



IMPACT OF INTEGRATING DISASTER RISK REDUCTION PHILOSOPHIES INTO INFRASTRUCTURE RECONSTRUCTION PROJECTS IN SRI LANKA

Roshani Palliyaguru¹, Dilanthi Amaratunga², Richard Haigh³

¹*School of the Built Environment, Heriot-Watt University, Edinburgh, Scotland, UK EH14 4AS*

^{2,3}*School of the Built Environment, The University of Salford, The Crescent, Salford, M5 4WT, UK*

E-mails: ¹r.palliyaguru@hw.ac.uk (corresponding author); ²R.D.G.Amaratunga@salford.ac.uk;

³R.P.Haigh@salford.ac.uk

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Abstract. Major impacts on infrastructures due to natural and man-made hazards could result in secondary and additional impacts, compounding the problem for those communities already affected by the hazard. Integration of disaster risk reduction (DRR) philosophies into infrastructure projects has been an important solution to mitigate and prevent such disaster risks, as well as for a speedy recovery after disasters. “Vulnerability reduction” is defined by the research community as an enabler which facilitates the process of DRR. However, there is a research need to identify the most beneficial DRR strategies that would result in vulnerability reduction in an effective way. As part of this main aim, this paper seeks to explore the nature of various vulnerabilities within infrastructure reconstruction projects and their respective communities and to evaluate the DRR practises within these projects. Finally the paper attempts to map the effects of integration of DRR into infrastructure reconstruction on vulnerability reduction of infrastructure reconstruction projects and the communities which benefited from such projects. This study adopts the case study approach and the paper is entirely based on data collated from semi-structured interviews and a questionnaire survey conducted within one case study (a water supply and sanitation reconstruction project) in Sri Lanka and expert interviews conducted in Sri Lanka and the United Kingdom. Results reveal that emergency preparedness strategies are the most important group of DRR strategies, while physical/technical strategies are also very important. However, none of the emergency preparedness strategies are satisfactorily implemented, while most of the physical/technical strategies are adequately implemented.

Keywords: disaster risk reduction, infrastructure reconstruction, infrastructure vulnerability, community vulnerability, water supply and sanitation reconstruction projects.

1. Introduction and literature review

1.1. Background

People have been living with risks ever since they first joined efforts, shared resources and assumed responsibilities (Jeggle 2005; Hayles 2010). Thus, communities and built environments have long been exposed to various threats with diverse effects and resultant losses (Bosher *et al.* 2009). Disaster risk reduction (DRR) has become one of the important solutions to mitigate and to prevent disaster risks and for speedy recovery after disasters (Palliyaguru, Amaratunga 2008; Ginige *et al.* 2010; Kulatunga 2010).

1.2. Infrastructure and infrastructure reconstruction

The term “infrastructure” has different meanings in different fields. Infrastructure includes both “hard” and “soft” assets of societies (Anand 2005) and appears in many forms as economic infrastructure, social infrastructure, information technology infrastructure, etc. The President’s Commission on Critical Infrastructure Protection (PCCIP) (1997) in the United States defined the term infrastructure as “a network of independent, mostly privately-owned,

man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services”.

Economically infrastructures are seen to be the structural elements of an economy, which allow for production of goods and services without themselves being part of the production process. These infrastructures primarily consist of transportation services (road, railways and bridges), energy and utilities (electricity, gas), water supply and sanitation services, telecommunication systems, health services, education, essential government services etc. In contrast, Jost (2000) distinguishes infrastructure facilities between object-oriented systems such as hospitals, police and fire stations and central food storage and network-oriented systems such as electricity, gas, water, and sewer systems. This research deals with the economic infrastructure, which is generally formed as network-oriented systems and comes to society as a product or an output of the construction industry.

A sudden disruption of infrastructure affects everyone. The creation of significant negative consequences to infrastructure would lead to major physical reconstruction. Infrastructure reconstruction after major disasters involves

immediate and temporary restoration, medium-term and long-term reconstruction of infrastructure. The differences between a routine infrastructure construction project and an infrastructure reconstruction project may appear in many folds. Infrastructure reconstruction is affected by the housing reconstruction process, particularly that of the beneficiaries of a particular infrastructure project (Devi 2010). Several differences are encountered in the project cycle of these two types of project, in terms of decision-making processes and key decision makers, procurement systems, funding arrangements, and especially the need assessments (Nigim *et al.* 2005; Devi 2010). Post-disaster reconstruction is a very challenging task that decision makers and recovery practitioners in disaster-affected areas have to undertake within a limited period of time (Chang *et al.* 2010a, b). In a reconstruction project, the process is often somewhat ill planned due to financial constraints, limited time and lack of resources. Chang *et al.* (2010) attribute the failures of most of the reconstruction projects to lack of resources for reconstruction: inadequate funding, and lack of high quality physical and technical assistance. More importantly routine construction differs from reconstruction based on the legislative point of view. Accordingly, it is noted that although legal measures are available for routine construction aimed at a safer and more sustainable environment, there is often little provision in legislation to facilitate reconstruction projects.

The benefits of infrastructure tend to temporarily or permanently cease due to disaster risks. As emphasised by authors such as Keraminiyage (2011), Oh *et al.* (2010), major impacts on infrastructure facilities due to natural and man-made hazards could result in secondary and additional impacts, compounding the problem for those communities already affected by the hazard. This is because the impact on infrastructure creates a vicious cycle, amplifying the impact of the disaster to the affected community. It is a transfer of impact on the infrastructure to the community. In order to overcome or limit these infrastructure losses, it is important to identify patterns and ways in which infrastructure facilities have so far been lost, damaged and affected due to disasters.

1.3. Vulnerability of infrastructure to natural disasters

Earthquakes, storms and torrential rains, are some of natural phenomena we refer to as “hazards” and are not considered to be disasters in themselves (Wisner *et al.* 2003). Disaster risk is generated when potential hazards interact with vulnerable conditions (DFID 2004; McEntire 2001; Wisner *et al.* 2003). UN/ISDR (2004a) describes vulnerability to hazards as the degree of exposure of the population/property and its capacity to prepare for and respond to the hazard. It is further defined by UN/ISDR (2004a, b) as “*a set of conditions and processes resulting from physical, social, economic and environmental factors that increase the susceptibility of a community to the impacts of hazards*”. On the other hand, McEntire *et al.* (2010) view vulnerability as a product of four components, which are risk, susceptibility, resistance

and resilience. Here, the entire environment is classified into two sets as physical environment (which consists of natural systems, built environment structures and technological structures) and social environment (which consists of individual and groups of individuals, cultural systems, political systems and economic systems).

Buckle *et al.* (2001) recognise different levels of resiliency and vulnerability. Although the concept of resiliency is defined outside vulnerability, the view presented here is useful in understanding the different levels of various vulnerabilities. Accordingly, it is evident that not only people but also the built-environment structures such as road networks, water supply and sanitation projects are too vulnerable to disasters. Furthermore, McEntire (2001) and McEntire *et al.* (2010) claim that there are innumerable variables interacting to produce a future of increased vulnerabilities which in turn have been categorised under physical, social, political, economic and technological headings. In relation to all the above views, it is apparent that all different types of vulnerabilities are commonly applicable to communities (people) and built-environment structures. On the other hand, Wisner *et al.* (2003) propose a model called “Pressure and Release model” (PAR model) to represent the risk process. PAR model shows how disasters occur when natural hazards affect vulnerable people and it indicates progression of vulnerability, starting from root causes which lead to dynamic pressure and finally to unsafe or vulnerable conditions.

In this context, the possible reason for damaged infrastructure facilities and services is the resultant disaster risks due to natural or man-made hazards, connected with vulnerable infrastructure facilities and vulnerable communities. Segments of infrastructure in numerous countries have been repeatedly subjected to natural and man-made disasters (Nigim *et al.* 2005; Oni 2010). Nevertheless, it attracted great concern after the PCCIP submitted a report which highlighted the topic of critical infrastructures in 1997 (Robles *et al.* 2008).

A fact regarding physically concentrated infrastructure has been raised by Parfomak (2008), who explains, with clarity, that infrastructures may be particularly vulnerable to geographic hazards such as natural hazards, epidemics, and certain kinds of terrorist attacks when they are physically concentrated in a limited geographic area. This raises the issue of interdependency of infrastructures, which means that mutual dependency and interconnectivity of two or more infrastructure facilities with each on different scales of complexity (Leavitt, Keifer 2006; Peerenboom *et al.* 2002). Authors such as Oh *et al.* (2010) and Robles *et al.* (2008) also discuss the interdependencies of infrastructures and the various effects of this characteristic nature of infrastructures. There are certain infrastructures that heavily depend on services provided by some other infrastructure, for example a water supply and sanitation system depends on an uninterrupted supply of power. The PCCIP (1997) noted, high interdependencies and complexities of infrastructures would result in rather minor and routine disturbances in one infrastructure yet leading to major failures in another infrastructure.

Peerenboom *et al.* (2002) identify four types of infrastructure interdependencies as follows:

- Physical interdependency – material output of one infrastructure is used by another infrastructure;
- Cyber interdependency – infrastructure depends on information transmitted through information and communication infrastructure;
- Geographic interdependency – two or more infrastructures are located in the same area and can be affected by a local event;
- Logical interdependency – condition of one infrastructure depends on the condition of another infrastructure in a way that is not physical, cyber or geographic (e.g. linkage through financial markets).

The extensive use of technology has dramatically increased cyber interdependencies across all infrastructures and has contributed to their increased complexities (Peerenboom *et al.* 2002). On the other hand, technical complexity may also permit interdependencies and vulnerabilities to go unrecognised until a major failure occurs (PCCIP 1997). Despite the positive impacts of advanced technologies they could result in greater cyber interdependencies that make infrastructures more vulnerable. Thus, depending on the nature of interdependency, infrastructures can be either physically and/or technically vulnerable. In terms of physical and technological vulnerabilities of an infrastructure system, vulnerability can be generally distinguished between the systems' vulnerability and the vulnerability of each component (service lines, structures or control systems) (Jost 2000). Conventional vulnerability assessments more often concentrate only on structural vulnerability (damage to the structural system), but the functional vulnerability is important because it is recognised that functional vulnerability is greater in frequency than structural vulnerability and functional failures precede structural failures (Jost 2000).

Notwithstanding the physical, technological, structural and functional vulnerabilities; infrastructure facilities can also be vulnerable in terms of social, cultural, political, economic and developmental aspects. Not only do social environments encounter such vulnerabilities but also built environment facilities would possess such vulnerabilities, possibly due to inadequate capacities and cultural barriers of institutions and professionals involved in planning, designing, construction and maintenance of those facilities; in addition, economic constraints may affect construction activities. The key role and the expertise that the built environment discipline could bring forth in the development of society's resilience to disasters, is subject to discussion in more recent research such as Boshier (2008), Boshier *et al.* (2009), Haigh and Amarantunga (2010), Haigh *et al.* (2006). Haigh and Amarantunga (2010) call for an inter-disciplinary strategy within the built environment discipline in order to contribute to increased resilience. Moreover, Boshier *et al.* (2009) researching on improved resilience through a multi-stakeholder approach, uncover the fact that the key construction stakeholders' active role in mitigating flood risk is not sufficient and it is the pre-construction phase of a

building's life cycle that is the most critical phase when key stakeholders need to adopt flood hazard mitigation strategies. Wamsler (2006), presenting a very valid point, claims that while the construction sector plays a key role in mitigating structural aspects, the developers and planners should be able to positively influence the non-structural aspects of construction. However, more research, together with empirical evidence, is required in the area of integration of non-structural disaster risk management and the built environment (Boshier *et al.* 2007).

In this context, there are many reported incidences of high costs of damage to infrastructure due to various hazards all over the world and specifically in Sri Lanka due to natural or man-made hazards. The nature of impact or the extent of damage on infrastructure could vary depending on the type of hazard it faces, its magnitude, and the prior preparedness (Devi 2010; Freeman, Warner 2001). According to Devi (2010) and Freeman and Warner (2001), most disastrous hazards that severely damage infrastructures are floods, earthquakes, hurricanes and landslides. UN/ESCAP (2006) reports that half of the world's natural disasters and 70 per cent of all floods have been recorded in Asian countries and much of the damage inflicted by floods is to the infrastructure. By some estimates, infrastructure losses account for 65 per cent of all flood losses (UN/ESCAP 2006). Freeman and Warner (2001) affirm that small changes in climate change result in large increases in infrastructure damage. Robles *et al.* (2008) believe that natural hazards could greatly affect infrastructures such as the transportation sector. For instance, Oh *et al.* (2010) recognise that transportation infrastructures are the most vulnerable type of infrastructure to floods. Approximately 50 per cent of the World Bank's total lending over the last decade is equivalent to the total cost of damage to infrastructure due to natural disasters in the Asian context (Freeman 2000; UN/ESCAP 2006). The annual investment needed for post-disaster reconstruction of infrastructure and economic recovery in developing countries of the Asian and Pacific region would require an estimated US Dollars 15 billion, for a total infrastructure-financing requirement estimated at US Dollars 55 billion per year (UN/ESCAP 2006).

Sri Lanka was one of the hardest hit countries by the tsunami 2004 disaster; the destructive ocean waves devastated the coastal infrastructure such as roads, railways, power, telecommunications, water supplies and fishing ports, which were already in a seriously debilitated condition due to the ethnic conflict, maintenance negligence, lack of development investment and the effects of high rainfall and flooding in recent years (ADB 2005; ADB *et al.* 2005). Approximately eight hundred (800) kilometres of national roads together with approximately one thousand five hundred (1,500) kilometres of provincial and local government roads were damaged by the force of the tsunami, along with twenty five (25) bridges and causeways located in the North, East and South of the country (GoSL 2005; RADA 2006a, b). In the rail sector, sections of track work, bridges, signalling and communications systems, buildings and some rolling stock were severely damaged on the one hundred and sixty (160)

kilometre long coastline between Colombo and Matara (GoSL 2005). Ten (10) of the twelve (12) fishery harbours were damaged, while eight (8) were completely destroyed (GoSL 2005). While the electricity distribution system and service connections suffered damage throughout the tsunami affected areas, the water supply systems reported damages on portable water treatment, reticulation systems, and local supply systems (mainly ground water sourced) suffered due to salt water intrusion (GoSL 2005). The damage to Sri Lanka's infrastructure from the tsunami is estimated to be over US Dollars 1.7 billion.

1.4. Towards a more proactive approach to vulnerability reduction: Disaster risk reduction

Prevention (eliminating) or mitigation (reducing) of disaster risk can be achieved by prevention or mitigation of hazard and/or vulnerabilities. The best way of preventing or mitigating disaster losses has been identified as preventing or mitigating vulnerabilities, which is commonly called "vulnerability reduction". Stenchion (1997) reiterates the fact that "*development and disaster management are both aimed at vulnerability reduction*". Accordingly, it is imperative that our future paradigm incorporates a broad scope of variables and considers the importance of vulnerability reduction through development and disaster management activities alike (McEntire et al. 2002). Thomalla et al. (2006) identify DRR as one of the four ways of reduction of vulnerability to natural hazards. Thus, it is evident that DRR should be aimed at vulnerability reduction. In other words, vulnerabilities can be reduced through DRR strategies.

The impetus for the DRR came largely with the severe loss of life and property due to natural and human induced disasters. UN/ISDR (2002) views disaster reduction as "*taking measures in advance to address vulnerabilities, reduce risk and anticipate hazards, which involve environmental protection, social equity and economic growth, the three cornerstones of sustainable development, to ensure that development efforts do not increase the vulnerability to hazards*". UN/ISDR (2009a) defines it as "*systematic development and application of policies, strategies and practises 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*".

Wisner et al. (2003) proposed model called "Access model" is a more expanded version of their PAR model described in section 1.3 and it depicts how vulnerability is initially generated, what happens as a disaster unfolds, how conditions need to change to reduce vulnerability and thereby improve protection and the capacity for recovery. The model explains how people earn a livelihood with differential access to material, social and political resources to reduce the vulnerabilities (Wisner et al. 2003). Moreover, "2009 Global Assessment Report on Disaster Risk Reduction: Risk and poverty in a changing climate" by UN/ISDR (2009b) present a range of DRR strategies to overcome vulnerabilities. It is evident from these sources that the concept of DRR not only refers to structural or technically advanced measures but also to soft methods such as poli-

cies, planning and knowledge management, as it is confirmed by Mileti (1999) as well. For example, Lawther (2009) emphasises the importance of community involvement in post disaster re-construction to the overall success of housing and infrastructure redevelopment.

1.5. Integration of disaster risk reduction strategies to infrastructure reconstruction

Within the grounds of the closer two-way relationship between disasters and development, it is apparent that disasters provide windows of opportunities for development. Many authors such as Lewis (1999), UN/ESCAP (2006) and Thiruppugazh (2007) discuss the opportunistic nature of disasters. Disasters can highlight particular areas of vulnerability, for example in areas where there is serious loss of life and physical structures indicate the general level of underdevelopment (Stephenson, DuFrane 2005), because the losses from natural disasters are sometimes viewed as results of development that are unsustainable (Mileti et al. 1995 cited McEntire 2004; Oh et al. 2010). This underdevelopment may be due to social factors (social vulnerabilities), or economic factors (economic vulnerabilities) or some other. In this sense, reconstruction can therefore be used as a development opportunity to help reduce various disaster risks through the particular attention to various vulnerabilities. This necessitates integration of DRR into reconstruction.

DRR strategies can be categorised in various ways. Integration of DRR philosophies into infrastructure reconstruction projects can be done at different levels. Starting from the policy and planning strategies, they are extended to physical/technical strategies, emergency preparedness strategies, natural protection strategies and knowledge management strategies. However, there is a need to identify the most advantageous DRR strategies which would not only make built environment facilities more disaster "*resistant*" but also make them less "*risky*" and the communities benefiting from the facilities more "*resilient*" and less "*susceptible*" to disasters: basically, the ability of DRR strategies to vulnerability reduction. In this context, an empirical investigation was conducted with the aim of exploring the effects of integration of DRR strategies into infrastructure reconstruction projects on vulnerability reduction of such projects and the communities that benefited from them.

2. Research methodology

The case study approach was selected as the main research strategy of this study supported by expert interviews. The study conducted two case studies in Sri Lanka but this paper is entirely based on the first case study conducted within a water supply and sanitation reconstruction project after the tsunami of 2004. The other case study was conducted in the southern part of Sri Lanka, and was concerned with road reconstruction.

In the process of selecting relevant case studies, the main focus was given to the most suitable case studies able to answer the research questions of the study. In selecting cases from the chosen population, this study used the theo-

retical sampling and purposive sampling strategies. One of the operational criteria to select cases was, within which the process of integration of DRR is recognised as important but do encounter challenges during the integration. The researcher identified a list of suitable post-disaster infrastructure reconstruction projects that have undergone the process of integration of DRR at different levels (road reconstruction, water supply and sanitation reconstruction, and bridge reconstruction). The scale of the infrastructure reconstructions projects, the level of integration of DRR practices and the timescale of implementation of reconstruction all contributed in the decision to select post-tsunami infrastructure reconstruction projects in Sri Lanka. Later, a screening process was carried out based on the selected list of post-tsunami infrastructure reconstruction projects. However, one of most important aspects in the selection of cases was the accessibility of cases, relevant data within the cases and knowledgeable respondents. Accordingly, the need was to select on-going or recently completed post-tsunami infrastructure reconstruction projects, in which suitable interview and questionnaire respondents could be found who could best provide information about the phenomenon. The screening process involved questioning people with knowledge about each case and then collecting relevant documentation from the cases prior to short listing them for the study. Accordingly, the final selection of a water supply and sanitation project (case study 1) and road reconstruction project (case study 2) was made.

The case study project addressed in this paper (“*Water Supply and Sanitation Reconstruction Project*”) is a project initiated as a post-tsunami (Indian Ocean tsunami in December 2004) reconstruction project with the aid of United States Agency for International Development (USAID). The water supply project is located at one of the worst tsunami affected areas in Eastern Sri Lanka. People in the area were experiencing a long-term ground water problem which was further exacerbated by the tsunami of 2004. Even the main sources of water such as individual wells were severely damaged and ceased to function after the tsunami disaster. Instead of reconstructing the heavily damaged traditional systems, the case study water project was initiated as an improvement to the existing water supply system in the area. The project is valued at 6.8 million US Dollars and completed in 2008. The reconstruction work was undertaken by an American construction consultancy group together with its local appointed staff in Sri Lanka and a Sri Lankan contractor. Data were collected from the case study project just after its physical completion.

Case study consists of a series of semi-structured interviews and a questionnaire survey. The questionnaire survey was mainly conducted as a triangulation for semi-structured interviews. It ensured the depth of the study by using multiple sources of evidence. Thus, the same issue was investigated quantitatively and qualitatively. Accordingly, the data were gathered using three semi-structured interviews and six questionnaires from project participants attached to the water supply and sanitation reconstruction project. Whilst semi-structured interviews were

conducted among a civil engineer, a project manager and a quality engineer, care was taken not to distribute the questionnaires among those who had already taken part in semi-structured interviews within the same case study. Ten (10) questionnaires were distributed within the case study project and six (6) completed questionnaires were returned to the researcher.

The semi-structured interviews were conducted and analysed first. Later, the questionnaire survey was conducted by incorporating the issues raised at the interviews. The semi-interview guideline was prepared with the aim of capturing the respondents’ knowledge and experience on the integration of DRR strategies into the reconstruction project, the actual practice of DRR strategies within the reconstruction project, the challenges associated with integration of DRR into the reconstruction project and vulnerabilities of the infrastructure project and communities that benefited from such projects. After analysing the semi-structured interview results, the authors investigated the opinion of the respondents and behavioural variables of the case study in two respective questions in the questionnaire survey. The aim of this was to identify any differences between the importance and implementation/considerations of DRR strategies within the infrastructure reconstruction project; and the most prevailing vulnerabilities of infrastructure projects and communities. The types and factors forming vulnerabilities were identified from a comprehensive literature review and the identified list was further improved through the semi-structured interviews. Thereafter a comprehensive list was prepared and it was used as the basis for the case study questionnaire survey. While semi-structured interviews were analysed using NVivo (version 8) software, the questionnaires were analysed using descriptive statistics techniques.

The case study approach carries the difficulty of generalising the findings to a wider population. Therefore, expert interviews were conducted in Sri Lanka and the United Kingdom because their findings are not context specific and therefore the overall study ensured its ability to generalise to suitable domains. The experts were selected based on their expertise in infrastructure construction/reconstruction and disaster management disciplines. Accordingly, two expert interviews were conducted in the United Kingdom and one expert interview was conducted in Sri Lanka. The reason for selecting experts from the United Kingdom was to capture the best practice in the developed world which can be incorporated into developing country practices. The findings of expert interviews were of immense use in interpreting the case study findings, especially in describing the impact of integration of DRR into infrastructure reconstruction on vulnerability reduction.

3. Case study findings

3.1. Vulnerabilities of infrastructure reconstruction projects and communities

Vulnerabilities of water supply reconstruction project

In the questionnaire survey, the data was gathered using likert scales as follows:

- 1 and below = Not present at all;
 1 to 2 = Present to a very little extent;
 2 to 3 = Somewhat present;
 3 to 4 = Present;
 4 to 5 = Present to a great extent.

As tabulated in Table 1, the mean values were calculated against each factor forming water supply project vulnerability and the average mean values were calculated against each type of vulnerability.

According to Table 1, none of the vulnerability types are found to be “present to a greater level” or at the level called ‘present’. The highest average mean values are found to be associated with the technological, economic and developmental vulnerabilities (mean 2.50) while the political (mean 2.38) and physical (mean 2.33) vulnerabilities have respectively become next in-line. These mean values indicate that they are present at a level called “somewhat present” within the project. The next in line are cultural (mean 2.00) and social (mean 1.75) vulnerabilities which are “present to a very little extent”.

In terms of the factors forming vulnerabilities, the highest mean values are obtained by “isolated or weak disaster related institutions related to water supply reconstruction” (mean 3.50), “minimal support for disaster programmes amongst elected officials” (mean 3.00), “lack of funding for water supply project and lack of resources for disaster prevention, planning and management within water supply project” (mean 3.00), “failure to purchase insurance against potential economic losses of water supply reconstruction project” (mean 3.00), and

“inadequate routine and emergency preparedness” (mean 3.00), of which the first two factors form political vulnerabilities, the next two factors form economic vulnerabilities and the last factor forms developmental vulnerabilities of the project respectively.

Vulnerabilities of communities benefiting from water supply reconstruction project

The same procedure was adopted to explore the level of vulnerability of the communities who benefited from the water supply reconstruction project. As shown in Table 2, the mean values were calculated against each factor forming communities’ vulnerabilities and the average mean values were calculated against each type of vulnerability.

According to Table 2, the highest average mean values are shown by physical (mean 3.75), technological (mean 3.50), political (mean 3.50) and social (mean 3.25) vulnerabilities, which are found to be present at a level called “present” within the communities. In addition, cultural (mean 3.00) and economic (mean 2.88) vulnerabilities are “somewhat present” within the communities.

In terms of the factors forming vulnerabilities, the highest mean values are obtained by “isolated or weak disaster related institutions” (mean 4.50), “communities’ failure to purchase insurance against potential economic losses” (mean 4.50), “lack of resources for disaster prevention, planning and management within communities” (mean 4.50), “proximity of people to natural hazards” (mean 4.00) and “inadequate routine and emergency

Table 1. Vulnerabilities of the water supply reconstruction project

Types of vulnerabilities	Factors forming water supply reconstruction project vulnerabilities	Mean	Average mean
Physical Vulnerabilities	Proximity of water supply reconstruction project to natural hazards	2.50	2.33
	Degradation of the environment due to water supply reconstruction project	2.00	
	Interdependencies of water supply project with other infrastructure (two or more infrastructures depend on each other)	2.50	
Technological Vulnerabilities	Project participants’ over-reliance upon or ineffective warning systems	2.50	2.50
	Project participants’ inadequate foresights regarding new technology for reconstruction	2.50	
Social Vulnerabilities	Project participants’ limited education (including insufficient knowledge) about disasters	2.50	1.75
	Marginalisation of specific project participants (e.g: women)	1.00	
Cultural Vulnerabilities	Project participants objection to safety precautions and regulations	2.00	2.00
	Dependency and absence of personal responsibility within water supply reconstruction project	2.00	
Political Vulnerabilities	Minimal support for disaster programmes amongst elected officials	3.00	2.38
	Inability to enforce or encourage steps for mitigation within water supply project	2.00	
	Over-centralisation of decision making within water supply project	1.00	
	Isolated or weak disaster related institutions related to water supply reconstruction	3.50	
Economic Vulnerabilities	Lack of funding for water supply project and lack of resources for disaster prevention, planning and management within water supply project	3.00	2.50
	Failure to purchase insurance against potential economic losses of water supply reconstruction project	3.00	
	Project participants’ pursuit of profit with little regard for consequences	1.50	
Developmental Vulnerabilities	Project participants’ carelessness/ inadequate foresights regarding designing and reconstruction of water supply project considering consequences of disasters	2.00	2.50
	Lack of detailed planning and structural mitigation of water supply reconstruction project	2.50	
	Inadequate routine and emergency preparedness	3.00	

Table 2. Vulnerabilities of communities that benefited from water supply reconstruction project

Types of vulnerabilities	Factors forming community vulnerabilities	Mean	Average mean
Physical Vulnerabilities	Proximity of people to natural hazards	4.00	3.75
	Degradation of the environment	3.50	
Technological Vulnerabilities	Communities' over-reliance upon or ineffective warning systems	3.50	3.50
	Communities' inadequate foresights regarding new technology for reconstruction	3.50	
Social Vulnerabilities	Communities' limited education (including insufficient knowledge) about disasters	3.50	3.17
	Massive and unplanned migration to urban areas	3.00	
	Marginalisation of specific social groups and individuals	3.00	
Cultural Vulnerabilities	Communities' lack of concern towards disasters and inadequate foresights regarding consequences of disasters to water supply project	2.50	3.00
	Community's objection to safety precautions & regulations	2.00	
	Inadequate routine and emergency preparedness	4.00	
	Dependency and absence of personal responsibility within communities	3.50	
Political Vulnerabilities	Minimal support for disaster programmes amongst elected officials	3.00	3.50
	Inability to enforce or encourage steps for mitigation	3.50	
	Over-centralisation of decision making within communities	3.00	
	Isolated or weak disaster related institutions	4.50	
Economic Vulnerabilities	Growing divergence in the distribution of wealth	1.50	2.88
	Communities' pursuit of profit with little regard for consequences	1.00	
	Communities' failure to purchase insurance against potential economic losses	4.50	
	Lack of resources for disaster prevention, planning and management within communities	4.50	

preparedness" (mean 4.00), of which the first factor forms political vulnerabilities, the next two factors form economic vulnerabilities, the fourth factor forms physical vulnerabilities and the last factor forms cultural vulnerabilities respectively. Although two factors have obtained the highest mean values out of the four factors forming economic vulnerabilities, the average mean value of economic vulnerabilities has obtained the lowest average mean value among all other types. This can be mainly attributed to the low rate of responses from the respondents on two factors, "growing divergence in the distribution of wealth" and "communities' pursuit of profit with little regard for consequences". Most of the respondents have indicated that they have no opinion about the existence of these two factors.

3.2. Current position of disaster risk reduction practises within infrastructure reconstruction projects

Data regarding the current position of DRR practises within the infrastructure reconstruction projects was gathered through the same questionnaire survey. It collated the data regarding the importance of integration of DRR into the water supply reconstruction project and their actual level of implementation/consideration within the project. According to the average mean value calculations, the emergency preparedness strategies (mean 4.60) were identified as the most important group of DRR strategies while physical/technical strategies (mean 4.10) are also found to be "very important". In addition, the natural protection strategies are considered as "important" with a mean value of 4.00 and the knowledge management strategies were identified as the least important group of DRR strategies, but still with an average mean value of 3.92, indicating that they too are "important".

Fig. 1 depicts the comparison of importance of physical/technical strategies and their level of implementation/consideration within the water supply reconstruction project. According to Fig. 1, it is evident that most of the physical/technical strategies are considered as "very important" or "important" except the strategy called "flood proofing of tube wells". However, all of them seem to be adequately implemented within the project, sometimes even to a greater extent than its level of importance.

Fig. 2 depicts the comparison of importance of emergency preparedness strategies and their level of implementation/consideration within the water supply reconstruction project. Although most emergency preparedness strategies are considered "very important", none of them are satisfactorily implemented to the extent of their importance to the project. More importantly, it is discovered that "pre-positioning/strategic stock piling of relief material" and "construction professionals (project participants) disaster preparedness after reconstruction" are two strategies which are not adequately implemented at all.

Although natural protection strategies are identified as "important" group of strategies (mean 4.00), they too are not adequately implemented (mean 2.50).

Fig. 3 depicts the comparison of importance of knowledge management strategies and their level of implementation. Accordingly, "project participants' engagement in training & educational/awareness programs on infrastructure safety" (mean 5.00) and "communication, information management and sharing inside the project" (mean 4.50) are considered "very important" strategies while others are considered "important" except "communication, information management and sharing outside the project" (mean 3.00) which is identified as "moderately important". Most of all, knowledge management strategies are adequately implemented to the extent they are considered

red important except “community engagement in project decision making and physical reconstruction”. Although this strategy is considered “important”, it is only “sometimes” implemented, which is not adequate. Further, “communication, information management and sharing inside the project” need some improvements as it is considered a “very important” strategy but only “very often implemented”.

3.3. The impact of integration of disaster risk reduction into infrastructure reconstruction on vulnerability reduction

This section is intended to map the expert interview respondents’ views regarding the influences of integration of DRR into infrastructure reconstruction with the case study questionnaire survey results on the exiting project and communities’ vulnerabilities and the level of importance and level of implementation/consideration of DRR strategies. The mapping exercise identified a range of DRR strategies that was helpful in eliminating vulnerabilities and DRR strategies that can be further implemented within the project to eliminate the existing vulnerabilities.

Vulnerability reduction of water supply reconstruction project

According to the questionnaire survey results, the highest levels of vulnerabilities are associated with technological, economic, and developmental vulnerabilities. In terms of technological vulnerabilities, the experts emphasised the importance of regular upgrades of warning systems and proper lines of communication when warning systems are activated. Infrastructure reconstruction projects need to establish such lines of communication through proper coordination with relevant external entities during reconstruction and also during functioning of infrastructure facilities. In addition, the experts emphasised the importance of “future scenario planning” as an effective way to role-play the warning systems and emergency preparedness strategies, which makes project participants more proactive about imagining disasters and their effects while they are aware of the extent to which they should rely on such warning systems. This is similar to having necessary training and awareness programs on warning systems and how to react to them. Apart from that, lack of intelligence and

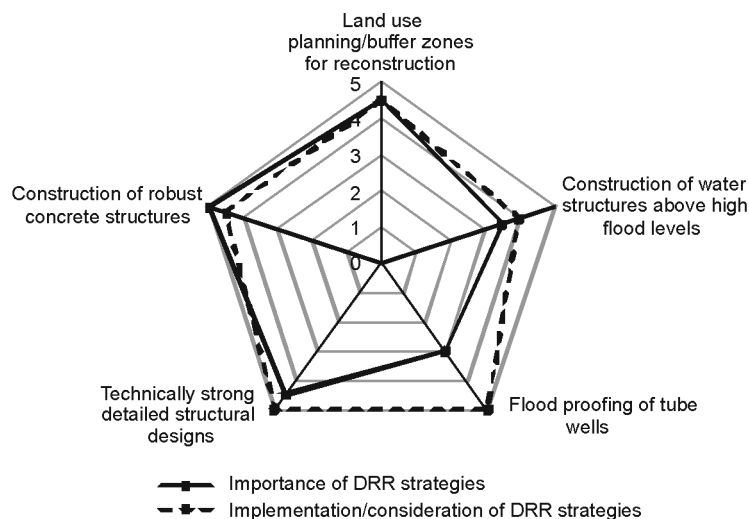


Fig. 1. Comparison of importance of physical/technical strategies and their level of implementation/consideration

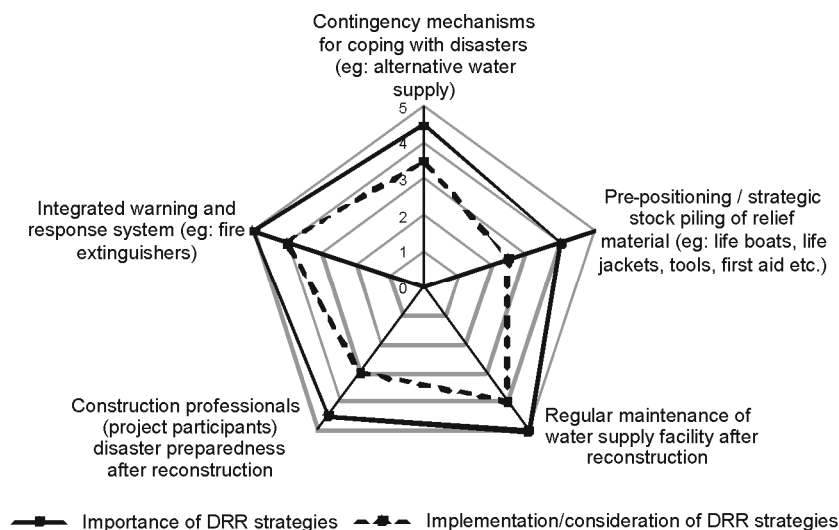


Fig. 2. Comparison of importance of emergency preparedness strategies and their level of implementation/consideration

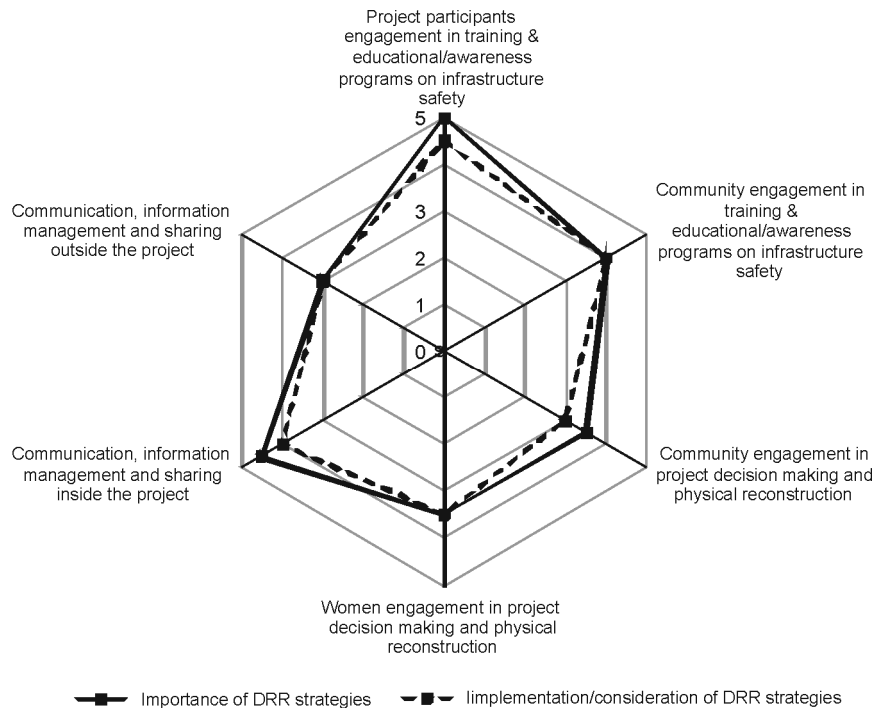


Fig. 3. Comparison of importance of knowledge management strategies and their level of implementation/consideration

lack of professionalism in the people and lack of coordination between different professionals within the reconstruction project are other issues to be eliminated to overcome technological vulnerabilities. As a remedial measure, in addition to project participants' engagement in training and educational/awareness programs, the experts encourage more synergy within professionals with improved coordination of different professions involved in the project. Thus the experts identify the importance of overall coordination of different professionals involved in the projects to share their knowledge regarding warning systems and how to deal with such warning systems. On the other hand, it is imperative to be familiar with the local construction technologies, design features and construction materials in order to overcome unnecessary reliance on new technologies which would not necessarily suit the local context. It can be achieved by improving community engagement in project decision making and physical reconstruction. However, according to the questionnaire survey analysis, the technological vulnerabilities are 'somewhat present' within the project due to a lack of the above mentioned DRR strategies within the project. The questionnaire survey results showed evidence that an inadequate level of implementation/consideration of emergency preparedness strategies and knowledge management strategies was present.

As far as the economic vulnerabilities are concerned, the experts see that economic vulnerabilities are mostly out of project control except strategies that can be adopted to save costs and make project participants take rational and equitable decisions in better integrating DRR into infrastructure reconstruction. DRR strategies such as conducting disaster impact assessments are identified as important in this regard. In addition, the experts emphasised

the importance of conducting whole life cycle assessments, which facilitate measuring financial effectiveness of DRR strategies and finally to make rational decisions about integrating DRR into infrastructure reconstruction projects. Further, proper training and awareness could overcome the lack of professionalism of project participants and make them aware of any relevant regulations with regard to "*project participants' pursuit of profit with little regard for consequences*". In this context, the project had been somewhat economically vulnerable due to the lack of these strategies within the project.

As far as the developmental vulnerabilities are concerned, expert interview respondents attribute "*project participants' carelessness, inadequate foresights regarding designing and reconstruction of infrastructure projects*" to a lack of recognition of different cultures and also to the poor communication, and lack of coordination. So the experts suggested the importance of "*communication, information management and sharing outside and inside the project*", mainly to share hazards and vulnerability related data and to make project participants aware of existing national, organisational policies, regulations and any relevant tools helpful at the design phase. Apart from that, the experts realised the importance of organisational level regulations in this regard and at the same time people being familiar with them through building capacities of project participants on detail structural designing and planning with particular aim emphasis on DRR. Projects can also suffer from a "*lack of detailed planning and structural mitigation of infrastructure reconstruction projects*" due to a lack of time available for further study of the scenarios to come up with detailed plans and a lack of preparedness to face such situations. This is where the importance of existing information on disaster risks be-

comes important. According to the experts, if designers know the real risk, they incorporate them into the project in the form of physical preventative (structural mitigation) measures. However, designers do not spend time on looking for risk data unless they are readily available. On these grounds, the proposed disaster impact assessment to the Sri Lankan construction industry is identified as a very useful planning tool in order to overcome the problem of lack of detailed planning and structural mitigation of infrastructure reconstruction projects. In addition, the experts highlighted the importance of having professionally qualified people in scenario planning and practising in eliminating the lack of detailed planning and structural mitigation of infrastructure reconstruction projects. In the same manner, “*inadequate routine and emergency preparedness*” can be overcome by having proper coordination inside and outside projects of a lack of coordination with external entities and even inside the projects during reconstruction would prohibit built environment professionals from effectively understanding the possible opportunities available outside the project during emergencies. In addition, the importance of practise and repetition are highlighted by the experts. Further, there are useful tools that encourage developers, architects, engineers and those working on a project to look at things systematically and undergo necessary criteria in planning emergency preparedness activities. Furthermore, the importance of “*project participants’ engagement in training & educational/awareness programs on emergency preparedness*” was highlighted by all interview respondents. Moreover, it is valuable to obtain the service of emergency management professionals during the reconstruction processes of built environment facilities. However, according to the questionnaire survey analysis, the developmental vulnerabilities are found to be “somewhat present” within the project, which can be accordingly attributed to a lack of the above mentioned DRR strategies within the project. It was evident from the questionnaire survey results that “*communication, information management and sharing inside the project*” need some improvements as it is considered a ‘very important’ strategy but only ‘very often implemented’. Although the questionnaire results indicate that “*communication, information management and sharing outside the project*” is “moderately important”, the experts interviews suggest it is a strategy useful in eliminating the developmental vulnerabilities of the project and thus need further improvement.

As far as political vulnerabilities are concerned, the majority of the experts identified that most factors forming political vulnerabilities of reconstruction projects are out of the project control. However, they identified certain popular strategies for managing such factors, which sometimes fall outside the concept of DRR. Accordingly, “*minimal support for disaster programmes amongst elected officials*” is claimed to be due to an imbalance of all of the other factors, lack of economic resources, lack of ability, and lack of knowledge. As the experts noted, there are certain countries where communities get minimum support for disaster programmes due to religious, tribal or cast grounds. In this context, the

only strategy that infrastructure reconstruction projects can take up on overcoming minimal support from amongst elected officials is to improve communication, information management and sharing outside the projects. According to the experts, this might improve, at least to some extent the links between infrastructure reconstruction agencies and political agencies such as government ministries. In addition, poor communication was identified by the experts as an issue leading to “*inability to enforce or encourage steps for mitigation within infrastructure reconstruction projects*” too. Therefore, appropriate communication with relevant entities outside and inside the project is a strategy to overcome this factor. Apart from that, the experts view this inability as being due to the perception that integration of DRR is going to cost a lot more. To bring in cost comparison techniques as evidence to how much a DRR integrated project would cost compared to one which has not integrated DRR is an effective way of overcoming this issue to a certain extent. Moreover, “*isolated or weak disaster related institutions related to infrastructure reconstruction*” is a factor forming infrastructure reconstruction projects as politically vulnerable but which is again often out of project control. However, the experts explained the reasons for such grounds based on the Sri Lankan context. Accordingly, they stated that the local governments are not appropriately looped; the mechanism goes through the administrative hierarchy instead of the political hierarchy, which has resulted in a lack of coordination. In this context, communication, information management and sharing outside the project would be a better option to deal with any relevant institutions in order to get maximum benefit from them. In this context, as the questionnaire survey analysis reveals the political vulnerabilities are “somewhat present” within the project, it can be attributed to a lack of “*communication, information management and sharing inside the project*” and “*communication, information management and sharing outside the project*”.

Experts identified 6 key strategies to minimise the “*proximity of infrastructure reconstruction projects to natural hazards*”. However, physical/technical strategies have become more popular DRR strategies due to pressure coming from societies to build back immediately after a disaster. Thus physical/technical strategies such as construction of raised roads and construction of water structures above high flood levels were identified as the most effective strategies in reducing the exposure of infrastructures to natural hazards. Further, physical/technical strategies such as proper land use planning and buffer zones for reconstruction are productive strategies which permit infrastructure projects to be relocated into safer places. However, commenting on implications of physical/technical strategies, the experts raised the issue of ignorance of very complicated processes involving more political, legal, environmental, social and cultural strategies that are able to provide more sustainable, long term solutions to proximity of infrastructure to natural hazards. The importance of proper policy and planning strategies was therefore highlighted, which are beneficial in achieving such long-term, sustainable solutions to proximity

issues. However, it is important that these national or local level policies are backed up by the necessary legal arrangements for their enforcement. Furthermore, the experts identified environmental solutions in the form of natural protection strategies such as reforestation and vegetation of plants as solutions to overcome proximity issues and also the factor called “*degradation of the environment due to infrastructure reconstruction projects*”. In addition, environmental degradation can be overcome using environmental strategies and policy and planning strategies such as environmental ethics, corporate social responsibility and corporate environmental responsibility. Focusing on the Sri Lankan context, the experts noted another important policy and planning issue to overcome the problem of degradation of environment: linking regular EIA (Environment Impact Assessment) process and the proposed DIA (Disaster Impact Assessment) process in reconstruction projects. On the other hand, infrastructures are normally interdependent with other infrastructures during their normal functioning, during their construction or reconstruction and during disaster situations. Disrupted links create much worse effects if they are not properly rectified or necessary contingency plans are not in place. The cause of such failures can be attributed to a lack of coordination between relevant parties. Therefore, proper coordination with external entities responsible for interrelationships of infrastructures is an important strategy not only at normal times but also during reconstruction phases. As interdependencies cannot be necessarily overcome by having a master plan, because interdependencies between different infrastructures can be very different from one another, planning and consideration of interdependencies is important during reconstruction of a particular infrastructure considering the specific context of the project in focus. Experts thus argue that each infrastructure reconstruction project should necessarily install or plan for suitable contingency planning strategies depending on their own circumstances. According to the questionnaire survey analysis, the water supply reconstruction project is physically vulnerable to some extent. As it further identifies that physical/technical strategies are satisfactorily implemented within the project, the causes of existing physical vulnerabilities can be attributed to a lack of concern about the complicated process involving more political, legal, environmental, social and cultural strategies that are able to provide more sustainable, long term solutions to the proximity of infrastructure to natural hazards, the lack of implementation of natural protection strategies and the lack of emergency preparedness strategies such as contingency planning to face disaster situations.

Cultural and social vulnerabilities are present within the project to a very little extent because most of the relevant DRR strategies are adequately implemented within the project. “*Project participants’ objection to safety precautions and regulations*” is a factor which arose due to their negligence of DRR initiatives or due to the assumption that DRR would cost more money in the project. Hence the projects need to overcome project participants’ negligence by adopting effective strategies. As

reported by the experts, making project participants more aware about policies, regulations, and guidelines available regarding integration of DRR practises to infrastructure reconstruction projects would be a useful strategy in this regard. However, as emphasised by the experts, there are instances where logical, risk assessed decisions need to be taken based on the content and context of the particular situation, going beyond a set of generic rules. Further, it is important to dispel such assumptions that DRR would cost more money in the project. Bringing in cost comparison techniques to evidence how much DRR integrated projects would cost compared to one which has not implemented DRR will therefore be an effective strategy to overcome “*project participants’ objection to safety precautions and regulations*”. The same strategies adopted in overcoming project participants’ negligence is applicable in overcoming “*dependency and absence of personal responsibility within infrastructure reconstruction projects*” because it is a rule of thumb that professional people should act in a professional way regardless of the situation. On the other hand, as noted by the experts, it is important to understand that everybody involved in reconstruction projects can often say what is good and the benefits that can be gained. The questionnaire survey findings revealed that “*project participants engagement in training & educational/awareness programs on infrastructure safety*” is an important strategy and also satisfactorily implemented, the existing cultural vulnerabilities can be further overcome by incorporating necessary elements to training & educational/awareness programs to make project participants more aware of policies, regulations, and guidelines available regarding integration of DRR practises to infrastructure reconstruction projects.

As far as the social vulnerabilities are concerned, it is “present to a very little extent” within the project because most of the necessary DRR strategies are adequately implemented within the project. As the experts emphasised, drawing out the experiential knowledge that is implicit in everybody (with regard to disaster reconstruction) and making it explicit is important because otherwise, the implicit knowledge would not be properly transferred to necessary bodies so making them vulnerable with insufficient knowledge about disasters and the consequential effects and strategies to reduce such vulnerabilities. In this context, managers need to have the techniques in place to capture the learning and the experience of those people. In that way, these learning processes are directly helpful in overcoming project participants’ limited education (including insufficient knowledge) about disasters and on the other hand it can lead to proper professional training, both formal and informal training on construction workers and learning issues related to hazard mitigation and emergency preparedness. As noted by some experts, limited education can only be solved by having proper capacity building programs and through making them familiar with existing guidelines, policies and the regulations at national, regional, local, and organisational levels due to their lack of knowledge about those important guidelines and also due to a lack of communication between major construction

related sectors. Furthermore, “*marginalisation of specific project participants (e.g women)*” is another factor contributing to infrastructure projects being socially vulnerable to disasters. It is a factor closely related with project participants’ limited education (including insufficient knowledge) about disasters and therefore as noted by the experts, it is quite important to recognise that everybody has something to contribute to preventing the next disaster. Apart from that, adequate participation of all marginalised parties on professional training, learning issues related to hazard mitigation and emergency preparedness can be helpful in overcoming the problem of marginalisation to a great extent as in the same manner as explained in the previous paragraph. According to the questionnaire survey findings, it was revealed that social vulnerabilities are present within the project to a “very little extent”, the rest can also be overcome by properly capturing the learning and the experience of project participants, incorporating necessary elements to training and educational/awareness programs to make project participants more aware of policies, regulations, and guidelines available regarding integration of DRR practises to infrastructure reconstruction projects and by improving communication between major construction related sectors.

Vulnerability reduction of communities benefiting from the water supply reconstruction project

The highest average mean values are shown by the physical, technological, political and social vulnerabilities, which are found to be present at a level called “present” (refer to table 2). In addition, the communities are somewhat culturally and economically vulnerable.

As far as the physical vulnerabilities of the communities are concerned, it was evident that many people live close to hazard prone areas due to their deprived economic conditions. People tend to outweigh the danger of a disaster against the rewards. In a county like Sri Lanka, it is not easy to address these issues because the government then has to step in and encourage people to move away. In this context, alleviating poverty is the most effective strategy to overcome the communities’ proximity to hazards. Major infrastructure reconstruction projects can be of immense help in this regard by providing opportunities to local communities to actively take part in reconstruction projects. Apart from that, integration of DRR strategies such as land use planning into infrastructure reconstruction which may result in infrastructure facilities being relocated to safer places might sometimes give some incentive to people to move away from hazardous areas. As emphasised by the experts, land use planning can obviously reduce the proximity of communities to hazards. However, it is a long and time consuming process and it has been something highly impractical in a country like Sri Lanka due to communities’ social, cultural and livelihood characteristics and their personnel attitudes. Therefore, these are some important aspects to be effectively balanced during reconstruction. Moreover, the effects of detailed planning on overcoming communities’ proximity to natural hazards were highlighted by the experts. It is especially important in planning of infrastr-

structures such as road networks. Here, the location specific characteristics of the communities are to be taken into consideration during the planning phases of road reconstruction projects. As noted by the experts, the construction professionals should be able to understand all the characteristics of communities before deciding to relocate or some other major changes to infrastructures. This leads to the important DRR strategy called “*community engagement in project decision making and physical reconstruction*”. “*Environment degradation*” has to be overcome by integrating necessary policy and planning strategies and natural protection strategies to infrastructure reconstruction projects. However, as revealed by the questionnaire survey, the communities are physically vulnerable to hazards. This can be attributed to a lack of “*community engagement in project decision making and physical reconstruction*”, no relocation of infrastructure and lack of natural protection strategies.

In terms of overcoming the technological vulnerabilities of the communities, the experts noted that warning systems need to be regularly upgraded and at the same time the communities should be educated about those upgrades. There is a tendency that people neglect some disaster warnings due to conflicting warnings given by different entities. Therefore, it is important to make communities aware of the existing warning systems, possibly by “*community engagement in training and educational/awareness programs*” with particular focus on how warning systems work and further by “*community engagement in project decision making and physical reconstruction*”. On the other hand, although the communities are not necessarily supposed to be aware of new technological advances in infrastructure reconstruction projects, they become technologically vulnerable when they have “*inadequate foresights regarding new technology for reconstruction*” because it is a factor that makes them less aware of newly added features/benefits of infrastructure projects. As noted by the experts, the communities should be aware of what alternative services are available in case of disruption of infrastructure due to disasters and how to get connected to such services. Therefore, necessary activities should take place to make communities aware of these. In that way, again “*community engagement in training & educational/awareness programs*” and “*community engagement in project decision making and physical reconstruction*” are two important DRR strategies which are useful in making communities aware of new technological advances of infrastructure reconstruction projects. According to the questionnaire survey results, although “*community engagement in training & educational/awareness programs on infrastructure safety*” had adequately taken place, the communities are identified as technologically vulnerable. The reason can be therefore attributed to a lack of “*community engagement in project decision making and physical reconstruction*”.

Although the communities are found to be politically vulnerable, the factors forming such vulnerabilities are out of project control, according to the experts. Social vulnerabilities of the communities can be largely overcome by having communities involved in necessary trai-

ning & educational/awareness programs and by engaging them in project decision making and physical reconstruction. This would not only allow communities to learn, but also construction professionals to learn and share communities' knowledge. This knowledge exchange is an effective 'bottom-up' approach. The experts did not claim any major DRR strategies useful in overcoming "massive and unplanned migration to urban areas". On the other hand, the communities become socially vulnerable due to marginalisation of some social groups and individuals. Marginalisation of the communities can take place in the form of lack of access to services provided by the infrastructure projects during their normal functioning or during disaster situations. As noted by the experts, in certain post-disaster reconstruction work, infrastructure service providers reinstall disaster affected infrastructure assuming the entire community has equal access to those infrastructures. However, in certain South Asian regions, there are instances that some infrastructure services are available only to a limited group of people, mainly due to prevailing political and cultural situations such as on cast grounds. In addition, the communities can become marginalised due to a lack of opportunities to actively take part in infrastructure reconstruction projects. According to the experts' views there are DRR strategies which are able to bring many benefits to the projects and the communities, apart from eliminating marginalising community members. Accordingly, there are instances where infrastructure reconstruction needs the knowledge of the local communities. Apart from that, "women" are another community group more often subject to marginalisation. The marginalisation of women was noted as an important issue especially in reconstruction of water supply and sanitation projects. Thus, there is no one fit solution, but infrastructure planning should be based on the prevailing conditions in the local settings. Therefore, as emphasised by the experts, arguably the best way to understand is to work with the people. However, it might be difficult for the governments to get fit people to actually work on infrastructure reconstruction projects. In such situations, it is advisable to get the service of people who are struggling due to poor economic conditions or who may have lost their livelihoods, and they can be trained and used as part of the reconstruction effort. According to the questionnaire survey results, although "community engagement in training and educational/awareness programs on infrastructure safety" had adequately taken place, the communities are identified as socially vulnerable. The causes of this can therefore be attributed to a lack of understanding of local community needs and lack of "community engagement in project decision making and physical reconstruction".

As far as cultural vulnerabilities of the communities are concerned, it is possible to overcome using some DRR strategies. "Communities' lack of concern towards disasters and inadequate foresight regarding consequences of disasters to water supply project" can be overcome by engaging the communities in project decision making and physical reconstruction and by directing those actively engaged workers for necessary training and education/awareness programs.

"Communities' objection to safety precautions & regulations" was also identified as a factor to be overcome by making communities aware of potential benefits of any proposed safety precautions & regulations related to infrastructure reconstruction projects. According to the experts' views, "inadequate routine and emergency preparedness" is again a factor that can be overcome by making communities aware about how to react in case of an emergency with regard to receiving the service of a particular infrastructure (for example, water supply and sanitation projects) or the alternative services supplied by such infrastructures during emergency situations. Finally, "dependency and absence of personal responsibility within communities" was identified as something which needs to be eliminated by improving community engagement in project decision making and physical reconstruction. In that way, almost all factors contributing to the communities being culturally vulnerable are eliminated by improving community involvement in infrastructure reconstruction projects and by conducting necessary training and awareness programs on the matters of concern.

In terms of economic vulnerabilities, although none of the experts appropriately identified any DRR strategies beneficial towards overcoming "communities' pursuit of profit with little regard for consequences", "communities' failure to purchase insurance against potential economic losses" and "lack of resources for disaster prevention, planning and management within communities", they emphasised some DRR strategies which are beneficial in overcoming "growing divergence in the distribution of wealth". Experts believe that reconstruction gives an opportunity to people to take part in reconstruction activities so that they can overcome issues such as hunger and loss of employment. However, the benefits are not equally distributed among all individuals and social groups due to a lack of coordination between the communities and reconstruction agencies. Therefore, infrastructure reconstruction projects need to have better coordination with communities to identify their wealth needs with regard to the particular service supply of the infrastructure project in focus. Although coordination in this nature does not fall under the DRR concept, issues such as demand forecasts need to be appropriately calculated with proper understanding of community needs. As noted by the experts, demand forecasts are also important in planning appropriate emergency preparedness strategies such as contingency plans.

4. Conclusions

The concept of DRR is an important solution to mitigate and to prevent disaster risks and for speedy recovery after disasters. The literature suggests that aiming at 'vulnerability reduction' is a useful approach in integrating DRR into necessary social or physical elements. The empirical results revealed the existing practise of DRR within a water supply reconstruction project in terms of their importance and level of implementation. Accordingly, emergency preparedness strategies were identified as the most im-

portant group of DRR strategies, while physical/technical strategies were also identified as a very important group of DRR strategies. Although the emergency preparedness strategies are considered very important, none of the emergency preparedness strategies are satisfactorily implemented to the extent of their importance to the project while most of the physical/technical strategies are adequately implemented. In addition, although the natural protection strategies are identified as an 'important' group of strategies, they too are not adequately implemented. Furthermore, the knowledge management strategies were identified as the least important group of DRR strategies, but still considered 'important' to the project. Although most of the knowledge management strategies are adequately implemented to the extent of their importance, "community engagement in project decision making and physical reconstruction" and "communication, information management and sharing inside the project" need some improvements.

Further, the empirical investigation identified that different types of vulnerabilities exist within the water supply reconstruction project and the communities benefiting from the project. Accordingly, it shows that the DRR strategies should mostly aim to reduce technological, economic, developmental, political and physical vulnerabilities of the infrastructure reconstruction projects and physical, technological, political and social vulnerabilities of the communities benefiting from the projects, in that particular order of priority. Other than that the communities face cultural and economic vulnerabilities to some extent. However, the DRR strategies have a limitation on ability to address all these types of vulnerabilities because some of them are out of project control, for example, political vulnerabilities. Secondary attention must be given to the cultural vulnerabilities of both infrastructure reconstruction projects and communities and social vulnerability of infrastructure reconstruction projects.

The expert interview results revealed the additional DRR strategies and improvements to present DRR strategies in the water supply and sanitation reconstruction project. Accordingly, it can be concluded that much more improvement is required within the emergency preparedness strategies and the natural protection strategies. In addition, knowledge management strategies need further improvements in the areas of "project participants engagement in training & educational/awareness programs on infrastructure safety"; "community engagement in project decision making and physical reconstruction"; "communication, information management and sharing inside the project"; and "communication, information management and sharing outside the project".

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Roshani PALLIYAGURU. Dr, Lecturer at the School of the Built Environment, Heriot-Watt University, UK. She is a member of the Australian Institute of Quantity Surveyors. Her research interests include effects of disaster risk reduction in built environment on socio-economic development process; and application of vulnerability reduction principles into infrastructure construction.

Dilanthi AMARATUNGA. Professor, leads the University of Salford's Centre for Disaster Resilience, responsible for supporting research on disaster management portfolios. She is also the Associate Head of International Development for the School of the Built Environment. Her research interests include: post-disaster reconstruction including conflict mitigation, gender and projection; capability and capacity building in managing disasters; socio-economic measures for conflict-affected re-construction and women in construction. She is the Co-Editor of the *International Journal of Disaster Resilience in the Built Environment*. She has presented widely at international conferences, has led international disaster management workshops and seminars and is working actively with the United Nations.

Richard HAIGH. Dr, Senior Lecturer at the Centre for Disaster Resilience, School of the Built Environment, University of Salford, UK. He is the Editor of the *International Journal of Disaster Resilience in the Built Environment* and a theme leader of the International Institute of Infrastructure Reconstruction and Renewal. His research interests include the conceptual understanding of resilience in the built environment, and conflict sensitive reconstruction.