclusively of natural origin (Khan *et al.*, 2008). Man-made hazards are those caused by human negligence, explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife, etc. (Khan *et al.*, 2008). In contrast to the classification made by the UN/ISDR (2004b), Khan *et al.* (2008) perceives other forms of hazards called socio-natural hazards, which are caused by both natural and man-made phenomena. Accordingly, landslides, floods, droughts and fires fall into this classification. Khan *et al.* (2008) adopted the summarised classification of hazards produced by the Central Board of Secondary Education (CBSE) (2006) as depicted in Table 1.

Table 1: Classification of hazards

Type of hazard	Hazard
Geological hazards	Earthquake, tsunami, volcanic eruption, landslide, mine fire
Water and climatic hazards	Tropical cyclone, tornado and hurricane, flood, drought, hailstorm, cloudburst, landslide, heat and cold wave, snow avalanche, sea erosion
Environmental hazards	Environmental pollution, Deforestation
Biological hazards	Human/animal epidemic, pest attack, food poisoning
Chemical, industrial and nuclear accidents	Chemical disaster, industrial disaster, oil spill/fire, nuclear
Accident related hazards	Boat/road/train accident/air crash, rural/urban fire, bomb/serial bomb disaster/blast, forest fire, building collapse, electric accident, festival related, mine flooding

(Source: CBSE 2006 cited Khan *et al.*, 2008)

1.5 Vulnerabilities

Vulnerability is a term used in the field of risk, hazard, and disaster management as well as in the areas of global change and environment and development studies (Weichselgartner, 2001). The term ‘vulnerability’ is defined as “*the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impacts of hazards*” by the UN/ISDR (2004a: p.16, 2004b). According to the UN/ISDR (2004a), vulnerability to hazards is expressed as the degree of exposure of the population/property and its capacity to prepare for and respond to the hazard. Buckle *et al.* (2000: p.9) adopt the definition of vulnerability provided by the glossary produced by Emergency Management Australia (1998) as “*the degree of susceptibility and resilience of the community and environment to hazards*”. For Wisner *et al.* (2003: p.11) vulnerability means “*the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard (an extreme natural event or process)*”. However, the definition of vulnerability is still vague and thus there is no common conceptualisation of vulnerability among scholars (McEntire *et al.*, 2010; Cutter, 1996 cited Weichselgartner, 2001). On the other hand, vulnerability is viewed, by McEntire (2001), as a product of four components: risk, susceptibility, resistance and resilience (see Figure 2).

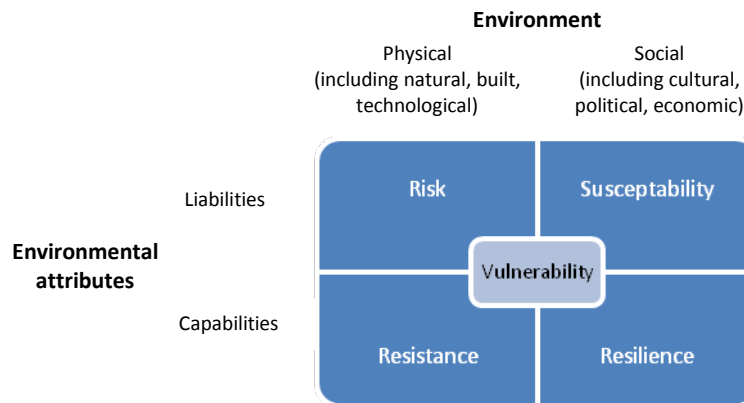


Figure 2: Components of vulnerability

(Source: McEntire, 2001)

Here, the entire environment is classified into two parts: physical environment (which consists of natural systems, built environmental structures and technological structures) and social environment (which consists of individuals and groups of individuals, cultural systems, political systems and economic systems). The terms risk, susceptibility, resistance and resilience are described by McEntire (2001) as follows:

- Physical environment has a *risk* due to its proximity or exposure to hazards, which increases the probability of disaster and the potential for losses (Buckle *et al.*, 2000; Reynolds, 1993)
- Social environment is *susceptible* to disasters due to social, political, economic, and cultural forces and activities that determine the proneness of individuals and groups to being adversely affected by disasters (Buckle, 1995)
- Physical environment's ability to resist the damage imposed by hazards is called *resistance* (Norton and Chantry, 1993)
- The capacity of the social environment to cope or the ability to react or effectively recover from a hazard that becomes disastrous is called *resilience* of social environments (Buckle *et al.*, 2000; Mileti, 1999)

Although McEntire (2001) uses the term 'risk' to mean the physical environment's proximity or exposure to hazards, it can be termed differently to avoid any confusion; because the term 'risk' has an overall meaning and 'vulnerability' is certainly a part of 'risk'. Therefore, the term 'risk' in McEntire's (2001) definition can be replaced with a more meaningful term such as 'fragility'.

Reflecting a similar meaning, Weichselgartner (2001) sees vulnerability from the perspective of:

- Individual vulnerability - personal or individual potential for, or sensitivity to, losses that have both spatial and non-spatial domains
- Social vulnerability - susceptibility of social groups or society at large to potential losses from disastrous events
- Technical vulnerability - the vulnerability of a house, an electricity grid, or transport infrastructure, for examples, in a technical sense

Weichselgartner (2001) also identifies a social environment's susceptibility and resilience, and a physical environment's fragility and resistance to disasters, as components of vulnerability in a more compact manner, using different terminology.

Although the term 'exposure' is considered to be a separate component of risk in certain literature, such as ADRC (2005), other researches define it one of the aspects of the entire concept of 'vulnerability'. In ADRC (2005), 'exposure' refers to that which is affected by disasters, such as people and property where growing exposure results in an increased number of natural disasters and greater levels of loss. A community is said to be at 'risk' when it is 'exposed' to 'hazards' and is likely to be adversely affected by its impact (Khan *et al.*, 2008). In general, 'risk' is defined as the expected loss of lives and property due to hazards. If a community or a property is more exposed to hazards, then it is said that it is more vulnerable to hazards. Furthermore, UN/ISDR (2004a) claims that exposure and capacity are the root causes of vulnerability, which is a further justification of the vulnerability concept emphasised by McEntire (2001) in Figure 2. Capacity can be defined as resources, means and strengths that exist in communities, properties, households and which enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster (Khan *et al.*, 2008).

However, vulnerability does not only stand for exposure to hazard and lack of capacity, but it represents a series of resultant states of social, economic, political, cultural, environmental, physical, and technological under-development processes, before, during and after disaster situations (Jigyasu, 2004; McEntire, 2001). Based on a similar argument, Wisner *et al.* (2003) claim that vulnerability involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets are put at risk by a discreet and identifiable event. Eshghi and Larson (2008) note that vulnerability is influenced by factors

such as location, state of housing, level of preparedness and ability to evacuate and carry out emergency operations. Different societies have differing levels of vulnerability; this is one reason why hazards of a similar type and intensity can have quite varied effects on different populations (Eshghi and Larson, 2008). McEntire (2001) claims that there are innumerable variables that interact to produce a future of increased vulnerabilities that in turn have been categorised under physical, social, cultural, political, economic and technological headings as depicted in Table 2.

Table 2: Factors forming vulnerabilities

Type of vulnerability	Variables which interact to produce vulnerabilities
Physical vulnerability	Proximity of people and property to triggering agents Improper construction of buildings Inadequate foresight relating to the infrastructure Degradation of the environment
Social vulnerability	Limited education (including insufficient knowledge about disasters) Inadequate routine and emergency health care Massive and unplanned migration to urban areas Marginalisation of specific groups and individuals
Cultural vulnerability	Public apathy towards disasters Defiance of safety precautions and regulations Loss of traditional coping measures Dependency and absence of personal responsibility
Political vulnerability	Minimal support for disaster programmes amongst elected officials Inability to enforce or encourage steps for mitigation Over-centralisation of decision making Isolated or weak disaster related institutions
Economic vulnerability	Growing divergence in the distribution of wealth The pursuit of profit with little regard for consequences Failure to purchase insurance Sparse resources for disaster prevention, planning and management
Technological vulnerability	Lack of structural mitigation devices Over-reliance upon or ineffective warning systems Carelessness in industrial production Lack of foresight regarding computer equipment/programmes

(Source: McEntire, 2001)

Velasquez and Tanhueco (2005), working on the social issues of disaster vulnerabilities, have identified hazard experience; awareness of hazards, their effects on livelihood and income; hazard consequences to persons and property; health and capability to obtain medical treatment; socio-demographic qualities; availability of social support systems; social aspects of structure vulnerability to hazards; and the implementation of land use controls as the major issues contributing to the vulnerability of the focus groups in their research. Although some of the issues were identified in Velasquez and Tanhueco's (2005) research as social vulnerabilities, similar types of issues are categorised under different headings in McEntire's (2001) research. However, the different issues identified by Velasquez and Tanhueco (2005) are important

in enhancing McEntire's (2001) list and, thereby, establishing a more convincing list of factors. In this way, many authors such as Pelling (2011 and 2007), and Wisner *et al.* (2003), have researched the issues contributing to vulnerability. Thus, social vulnerability alone would not make physical and social environments vulnerable to disaster since there are many other factors that contribute to vulnerability such as poor land-use planning, inadequate construction, environmental degradation, cultural attitudes and practices, law and policy, lack of planning, insufficient training, ineffective warning systems, communication failures, and failure to improvise (McEntire *et al.*, 2010).

Moreover, Buckle *et al.* (2001) recognise certain levels where resilience and vulnerability could exist. Although the concept of resilience is defined outside vulnerability in their research, the view presented by them is useful in understanding the different levels of vulnerability that could exist. Figure 3 illustrates the three levels as personnel factors, community factors and structural factors. Accordingly, while demographic groups such as women, children, and the vulnerable are deemed personnel factors, communities, agencies, infrastructures, and systems appear under community factors as they have different perceptions of who is vulnerable and who lacks resilience. The third level, structural factors, refers to contextual issues such as change and development in an area or to a community, social and demographic trends, and economic condition etc.

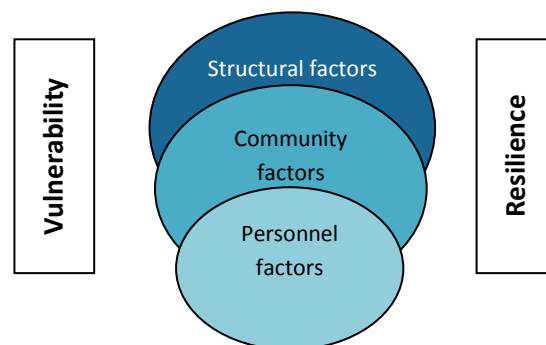


Figure 3: Levels of resiliency and vulnerability

(Source: Buckle *et al.*, 2001)

Therefore, it is evident that it is not only individuals and communities that are vulnerable to disasters but also built-environment structures such as road networks, water supplies and sanitation projects. Thus, all of the vulnerabilities tabulated in Table 2 are commonly applicable to individuals, communities and built-environment structures.

In this way, the concept of vulnerability has been defined by different authors in various ways. However, it is now evident that disaster risk is developed due to hazards; and the vulnerabilities of social and physical environments to those hazards. There are certain measures called '*disaster risk reduction strategies*' proposed by academics, the research community and practitioners in order to overcome the disaster risks. The next section presents the critically reviewed literature concerned with the concept of 'disaster risk reduction' and current opinion of this concept.

3. Disaster risk reduction and its typologies

The impetus for disaster risk reduction (DRR) comes largely from the severe loss of lives and property due to both major and minor natural and human induced disasters. The substantial effects of DRR initiatives have now been recognised by the engineering community, scientists and the policy makers. DRR is aimed at tackling the fundamental elements of disaster risk: vulnerability and hazards (DFID, 2006). UN/ISDR (2004b) defines DRR as "*the conceptual framework of elements considered with the possibilities to minimise vulnerabilities and disaster risks throughout society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development*". UN/ISDR (2009) defines the term as a "*systematic development and application of policies, strategies and practices to minimise vulnerabilities and disaster risks throughout society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development*". DRR encompasses measures to curb disaster losses by addressing hazards and the vulnerability of people to them (DFID, 2005a). However, it is evident from these definitions that the concept of DRR not only refers to structural or technically advanced strategies but also soft methods such as policy and planning and knowledge management strategies (Mileti, 1999). As Weichselgartner (2001) emphasises, although the complex nature of natural disasters has led us to believe that 'hard engineering measures' are more superior than 'soft methods', it is highly important to consider soft methods within the DRR process and make use of social approaches rather than physical approaches.

There is a wide range of DRR strategies which have been categorised in different ways by the research community. Literature identifies various classifications of DRR strategies. Mercer (2010) broadly identifies them as DRR policies and strategies which need to evolve from a top-down as well as bottom-up

perspective. However, the importance of appropriately linking the grassroots strategies with appropriate top-down strategies and local government interventions is also highlighted (Mercer, 2010).

Nateghi-A, (2000) provides a basic classification of disaster mitigation strategies as:

- Preparedness measures: to provide warnings, establish contingency plans and develop the capacity for emergency response
- Prevention/mitigation measures: to reduce vulnerability and thereby risks on a long-term and permanent basis

Nevertheless, surpassing this basic classification Nateghi-A (2000) proposes a comprehensive classification of a range of techniques that the city of Tehran instigated to mitigate earthquake disasters which are as follows:

- Engineering and construction measures:
 - Engineering measures that result in stronger individual structures that are more resistant to hazards
 - Engineering measures that create structures whose function is primarily disaster protection, including earthquake shelters
- Physical planning measures: measures that result in proper selection of sites for settlements and structures to avoid hazardous areas
- Economic planning measures: measures that enable communities to become economically stable to withstand losses and measures that make it possible for communities to afford higher levels of safety, for example diversification of economic activities
- Policy guidance measures:
 - Organisational and procedural measures
 - Educational measures: professional training of engineers, planners, economists, social scientists and other managers to include hazard and risk reduction within their normal area of competence, and political will which results in institutionalisation of disaster mitigation
- Public response measures: measures that result in a disaster 'safety culture' in which the general public are fully aware of potential hazards and their vulnerabilities allowing them to protect themselves as fully as they can and fully support efforts made on their behalf to protect them.

A relatively similar version of Nateghi-A's (2000) basic classification of DRR strategies has been produced by Concern Worldwide (2005), a non-governmental, international, humanitarian organisation dedicated to the reduction of suffering and working towards the ultimate elimination of extreme poverty in the world's poorest countries. Accordingly, the term 'DRR' includes the three aspects of a disaster reduction strategy:

- Mitigation,
- Preparedness and
- Advocacy

The three categories are not mutually exclusive (Concern Worldwide, 2005). Mitigation measures can be divided into infrastructural and non-infrastructural measures that reduce the frequency, intensity, scale and impact of hazards. Preparedness plans often include capacity building. These are usually knowledge based and include early warning systems that monitor and predict the occurrence of hazards, and contingency plans for effective responses. Advocacy seeks to favourably change policies and practice by networking and influence (Concern Worldwide, 2005).

The DFID (2005b) has produced a clearly understood classification of DRR strategies as:

- Policy and planning measures: national plan for protection against disasters, including preparedness and contingency planning; land-use planning; integrated management of flooding and water supply; integrated warning and response system; improving networks/links with local governments
- Physical preventative measures: flood defences (e.g. dam, multipurpose, seaborne) and sea walls; natural protection against floods (e.g. reforestation of watersheds); installation of drainage pumps
- Physical coping and/or adaptive measures: resilient roads and infrastructure (e.g. raised roads); resilient water supply systems (e.g. boreholes, raised hand-pumps); design and building of contingency mechanisms for coping with disasters (e.g. escape roads)
- Community capacity building measures: training communities for disaster preparedness; public warning systems

In reviewing the already established DRR strategies and their classifications, it is evident that there are strategies that fall under policy and planning strategies, physical/technical strategies, emergency preparedness strategies, natural protection strategies and knowledge management strategies. These could exist at international, national, institutional, project/programme and community/individual levels. What

international, national and community levels stand for is clear; institutional level stands for local and urban authorities, construction companies etc.; project/programme level stands for construction or reconstruction projects and disaster mitigation programmes etc. Policy and planning strategies, including various guidelines and frameworks, could exist at international, national or institutional level; they have a direct effect on each other from top to bottom as well as at project/programme level and community and individual level DRR strategies. Physical/technical strategies, emergency preparedness strategies and natural protection strategies could exist at project/programme level while knowledge management strategies could take place at both the project/programme and community and individual levels. Figure 4 clearly depicts this proposed classification of DRR strategies. The dotted lines indicate the influence of policy and planning strategies on different levels, and at each of the following levels. All of the categories of DRR strategies are of paramount importance to social and physical environments. However, the applicability of the concept of DRR is not limited to a particular timeframe. Effective DRR happens well before disasters strike, but also continues afterwards, building resilience to future hazards (DFID, 2005a).

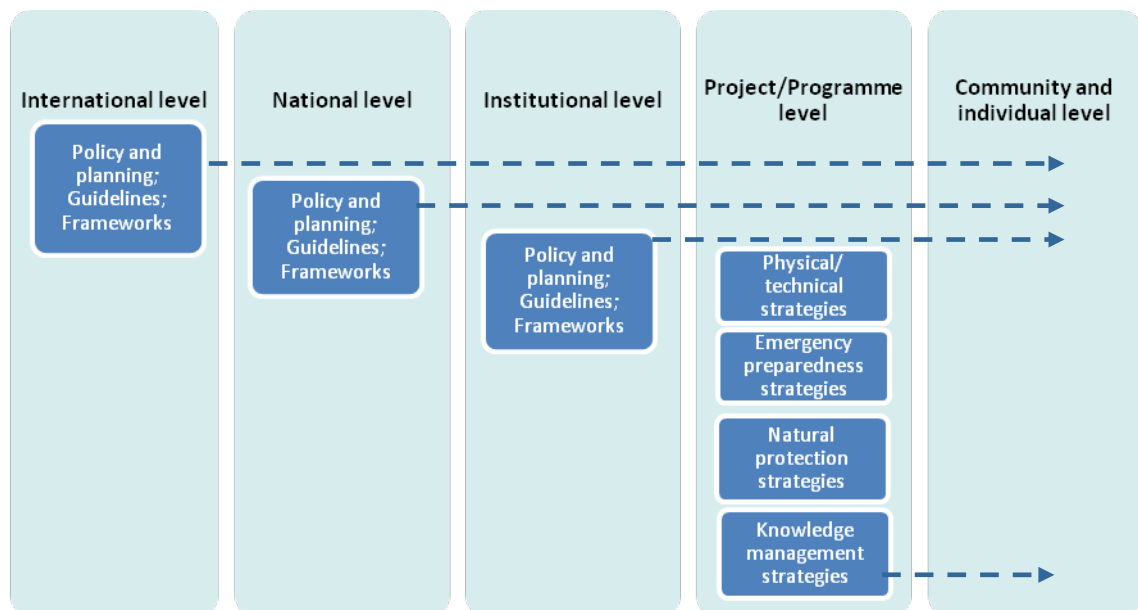


Figure 4: Classification of disaster risk reduction strategies

4. Discussion: Constructing a holistic approach for DRR

In order to establish a holistic approach to DRR, it is important to explore the significance of DRR on vulnerability reduction: how DRR strategies may potentially support vulnerability reduction. This understanding will enable decisions to be made on which DRR strategies could address triggering agents, functional areas, actors, variables, and disciplines pertaining to disaster events.

The prevention and mitigation of disaster risk can be achieved through:

1. the prevention or mitigation of hazards; and/or
2. prevention or mitigation of vulnerabilities.

However, there are preventable and also unpreventable hazards (Cannon, 1993 cited McEntire, 2005). Palliyaguru and Amaratunga (2011) claim that certain hazards, such as, floods are preventable by means of prevention of associated vulnerabilities while hazards such as earthquakes are unpreventable. Therefore, it is claimed that although these hazards are preventable or not, their effects and losses can be prevented or mitigated. The best way of preventing or mitigating disaster losses has been identified as preventing (eliminating) or mitigating (reducing) vulnerabilities, which is commonly called '*vulnerability reduction*' (Palliyaguru and Amaratunga, 2011).

McEntire (2004) acknowledges that we can certainly limit, although not completely eliminate, vulnerability to disasters. Rautela (2006) clearly states that all risk reduction related efforts are associated with reducing the vulnerability of the community as this is the most critical issue that forms and enhances disaster impact. Weichselgartner (2001: p.87) also offers the same argument and claims that "*the concept of vulnerability can provide a vehicle to explore a contextual approach to the reduction of losses due to natural hazards, and address the salient issues of sustainability and quality of life*". Stenchion (1997) reiterates that development and disaster management are both aimed at vulnerability reduction. In this context, McEntire *et al.* (2002) emphasise the importance of incorporating a broad scope of variables in the future paradigm and considering vulnerability reduction through development and disaster management activities alike. Yodmani (2001), researching on proactive disaster management with particular foci on reduction of disaster risks, emphasises that DRR can make a significant contribution to protecting vulnerable communities, their lives, assets and livelihoods. It can be argued that DRR strategies aimed at helping poorer communities should work towards reducing economic vulnerability and at the same time capitalise on, and perhaps foster, the inherent social and cultural capacities of the poorer communities, because disaster risks are originated and exaggerated by economic, social, political, environmental factors (Mercer, 2010). Moreover, Thomalla *et al.* (2006) identify DRR as one of four methods used by the research and policy communities involved in reduction of vulnerability to natural hazards; the other three are identified as climate change adaptation, environmental management and poverty reduction. Focusing their research on disaster reduction and climate adoption as principle methods of vulnerability reduction, they claim that both have currently failed to reduce vulnerabilities. On the other hand, in discussing DRR and climate change adaptation, Mercer (2010) claims

that DRR evolved from both a top-down and bottom-up perspective, and climate change adaptation generally emerged from a top-down driven policy that was initially not adequately connected to the communities directly affected by climate change. ADRC (2005) states that a reduction of vulnerability can be achieved through mitigation and preparedness strategies. Thus, it is evident that DRR should be aimed at vulnerability reduction. In other words, vulnerabilities are reduced by adopting DRR strategies.

Presenting an improved model of vulnerability reduction, McEntire *et al.* (2010) identified four ideal types of vulnerability reduction: *physical science school*, *engineering school*, *structural school* and *organisational school*. While all four types possess their own strengths and weaknesses, two are categorised as technocratic and the remaining two as sociological (McEntire *et al.*, 2010). According to McEntire *et al.* (2010) they are as follows:

- *Physical science school* - concentrates on living in safe areas and focuses mostly on exposure to hazards and risk reduction. As discussed by Mileti (1999), Mileti *et al.* (1995), Reddy (2000), Chakraborty *et al.* (2000), this school relies heavily on the analysis of the physical environment
- *Engineering school* - concentrates on the built environment and ways to increase resistance through construction practices and methods of fabrication
- *Structural school* - concentrates more on traditional notions of vulnerability than the other three, and it stresses susceptibility based on socio-economic factors and demographic characteristics including race, ethnicity, gender, age, and other factors. This is a relatively new school of thought. The main idea is that the individual is made vulnerable first and foremost due to their social structure and not necessarily by other choices they make in life
- *Organisational school* - stresses resilience or the effectiveness of response and recovery operations, concentrates on stressing the importance of preparedness, leadership, management, and the ability to adapt, improvise, and be creative.

In addition, McEntire *et al.* (2010) propose strategies to overcome each school of vulnerability. Table 3 summarises these strategies, which are similar to the DRR strategies discussed in Section 3.

Table 3: Disaster risk reduction strategies to overcome vulnerabilities

Vulnerability school	Strategies to overcome vulnerabilities
Physical science school	Creation of warning systems Cautious development Environmental protection Complete relocation of vulnerable communities in extreme cases Land-use planning Careful settlement patterns General categorisation of a place's "hazardousness"
Engineering school	Ways to increase resistance through construction practices and fabrication methods Build structures and infrastructure adequately
Structural school	Improve socio-economic and demographic factors (e.g. race, ethnicity, gender, age, poverty) that usually increase a community's susceptibility
Organisational school	Effective response and recovery operations Effective preparedness Effective leadership, management, and the ability to adapt, improvise and be creative to help improve disaster activities

In this context, a theoretical framework was developed (see Figure 5) based on the above presented literature review and an overall understanding gained through the doctor research. It clearly categorises the DRR strategies that can be effective in overcoming factors forming various vulnerabilities as listed in Table 2.

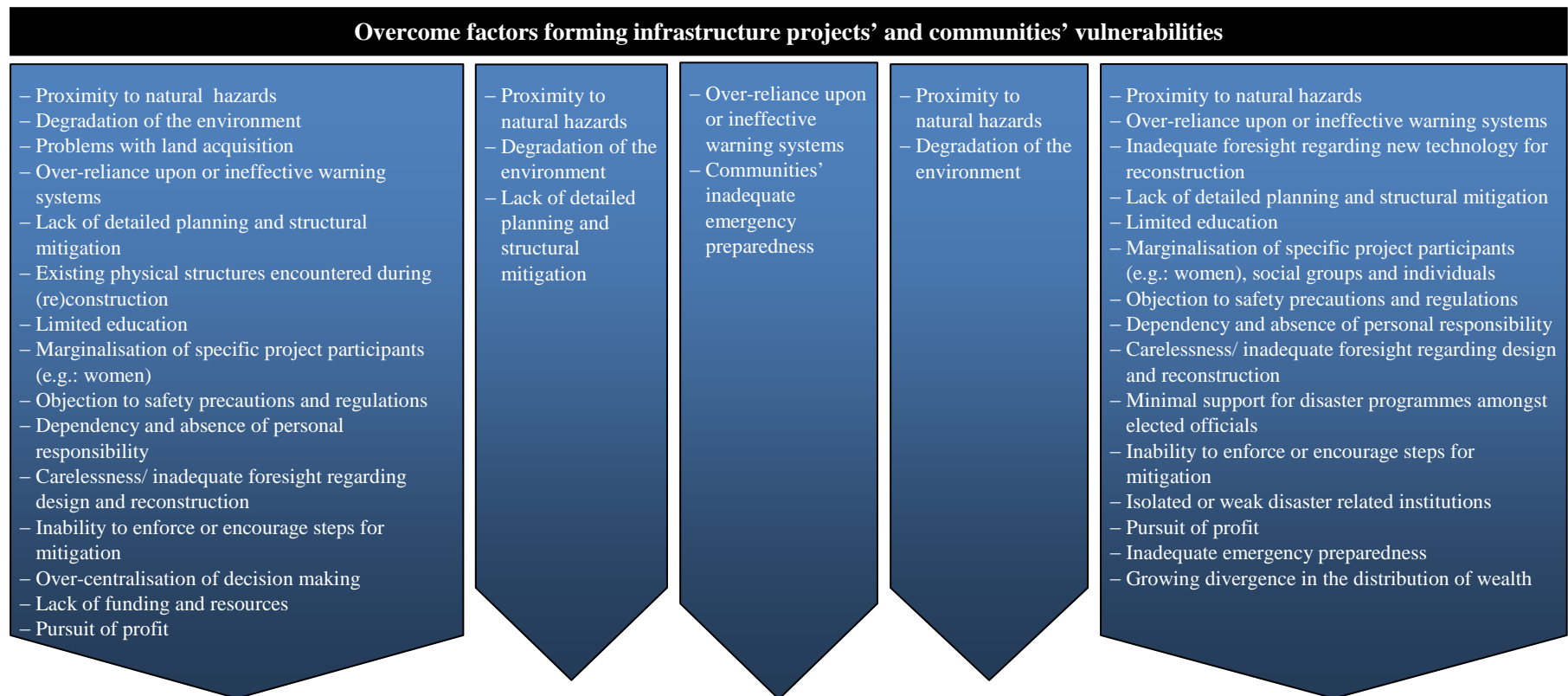
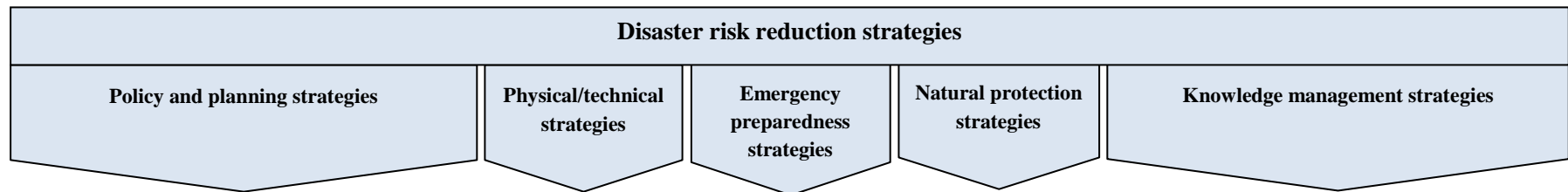


Figure 5: Framework on influence of disaster risk reduction strategies on vulnerability reduction

Based on Figure 5, the influence of DRR strategies on vulnerability reduction is summarised in Table 4.

Table 4: Influence of DRR strategies on vulnerability reduction

DRR strategies	Types of vulnerabilities that can be overcome
Policy and planning strategies	Physical, social, cultural, political, economic, technological
Physical/technical strategies	Physical, technological
Emergency preparedness strategies	Physical, technological, social
Natural protection strategies	Physical
Knowledge management strategies	Physical, social, cultural, political, economic, technological

As research suggests, international, national, and institutional level policies can be of greater influence in reducing all types of vulnerabilities by addressing all the factors that form such vulnerabilities (see Table 2). What is lacking in the current policies is identification of the major factors forming projects' and communities' vulnerabilities to them. It was further identified that physical/technical strategies and emergency preparedness strategies are more effective in reducing physical and technological vulnerabilities because they are more technical and technological oriented and in turn would result in effective location of infrastructures and make them technically and technologically more robust. However, emergency preparedness strategies can further result in reduction of social vulnerabilities because they can largely overcome social factors such as lack of education, over-reliance upon or ineffective warning systems, communities' inadequate emergency preparedness etc., which form social vulnerabilities. While natural protection strategies are mainly effective in terms of reducing physical vulnerabilities, knowledge management strategies are found to be useful in overcoming all forms of vulnerabilities. Knowledge management strategies predominantly involve improving the educational standards of construction professionals and communities; improving women's engagement in project decision making; and improving communication, information management and sharing inside/outside projects.

5. Conclusions

The term 'disaster risk reduction' encompasses a wider range of issues relating to disaster risk management. Presenting an integrated approach, this paper presents an effective classification of disaster risk reduction strategies. It classifies disaster risk reduction strategies under five major categories such as policy and planning, physical/technical, emergency preparedness, natural protection and knowledge management strategies. These exist at the international, national, institutional, project/programme and community/individual levels. Most of the other classifications offered by researchers and practitioners are only limited to a few categories of strategy,

but this study has covered the whole spectrum of issues from international to community/individual level to produce an effective classification of disaster risk reduction strategies.

The primary aim of this paper is to establish a holistic approach for disaster risk reduction. It seeks to establish the link between the theoretical constructs called 'disaster risk reduction' and 'vulnerability reduction'. This resulted in enquires into the effects of disaster risk reduction strategies on vulnerability reduction as the literature review claimed that an effective way of mitigating disaster losses is to reduce vulnerabilities, which is commonly called 'vulnerability reduction'. The proposed theoretical framework elucidates the influence of disaster risk reduction strategies on variables which interact to produce vulnerabilities. Furthermore, the literature review and the empirical investigation of the doctoral research, on which this paper is based, reveals that policy and planning strategies and knowledge management strategies are useful in overcoming all six types of vulnerability (physical, social, cultural, political, economic, technological vulnerabilities). Moreover, that physical/technical strategies are beneficial for physical and technological vulnerability reduction; emergency preparedness strategies are beneficial for physical, technological and social vulnerability reduction; and natural protection strategies are best for physical vulnerability reduction.

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