Infrastructure Resilience in the Samoas – Policy Approaches

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Abstract

'Resilience' is a term that is increasingly being used regarding community development issues. It is a particular issue on Pacific Islands where development issues exist, and the exposure of communities to natural hazards is apparent. Climate change is increasingly affecting Pacific Island communities. Many Pacific Island communities live on low-lying atolls, and communities on 'high' islands are generally located close to the coast. Both sets of communities are therefore highly exposed to storm and high seas events. Additionally, earthquake, tsunami and volcanic hazards exist. Infrastructure is a key aspect of resilience. Policies and technical issues regarding infrastructure resilience globally are the subject of a literature review. Research presented compares the policies taken to resilient infrastructure in (Western) Samoa against those taken in American Samoa. These two territories shared common cultural histories until the 19th century, both are 'high' islands and both face a similar range of natural hazards faced due to their relative close proximity in the Pacific Ocean. Analysis highlights where lessons can be learnt both globally and from the Samoas' approaches to resilient infrastructure. The lessons learnt in this thesis include the value of taking a holistic approach to disaster risk reduction, involving the community in hazard identification and disaster risk reduction, and working on these issues in a timely manner. Additionally, it is seen that careful long-term planning of land use with natural hazards in mind, which is found to be an economically sound approach, is of value in disaster risk reduction.

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1 CHAPTER ONE: INTRODUCTION

1.1 An overview of this research

This research focuses on disaster risk reduction and the resilience of infrastructure (roads, water and sanitation, power supply and communications equipment). The study will explore governmental approaches to analysing infrastructure resilience and the means of militating against disaster. As a means of analysis and comparison of approaches, the actions and approaches taken in the state of Samoa (formerly called 'Western Samoa', but from now on to be referred to simply as Samoa) are compared against the actions and approaches taken in American Samoa. Both island states had, until the nineteen century, a similar history. Both island states, located in a similar area of the Pacific Ocean, and both being 'high' islands, are subjected to similar natural hazards. The size of the population is greater in Samoa (around 179,000 in 2009) compared to American Samoa (around 66,000 in 2010). However in terms of analysis and comparison of policies and approaches to disaster risk reduction, this population difference is not seen to be significant. Due to the above similarities of geography and population, but being parts of differing political systems (Samoa independent, but aligned with New Zealand, and American Samoa being a dependent US territory), the comparison of approaches taken may be due to political and developmental reasons.

This thesis is a policy analysis, a factor which affects the methodology chosen. The thesis presents a literature review that outlines 'best practice' for disaster risk reduction, both globally and specifically for Pacific Island states. The collection of information from the Samoas for the original research part of the thesis, focussing on a specific policy issue, is gathered from key informants. The voices chosen know the issues in some depth, and each person was able to comment with authority on the specific aspects of the work they are carrying out, explaining the reasons for the choices made and the results of the works carried out. Analysis and conclusions are taken from these strands of study.

The outputs of this thesis are a set of 'lessons learnt' regarding disaster risk reduction and infrastructure resilience. In one aspect, best practice for disaster risk reduction globally is relatively easily defined, with a strong set of authoritative documents produced by the World Bank, the United Nations Development Programme and other influential international organisations. The manner in which this best practice is implemented in-country however, specific to the Samoas, leads to a set of lessons learnt specific to the contexts on those island states, although these learnings are applicable to many Pacific Island states.

1.2 Why this subject was chosen

This subject allows investigation and learning in disaster risk reduction philosophies and practices globally, and particularly for the Pacific. A substantial quantity of research has recently been carried out globally into disaster risk reduction, driven by climate change and climate variability issues. Climate change is likely to affect large populations living in low-lying or vulnerable areas such as in the flood plains and river deltas of Bangladesh, or on Pacific Island (both 'high' islands or low-lying ones). Indeed, the very viability of low-lying countries such as the Maldives and Kiribati may be influenced by sea-level rise. Climate change therefore has the potential to have a large effect on individual populations, and the study on the influence of climate change on societies has driven this area of research. Climate change mitigation (ensuring lower carbon emissions are released to the atmosphere) is not directly addressed within this thesis, however as will be seen in Section 3.4.2, *Vulnerabilities to natural hazards (for small island states)*, it is an influence on the choice of power sources for some small and remote islands. Climate change adaptation (changing practices or physical items, such as infrastructure) is more closely addressed within this thesis.

The comparison of how the issue is addressed in Samoa (supported by Australia / New Zealand), against the approach taken in American Samoa (a US dependant territory) allows a relatively 'pure' comparison of two geographically close,

ethnically similar, but politically different countries. Parallel political systems may well give rise to different approaches to similar subjects, and this issue will be drawn out in this thesis, specific to infrastructure policies.

As a first step, and in order to understand the demand for resilient infrastructure, the concept of vulnerability, and its corollary, resilience, is explored within the literature review (Section 3).

This combination of development studies issues and civil engineering (both areas of study and interest to the author), alongside the geographical and political proximity of the issues in the thesis make this a relevant and timely thesis.

1.3 Hazards in the Pacific, and their economic effects

Statistics on disasters in the Pacific area are instructive. Bettencourt et al (2006, Table 1, p 2) summarise the natural hazards thus:

Reported disasters in the Pacific Islands (1950 – 2004)

	Number	**Reported fatalities**	**Population affected**	**Reported losses (in 2004 US$, million)**
Windstorms	157	1,380	2,496,808	$5,903
Droughts	10	0	629,580	$137
Floods	8	40	246,644	$94
Earthquakes	17	53	22,254	$330
Others*	15	274	21,520	$60

* ‘Others’ includes landslides, tsunamis, volcano eruptions, wild fires and epidemics.

As can be seen from the table above, the large majority of reported disasters have been from climate related events, particularly windstorms (cyclones). This is of

interest, as it demonstrates why a considerable focus in the disaster risk management field has been on weather related events. It also demonstrates why an increasing weather related hazard, through the effects of climate change, will be of particular interest to the Pacific Islands.

Economically, the effects on selected Pacific countries are demonstrated below:

Estimated economic and social impact of disasters in selected Pacific Island countries (1950 – 2004)

Country	No. disasters reported	Total reported losses (in 2004 US$)	Average population affected in disaster years	Average impact on GDP (%)
Fiji	38	$1,175,600,000	10.8%	7.7%
Samoa	12	$743,400,000	42.2%	45.6%
Vanuatu	37	$384,400,000	15.5%	30.0%
Tonga	16	$171,100,000	42%	14.2%

Source: Bettencourt et al (2006, p2)

Although in New Zealand terms, the figures for total reported economic losses are not extreme, the percentage rates of population affected and the effect on the various economies of the various islands due to economic shocks is clear. As will be seen in Section 3.2, such economic losses to hazard events have marked consequences to the development of a community. With increasing vulnerability to hazards, both human and economic losses are likely to worsen.

1.4 Post-disaster work and pre-disaster work

In terms of disaster risk, practitioners divide the broader subject of Disaster Risk Management (DRM) into the narrower subjects of 'Disaster Risk Reduction' (DRR), normally focussed on the pre-event provision of trained staff, appropriate government systems and provision of resilient infrastructure and 'Disaster

Management' (DM), normally focussed on the post-disaster logistics of delivering aid to affected communities.

Although different areas of work, often addressed by very different sets of expertise, the two areas of DRM do interact, as will be seen in Section 3.5.1: *Long term planning against natural hazards*. This is mostly in relation to long-term infrastructure plans mitigating against hazards, but also providing necessary buildings or other infrastructure for response and recovery activities to be staged from, post disaster. This thesis is focused on the pre-event planning and delivery of resilient infrastructure, and is therefore very much aligned with the Disaster Risk Reduction field of work.

1.5 Related worldwide research

Research is ongoing on a number of issues that affect the subject of infrastructure vulnerability. These include the following areas.

Climate change and variability has attracted a large quantity of research as will be seen in section 3.3.3.1. Research on climate change was largely initiated in the 1990s and is becoming more sophisticated due to the improved capacity of computers that can process the vast quantities of data required to produce climate change models. Secondly, as the weather events of each year are measured and analysed, more data becomes available for matching the outputs of the research models against the actual observed weather patterns. This allows models to be calibrated more closely, and to be adapted to the climate changes observed, giving ever greater certainty as to how climate change and variability will affect the planet, and in specific locations.

In addition to the research on changes in climate noted above, further research is ongoing into the physical effects of climate change and sea-level rise, including how far the sea is anticipated to rise, and the effects of this on wave levels and saltwater intrusion into freshwater systems on islands (see Section 3.4).

Other research is ongoing to the social effects of climate change on various communities worldwide. The fear of communities abandoning traditional lands, or of mortality from disasters, are the more extreme drivers of research into social effects. This will be seen further in Section 3.1, *Population vulnerability to natural hazards*.

The above are merely the larger broad areas of research that inform the understanding of infrastructure vulnerability. There is also a wide range of related and associated research alongside the above areas of study.

1.6 Overview of geopolitical history

The following provides a brief geopolitical history of Samoa and American Samoa. This gives an understanding of why and how the two separate states became to be governed by two very separate political systems, despite sharing close geographical locations, and sharing similar ethnic and cultural histories.

1.6.1 Samoa

Samoa, as a Polynesian island group, was very much subject to patterns of population, contact and trading during the early Polynesian / European contact period. Samoa is perhaps slightly less typical of other Polynesian island groups in that it has had affiliations with a number of outside countries. Early trading was carried out between the Polynesian people and variously British, American and German traders, amongst others. As trade and missionary activity increased, and without (to the Europeans' perspective) an individual Samoan in control of the islands, relative chaos ensued, with at least seven attempts to create governments between 1876 and 1889 (Campbell, 2003). Civil war and rebellions ensued. A conference between the United States, Germany and Britain (notably, without Samoan input) decided that Samoa should be an independent nation, and the Swedish monarch was chosen as a neutral person who could identify a Samoan head of state. The Samoan chosen, Malietoa Laupepa was ineffectual and lasted effectively only a few years until a rebellion. In amongst this, the

dominant trading company, Godeffroys, which had strong German links, wielded some level of political power within the country.

In 1899, Germany and the United States agreed on the partition of Samoa, with 'Western Samoa' (now Samoa) claimed by Germany, due to a great deal to the activities of the Godeffroys trading company. American interests in Eastern Samoa (now American Samoa) were chiefly around the strategic value to the United States of the port of Pago Pago. The German rule of Samoa lasted just 14 years. Due to the effects of both the First and Second World Wars, military control of the 'Eastern Pacific' was taken by the British Empire. In 1947, Samoan and New Zealand political interests aligned, and New Zealand effectively became the colonising country of Samoa. New Zealand took a relatively progressive line regarding the control of the country, creating reforms which led, as early as 1952 to the creation of a timetable for movement towards full independence, which was finally achieved on 1 January 1962 (Campbell, 2003). A treaty of friendship, signed by a representative of each country, affirmed an "intimate" relationship between the two countries with, for example, New Zealand taking on various foreign policy tasks on behalf of Samoa, and allowing "equitable treatment" of the respective nations' citizens.

Although independent, Samoa has retained a strong connection with New Zealand. This is partly due to the above political and trading machinations, but also largely because the two countries are both Polynesian nations. Many Samoans live and work in New Zealand, further strengthening the cultural connections between the two countries.

It is for the above reasons that Samoa has retained a strong political and cultural connection with New Zealand, perhaps more so than with any other external nation.

1.6.2 American Samoa

Eastern Samoa, now American Samoa, was claimed by the United States in the late 19th Century. Although culturally and ethnically close to Samoa, since the

time of that claim by the United States, Samoa and American Samoa have taken varying political directions.

On gaining control of Eastern Samoa (from now on in this thesis, to be known as American Samoa), the United States made "no philosophical or ideological pretensions" (Campbell, 2003). Until the First World War, American Samoa was administered by the US Navy, with a succession of Naval Commanders taking governance of the territory, each for two-year stints. The Commanders generally took a paternalistic approach, treating the local population as child-like and in need of protection. This situation was apparently not particularly challenged by the local population. The benefit, from the US point of view, in being in American Samoa was the use of the port at Pago Pago. No particular economic potential was seen by the US in the remainder of American Samoa, and therefore the US Navy was the only significant economic/trading activity in the country, apart from relatively low levels of copra trading, which were also administered largely by the US Navy. The US Navy retained effective governance of American Samoa until 1951, at which time the US Department of the Interior took governance. Whilst Washington made some moves towards creating independence for American Samoa, these were not actively supported by the local population, who preferred to retain the benefits of budgetary support and relatively free access for the population to the United States mainland. It was not, however, until 1975 that a governor was first elected for American Samoa.

In the above way, American Samoa has retained political alignment with the United States of America, with political and administrative systems coming from the US. Of particular note is the continued involvement of the US Department of the Interior, which administers the 'American Flag' nation. 'American Flag' states in the Pacific are: American Samoa, the Commonwealth of the Northern Marianas, Guam, the Federated States of Micronesia, the Republic of the Marshall Islands, and the Republic of Pulau. Whilst American Samoa has not been integrated into the US as a State (as has Hawai'i), it remains under the control and protection of the United States. Those born in American Samoa to American Samoan parents may take United States nationality, which allows them

to reside and work in the United States, but not citizenship. This means that they cannot vote in State or Federal elections in the United States.

In the above way, it can be seen that although culturally and ethnically strongly aligned with other Polynesian islands and peoples, particularly with its near-neighbour Samoa, politically, American Samoa runs along markedly different lines to other Polynesian islands in the region, strongly aligned to US political systems.

1.7 Outline plan of this thesis

After this initial introduction, Chapter Two describes the methodology used for the information gathering and analysis in this thesis. A literature review is included in Chapter Three, which demonstrates the knowledge and understanding on resilient infrastructure globally, then more specifically for small island states and then specifically for Pacific Island states. It concludes by capturing 'best practice' for the study and analysis of resilient infrastructure, applicable for Pacific Island states, which clearly covers the Samoan and American Samoan contexts. Based on an understanding of this best practice, Chapters Four, Five and Six outline the practices and policies taken in Samoa and American Samoa, and by external governments, United Nations and International Finance Institutions regarding resilient infrastructure in the Samoas. The approaches taken are compared to the best practice identified in Chapter three. An analysis of the approaches taken is presented in Chapter Seven, including the development of what lessons can be learnt by the Samoas themselves, and lessons which can be taken by other organisations and locations relevant to other contexts. Final conclusions are presented in Chapter Eight.

2 CHAPTER TWO: METHODOLOGY

This chapter outlines the author's positionality as a means of giving context to how the author has understood and carried out the analysis within this thesis. This will be seen to be particularly relevant in that the author's past experience as an engineer has given context and undoubtedly affected his view on resilient infrastructure. The chapter then outlines the background to the analysis within the thesis, demonstrating why specific analysis methods were chosen for this.

2.1 My positionality and positioning this thesis

To give context to the approach that the author has taken to this thesis, the following is an explanation of his background, work experience and past study, as this has a large effect on how he has approached this subject, and his understanding of some of the issues faced.

I was brought up in the United Kingdom, where I attended school and university. I am from what would be termed a 'middle class' environment. I have a Bachelor's degree in Civil Engineering, a Masters of Business Administration and a Masters of Water and Environmental Management (for developing countries and low-cost contexts).

My work experience has been in both 'developed' civil engineering environments, principally in road construction and maintenance, and in the 'humanitarian contexts' of Ethiopia and Uzbekistan, where I performed work on engineering and public health projects. Apart from living in New Zealand for the past six years, I have no experience of living and working in Pacific countries.

All of the above has shaped the way in which I view the world and the way in which I approach subjects. This aspect should be borne in mind in the reading of this thesis. It should be noted that I am effectively an 'outside observer' of

policies produced by, and affecting, Samoa and American Samoa, but one able to draw upon my professional experience as an engineer.

The sectors of development studies and civil engineering do not often cross, even though the two sectors have much common ground. Development studies looks at holistic political systems whereas the civil engineering field may be seen as one of the key implementers of the resulting policies. The skill-sets of these two sectors are different (social sciences and technical/science) which is why the sectors rarely cross. The contribution of this thesis may be seen as providing a bridge between these two parallel sectors of work. Overall it must be stressed however that this is a development studies thesis, and even though I have the civil engineering technical training, this thesis looks in a holistic manner at the development studies related field of policy.

2.2 Analysis method choice

This thesis includes a policy analysis. This factor shapes the nature of the literature review, the collection of data and the resulting analysis. As a policy review, the collection of original information for analysis is from both key documents and authoritative voices for each of the island states of Samoa and American Samoa.

The nature of policy analysis is key to the choice of information gathering and analysis methods. For policy on resilient infrastructure, as in many other fields, there are choices regarding policies taken by governments. These policies can concentrate on specific issues or can concentrate on specific communities, or on why or how to engage with communities. As such, there is no underlying 'truth' or 'concrete conclusion' as could be found in a 'hard science' thesis. The policies taken by different governments or organisations in different contexts are often a product of the social context, with resulting meanings and policy choices. Further, as demonstrated in the positionality statement at the start of this Chapter, the author also has his own understanding of resilient infrastructure issues, and is

therefore not an objective outsider to this sector, but effectively a part of the engineering and development sectors, and therefore a part of this research.

The nature of the information gathering and analysis within this thesis means that a quantitative analysis cannot be taken for this thesis with an expectation of concrete results. Rather, given the meanings taken by individuals in key positions at the relevant government bodies and relevant organisations, a qualitative research method has been undertaken. The literature review has been carried out based on qualitative information gathering. Similarly the information gathering specific to Samoa and American Samoa has been carried out from both key informants in specific governmental and other organisations, and from reports or documents recommended for viewing by these informants. Most of these documents were available publically, often on the internet, whilst some documents were viewed in final draft format.

Interviews with key informants were carried out face-to-face where possible, however due to the locations of some informants, some interviews were carried out by telephone, or where not convenient, by e-mail exchange. The locations and availability of the relevant informants meant that information gathered for Samoa was by telephone or face-to-face contact with key consultant staff, and by e-mail with the Samoan Government employee. All contact with American Samoan Government department staff was by e-mail exchange. All of the above contacts were under a structured interview format, with follow-up contact made where any clarification or additional information was required.

The information gathered from the Literature Review in Chapters 3 to 6 is analysed in Chapter 7, where the approaches and policies taken within, and for, the respective countries are compared with each other and with other related contexts. This analysis leads to a set of lessons that can be learnt both from the individual countries and from a comparison between the two approaches taken in and for Samoa and American Samoa. Again, the analysis is carried out on a qualitative basis as quantitative methods were not relevant to the style of information gathered. Finally, conclusions are drawn from the above analysis and presented in Chapter 8.

2.3 Interviews for information gathering

Informants of original information for this thesis were found through personal contacts with this thesis writer, and from introductions from those contacts. A list of participants, and the manner in which they were 'found' (or introduced to the author) is presented in Appendix 1.

Information gathered

The contacts were knowledgeable in their subject areas, and due to their positions and understanding of the work carried out by the American Samoan and Samoan Governments, it was not considered necessary to seek additional contacts regarding this subject matter.

All of those approached, as above, agreed to participate in the research. There were no refusals to participate. All will be supplied with a copy of this thesis, when finalised.

3 CHAPTER THREE: LITERATURE REVIEW

This chapter sets the context for the remainder of this thesis, describing the choice of a definition of 'infrastructure', as different organisations and contexts require their own specific descriptions of infrastructure. Further contextual descriptions are given for hazards, with choices of the types of hazards chosen for analysis. One of the key issues within this chapter however is a description of the concept of the vulnerability of communities to natural hazards. As will be seen, there has been an evolution of thought on this concept, starting in around the 1970s. Once these basic concepts are described, the chapter then demonstrates understandings of vulnerability of communities to natural hazards firstly at a global, generic, level. Literature specific to natural hazards on small island states is then presented, as this gives context to understandings of why small island states are particularly vulnerable. Finally, literature specific to community vulnerabilities to natural hazards on Pacific Islands is presented. The above information demonstrates present thinking on 'best practice' for community vulnerability to natural hazards.

The above information sets the basis of understanding and context for the remainder of this thesis.

3.1 Basic definitions and scope

3.1.1 What is meant by 'resilience'?

There are many definitions of resilience. One such example is provided by the United Nations Office for Disaster Risk Reduction (UNISDR, 2012): "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions." Alternatively, the New Zealand Treasury has adopted the following wording "The ability of a system to withstand or recover quickly

from a significant disruption." Whilst the exact wording for a definition of resilience (or vulnerability) may be debated, the key test for the concept of resilience is how it may be measured. A measurable definition would provide greater certainty of the concept. However there is currently no commonly agreed measurable definition of resilience. This aspect is explored further in Section 3.2.2.

The words 'resilience' and 'vulnerability' have been used increasingly in the past decades, whilst the field of disaster risk reduction has been developed. The two words are the corollary of each other, and both are widely used. Some in the field prefer the use of 'resilience', implying the positive aspects of community empowerment, and this word appears to be increasing in usage in comparison to the more negatively focussed 'vulnerability'.

3.1.2 Focusing on the medium and large scale hazards

What is meant in this context by a disaster or natural hazard? There is a scale of disaster from the household level (injuries from isolated or minor hazards) up to the global. Minor-scale events are not generally the subject of infrastructure policy. The smallest type of event that would be captured by disaster risk reduction policy would be minor and frequent events, such as rivers that cause repeat damage to a road. At the very large scale, there have been a number of global events during the earth's history with massive and widespread consequences, such as the event that killed much dinosaur life on earth. Wisner et al (2004: p37) note that there have been five mass-extinction events over the past 400 million years. These massive events are too huge for infrastructure or social adaptation systems to mitigate against, and as such, are too large for the context disaster risk reduction, or of this thesis.

This thesis is therefore aimed at the 'medium scale' event in comparison to the extreme examples given above. It is aimed at the types of hazards and events for which policies regarding the resilience of infrastructure can have an effect. Such events include earthquakes, tsunami, volcanic and weather events such as cyclones or tropical storms and their follow-on effects such as flooding and

landslips. Disasters, as approached in this thesis, are those events that affect human life and infrastructure resulting from the above range of natural hazards.

There is a substantial and authoritative literature on the identification and analysis of natural hazards, typified by texts by Smith and Petley (2009), Tobin and Montz (1997) and Burby (1998). These texts provide a framework for analysing hazards, and work towards mitigating their effects from a technical standpoint.

3.1.3 What is infrastructure in this context?

There is a variety of definitions of 'infrastructure'. Most definitions relate to physical assets such as:

- roads and transport facilities
- water treatment facilities and supply pipework
- wastewater pipework and treatment works
- energy supply facilities
- solid waste facilities
- seawalls and
- communications equipment (including fibre optics and associated cabling).

Some definitions, particularly from highly industrialised contexts, provide wider definitions. Parfomak (2008) and O'Rourke (2009), writing for the USA context, both include the above physical resources, but extend the concept to include less tangible infrastructure such as banking and internet networks.

Infrastructure resilience in the Pacific, and the focus of this thesis, is purely on the physical infrastructure outlined above. Although banking systems certainly exist in the Samoas, it is not the type of infrastructure that would normally be affected by weather or natural hazard events, and is therefore not the subject of normal infrastructure resilience studies in this context.

3.1.4 What is infrastructure vulnerable to?

Different sets of infrastructure will be vulnerable to different sets of natural hazards. In general, roads are generally more susceptible to water hazards, such as flooding, wash-out and coastal effects. Overhead cables for power supply may be vulnerable to high winds but resilient to seismic hazards, with buried cables more vulnerable to seismic events. Water and wastewater pipework may be resilient to wind storms, but vulnerable to water wash-out or blockage resulting from run-off of sand and silt from rain storms. As can be seen, each set of infrastructure can have differing vulnerabilities to specific hazards. Further, overhead power lines, for example, will traverse different kinds of landscapes, each posing different natural hazards. This means that, in terms of disaster risk reduction, specific items of infrastructure should be analysed according to the risk they face from exposure to the varying natural hazards of the terrain they pass through.

3.2 Population vulnerability to natural hazards

3.2.1 How development projects affect vulnerability

3.2.1.1 The concept of vulnerability

Studies by Wisner et al (2003) and UNDP (2004) demonstrate how exposure to a hazard is different to human vulnerability to natural hazards. To be vulnerable to the hazard, a person must both be exposed to the potential hazard and be vulnerable to the effects of that hazard. Consider the examples of two island states, Haiti (GDP $1,200) and Japan (GDP $34,200) (CIA, 2011). Both have suffered significant earthquakes in the recent past. The infrastructure, including buildings, in Haiti did not perform well in a Richter 7.0 seismic event causing 230,000 deaths (BBC, 2010). In Japan however, with the much larger Richter 9.0 event, there was a total of 10,000 deaths, with only around 2,000 of these estimated to be from the earthquake, the reminder of deaths resulting from the following tsunami (Next Big Future, 2011). The population exposed to the events was very different (higher in Japan), and the magnitudes of the disasters also

different (larger in Japan), but the mortality rates were much lower in Japan. This example outlines how human vulnerability to one natural hazard, earthquakes, has provided clearly different outcomes for two populations. The same concept remains relevant for the exposure to other natural hazards such as flooding, cyclones and landslips. Potential exposure to each of these hazards is faced by many populations in many countries, however the mortality rates are different in each country, depending on the vulnerability of the respective populations to that risk. This vulnerability often depends on the resilience of the infrastructure and buildings in the relevant context.

Following this logic, it is therefore insufficient to state after a disaster that infrastructure was lost as a result of a natural hazard. Rather it is better to state that the infrastructure was in a location at risk from the natural hazard in the first place, or was designed to standards insufficient to withstand the hazard.

The above demonstrates vulnerability from a fairly technical viewpoint. As will be seen in Section 3.4.3.2, there is an opposing view that, rather than seeing populations as vulnerable, even passive, to hazards, community coping mechanisms provide resilience. Both views have merit, and perhaps this is the meeting point between the 'civil engineering' world (technical analysis of hazards and of provision of infrastructure) and the 'development' world (human geography and analysis as to the responses of individuals and communities to hazards and risk). This aspect will be drawn out further throughout this Chapter.

3.2.1.2 Development and vulnerability

The relationship between development and human vulnerability is an interesting one. The UNDP (2004) report outlines how the vulnerability of populations to natural hazards is different to human development, but can sometimes be strongly correlated to it. The UNDP developed two coarse measurement tools that demonstrate this relationship. The examples of Japan and Haiti again are informative. Consider the figures given in Table 1, below. These figures demonstrate that the long-term decisions taken in development (including

infrastructure decisions) in Japan, coupled with higher access to resources, has led to a high level of resilience to natural hazards, as demonstrated by higher 'relative vulnerability' figures. Conversely, the lower level of relative development (as measured according to the UN human development index) in Haiti or, for example Armenia, is correlated to populations more vulnerable to natural hazards.

	Human Development Index (average 1980 to 2000) (low figure demonstrates lower human development)	**Relative vulnerability to earthquakes** (low figure demonstrates low vulnerability)
Japan	0.928	2.81
Mexico	0.790	103
Armenia	0.745	7653
Haiti	0.467	(no figure given, pre 2010 earthquake, but likely now to be high)

(Source: UNDP, 2004)

Table 3-1 – Human Development and Vulnerability

The above UN assessment system of ranking human development, and of ranking vulnerability to natural hazards, does bring up one other interesting set of data, in that some states have moderate human development index rankings (Mexico 0.790 average, 1980 to 2000), but relatively higher vulnerability to natural hazards (relative vulnerability 103). This demonstrates that gains in human development in Mexico may be at risk from natural hazard events.

As shown above, the UNDP (2004) text outlines that at country-level, many poorer populations are more vulnerable to natural hazards than richer ones, a result that Freeman and Warner (2001) agree with. Milch et al (2010) investigate this concept at a community level, with a study outlining the effects on a population from an earthquake in Peru in 2007. This study found that women, the very young and very old had the highest mortality rates as a direct result of the earthquake. Further, the study demonstrated a correlation between living

conditions and educational attainment with displacement of people after the earthquake. Even though equally exposed to the same hazard, the more vulnerable members of the population suffered more. For a different hazard, Khan (2011) noted that low-income people who were dwelling in the cheaper land area of a floodplain were the most affected by the 2010 floods in Pakistan.

3.2.1.3 Economic losses

"Any development activity has the potential to either increase or decrease disaster risk." (UNDP, 2004)

Losses from disasters are not just human. A number of authors, including Wisner et al (2003) outline the increasing economic losses that are due to natural hazard events. Indeed, Freeman and Warner (2001) suggest that many of the economic gains made through development are being wiped out by the effects of natural hazard events, mainly in low-income environments. Both Benson (2009) for the case of the Philippines and Silbert (2010) for the case of small islands, go on to outline that in some cases the costs incurred in the post-event response and recovery from natural hazard events can reduce government budgets for education and health services, impacting further on long-term economic development and growth.

Due both to human and economic losses, Freeman and Warner (2001) and the UNDP (2004) outline that disaster risk reduction should be mainstreamed into development at an early stage in order to mitigate against its larger effects. For example, town planning and infrastructure initiatives must take hazard identification into account at an early stage, as is more likely to have occurred in Japan than in Haiti. In this manner the long-term vulnerability of populations to natural hazards can be decreased.

3.2.2 Measuring vulnerability to natural hazards

Apart from the Vulnerability Index calculated by the UNDP, as seen in section 3.2.1.2 above, a number of attempts have been made to measure vulnerability to

natural hazards. An early example of this was a study carried out by Kaly et al (1999) which attempted to measure, at a country level, environmental vulnerability, which included vulnerability to natural hazards. The authors piloted a tool for measuring environmental vulnerability in three Pacific countries – Australia, Tuvalu and Fiji. A similar concept, on a much wider scale, was followed in the UNDP (2004) study in which a 'Disaster Risk Index' (DRI) was calculated for each country in an effort to define the vulnerability of each country. The DRI is, by the UNDP's own admission, relatively 'coarse' and broad-brush in that it focuses on only three natural hazards: earthquakes, tropical cyclones and floods. Further, the DRI was calculated only from mortality rates, as these were the only relatively accessible and reliable data sets available for the study (UNDP, 2004: p32).

The above studies measured vulnerability at the country level, and were necessarily coarse in their approach. Other studies have attempted to measure vulnerability at a finer level with assessments at the individual level, which could be collated up to community or group levels. One such study was carried out by Birkmann and Ing (2008) in Sri Lanka which provided enough detail to demonstrate that the ability to recover from the 2004 tsunami did not depend on an individual's income or resources, rather on the income and resources at the household level. Another study was carried out by Mustafa et al (2011) which mapped vulnerability from material, institutional and attitudinal causes. This study provided enough detail to show that data could be collected that would demonstrate social interdependencies. Neither of these individual or community level studies were extended to country-level studies.

Silbert (2010) suggests that mortality may not be the most appropriate measure of vulnerability to natural hazards, due to the nature of measurement that it provides. Instead she argues that financial loss could be a measurement tool. This is a factor that the UNDP address within their logic for choosing mortality as a measurement factor, as financial loss can be hard to calculate from a specific disaster. Direct economic losses from factors such as damaged infrastructure can be relatively easily calculated. However secondary effects such as loss of economic activity can be hard to calculate. Further, reporting by governments

can sometimes skew reported losses, with in extreme cases governments overstating losses (as a ploy to attract recovery resources) or understating losses (to 'cover over' politically damaging issues). The UNDP recognise that their mortality measurement method is coarse, but found it to be the most reliable for country-level studies.

The above highlights that it is difficult and time-intensive to measure vulnerability at the individual level, but country-wide assessments can provide insights into general vulnerability to natural hazards at country/economic level.

Of the above studies and measurement tools, only the report of the UNDP study makes reference to infrastructure resilience. None of the above tools include infrastructure resilience as a measurement factor of vulnerability. This may be a factor of the complexity of measuring vulnerability to infrastructure failure, across different locations and different forms of infrastructure (roads, power etc.).

3.2.3 Factors driving vulnerability

A number of factors drive vulnerability to natural hazards including exposure to a physical hazard (earthquake, cyclone etc.), human induced hazards (environmental damage from logging, waste management etc.), poor governance, violent conflict, gender and age vulnerabilities.

Wisner et al (2003) suggest that a person's risk of disaster is a factor of exposure to a natural hazard multiplied by their vulnerability. The vulnerability may be due to low income, few family connections, poor governance issues or other societal issues. If someone is not exposed to a natural hazard, there is little hazard risk. Alternatively, if they are located close to a hazard and are vulnerable due to any, or all, of the above social factors, they are at higher risk.

Looking at a specific event, Yeo and Blong (2010) looked back at one flooding event in Fiji in 1931 which neatly encapsulated the concepts raised by Wisner et

al. A hurricane and associated flood caused the deaths of 225 people, mainly in the North West coast of the island of Viti Levu. Only 24 of the deaths of this disaster were native Fijians, who had built their houses in safer locations that were less affected by the extreme weather event. Additionally, many were able to swim and many knew to climb up within the structures of their dwellings during the event. In contrast, the immigrant Indian population suffered 152 deaths as they were living in flimsy houses in more hazardous flood plain areas and generally could not swim. Reinforcing the benefit of local indigenous knowledge, as seen in the case of Fiji, above, Yeo and Blong also note the case in 1852 in which Aborigines in Australia warned European settlers against settling in a flood plain. During one severe storm event, the Aborigines were able to lead many Europeans to safety, although 89 died as a result of the flooding event.

Although many studies demonstrate the more system-wide causes of vulnerability, and imply some of the reliance on infrastructure, none make explicit links between them. Bosher and Dainty (2011) refer to this link, detailing how the design and construction of infrastructure can make it more resilient, and therefore provide greater resilience for communities. They demonstrate that in order to provide resilient infrastructure, a holistic view must be taken, including both the technical (infrastructure) and social aspects of vulnerability of a community, and that addressing individual factors of vulnerability may not address overall risk. For this reason, they outline that in order to reduce risk, communities should be involved in the identification and implementation of risk reduction efforts. This allows for a more holistic approach to analysing a community's vulnerability to natural hazards, in association with wider development issues.

With a separate focus, Nathan (2008) investigates societies' perceptions of risk, including people's perceptions of hazards. If people are not aware of the hazard, particularly if it is not visible, they will not be able to address it. Nathan found that people tend to neglect low-probability high-consequence risks (as many natural hazards are) in favour of high-probability low-consequence risk (such as personal security risks). This issue has an impact on societies' treatment of

hazards, and also goes some way to explain why indigenous knowledge with longer-term perspectives of hazards leads to greater resilience to natural hazard events. Bankhoff and Hilhorst (2009) follow this theme further, noting that governments can have differing approaches to risk, giving the example in the Philippines of a government controlled evacuation of a community in the face of a volcanic eruption, whilst failing to act upon the more apparent and ongoing risk of poor traffic safety on the roads. These different views of risk shape people's actions before, during and after emergencies.

The key factors that can be seen to drive vulnerability to natural hazards can therefore be seen to be exposure to a hazard, poverty, poor governance, a lack of planning for disaster and low awareness of risk levels specific to natural hazards (at government, community and individual levels).

3.3 Natural hazards

Natural disasters can be broadly categorised into slow onset, rapid onset and evolving disasters. A broad categorisation of each follows.

3.3.1 Slow-onset disasters

Slow-onset disasters, as the name suggests, include disasters that do not have a clear or immediate start or end. These may include long-term weather effects such as drought and a potentially resulting famine. Such long-term events can have profound effects on the resident populations. Droughts can lead to crop failures, requiring replenishment of food stocks, or in more severe cases, can lead to population movements. A number of authors, summarised by Boston, Nel and Righarts (2009), make a connection between such stressed environments and a higher likelihood of armed conflict, as factions of populations, or outsiders, attempt to control viable land or specific resources such as water sources. In more general terms, Wisner et al (2003) put forward that the richer segments of societies may be able to escape slow-onset disasters as they may have the funds

to relocate, or buy additional food or access to water. The poorer segments of societies may not have such funds, and may therefore be unable to escape.

Another form of slow-onset disasters may be armed conflict. Armed conflict may or may not have anything to do with natural resources, but for the populations caught in the cross-fire, the effects of an armed conflict may have similarities to the effects of a natural hazard event. Armed conflicts are commonly termed as 'complex emergencies'.

Although slow-onset disasters, as described above, may have profound effects on populations, they do not often have significant widespread effects on infrastructure. As such, they are considered less within this thesis than rapid-onset hazards, which more often have effects on infrastructure.

3.3.2 Rapid-onset

Rapid-onset disasters are those that commence with little or no warning. They are normally categorised as events that include storm and weather related events, and their resulting effects such as floods and landslips. Other rapid-onset disasters may include geophysical events such as earthquake, volcanic events and tsunami. Although some notice may be possible before such events happen, this is normally limited to perhaps a couple of days in the case of a large storm event, or perhaps a few hours in the case of a distant-source tsunami. Other events may have virtually no warning signs, such as near-source tsunami, earthquakes and some volcanic events.

Due to the lack of warning of such rapid-onset events, Wisner et al (2004) put forward that they are 'community levellers', affecting wider spectrums of society. Other hazard events, for example an earthquake event that strikes a town or region, may more truly be the 'community leveller' outlined by Wisner et al.

In any case, rapid-onset events are those that have the greatest effect on infrastructure. Road networks are particularly vulnerable to storm events, with the resulting floods, river action and landslips. Earthquakes particularly affect

surface-level and buried infrastructure, such as roads, water, wastewater and stormwater infrastructure, particularly in areas where liquefaction is an issue. Clearly tsunamis will affect infrastructure at the coastline rather than inland, however coastline infrastructure may include road networks (particularly on 'high' Pacific islands where the road network may effectively be a coastal road around the island) and ports. Due to the stronger effects of rapid-onset events on infrastructure, this thesis is most concerned with rapid-onset hazards.

3.3.3 Evolving disasters

Climate change may be considered to be an evolving disaster, whilst urbanisation may be considered a factor in changing, long-term, people's vulnerability to hazards. This is explained further, as follows.

3.3.3.1 Climate change

Related to both rapid and slow-onset events is the evolving dynamic of climate change and climate variability. The effects of climate change can be seen in changing weather patterns across the Pacific, making some areas drier, some wetter, and almost all locations subject to more extreme and frequent weather events. Jones (2001) outlines the specifics of how computer models have been generated to predict the effects of climate change. Due to the computer power available in 2001 however, the coarse granularity of the resulting information did not allow specific country or location analysis. Instead, analysis was only available on a regional basis. As computer power becomes greater, climate change models are becoming more reliable and able to predict with greater certainty the long-term effects of climate change. In addition to greater computer modelling capacity, as each year's worth of weather passes over us, the models can be more closed correlated to weather patterns. This allows greater certainty in predicting how weather-based hazards may impact on specific locations, and therefore provides greater certainty for the design of infrastructure.

It is worth defining two terms that are increasingly being used relating to climate. The first is 'climate change', the term used for long-term changes in temperature,

affecting, for example, the temperature of the oceans or atmosphere. The second term is 'climate variability' which refers to effects such as changing seasonalities (wetter winters, drier summers) or more extreme weather events (high winds).

Despite advances in the measurement and modelling of climate change, uncertainty remains as to its likely final effect. Due to this uncertainty, Willows and Connell (2003), the UKCIP (2005) and Sussman and Freed (2008) have created decision frameworks for deciding on adaptation steps that can be taken regarding climate change. Due to the long-term nature of climate change, there are a number of actions that can be taken at any stage of development that can be termed as 'no regrets' actions. These include, for example, designing infrastructure to take into account potential long-term effects of climate change, particularly if they can be delivered for the same, or at least a similar cost, and particularly if they provide other benefits regarding resilience of infrastructure. It is the aim of most infrastructure designs to take 'no-regrets' decisions that provide high resilience at minimal additional cost. The reality is however, that even if the designer has taken climate change into account, most infrastructure requires some incremental additional cost to 'climate-proof' the infrastructure. Such approaches can be seen in more detail in Section 3.4.3.

3.3.3.2 Urbanisation

Campbell (2010) outlines the increasing urbanisation of some islands in the Pacific. Urbanisation can result in greater vulnerability to natural hazards. This is because of the greater environmental resource required to supply urban areas (with a concentration of power and water supplies), and because more people are concentrated in one area, which, if hit by a hazard, makes more people vulnerable from that event. Campbell suggests that most existing emergency planning has been directed at rural populations, again adding to the risk for urban populations. Long term planning initiatives gain relatively little support in many locations, particularly low-income ones, which means that housing and community buildings continue to be built, or maintained, in vulnerable locations.

One of the clear messages of the UNDP (2004) document 'Reducing disaster risk: A challenge for development' is that good town planning is a significant factor in reducing the vulnerability of populations to natural hazards. For example, by preventing people from living in gullies or at-risk flood-plains, populations will not be living in hazardous locations. Similarly, for Pacific island settings, town planning may be a good tool in preventing populations living in more vulnerable coastal locations. It is for this reason that the UNDP advocates for good local governance and enforcement, as such long-term plans can direct 'good' choices by local authorities as to what locations may be most suitable for accommodation, and what locations may be best for industrial areas or recreation.

3.4 Managing vulnerabilities to natural hazards

3.4.1 Vulnerability - Globally

As detailed in Section 3.2.1.1, development levels shape vulnerability. Unplanned or haphazard development can raise human vulnerability to natural hazards. A great deal of work has been carried out with regard to defining, measuring and reducing vulnerability. The UNDP (2004) report synthesises much of this work and focuses attention on long-term strategies to provide lower vulnerability. This includes providing good town planning (to make sure that people do not live in vulnerable locations), providing awareness raising information to institutions and populations, and implementing long-term infrastructure approaches to reduce long-term vulnerability. In short, the report outlines that Disaster Risk Reduction measures should be mainstreamed into development plans and activities. As a related issue to the long-term approaches advocated, one of the cross-cutting aspects identified by the UNDP is the issue of governance. With stronger governance, it is argued, comes the ability to improve both planning and enforcement of town planning initiatives.

At a more sophisticated level, Parfomak (2008) outlines how individual elements of an infrastructure or sector may be considered resilient, but as a whole, the

system may be vulnerable. An example of this may be where utilities or private companies have congregated close by to each other, making them collectively vulnerable to disaster. This may be considered applicable to the Samoas, for example where a road bridge, adequate for transport infrastructure, also carries water pipework, power cables and telecommunications cabling. Each individual element may be considered relatively resilient, however as a whole, they may represent a high level of risk in the case that the bridge is damaged as a result of a natural hazard. Due to this potential congregation or accumulation of collective risk, Parfomak argues that the free market, or specific utility managers, sometimes require regulation by the Government. This may be made through a number of methods of intervention, such as 'prescriptive siting', 'environmental regulation', 'encouraging geographic dispersion' and 'ensuring infrastructure survivability' (Parfomak, 2008, p13-17). Such interventions may be required of the government, again reinforcing the need for good governance in terms of reducing overall vulnerability to natural hazards.

With regard to infrastructure loss from natural hazards, Freeman and Warner (2001, p12) outline that earthquakes create higher housing damage compared to other natural events. However flooding has the largest effect on infrastructure, with almost half of infrastructure economic losses due to flood damage to roads. They also outline that the location of infrastructure close to coastal regions puts further risk to infrastructure from flooding causes.

Using the specific example of the Philippines, two papers (Benson, 2009 and Bankoff & Hilhorst, 2009) outline community and governmental aspects of disaster risk management. The Philippines are exposed to many natural hazards, including a high number of tropical cyclones, plus earthquakes and volcanoes. Despite this repeated exposure to natural hazards and the ensuing set of disasters, the Government appears unable to mitigate against future disasters, instead focussing on spending its budget on the post-event mop-ups after disasters. This tends to divert resources away from other development initiatives such as public health and education. As Benson (2009: p14) puts it, "…disasters are persistent, annual events, continually gnawing away at development gains in the Philippines." What activities relating to Disaster Risk Reduction do take place

tend to be funded and driven by external agencies and are uncoordinated and disjointed. As the issue lacks overall leadership or direction, the issues of inadequate legislation, lack of strategy and lack of a (feasible/functioning) lead agency are unlikely to be addressed in the short term. In addition to this inefficiency, the central government and NGO actors were taking different approaches to disasters with, post-disaster, the Government tending to restore society to 'normalcy', (Benson, 2009: p20) whereas NGOs would attempt to tackle the root causes of vulnerability, tending to take differing approaches to disaster recovery. This is, unfortunately, a good example of how a lack of leadership and strategy can lead to an almost perpetual underperformance in disaster risk reduction and a continued vulnerability to natural hazard events.

3.4.2 Vulnerability - For small island states

There are a number of aspects in which small island states may be vulnerable. Three of these aspects are focussed on here, namely the locations of communities and infrastructure on islands, coastal erosion (or sand management) and power supply.

3.4.2.1 Locations of communities and infrastructure

Why are small island states particularly vulnerable to natural hazards? ECLA (2000) explore a number of ways in which small island states are vulnerable in general. Factors which cause vulnerability include limited land resource, which can severely restrict the amount of land that is available for development, so that when populations expand, some live on marginal land or in locations exposed to hazards. This lack of land also impacts key functions such as solid waste disposal. A good example of this is on Tarawa in Kiribati, where the safe disposal of solid waste has become a particular issue. Small islands are often very exposed to weather and coastal hazards, particularly wind storms and associated rainfall. Furthermore, many small island states have specific natural hazards, including volcanic (where the island itself may be the visible section of a largely submerged volcano), seismic and exposure to potential tsunami. The

above environmental vulnerability factors are echoed by Pelling and Uitto (2001) who bring in wider globally evolving vulnerability factors that may increase future vulnerability of 'small island developing states', including the issues of climate change (which cuts across many of the above issues) and urbanisation. The terrain and nature of small island states often mean that they suffer from limited opportunities for diversification in their economies, which can be weak as a result. Finally, and again due to smaller populations, they often suffer from weak institutional capacity and have high relative costs of infrastructure per head of population. Witter (2004) brings together these concepts, showing that the above vulnerabilities, which he categorises into economic, social and environmental, interact with and often reinforce each other. In other words, environmental vulnerability (including exposure to natural hazards) can have knock-on effects to the economic and social spheres and vice versa. Silbert (2010) articulates the issue differently, outlining that small islands are limited in their options of risk diversion (the opportunity to diversify economic activities) and smoothing (small islands may suffer large shocks from natural hazards).

Like ECLA, Douglas (2006) emphasises the relative cost of natural hazards to small island states, demonstrating that due to exposure to the range of natural hazards, especially regular and repeat hazards such as windstorms, a higher proportion of their GDP may be taken up in continuous high hazard management programmes. This can make their respective economies weaker and can heighten the effects of disaster when it does occur.

A number of texts highlight how a large proportion of island communities are located on the coasts of small islands. Mimura (1999) highlights this aspect, explaining how 'high' islands (for example, the top of a volcano rising from the ocean floor) often have rugged topography in the interior of the island, which is not suitable for either agriculture or habitation. Flatter land tends to be nearer to the coastline. Similarly, fresh groundwater is normally accessible in sandier soils near the coastline. Further, livelihoods are mainly located near the coastlines, either from land-based agricultural activities or from sea-based fishing or other activities. Island communities therefore tend to live near the coast. 'Low' islands, often atolls, are generally relatively small, and again many livelihoods on 'low'

islands are closest to the coast, meaning that the respective communities are also likely to live there. Mimura goes on to outline that because of the topography and the locations of settlements, infrastructure tends to follow around coastlines of small islands.

The result of both communities and infrastructure being located near the coastline is that both are exposed to coastal (sea-related) hazards. Further, as the communities and infrastructure on high islands are normally located at the bases of hills, they are further exposed to flooding and landslip hazards from above. The above reasons lead specifically to exposure to the following hazard sets:

Coastal hazards	'Base of slope' hazards	Related hazards
Coastal erosion	Flooding	High wind exposure
Sea-level rise	Landslips	Saltwater intrusion to (fresh) groundwater
High seas (from storm events)	Artificial dam creation and release	
Inundation		
Tsunami		

Table 3-2: Small island natural hazards

3.4.2.2 Coastal erosion (sand management)

Many small island states have a balancing act in regard to sand resources. Sand in many such locations is created by biological action on coral reefs, with relatively slow replenishment rates. This sand may be captured at the island by environmental processes, or may be washed out to deeper water. What sand is captured, explains Gillie (1997), can act as a natural buffer zone between the wave action of the sea and inland communities and productive land. These sand 'buffer zones' (or beaches) ebb and flow over decades, perhaps being eroded in one large storm event, or being added to in another. One issue for small islands is that sand is a valuable resource for road and building construction, and this is where the balancing act becomes most evident – the sand is a valuable

commodity, but provides environmental protection. Some islands have created plans for the control of sand resources, which matches Gillie's recommendation that sand removal should be prohibited, in favour of retaining the coastal buffer zone that it provides. Osti et al (2009) typify a body of research that outlines that mangrove forest at the coastal margin can provide protection against tsunami and they advocate for the planting of mangrove trees. Gillie however outlines that it is difficult to encourage mangrove growth if the sand is not present long-term as the base of the mangrove planting, and such planting can become of marginal benefit. In other words, mangroves may grow quickly and provide environmental protection to island dwellers, but are only viable where there the topography and environment maintain sand in an area anyway, as a 'foundation' to the mangrove.

Attempts to control sandy beaches, or to mitigate against wave action, typically do not work, as Gillie outlines that groynes and seawalls do not hold sand in one place, but merely act as a hard surface against which the sea action creates turbulent eddies, which can disperse / remove the sand. On removal of the sand, the seawalls, for example, become the hard surface against which the sea acts. Such seawalls can become relatively exposed to deeper wave action due to the removal of sand and other material which previously supported the beach. Once sand is washed away from a seawall, it can in turn become unstable and be washed away. In this way, seawalls may hasten the advancement of sea action into the interior of an island rather than mitigate against it.

3.4.2.3 Power supply

Another aspect of infrastructure vulnerability on small islands is power supply. Stuart (2006) outlines how most small island states are not located close to large continental masses which normally have power-production facilities and associated cabling. Small islands therefore have to generate their own power. Small islands normally do not have the population bases to support large power-station construction or operations. The use of fossil fuels for small islands tends to be expensive, and it can be environmentally risky, as it must be shipped in, and the transfer of fuel from ship to shore can be fraught with difficulties. In addition to these factors, it is risky from a power-supply perspective to have only

one generator per island, as these normally have no redundancy in case of damage or maintenance routines. Despite all of these difficulties, and in contrast, small island states often have access to an abundance of natural energy sources (wind, solar and wave power). However these are, at the time of writing, relatively new technologies, and relatively unreliable or expensive in terms of essential energy sources. Stuart suggests that the policy makers and infrastructure owners on many small islands tend to act conservatively, leading to slower adoption of alternative energy sources. There appears to be great scope for moving from single large fossil fuel power station generation to the more adaptable generation of power from sustainable sources from multiple sources (wind, sun, waves).

As can be seen from the above, small island states often are relatively more exposed to natural hazards, particularly coastal ones. They face additional difficulties of limited natural resources such as sand and have quandaries in producing power. Of highest concern however is the exposure of communities and infrastructure to both sea-action, flooding and landslips. All of these hazards can additionally have severe implications for freshwater supply, due to potential salination of fresh water held in sand layers. For more details on this issue, see section 3.4.3.1.

3.4.2.4 Small island state vulnerability overview

As can be seen from the above, in modern times, for good reason during non-emergency times, small island populations and infrastructure tend to be located near the coast. Whilst this makes good sense economically during non-emergency times, this does put the population at risk during coastal hazard events. The communities involved therefore have a choice of moving inland, away from coastal hazards, or taking long-term chances with storm events.

Power supply in small island states has been seen to be problematic using imported fossil fuels, but the initial cost of changing to sustainable but potentially irregular wind or solar power sources may make such changes

challenging, particularly to small power supply organisations that may employ just a few staff.

In addition to the above coastal and power supply issues, sudden events, such as hazard events may make disproportionately high shocks to small island economies, as seen in the high % of GDP events noted in section 1.3. Recovery from such hazard events can therefore be particularly challenging from small island states.

3.4.3 Vulnerability - in the Pacific

3.4.3.1 Pacific natural hazards

As was seen in Section 1.3, in terms of the number of disasters in the Pacific, the vast majority (76%) are caused by windstorms, producing a similar level (73%) of the population affected by disasters, and causing 90% of the reported disaster-related economic losses between 1950 and 2004. Cumulatively, weather events including windstorms, droughts and floods accounted for 85% of disasters, and 93% of economic losses. With the frequency and intensity of weather events set to rise through the effects of climate change, it is clear why the majority of effort in disaster risk reduction in the Pacific is focussed on weather events. Although events such as the Samoan tsunami in 2009 receive a very high profile in the media, such events are relatively uncommon and affect a smaller population overall compared to weather events.

Bettencourt et al (2006) note that the likelihood of weather events affecting countries within the Pacific is therefore high, and as some of the effects of the weather events can be mitigated against, it is worth preparing for the events before they happen. This aspect will also be expanded upon in Section 3.5.2 regarding the economic viability of preparing for disaster events.

Although much of the above relates to direct damage from disasters, Pacific Islands face additional challenges in that freshwater resources are commonly

restricted and are vulnerable to saltwater intrusion, an aspect captured by Mirti and Davies (2005). Freshwater is lighter (less dense) than seawater, and therefore 'floats' above saltwater, particularly in sand or in sandy soils, as is the case in many Pacific Islands. If an island is overtopped by waves, the saltwater can soak into the sand and salinate the freshwater held in the sand. Such an event would potentially have high consequences for a small community on a remote low-lying island without other viable freshwater sources. With a series of smaller or moderate events, groundwater supplies can be gradually salinated and become unfit for consumption. With present technologies, de-salinating water is a very expensive and energy-intensive process. This salination of fresh water supplies is one reason why sea-level rise is focussed upon particularly in discussions on climate change in the Pacific.

In relation to disasters facing Pacific Islands, a further distinction made by Mirti and Davies (2005) is between 'high' Pacific Islands which are typically rocky remnants of volcanoes (Fiji, Samoa) or the results of tectonic activity (Papua New Guinea, New Caledonia), against the 'low' islands typified by coral atolls (Tokelau, Kiribati). The nature of disasters will be specific to the location and nature of the islands concerned. Clearly, landslips are more likely to be restricted to the 'high' islands, effects of seawater over-topping islands is more likely to affect the 'low' islands. Despite this, and as seen in Section 3.4.2.1, the freshwater supplies of both 'high' and 'low' islands may be affected by saltwater intrusion.

3.4.3.2 Pacific community and infrastructure vulnerability

Regarding Pacific Island community vulnerability, there are two main sets of texts relating on the one hand to the technical understanding and treatment of natural hazards and on the other hand to community coping mechanisms in the face of disasters.

Regarding the technical understanding and treatment of hazards, two studies that are now, in relative terms, dated due to the continually evolving understanding of climate change and climate variability are those from Primo (1997) and Nunn

(1997). Primo focuses her attention on the likely effects of sea level rise on the island of Kosrae in the Federated States of Micronesia (FSM). In tune with many articles of the era on the identification of the possibility of climate change, but with limited proof of its effects, she outlines that there may be some 'no regrets' actions that may be taken to mitigate against sea level rise. However she believed more information was required, particularly relating to coastal zone management. She also highlighted that to carry out studies on this subject, there was (in 1997) a lack of engineering expertise in-country, and that any research would have to be carried out by external consultants. One issue highlighted however was the need to engage with local community structures in order to deliver appropriately directed strategies or improvements. Nunn (1997) makes note of sea-level rise issues in Samoa, noting that by 1997 the Government of Samoa had already moved one road inland 'several kilometres' in order to avoid coastal erosion risks. He also noted that, as in the FSM, it is essential to integrate with local community structures and governance in order to deliver strategies and implement changes or improvements.

In 2005, the Asian Development Bank (ADB) produced case-studies focussing on adaptation to climate change in the Pacific. The case studies were from the FSM and the Cook Islands, and included one example from each small island state on how adaptation to climate could be managed. The case study from the FSM outlined in detail how a roading project in one 'high' island was planned to be carried out. Two designs for the road were delivered, one based on historic weather (specifically rain) patterns, and one on projections of future weather patterns based on predicted climate change. The case study demonstrated that there would be an 'incremental cost' to climate-proofing (allowing for the increased rainfalls predicted) the design of the road. It was further demonstrated that as the incremental cost was relatively low, there was a high economic benefit to spending the additional (incremental) budget to climate-proof the road. At the time of writing the case study, the Government of the FSM were planning to apply for funding from development institutions for the incremental funding. The tone of the case study suggested that, at the time, there were international funding mechanisms available that would probably match the incremental funding needs of this infrastructure project.

In contrast, other articles relate to the vulnerability of the local Pacific populations. Lewis (2009) outlines three kinds of Pacific community vulnerability: indigenous (primarily from natural hazards), exogenous (primarily from outside human activities such as colonial actions or violent conduct) and derivative vulnerability (created one at a time, affecting future vulnerabilities, such as deforestation of an area or building a runway over agricultural land). Lewis suggests that local populations can have resilience to indigenous hazards, but limited resilience to exogenous hazards. He further outlines that since colonial rule, the self-help activities of local communities has been replaced by a dependence on external assistance. The increasing reliance on external assistance at the expense of community system resilience is strongly supported by Campbell (2010) who outlines some of the mechanisms through which Pacific Island communities historically ensured their own resilience. Such mechanisms included living on higher ground, constructing resilient buildings (dependant on the specific island and perceived hazard) and choice of crops (favouring resilient but low yield compared to vulnerable high-yield crops). As the colonial powers moved in, the various communities came to rely on colonial relief in times of emergency, and local systems were comparatively lost. This process became most established after 1945 but prior to political independence of the islands (broadly, from the 1960s to the 1980s). Since the 1980s, responses by the international community to disasters in the Pacific have been patchy, leading in some countries to a greater focus on local planning and resilience efforts. In this way, Pacific communities are becoming more exposed to natural hazards as they have progressively lost their natural resilience to those hazards. Formerly resilient communities have therefore become vulnerable communities.

In a separate paper, Campbell (2009) gives further detail on factors of local community resilience to natural hazards. He outlines three aspects of resilient Pacific communities, namely food security, cooperation and settlement factors. Some aspects of resilient behaviour traditionally may have been directed at natural hazards, whilst other in-built resilience to natural hazards may in fact have been delivered for reasons that had nothing to do with natural hazards, but

happened to provide resilience. Through local systems, communities built up a variety of means of providing resilience to natural hazards.

One common thread from the texts of Lewis (2009), Campbell (2009) and Primo (1997) is that communities, despite some losses, retain knowledge on natural hazards in their home locations. Communities are able to comment, normally with authority, on their understandings of natural hazards.

Specifically regarding Samoa and American Samoa, these island groups are, in many ways, geographically similar. Both sets of islands are located in a similar area of the South Pacific and are both exposed to similar weather and sea-related hazards. Both sets of islands are 'high' islands, founded on volcanoes rising from the ocean floor. Hazards are seen to be volcanic, seismic, weather related (high winds, high rainfall with the associated potential for flooding and landslips) and sea related (including high seas and tsunami). Both island states are subject to the vulnerability factors outlined in the sections above, particularly those relating to small island states and Pacific Islands. These hazards will be highlighted in more detail in Chapters 4 and 5 below, relating to the specific island nations.

3.5 Planning for natural hazards

3.5.1 Long-term planning against natural hazards

As seen in Section 3.3.1, there is a global recognition that long-term planning for long-term community outcomes, such as planning the locations of settlements and infrastructure need to take natural hazards into account. As will be seen in Section 3.5.2, this approach appears economically sound. There are two strands of thought specific to the effects of natural hazards on infrastructure that are worth considering, as follows.

Firstly, Transit New Zealand's (now the New Zealand Transport Agency) approach to the management of its State Highway roading network in regard to climate change issues is worth noting. Kinsella and McGuire (2005) outline how the effects of climate change are slowly developing, and although there is

increasing certainty about its effects, there is still not enough information to provide good evidence as to how road pavement construction should be designed. The authors suggest that the design of road pavements should, in the case of New Zealand, remain as it was at the time of writing, with design updates provided at cycles of replacement of pavements. Pavements in New Zealand have design lives of between 13-18 years for chipseal, and 15-20 years for asphalt pavements. The logic given is that it was not worth changing pavement designs on assets with such 'short' design lives with climate change probably taking longer than this to more clearly manifest itself. On the other hand, Kinsella and McGuire note that roading structures (bridges) are higher-cost items normally with 100-year design-lives, with many crossing water courses. The authors demonstrate that with such valuable assets at risk, it is worth retrofitting structures against the effects of extreme flooding events. This approach is given as an example of best-practice by Rayner (2010). In this way, it can be seen that climate change adaptation approaches can be taken for existing infrastructure, depending on the nature of the asset and the hazard faced by it.

On another strand of thought, Hosseini et al (2009) bring forward the need for considering not just the long-term vulnerability of infrastructure, but also the consideration of emergency needs, immediately post-event, for example, the need for robust buildings for 'Emergency Operations Centres', the need for local hospitals to cater for potentially isolated communities and for emergency evacuation buildings or locations. Additionally, there is a need to ensure that emergency access be maintained between communities, wherever possible, to allow emergency relief to access areas that require assistance. Such planning can best be carried out through the involvement of emergency management staff and communities during the design process of infrastructure. In this way, immediate post-event emergency needs can be better catered for.

3.5.2 Economic analysis (cost/benefit measures) and prioritising projects

Apart from the human resilience aspects of designing infrastructure to be resilient to natural hazards, there can also be clear economic benefits. Yumul et

al (2011) outline the stance taken by the government in the Philippines, where disaster management efforts have, in recent times, been focussed on post-disaster recovery efforts. Such work can be costly and does not mitigate against the loss of human life. The authors argue that this is not a sustainable or efficient approach to take, and that budget would be better spent on long-term risk-reduction efforts.

Bloomstein (1999) provides a methodology for calculating the cost of natural disasters. Direct costs of disaster are relatively easily identified and costed – such as impacts on roads and buildings. What is often not well captured in working out the secondary effects – economic loss of productivity of populations recovering from the effects of disaster rather than continuing economic activity. Further, Bloomstein (1990: p1) outlines how secondary disasters may occur: "high windstorms are followed by floods and landslides, floods by drought and drought by pest epidemics and famines." These follow-on effects are often not adequately accounted for in calculating the economic effects of disasters. Through such under-counting, it is possible that the true costs of disasters are often under-quantified in economic terms.

A number of texts, typified by a UNDP paper, outline that public investment should be subjected to cost benefit analysis "to enhance its sustainability and cost-effectiveness, and contribute significantly to the reduction of disaster risk" UNDP (2009, p177). Cost benefit analysis is a method of calculating the economic productivity of a specific intervention or project. It is calculated by dividing the future benefit of a project by its cost. A project that has exactly equal benefit to cost would have a ratio of one. A project that produced double the social benefit compared to its cost (and therefore would appear to be a good investment) would have a cost benefit ratio of two. By calculating the cost benefit ratios of projects, two outcomes are achieved. Firstly, an indication is gained as to whether a project is worth implementing, and secondly, cost benefit ratios can act as a ranking-system for potential future projects. The projects with the highest ratio are those most worth implementing, and therefore could be carried out first. Those with lower ratios are likely to be carried out subsequently, or not at all. It should be noted that, for example, the New Zealand Transport

Agency normally only considers implementing projects having a cost benefit ratio of four or above. Cost benefit ratios for infrastructure are often calculated by engineers as they are normally best placed to calculate the costs of a project, and often have guidelines for calculating the benefits of a project. This method can appear to be an impartial and fair system of prioritising future potential projects. The effect of different discount rates on cost benefit calculations may be seen in Section 7.5.1.

Relating to the Pacific Islands specifically, it should be noted that an out-of-session paper titled "Economic Costs of Natural Disasters in the Pacific Islands Region and Measures to Address Them" was compiled by SOPAC for the 2009 Pacific Islands Forum Secretariat (SOPAC, 2009). This paper outlined the economic advantage, as calculated from cost benefit ratios, of taking disaster risk reduction into account in future works. Due to this demonstrated advantage, the paper therefore advocated the mainstreaming of disaster management into government decision processes. Of note here is therefore that at Minister level, the economic benefit of carrying out disaster risk reduction initiatives, and of mainstreaming disaster management in development decisions, has been highlighted to the governments of Pacific Island states.

The use of cost benefit analysis should, however, come with a degree of caution. Firstly, and as noted above, there can be persistent under-counting of both costs and benefits: undercounting of secondary costs of disasters, as noted above, and therefore undercounting of the potential benefits from projects that mitigate against disaster. Secondly, Mechler (2003) outlines that cost benefit ratios should not be the only criteria for working out whether a project is economically viable, as the analysis of risk is a key element of the calculation that should be particularly assessed. By calculating the average values of risks (the expected return period of a major seismic event in Wellington is, say, 200 years), with the cost of such a disaster spread over many years, the extreme consequence of such disaster may not be taken into account by governments when planning infrastructure, who should take a risk-averse stance. Mechler puts forward specific analysis of an event in Honduras and the USA where, in taking into account the high risks faced with certain hazards, better planning for disasters

was achieved. A third issue with the use of cost benefit ratios for prioritising potential future projects is that as a tool it is well understood by engineers who are versed in calculating economic outcomes from projects, but less well understood by social scientists. Therefore, whilst costs of social projects may be easily calculated (staff costs, overheads etc.), the economic benefits of social projects can be harder to calculate or prove. Anecdotal evidence, for example from the Hutt City Council in New Zealand is that when cost benefit ratios were used as the basis of decision making, potential new Council projects put forward by the roading department were consistently favoured for funding compared to Council social-based projects, the benefits of which were harder to quantify. This means that, as a tool, by simply using cost benefit analysis for ranking the effectiveness of potential projects, unequal decisions may be taken for development outcomes.

Other means of prioritising potential future projects include various points-scoring/ranking approaches, typified by the system adopted by the Ohio, Kentucky and Indiana Council of Governments (FHWA, 2003). This system assigned scores to various aspects of potential projects, such as safety and community issues. It was found in this case that the use of such a tool was subjective, and led to inter-organisational disputes about the relative rankings for projects. In this case, the Council of Governments opted after some time to use cost benefit ratio prioritisation methods instead. As will be seen in the case of Samoa, 'multi criteria assessment tools' are a more formalised points-scoring approach that can also be taken to rank potential projects. Such assessment tools often use benefit cost ratios as one aspect of the decision making process.

3.6 Summarising best practice

From the above literature, some elements of best practice approach are evident. These can be summarised into three broad categories: the analysis of natural hazards; community involvement; and government investment and coordination.

The analysis of natural hazards

Analyse infrastructure according to the specific hazard it faces. Each type of infrastructure (e.g. roads, power cabling) faces different hazards in different locations. Detailed analysis should be taken of each element in each location for a full picture of infrastructure vulnerability.

Take into account evolving hazards (climate change/urbanisation) in the design of infrastructure. Any hazard analysis should take into account not just present hazards, but evolving ones too, as the design-life of infrastructure will span the effects of future changes.

Represent hazards to infrastructure in clear and intuitive ways. Once hazards have been assessed, it is best practice to map them in a simple way that people in the community can intuitively understand.

Community involvement

Community involvement is needed in decision making, including both disaster risk reduction and planning the post-disaster management. The community, when presented with a simple and intuitive mapping of hazards, can comment on their understanding of the hazard (triangulating the final assessment of the hazard) and make comment on their understanding of how best to treat the hazard. Local knowledge, often accumulated over decades, often demonstrates at least elements of best-practice for a specific location.

Government investment and coordination

Overall coordination of disaster risk management, including both pre-event disaster risk reduction, and post-event disaster management is necessary. Although the community will be often be best able to define its post-disaster response, the local government still retains the function of implementing a

response and recovery effort. Coordination of the two aspects of disaster risk management may then be provided by a holistic approach, and can be considered best practice.

Plan development of the long-term. Mainstreaming disaster risk management in planning development allows the potential for disasters to be taken into account across the spectrum of development activities, and can aid in 'disaster-proofing' future development gains.

The 'free market' cannot always decide optimal locations for infrastructure in terms of overall system resilience. The Government has to take an over-riding assessment of cumulative risk, and not simply assume that the private sector, or where relevant separate government departments, will provide overall resilient systems. Government retains an overview role in ensuring that the overall resilience of a community or area is attained.

Using cost benefit ratios in prioritising implementation. Cost benefit ratios provide a robust method of assessing and prioritising interventions, and their use is considered best practice. Caution should be taken however not to base all decisions purely on cost benefit ratios, as risk patterns and other community factors such as the protection of key cultural sites must also be considered in planning the resilience of future infrastructure. Further, cost benefit ratios often under-estimate the benefits of social-type projects.

3.7 Conclusions of the literature review

From the above literature review, 'best practice' regarding policies for resilient infrastructure have been identified. Looking forward, it will be possible to compare the respective policies of Samoa and American Samoa against these best practices. The best practices have demonstrated that hazard mappings must be produced that can be understood intuitively by non-technical people. This allows for politicians and communities to understand the realistic hazard risks they are facing, which allows for potential future investments to be assessed, and

allows for realistic planning for potential emergency events. Political and community involvement in understanding the risk, planning new infrastructure and planning emergency responses when hazard events occur has been seen to be very important in obtaining 'buy-in' to how to deal with hazard risks. This political and community involvement will, in some contexts, advocate for government investment and coordination in reducing natural hazard risks. Indeed, central governments should be taking a lead in commencing work on resilient infrastructure policies, taking into account the existing knowledge and needs of their populations, as seen above. Disaster risk management needs to be included (mainstreamed) in overall policy decisions, to ensure that policies and projects are not, in fact, making populations more vulnerable to natural hazards rather than less-so. Some tools, such as the use of cost-benefit analyses may assist governments in assessing impartially the relative benefits of different projects, allowing investment to be channelled efficiently to appropriate projects.

The specific cases of Samoa and American Samoa may now be assessed against the above identified best practices.

4 CHAPTER FOUR: INFRASTRUCTURE RESILIENCE POLICY APPROACHES IN SAMOA

The following chapter overviews Samoa's approaches to resilient infrastructure policies, ending with a comparison between Samoa's approaches and 'best practice' as outlined in Section 3.6 above.

4.1 Past approaches affecting infrastructure (investment / mitigation)

Unfortunately, due to a Samoan Government re-organisation in the 1980s, records on past decisions relating to infrastructure are now hard to locate. Regarding the approaches taken to infrastructure design and construction in the past, it appears that infrastructure in Samoa was constructed to standards appropriate to the time and context. Due to changing weather patterns, markedly changed traffic volumes and weight on roads, and increased populations, some of the infrastructure may no longer be thought to be either adequate for 'normal' supply, or resilient by modern standards. This is a situation that is not unique to Samoa or Pacific islands generally. Changing weather patterns, changes of land use and changing construction materials and techniques mean that much infrastructure around the world is similarly less resilient to natural hazards than more recently built infrastructure. A good example of this would be road bridges over rivers. Changing land-use upstream of rivers, combined with changing weather patterns leads to changing – often higher, or quicker and sharper – river flows following a rainfall event. These changes may cause scour (removal of the river bed) around bridge foundations, or may even lead to the river changing course altogether and diverting around a bridge, damaging the road either side of the bridge. Modern design standards are increasingly taking into account the effects of changed land-use and of the anticipation of shorter, but heavier, rainfall events on bridges and infrastructure generally, and taking into account the quicker run-off of rainwater from concrete or other hard surfaces. For the above

reasons, it would not be a surprise that some of Samoa's infrastructure would now be vulnerable.

4.2 How are infrastructure vulnerabilities assessed in Samoa?

In January 2001, the Samoan Government, in the form of the Ministry of Natural Resources and Environment (MNRE) initiated the Coastal Infrastructure Management (CIM) Project: CIM Strategy (CIM) (MNRE, 2001). This strategy was prepared for the MNRE by Beca International Consultants Ltd (Beca), based in New Zealand. The CIM plan identified, for the Samoan context that resilience is "to be Adaptive, Responsive and Quick to Recover…" (page 5). Further, the strategy outlined key approaches for the delivery of the strategy, namely 'National Principles for Management' and 'Local Principles for Management', with the sub-heading "An Ethic of Partnership". This was a key step that has strongly influenced the following nature of the CIM Project. As explained by Keith Frentz of Beca (telephone conversation, 20 May 2011), the political structure of Samoa is very traditional, with strong village (community) involvement in decision making. Additionally, around 85% of Samoa is community (village) owned, therefore the majority of decisions regarding local infrastructure would have to be channelled through local village community structures. The CIM Strategy further outlined that the infrastructure plan should have the following flow of actions (MNRE, 2001, p5):

National Principles for Management ⇕ Local Principles for Management *An Ethic of Partnership*	Information, Evaluation and Monitoring ⇩ Education and Awareness ⇩ Management and Use of Land and Resources ⇩ Intervention Actions *Tools and Actions*

Subsequent to the adoption of the above strategy, the MNRE procured Beca to produce Coastal Infrastructure Management Plans. Beca, in conjunction with MNRE staff, then contemplated how best to interact with the local village communities on gathering information on infrastructure. With the strategy identifying "Local Principles for Management" a Beca cross-disciplinary team experienced in planning, infrastructure and Pacific issues identified that, as part of the means of delivering the project, it was clear that local village community structures would have to be involved in the hazard identification and planning process (Michele Daly, personal communication, 3 May 2011). Samoa as a whole has over 40 districts. It was decided by the combined MNRE and Beca project team that each district would have to be consulted. The MNRE and Beca then proceeded to engage with every village in Samoa to produce their own Coastal Infrastructure Management Plans.

For community engagement on the above plans, it was noted by the project team that the matai (traditional chiefly leaders) within the Samoan village structures were predominately (around 95%) male (Keith Frentz, Beca, personal communication, 20 May 2011). In order to be more inclusive, the community engagement was extended to allow the participation of women and 'untitled' men in discussions.

Thus, representatives of the MNRE and Beca, spent around a week with each of the districts in Samoa, creating the Coastal Infrastructure Management Plans. In the first tranche, 15 districts were covered during the 2001 to 2003 period, with the remaining 27/28 covered between 2006 and 2008. During the consultations, the villagers were shown preliminary hazard mappings of their villages, as prepared by Beca staff. The villagers discussed these natural hazards, and the effects that they may have had on their district in the past. The potential effects of hazards were then considered on the various items of infrastructure in the village, including roads, water and power supply, and on key buildings such as schools and hospitals. The term infrastructure was also widened, in this case, to include culturally significant features such as cemeteries and churches. Further, potential projects for upgrading infrastructure were identified, but at that stage, not in any prioritised structure. The output of the village plans were collated into

District Plans. The resulting District Plans were then signed by the village heads, by the Chief Executive Officer of the MNRE, and by the Minister for the Natural Resources and Environment. Each of these District Plans were published for public viewing (MNRE, 2012). With both Central Government and Village input, the final District Plans were therefore an agreed view of the resilience (or vulnerability) of the infrastructure in the village at that time.

Having completed the above sets of plans, and therefore having an overview of the natural hazards, and infrastructure vulnerability facing them, the community also produced 'pre-plans' for action in the case that a natural hazard event took place. This could mean collection of the community at a safe location during a storm event, for example. This consulting process both educated the community in what hazards existed and raised their knowledge regarding what actions should be taken in case of an event. In this way, the resilience of both the physical infrastructure was potentially to be raised, but at least as importantly, the community resilience itself was improved.

Through the above process, the resilience of the infrastructure in Samoa was mapped. It identified a total of around 2,000 potential projects (Michele Daly, personal correspondence, 3 May 2011) around the country that could be performed to raise the resilience of infrastructure. As part of this collation of projects, the MNRE took into account factors such as the provision of 'loop' networks around the islands (as opposed to simple single-strand networks, for example in power or road networks) and other resilience factors.

Subsequent to the above process, the MNRE performed an additional task. It provided broad costings and Benefit Cost Ratios for projects and prioritised them through the use of a multi-criteria decision tool (Beca, 2010). This decision tool scored various aspects of projects under three categories – 'vulnerability/seriousness' (including the factors of culture, equity and co-benefits), 'manageability' (including the factors of land tenure, sequencing and project feasibility) and 'urgency'. Once overall scores were totalled for individual projects, a ranking of the various potential projects was produced.

The scale of the above task should not be underestimated. Through the above work, both Central Government and communities came to an agreed outcome on resilience, raised community awareness of natural hazards and created pre-plans for action in the case of hazard events. The subsequent prioritised list of potential infrastructure upgrade projects can therefore be seen to have been consulted upon, and is a work of relative robustness.

4.3 Vulnerability issues identified

Through the process outlined in Section 4.2 above, a number of broad vulnerability classes of infrastructure vulnerability were identified. These included the following":

Road access

It was identified that a large number of roads are potentially vulnerable to sea action, for example, from being washed out by storm events. As a result, it has been proposed that a number of roads be moved inland, away from the coast, in some cases quite significantly. It is understood that if this were to happen, other infrastructure types may follow – for example if a road is moved, a family home may be moved to match, along with the provision of utilities to that home. On a larger scale, power cabling could also be moved to align with the road.

Sea walls

In some cases, there have been recommendations for sea walls to be strengthened, constructed or lengthened.

Sand use

A policy is now being developed by the Samoan Government on the use of sand, as it is a relatively limited resource.

Water supply

The salinity of water supplies is increasing in some locations, an issue that may have longer-term infrastructure implications.

The above is a snap-shot of the vulnerabilities identified, and provides an example of the spread of issues that were identified as part of the Coastal Infrastructure Management Plan work.

4.4 Approaches by Government – treatment of vulnerabilities

It appears that the Samoan Government did not greatly take into account specifically, as would have historically been common internationally, infrastructure resilience, until the adoption of the CIM Strategy in 2001. The CIM strategy outlined, in broad terms, the following process:

1. identify hazards.
2. assess risks.
3. prioritise.
4. apply for funding.
5. implement.
6. create pre-plans for higher risks.

This full and holistic progression, involving both Central Government and the various communities, has led to comprehensive and robust plans. Clearly, the Samoan Government is taking infrastructure resilience seriously. This demonstrates the ability to plan, and could be seen as an example of 'good governance', although it should be recognised that only a few physical infrastructure projects have, as yet, been completed as a result.

Regarding the institutional framework in which the above work has proceeded, as has been seen, the work outlined above has been led and managed by the Samoan Government Ministry of Natural Resources and Environment. In response to the creation of the above strategy, and to the increasing negative environmental and community effects of urbanisation, the Planning and Urban Management Agency (PUMA) was formed. This agency started with little mandate or role, but has since grown in strength, credibility and scope, including

the expansion of its scope to rural areas (Keith Frentz, personal communication, 20 May 2011). For this reason, the management of much of the work outlined in Section 4.3 is now carried out by PUMA. One reason for the significant gains made by PUMA in the urban areas is that economic growth in Samoa has fuelled practices such as urban waste collection from households in Apia. This is partly due to the presence of returnees to Samoa from Australia, New Zealand and the USA. Apart from one other example of urban environmental advancement cited in Kiribati, the progress made in Samoa regarding infrastructure resilience understanding, and in solid waste management practices, appears to be almost unique within the Pacific Islands (Jones and Lea, 2008).

Through the above, it is apparent that the Samoan Government is taking the issue of infrastructure resilience forward. The progress made is not the result of a single pocket of Government making gains, rather an appropriately resourced Government Department making gains on an issue. In other words, these gains are not isolated or 'random' successes. The resulting holistic gains also demonstrate governmental management success.

4.5 Approaches by support governments

The Samoan Government would be unlikely to be able to fund all infrastructure resilience initiatives itself, in isolation, even those attracting a Benefit Cost Ratio of more than two. More likely is that it would look for assistance externally in funding potential projects. Traditionally, and as seen in Section 1.6, Samoa has strong ties with New Zealand. Equally, the New Zealand Government also demonstrates why it has strong ties with a number of Pacific nations through its existing policies, and as outlined on its website (NZAID, 2010a). This 'one page' policy statement outlines that "New Zealand has strong connections with many Pacific Countries due to constitutional relationships, migration, travel and trade." This strong connection translates to over 50% of New Zealand foreign aid being spent in the Pacific region. Clearly, this relationship would be expected, in future, to be a factor for both the Samoan and New Zealand governments in the assessment of project funding applications. For example, it is anticipated that the

New Zealand Government will deliver some NZ$23 million in development support to Samoa in the 2011/12 financial year (NZAID, 2012). The Australian Government takes a similar approach, with AusAID undertaking to deliver Aus$43.7 million to Samoa within the 2011/12 financial year (AusAID, 2012a). Part of this funding may include specific funding to the International Climate Change Initiative, including assistance to Pacific Island Countries (AusAID, 2012b).

Regarding policy on the environment and resilient infrastructure on Pacific Islands, Australia's and New Zealand's policies align very closely with that of the Pacific Islands Forum Strategy (NZAID, 2010b). This forum, a collaborative grouping of aligned Pacific Islands, including New Zealand, has produced a policy on 'Pacific regional environment and natural disasters'. (Note – the 'American Flag' states, including American Samoa, are not a part of the forum.) This policy, and particularly the manner in which it is a collaboration of both funding/donor and recipient Pacific Nations, provides a framework within which external funding partners, Australia and New Zealand included, can channel funds with agreed philosophies for action. These philosophies include the requirement for the provision of resilient infrastructure, and reiterates the need for steps such as good hazards analysis, public education, planning for effective response, the use for early warning systems, and promotes the use of disaster risk reduction activities. These steps strongly mirror the World Bank document (Bettencourt et al, 2006) that promotes good practice in disaster risk reduction in the Pacific.

As can be seen above, there is strong alignment between the recommendations of the World Bank, the Australian and New Zealand Governments with the planning and actions of the Samoan Government regarding disaster risk reduction, relating specifically to planning for more resilient infrastructure.

4.6 Samoan potential funding of infrastructure resilience

International funding applications

Whilst the Samoan Government, specifically the Planning and Urban Management Agency of the Ministry of Natural Resources and Environment, have produced some cohesive and evidence-based plans, in conjunction with the communities involved, relatively little implementation has been carried out, as of March 2012. However, as outlined by Keith Frentz of Beca (personal communication, 20 May 2009), the Samoan Government, seen as relatively stable by external governments, and having carried out the planning outlined above, is in a very strong position when applying for funding for infrastructure resilience projects. Additionally, with specific 'climate change' funding potentially available from multilateral finance institutions likely to be available in the coming years (see section 6.4), the Samoan Government has already carried out the planning necessary. Samoan funding applications are more likely to be approved as a result.

Internal funding decisions

In terms of decisions for funding infrastructure changes and upgrades, and as outlined in Section 3.5.2, Benefit Cost Ratios (BCRs) are a recognised means of prioritising funds for projects. As seen in Section 4.2, the Samoan Government has produced BCRs for a number of potential projects outlined in the Coastal Infrastructure Management Plan process. The approach taken in the case of this planning is that projects that attract a BCR of 0.8 are subjected to a feasibility assessment and an environmental assessment, with a view to further prioritised ranking and potential funding and implementation (Michele Daly, personal communication, 3 May 2011). It is conversely clear however, that projects with BCRs of less than 0.8 are unlikely ever to progress. It should also be noted that very low-cost projects with clear benefits, and culturally important projects, such as the protection of cemeteries, are not subjected to BCR calculations, and have been progressed without having to pass these tests.

Looking beyond the funding of resilient infrastructure in isolation, the Samoan Government is also assessing potential projects against 'village plans', which

include climate change adaptation, sustainable land management, biodiversity, renewable energy, natural hazards, emergency and disaster management plans, forestry, marine and agricultural developmental projects (ibid). This additional testing of projects against multiple alternatives could be expected to produce truly robust project prioritisation assessments, and take a wider developmental approach to the prioritisation of potential projects.

Regarding very expensive potential infrastructure resilience projects, these tend to be carried out by the Government's service providers, through their annual planning processes. For example, the roading authority will assign its own priorities for projects, as will the Samoa Water Authority, as will the remaining Government agencies (ibid).

Regarding the timing of the implementation of potential projects, the Assistant Chief Executive Officer of the Planning and Urban Management Agency (PUMA) explained (personal communication, 31 May 2011) that "Timing has not been a big feature in the documents, rather more an identification of actions." This was a conscious decision, taken so that projects could be identified at a village level without fear of particular projects being dismissed at an early stage due to any factor.

Thus, although funding is not presently flowing to many projects, the framework and planning are in place for projects to proceed, should the funding be available.

4.7 Lessons to be learnt on resilient infrastructure policies – Samoa

What lessons can be learnt from the work of the Samoan Government relating to infrastructure resilience planning? Referring back to the 'best practices' outlined in the literature review, section 3.6, the following can be seen:

Policy	Carried out?	Comments
The analysis of natural hazards		
Analyse infrastructure according to the specific hazard it faces	Yes / best practice	Engineering and village consultations carried out.
Take into account evolving hazards (climate change/urbanisation) in the design of infrastructure	Yes / best practice	Urbanisation, and climate change taken into account.
Represent hazards to infrastructure in clear and intuitive ways	Yes / best practice	Represented in CIMS documents.
Community involvement		
Community involvement is needed in decision making, including both disaster risk reduction and planning the post-disaster management	Yes / best practice	All communities consulted
Government investment and coordination		
Overall coordination of disaster risk management, including both pre-event disaster risk reduction, and post-event disaster management is necessary	Yes / best practice	Both at government and community levels
Mainstreaming disaster risk management (taking a holistic approach)	Yes / best practice	Hazard plans are being assessed against other village development plans.
The 'free market' cannot always decide optimal locations for infrastructure in terms of overall system resilience	Yes / best practice	The Samoan Government has taken an overall view of funding on infrastructure.
Using Benefit Cost Ratios in prioritising implementation	Yes / best practice	Exceptions for low-cost and culturally important items.

As can be seen from the above, the Samoan Government's approach, as implemented by the Planning and Urban Management Agency section of the Ministry of Natural Resources and Environment, has achieved 'best practice' in comparison to the practices identified in the Literature Review (Section 3 of this document) effectively against all of the factors identified.

5 CHAPTER FIVE: INFRASTRUCTURE RESILIENCE POLICY APPROACHES IN AMERICAN SAMOA

The following chapter overviews American Samoa's approaches to resilient infrastructure policies, ending with a comparison between American Samoa's approaches and 'best practice' as outlined in Section 3.6 above.

5.1 Past approaches affecting infrastructure (investment / mitigation)

The South Pacific Conference, held in American Samoa in 1962, was a major impetus for providing 'modern' infrastructure to the territory at that time (American Samoa Humanities Council, 2009). With planning for the conference starting just thirteen months before the conference itself, there was a rush to build an airport runway capable of landing jet aircraft, although there was no airport terminal at that time, and a 13km road connecting the airport to Pago Pago was constructed. Further building work was carried out, including a school building which, due to the absence of a hotel at the time of the conference, was used as accommodation for 100 of the conference delegates. Although this construction work, carried out within a short time-frame, was a great achievement, it should be noted that much of it was carried out by external (US mainland based) contractors, and did not have a great deal of long-term planning forethought. At the time, US Secretary Stewart L. Udall, overseeing the preparations, stated that "The truth is that we have not formulated any plans for the future of American Samoa… Our goal is to give self-government as quickly as possible. Statehood is not the ultimate. We have not worked out any special steps for the future." (ibid, p276). It seems, therefore, that the work carried out for the South Pacific Conference was carried out in a 'bubble' of thought, without particular reference to the long-term needs and requirements of the islands, although it should be

acknowledged that the work did provide the airport runway, a link-road and at least one school building at the time.

Infrastructure development work did continue after the South Pacific Conference. The Governor at the time, Governor H. Rex Lee, developed a plan to provide a road to every village in American Samoa within 'two or three years' (ibid). This was partially achieved, albeit later than the planned timeframe. Some work was carried out voluntarily by some of the communities served, where they hand-dug some sections of the roads.

Whilst the above provided some basic infrastructure for the island, a hurricane struck the territory in 1966. Damage was caused to the hospital and "parts of the new road suffered because there was no seawall". This event "provided the impetus to prioritise power generation, completion of the new hospital, and new building standards to maximum solidity" (ibid, p287). It appears that the original construction, carried out in a rush, suffered from a lack of rigorous planning or of thorough design.

Moving forward, in 2001 a workshop was held by the 'American Flag Pacific Islands' (Hawai'i, Guam, American Samoa and the Commonwealth of the Northern Mariana Islands, and the US-affiliated Pacific Islands, which include the Federated States of Micronesia (Yap, Pohnpei, Kosrae and Chuuk), the Republic of the Marshall Islands and the Republic of Pulau) on Climate Change and Variability (Shea, 2001). Although climate change has the potential to greatly affect Pacific Islands through more extreme storm events, and raising sea-levels, it is interesting that this workshop focussed only on climate-change, rather than on the wider subject of resilience to natural hazards. It is also interesting in that it was carried out only between the American Flag countries, demonstrating and reinforcing that parallel political systems within Polynesia and Micronesia meant that there was little apparent interaction between the Australian and New Zealand aligned Pacific Islands and the American dependant territories on disaster risk management. The outcome of the workshop was the identification of seven main aspects of 'Building Resilience': provide access to fresh water, protect public health, ensure public safety in extreme events and protect

community infrastructure, promote wise use of coastal and marine resources, sustain tourism and sustain commercial and subsistence agriculture (Shea, 2003).

5.2 Approach taken to community and infrastructure vulnerability/resilience

On 1 and 2 February 2011, a summit was held in Pago Pago entitled "Making Climate Change Local: Resilient Communities in the Pacific". Again, the seminar was largely (but not exclusively) directed at American Flag Pacific Islands. The report on the summit was produced in April 2011 (Doherty, 2011). Various working groups on this summit identified climate-change related issues, and made suggestions for their mitigation. These included items such as "Issue: sand mining. Resolution: Improve education about the negative implications of sand mining. Sample project: Enforce regulations and fines." (ibid, p 12). Similarly, the 'unsustainable infrastructure' issue included a suggestion that "most critical structures [be identified], bringing them to become energy efficient and hazard resilient" (ibid p15). In this way, both climate change mitigation (reducing carbon emissions) and adaptation (working to reduce the impacts of climate change) were addressed.

It should be noted that the above suggestions made do not have actions assigned to specific people or organisations, and no timeframes are identified. This was a deliberate output of the summit – to produce ideas for action. The US Department of Commerce is presently working on a Framework which "should contain more concrete plans, and designated agencies who will be tasked with many of the recommendations from the Climate Change Summit" (Kristine Bucchianeri, personal correspondence, 7 March 2012).

As of June 2011, American Samoa did not have any explicit policies regarding infrastructure resilience (Gene Brighouse, US National Oceanic and Atmospheric Administration (NOAA) staff member, personal correspondence, 10 June 2011). American Samoa's resilience work continues to be based on climate change

issues, which constitute most, but not all, of the natural hazard risk to the territory. No specific work appears to have been carried out regarding the resilience of infrastructure, although work has been carried out on climate-change effects to specific locations, including Fagatele Bay, and work is being carried out on the resilience of corals and habitats in the area (ibid). This provides a framework for action, with the hazard mitigation partially addressed through climate change issues.

In addition to the above, some pilot studies have been carried out with individual communities in American Samoa, specific to identify vulnerability to climate change (Emily Gaskin, NOAA Policy Analyst, personal correspondence, June 2011).

5.3 How vulnerable are American Samoan communities?

Vulnerability issues identified in the report on American Samoa's climate change summit (Doherty, 2011) can be seen to include:

Sand mining

It appears that regulations on sand mining exist, as the summit output stated that a sample project could be to "enforce regulations and fines". This demonstrates a governmental understanding of the negative impacts of sand removal, although it may also appear that any regulation of sand mining has not been as effective as it could have been.

Water quality

It appears that water quality varies throughout the year, as the summit plan included a suggestion to "release warnings to the public during periods of water quality concern".

Although mention was made at the above seminar to roading resilience to storms and tsunami, it was not apparent whether this was directed at the case of American Samoa or at Pacific Islands generally.

As can be seen, above, there is some understanding of the perceived vulnerability of American Samoan communities to natural hazard events, and actions are (March 2012) being formulated to understand more fully what those vulnerabilities are.

Whilst the above study presents understanding of the hazards, it appears that the American Samoan communities have not been involved in the identification of these hazards. This presents a 'gap' for the American Samoan community, in that whilst the summit held on climate change in American Samoa highlighted hazards, a holistic view has not been taken, including other hazards, the communities have not become aware of the range of potential hazards, including evolving ones, and the community's emergency planning has not been developed from this understanding.

5.4 Approaches by Government.

The US National Oceanic Atmospheric Administration (NOAA) office and the US Department of Commerce are taking the lead in addressing climate change issues in American Samoa. Both these organisations have staff 'off island' (either on the US mainland or on other Pacific Islands, mainly Hawai'i) and American Samoa-based staff addressing climate change issues. This provides specialist technical advice and management as and when required. Whilst this provides targeted advice, it has not been clear to the author of this thesis how these departments link in with the American Samoan providers of the infrastructure, and what ownership of the issues the infrastructure providers are taking. The creation of the framework for actions on climate change outlines specific actions for infrastructure providers however, without participation in the decision-making process leading to the actions, it is possible that actions may not receive the attention they require.

5.5 Approaches by support Governments

A staff member at the NOAA stated (Emily Gaskin, NOAA Policy Analyst, 14 June 2011), "As a US territory, American Samoa is often not eligible for a lot of climate project funding directed in the South Pacific Region (such as the PACC initiative funded by GEF/UNDP)." This demonstrates that American Samoa is more dependent on direct funding from the US mainland, and on satellite organisations such as the Pacific Disaster Center, based in Hawai'i. This highlights again the relative parallel political structures and thought processes of the Australia and New Zealand aligned countries and the US Flag Pacific Islands.

An example of within-American Flag Pacific Island approaches is the work carried out by the Pacific Disaster Center (PDC), an organisation working on natural hazards, based in Hawai'i, and aimed primarily at American Flag Pacific Island issues. The PDC has worked with 'a broad range of local agencies' to produce a mitigation plan against natural hazards in American Samoa (Pacific Disaster Center, 2011). This mitigation plan maps how various hazards will affect American Samoa, although the examples given on the fact-sheet only outline the main harbour at Pago Pago. It also outlines how further study is required to further understand the hazards faced, and further work is required to integrate the information more fully onto a GIS (computer based) system.

As demonstrated above, it can be seen that the US Federal (mainland) system is working for the requirements of American Samoa. It can also be seen that there appears to be little external assistance to American Samoa beyond what the US mainland provides, due to its status as a US territory.

5.6 Lessons to be learnt on resilient infrastructure policies – American Samoa

What lessons can be learnt from the work of the American Samoan Administration relating to infrastructure resilience planning? Referring back to the 'best practices' outlined in Section 3.6, the following can be seen:

Policy	Carried out?	Comments
The analysis of natural hazards		
Analyse infrastructure according to the specific hazard it faces	Limited	Some external and Climate Change analysis.
Take into account evolving hazards (climate change/urbanisation) in the design of infrastructure	Yes	For climate change, at government level.
Represent hazards to infrastructure in clear and intuitive ways	Limited	GIS hazard mappings only.
Community involvement		
Community involvement is needed in decision making, including both disaster risk reduction and planning the post-disaster management	Limited	One pilot study carried out.
Government investment and coordination		
Overall coordination of disaster risk management, including both pre-event disaster risk reduction, and post-event disaster management is necessary	Limited	One study carried out, limited in scope.
Mainstreaming disaster risk management (taking a holistic approach)	No	Climate change issues taken in relative isolation to other factors.
The 'free market' cannot always decide optimal locations for infrastructure in terms of overall system resilience	Yes	All infrastructure actions carried out by the administration.
Using Benefit Cost Ratios in prioritising implementation	No	

As can be seen, from the above, the American Samoan Administration's approach has achieved limited progress in many aspects of providing resilient infrastructure in comparison to the practices identified in the literature review

(Chapter 3). It should be noted that only some community involvement has been included, that a holistic approach generally has not been taken and that coordination has only been carried out on some specific aspects. In the context of Pacific Island states, it is likely that American Samoa is not unique in this respect.

6 CHAPTER SIX: APPROACHES TAKEN BY MULTILATERAL AND OTHER AGENCIES TO THE SAMOAS

Outside the governmental structures of Samoa and American Samoa and their supporting countries are the multilateral organisations and International Finance Institutions (IFIs). These organisations have the broad aim of raising developmental levels and channelling funds to developing countries. As such, in their choices of where to direct efforts and funds, they have the power to exert pressure to adopt policies or approaches. They can therefore have a great deal of influence in the realm of high-cost policies, particularly on issues regarding infrastructure. As such, it is worth outlining their potential influence on Samoa and American Samoa in terms of resilient infrastructure.

This section will therefore outline the policies taken by these organisations, demonstrating the influence of their outputs on infrastructure policies taken in the Samoas.

6.1 World Bank

The World Bank is a partner of the Global Environment Facility (see Section 6.4). In 2006, the World Bank produced a 'policy note', which comprised around 50 pages (in pamphlet style) of guidance on best practice for disaster risk management for Pacific nations (Bettencourt et al, 2006). The framework is broken down into six themes, namely:

Theme 1 – Governance – Organisational, Institutional, Policy and Decision-making Frameworks.

Theme 2 – Knowledge, Information, Public Awareness and Education.

Theme 3 – Analysis and Evaluation of Hazards, Vulnerabilities and Elements at Risk.

Theme 4 – Planning for effective Preparedness, Response and Recovery.

Theme 5 – Effective, Integrated and People-Focussed Early Warning Systems.

Theme 6 – Reduction of Underlying Risk Factors.

The above is holistic, and provides for disaster risk reduction initiatives through both community involvement and through physical works on infrastructure. Importantly, it outlines the flow of logic of hazard analysis informing infrastructure vulnerability, which informs both infrastructure planning processes and community emergency planning. It therefore takes a similar approach to that outlined at the end of the literature review in Section 3.6. The above World Bank policy note is referenced in this thesis in sections 3.4.3.1 and 4.5. The policy note is relatively prescriptive in terms of actions that governments may take in improving community and infrastructure resilience, and therefore may be taken by governments as a framework for action.

Whilst the above demonstrates the World Bank has produced a framework for action on resilience, Roberts, Wright and O'Neill (Roberts, 2005) suggest that 'major external institutions' (by which they imply the World Bank and other IFIs) advocate a policy to "diminish public sectors". In other words, Roberts et al indicate that IFIs advocate for 'small' governmental sectors, allowing market forces to dictate investment streams. The intent of the above World Bank policy note is to provide a framework for governmental action, which could appear to be at odds with the aim of minimising the size and influence of local governments. Roberts et al would probably argue that this would produce a tension between the World Bank's advocacy for small government and the framework of action outlined in the policy note.

6.2 Asian Development Bank

The ADB is a partner of the Global Environment Facility (see Section 6.4). The Asian Development Bank (ADB) has, within its area of scope, both mainland Asian countries and the Pacific Islands. It acts as both finance organisation (IFI) and provider of technical expertise. One document that demonstrates this technical expertise is the document in the 'Pacific Studies Series' – 'Climate

Proofing: A Risk-based Approach to Adaptation' (ADB, 2005), some technical contents of which are outlined in section 3.5.1. This document demonstrates the likely impact of climate change on Pacific Islands and provides a number of worked examples of ways in which climate change adaptation can be incorporated into the plans of governments. Whilst these examples include how to climate-change-proof National Development Strategies and how to anticipate health-effects on a population, it is the worked examples of how to deal with infrastructure design that are of interest in this thesis.

Two key examples from the above document are given of how to design infrastructure with climate change in mind. One example is of a break-water for a harbour at Rarotonga. The worked example demonstrates how historical data on storms and wave-heights should not be used as examples of potential future events, but demonstrates how wave-heights could be calculated for future events. Similarly, in a section on a road design for Kosrae in the Federated States of Micronesia, a worked example demonstrates how a bridge over one particular existing gully in the proposed route of the road would be designed. This design is worked through with historical stream flows used, and worked through again with the larger stream flows anticipated from climate-change-induced higher intensity rainfall events. Further, the costs of the two potential structures are calculated. The increase in costs for the structure taking climate change into account is called the 'incremental cost'. By carrying out this set of calculations, the designers have not only developed an appropriate design that will probably remain resilient for longer than a 'historically designed' structure, but also demonstrated the 'cost' of climate change adaptation in the design of this road. This ADB document then sets out how governments may apply for funding from specific international funding mechanisms for this incremental cost.

Although the above document is focussed purely on climate change issues, other ADB documents have been produced regarding the wider issue of disaster risk reduction. In 2008, the ADB also produced an action plan for implementing the ADB's disaster and emergency assistance policy (ADB, 2008). This action plan outlines a number of actions, including: the adoption of DRR to country partnerships strategy formulation, training initiatives for specific in-country staff,

establishment of an informal DRM network within the ADB, collaboration with regional partners and the development of a partnership with the World Bank to further develop DRR strategies in low-income and moderate-income countries. Technical input of the above nature enhances the understanding of designers and funders of infrastructure in the Pacific.

6.3 The United Nations Development Programme

The UNDP is a partner of the Global Environment Facility (see Section 6.4). In addition to the work of both the World Bank and the Asian Development Bank, the United Nations Development Programme (UNDP) has carried out various studies, and provided various strategy documents, focussed not specifically on Pacific Islands, but on global risk reduction issues (UNDP, 2004, 2009). These documents provide a summary of the wider understanding of the concepts of vulnerability and resilience. As such, the technical outputs of the UNDP in the above documents support the policy framework developed by the World Bank, as outlined in Section 6.1 above.

6.4 The Global Environment Facility

The Global Environment Facility (GEF) is a partnership between ten agencies:

- The UN Development Programme (see section 6.3 above)
- The UN Environment Programme
- The World Bank (see section 6.1 above)
- The UN Food and Agriculture Organisation
- The UN Industrial Development Organisation
- The African Development Bank
- The Asian Development Bank (see section 6.2 above)
- The European Bank for Reconstruction and Development
- The Inter-American Development Bank
- The International Fund for Agricultural Development

The GEF "serves as a financial mechanism" for a number of conventions, including the United Nations Framework Convention on Climate Change (UNFCCC) (Global Environment Facility Website, 2012). It is to this fund that World Bank and ADB documents point applications to incremental costs – as outlined in Section 6.2, regarding the additional costs for climate-change-proofing a structure on a potential road in Kosrae. This fund would be one of the prime funds to which Samoa would be likely to apply for funds, although as outlined in section 5.5 above, it is not a fund that the American Samoan administration can apply to, due to its status as a US Flag territory.

It is through the GEF therefore that the above ten organisations, including IFIs direct their contributions to adapt to climate change. The organisations therefore demonstrate a high level of cooperation in their activities. (See section 6.6 for comment on the impact of this cooperation between agencies.)

6.5 Pacific technical institutions

Within the Pacific, various technical institutions exist which work on, and have an understanding of, issues relating to disaster risk management and disaster risk reduction. These organisations are the Secretariat of the Pacific Community (SOPAC), the Secretariat of the Pacific Regional Environment Programme (SPREP) and the Pacific Disaster Center (PDC).

6.5.1 Secretariat of the Pacific Community: Applied Geoscience and Technology Division

The Secretariat of the Pacific Community: Applied Geoscience and Technology Division (SOPAC) provides technical input "for improving the livelihoods of Pacific communities" (SOPAC, 2012). As an organisation, it has produced a number of the documents referenced in this thesis (Bettencourt et al, 2006), (Kaly et al. 1999) (creation of a vulnerability index, to measure the vulnerability of communities to disasters), Mirti & Davies (2005) (an analysis of drinking water quality in Pacific Island countries) and the Pacific Islands Forum Secretariat (2009) (a document calculating the economic costs of natural

disasters in the Pacific Islands region). SOPAC is specifically focussed on engineering and technical issues regarding disaster risk reduction in the Pacific Islands region. As can also be seen, although its member states include almost all of the Pacific Island countries, and Australia, New Zealand and the USA, much of its work is with the Australia / New Zealand aligned countries. SOPAC is based in Suva, Fiji.

6.5.2 Secretariat of the Pacific Regional Environment Programme (SPREP)

The Secretariat of the Pacific Regional Environment Programme (SPREP) has a very similar membership to SOPAC, but also traditionally carries out much of its work with the Australian / New Zealand aligned Pacific countries. Its remit is on "the protection and sustainable development of the region's environment" (SPREP, 2012).

Focussed more on environmental issues, SPREP has produced documents which may influence disaster risk reduction measures, such as the UN Environment Programme document "Pacific Island Mangroves in a Changing Climate and Risking Sea" (Gilman et al, 2006). Whilst not specifically an over-arching response to climate change or community resilience, such documents do provide technical understandings of a number of resilience issues, some of which can directly affect the understanding of infrastructure resilience.

6.5.3 Pacific Disaster Center (PDC)

The Pacific Disaster Center (PDC), based in Hawai'i, has a similar vision to that of SOPAC, in that it is "an applied science, information and technology center, working to reduce disaster risks and impacts to peoples' lives and property" (PDC, 2012). PDC historically tends to work in the American Flag territories. Referenced within this document is the work carried out by PDC on a mitigation plan for American Samoa (PDC, 2011).

PDC works on a number of similar issues to both SOPAC and SPREP, specifically in identifying natural hazards, but extends this technical expertise to early warning systems for tsunami and storm events, which are conveyed to all Pacific Islands through PDC's website. It should be noted however that PDC's main focus of work is on hazard analysis and mitigation in the American Flag countries of the Pacific.

6.6 Summary on the impact of multilateral organisations

The Global Environment Facility (GEF), as outlined in section 6.4 is a key mechanism for delivering funding for climate change adaptation. As an organisation that combines financial contributions from its members, it must bear in mind the needs of its funders. This is where Pacific States wishing to access funding from the GEF need to ensure that they have aligned their policies to those of the ADB and the World Bank, two of the organisations within GEF that they are most likely to be in contact with for a variety of funding and other purposes. This is where the World Bank 'Not if But When…' document (2006), written for the World Bank by SOPAC, is so highly influential. Without accepting the framework for action by the World Bank outlined in that document, including governance issues, Pacific states are unlikely to be gaining the approval of the World Bank, and are therefore less likely to be able to access funding from the GEF. As seen in section 6.1, there is discussion as to whether the aims of the World Bank in maintaining 'small' government may be at odds with the policies outlined in the above framework, recommending various actions of Pacific state governments to increase resilience to vulnerability. This is where the Pacific states may need to work to the confines of the World Bank 'Not if But When…' framework. It should be recognised however that the above framework demonstrates global best-practice in terms of resilience, and therefore the Pacific states will often be accepting sound advice, originating from the Pacific region (SOPAC) in following the framework.

7 CHAPTER SEVEN: ANALYSIS

Having understood best-practice for disaster risk reduction in the literature review (Section 3) and the work carried out in Samoa (Section 4) and in American Samoa (Section 5), we can now analyse what these approaches may teach us.

7.1 Vulnerability of the Samoas to natural disasters

Are Samoa and American Samoa vulnerable to natural disasters? As has been seen in the various studies, the results of which are outlined in chapters 4 and 5, there are a number of natural hazard vulnerabilities that the Samoan communities are exposed to. Both countries are 'high' Pacific Islands, with communities mainly living near the coast. This puts both sets of communities particularly at risk from sea-related hazards. Both sets of communities are also vulnerable to the developing risks associated with climate change – from more intense storm events, from rising atmospheric temperatures and sea-level rise. Both sets of communities have suffered damage from storm events throughout recent history. The hazard profiles of the two countries therefore appear, as would be first be expected, to be relatively similar. Neither country is subjected to a clearly different or more intense hazard than the other, such as heightened volcanic or other risk.

Although the natural hazard risks to the respective populations appear to be broadly similar, the analysis of the natural hazard risks have been undertaken markedly differently in the two countries. Samoa has taken an all-hazards approach, highlighting potential hazards from tsunami, storm, earthquake and other risks, as well as taking into account the issue of climate change. American Samoa has investigated more specifically climate-change related risks, although broad hazard analysis mapping to a coarser level of detail has been carried out.

7.2 Disaster Risk Reduction work in the Samoas

As has been seen in Sections 4.7 and 5.6 comparing how Samoa and American Samoa have worked against best-practice in identifying and working to mitigate infrastructure vulnerabilities, the approach taken by Samoa closely follows best practice. Although this is the case, and although a great deal of planning has been undertaken, very little physical works have, as yet, been carried out. American Samoa has taken, so far, an approach which has achieved results in specific sectors or on specific issues, but has not taken a holistic approach to hazard mitigation, and like Samoa has not implemented any significant level of physical works. Because of Samoa's progress on the above issues, it is now well placed to apply for the funding from mechanisms such as the Global Environment Facility (see section 6.4).

Why has Samoa achieved so much more in this regard? Although Samoa and American Samoa have had similar geopolitical histories until around 1900, and divergent ones since, differences in approach to the issues do not appear to be due to any particular strand of geopolitical history. It does appear, however, that the approaches to infrastructure resilience taken in Samoa have been significantly more holistic in their approach. This may be because key staff in the Samoan government department of the Planning and Urban Management Agency (PUMA) took a Masters Degree in Resource Management in New Zealand, and followed the relatively holistic approach to land planning as detailed in New Zealand's Resource Management Act. Work streams regarding disaster risk reduction in American Samoa appear to be more 'silo-ed', creating a less holistic approach. Additionally, the work carried out in Samoa, prior to the implementation of physical works, is also being tested against non-disaster risk reduction based projects, in order that the wider developmental needs of communities are addressed alongside disaster risk reduction works. In addition to the above, the Samoan approach of consulting village communities throughout the process is feeding good information into hazard analysis, and is helping the community understand their own relative vulnerabilities to natural hazards, therefore helping the communities develop their own disaster management plans, in case a natural hazard event does take place.

Essentially therefore, there appears to be three key differences in the basic philosophies of approach taken in the two countries. Samoa is taking a more holistic approach. It has, due to starting thought on this issue back in 2001 (compared to more recent efforts in American Samoa), progressed further on this issue (timely action). Finally, in consulting its communities throughout the process, Samoa has wide buy-in of activities by its various communities (community involvement).

7.3 Approaches to Disaster Risk Management and Disaster Risk Reduction

As seen in section 6.6, the approaches taken by the various multilateral organisations appear to be highly aligned, and follow what many would consider to be 'best practice'. The accepted process for analysis and treatment of natural hazards, specific to disaster risk reduction for infrastructure, may be summarised as follows:

Analysis and treatment of natural hazard risk to infrastructure

Infrastructure owning organisations should go about resilience planning in the following way:

1. Carry out **vulnerability mapping** – demonstrating potentially vulnerable items of infrastructure. The results MUST be able to be intuitively understood by a non-expert (this mapping can be simply for the physical assets). Indeed, community members may hold much useful information relating to natural hazards in the area. Hazards to check would depend on the area, but could include seismic, volcanic, flood, tsunami, climate change adaptation etc.

2. Work out the **consequences to the community** (or supply chain, or cost of loss, whichever is most relevant) of failure of the item (this can be

broad-brush, but is needed in order to understand the need for any follow-on actions and their relative priority). Again, this MUST be in intuitive / simple to understand language. Once done, for the case of Pacific Islands, the hazard mapping and the consequences should be discussed with the community. In more technical applications, benefit cost ratios, incremental costs of climate change adaptation and political analyses may be appropriate.

3. Include, if necessary, **upgrade of assets** in future Asset Management Plans and implement.

4. Where consequences to the community are severe, **plan** work-arounds to mitigate against failure of the item until any upgrades are complete, in conjunction with the community potentially affected.

5. **Engage with both the community and the local civil defence body**, to ensure that approaches are understood across communities, and by the most likely emergency responders.

The consistency of approach to resilient infrastructure by the above range of organisations could indicate ‘group thinking’ (where communities listen so intently to each other that they miss ‘obvious’ other factors), or ‘centralised thinking’ (where the advice of just a few experts is taken on board by many others). It would appear however, that there is a diversity of institutions, governmental, international, and independent / consulting organisations that are coming to the same conclusions and are communicating similar messages. It appears unlikely, from this wide range of texts, that group or centralised thinking is apparent in this case. A different conclusion could be that the basis of disaster risk reduction to infrastructure, as summarised in the box above, is an accepted and rigorous approach to the issue.

7.4 Taking learnings out to other contexts

What can we take lessons from the experiences of the Samoas which may be of relevance to other countries and communities? As seen in section 7.2 above, Samoa's approach has been based on three key criteria: a holistic / best practice approach to disaster risk reduction, timely action and community involvement.

7.4.1 Taking a holistic / best practice approach to disaster risk reduction

Samoa has taken a holistic approach in mapping its natural hazards and in incorporating the outcomes of their community consultation within their development plans. This has required considerable effort by central government. However it has ensured that any ensuing works will be carried out incorporating developmental issues. This means that resilient infrastructure issues are not being carried out in isolation but alongside the developmental needs of the various communities. Clearly, as an extreme example, there would be little point in providing resilient roads if potable water could not be provided, or because crops could not be grown in-country (or the economic basis of the community were undermined in some way). Further, Samoa has followed the six themes outlined by the World Bank for planning resilient infrastructure, as detailed in section 6.1. By carrying out this process, Samoa has demonstrated that in terms of process, a holistic / best practice approach can be carried out.

7.4.2 Timely action

Samoa adopted its approach to disaster risk reduction in January 2001 (see section 4.2). Bearing in mind the complexity and effort involved in producing its Coastal Infrastructure Management Plans, it has made steady progress in the past twelve or so years. This indicates that the production of such plans takes time, even when resourced at levels that allows relatively constant progress. This is an aspect which other countries can learn from – that the development of such plans does take an extended time. Having carried out the work though, Samoa is now in a strong position to proceed with funding applications and potentially to

physical works. This is believed to be well in advance of many other Pacific Island nations.

7.4.3 Community involvement

With a population of 179,000 (2009 estimate), and with just over 40 villages, the scale of community consultation required in Samoa on the Coastal Infrastructure Management Plans would not have been as high as in many mainland Asian countries. On the other hand, such a population is well in excess of many other Pacific Island states, and in this respect, Samoa has demonstrated that community consultation on resilient infrastructure can essentially be carried out country-wide, if the government has the political will to undertake this task.

7.5 Other resilience factors of note

The following factors of note regarding disaster risk reduction are also worth considering, as a result of the experiences gained in the Samoas:

7.5.1 Economic factors

The ADB (2005 and 2008) supports a 'risk based approach' to Disaster Risk Reduction. Specifically, from the examples given in the texts, this appears to mean providing a calculated 'Benefit Cost Ratio' (BCR), or an economic assessment of the value of the risk reduction initiative for infrastructure investment. The use of, and calculation of, a BCR is discussed in Section 3.5.2.

Whilst the use of BCRs provides a familiar measurement method (for engineers and governmental economists) for calculating the relative benefit of different potential projects, the calculation of a BCR may be skewed in a number of ways, principally regarding the rules given for its calculation. Most major infrastructure providers have their own rules for producing economic assessments. Most governments also have their own defined 'discount rates' to be used for the

calculation of BCRs. The discount rate is effectively the interest rate at which the government chooses to value money year-on-year. It is equivalent to the interest rate available at banks when investing money. A high interest rate implies a high rate of return, a low interest rate implies a low return on investing money. The United Kingdom and United States of America and other countries presently use a discount rate of 3-4% for infrastructure investment decisions. New Zealand presently uses a rate of 8% (NZIER, 2011). Although on the face of it an administrative decision, the discount rate strongly affects the desirability of future projects. With a low discount rate (say 3%), economic benefits realised by projects in the medium to long-term future (say, over 10 years) may be substantial. A higher discount rate makes short-term benefits (in the following five years) gain greater weight than longer-term benefits. This means that with a high discount rate (such as 8%) short-term decision-making predominates. Long-term issues such as resilience of infrastructure, where natural hazards may have a massive effect, but only on 50- or 100-year cycles, using BCR calculations with medium or high discount rates, are given minimal weightings. A low discount rate allows for such long-term cycles to gain at least some realistic weighting.

There are economic rationales for choosing to use a particular discount rate. Using a high discount rate provides a robust and quantifiable basis in many investment decisions, but as seen above downgrades long-term infrastructure resilience as an investment option. Therefore, if a government is to be focussed on long-term resilience, it may choose a long-term decision-making discount rate.

7.5.2 Connectedness factors

Whilst BCRs may provide economic justification for investing in infrastructure, some potential projects or actions simply will not achieve a favourable BCR. Without a favourable BCR, it can be difficult for a government or community to justify expense on an action. This can be a major consideration for more remote or smaller communities, for example. Consider a fishing village located 20km from a population centre, connected by land only by an infrequently used but adequate road. Based purely on an economic assessment, it may be that the low

use of the road, and the low economic activity at the village means that a BCR indicates that it is no longer a good investment decision to continue to maintain the road. Economically, therefore, it would be justified to allow the road to fall into disrepair, and for the community to eventually be cut off by road access. In terms of connectedness, this may however effectively make the long-term presence of that community impossible, without connection to the facilities that the larger population centre provides. A decision as to whether to maintain the road may therefore become a political decision, based not on economic justification, but on other factors such as cultural or community issues.

Developing this idea further, an example of an upgrade to an existing road may be considered. Two routes appear viable, both costing approximately the same – one runs near to the coast, which makes the road vulnerable to coastal hazards. The other route runs partially through an urban area, but is seen to be resilient to natural hazards. In order to construct the road through the urban area, many existing residences would have to be removed or relocated. Again, it appears that in this fictitious situation, it would be a political decision for where to locate the upgraded section of road.

With the two above examples it can be seen that, even with good information available, infrastructure resilience can become a political decision, affecting different sections of communities in different ways. It is not possible, in this thesis, to address adequately this issue, rather to acknowledge that some resilience issues may become political in nature.

7.5.3 Measurements of resilience

Whilst the above sections discuss economic and political issues, measures of resilience could potentially aid both economists and politicians in decision-making for infrastructure resilience. As seen in Sections 3.1.1 and 3.2.2, there are presently no clear resilience or vulnerability measures. This makes infrastructure resilience a hard-to-define concept, and therefore one hard to make clear decision making on. Development of such measurements would provide a useful tool for the sector.

8 CHAPTER EIGHT: CONCLUSIONS

The objective of this thesis is to explore governmental approaches to analysing infrastructure resilience and the means of mitigating against disaster, comparing the polices taken in Samoa to those in American Samoa. Through the literature review best practice for disaster risk management was identified, and the approaches taken in the two island groups were compared against that best practice. Whilst the technical details of the two approaches have produced their own sets of learnings, some themes have become apparent from a development studies standpoint.

8.1 The importance and value of community participation

'Community participation' is a developmental term that is widely encouraged, in concept, by many organisations, including the World Bank, UN agencies and NGOs (Desai, 2008). However, its effectiveness and use has sometimes been called into question, with some governmental organisations accused of manipulating communities, or process outcomes, for their own purposes (ibid). Samoa's approach to disaster risk management is therefore an interesting and informative case. The Samoan government has made significant effort to engage with the community, and through this process has realised various benefits.

Firstly, the understanding of hazards facing both communities and infrastructure have been refined. Whilst the technical staff working on disaster risk management in Samoa were able to identify some hazards, the community were able to give additional information on past events, and highlight their perceptions of risk. The resulting hazard mappings were therefore more robust, and of greater use to both governmental agencies and the community. Secondly, through discussions on the hazards, both the governmental agencies and communities were better able to plan future potential infrastructure upgrades, and to plan emergency responses. The community facing the hazard will therefore be better prepared, both physically (infrastructure) and organisationally (understanding actions to be taken in hazard events) for hazard events. This process also helps

the government plan, long term, infrastructure management. Through this process, a prioritised list of infrastructure upgrades was identified. This helps the government agencies concerned to make good choices on expenditure. Thirdly, the government can rightly point to a robust and inclusive process to potential financiers of infrastructure upgrades or, particularly relevant presently, financiers of climate adaptation and mitigation projects, such as through the Global Environment Facility (see Section 6.4). Finally, the government's work on disaster risk management has been incorporated into village development plans. Therefore, the work on disaster risk management is not being carried out in isolation, but in conjunction with other work and issues, producing a holistic and encompassing response to issues.

As can be seen therefore, the Samoan Government and community are better placed to react to hazard events, and are better placed to manage their high-cost infrastructure. This is a case of community participation being used as a process to achieve a positive outcome for all stakeholders. It would appear that when engineers talk to communities, good outcomes are possible.

8.2 Policy focus on long-term horizons

Samoa has taken a long term view on village development and disaster risk management through the development of infrastructure management plans (called asset management plans in the engineering profession). The holistic nature of the work of the Samoan Ministry of Natural Resources and Environment (MNRE), integrating the development needs of communities with potential disaster risk reduction works, will provide well-targeted and efficient programmes that suit the needs of the communities. By starting this work in 2001, the MNRE are now at a stage where they can be applying for funding for physical works from international financing bodies. This demonstrates one aspect of disaster risk reduction and resilient infrastructure planning – that planning new infrastructure, retrofitting existing infrastructure, and allocating land to specific uses in town/land planning is a process that has to be viewed in the long-term. As the author of this thesis has seen from examples of seismic retrofitting work in

Christchurch carried out in the 1990s, engineers performing that work sometimes did not think that the benefits of their work would be seen within their lifetimes. Due to the earthquakes in Canterbury of 2010 and 2011, however, the value of the seismic retrofitting carried out are clear to see, just as the lack of seismic preparedness in other areas has also been visible.

In consulting the community, the Samoan Government has taken another step. It has identified infrastructure upgrades which the communities involved have either suggested or agree with. This generally ensures that natural resources are not being degraded in favour of short-win infrastructure upgrades.

This long term view, it appears, will achieve good outcomes for sustainable development, in the sense that the actions of the present generation, at local level in Samoa, will not be compromising the ability of future generations to meet their needs. This strongly matches the 'sustainable development' philosophy concept encouraged in development sectors since the 1980s (Zoomers, 2008).

8.3 Appreciating political / administrative processes

Whilst the efforts made in disaster risk management in Samoa can be seen to be having significant future positive effects, it appears that this approach is not being adopted across the Pacific. The example shown in American Samoa demonstrates that in at least that context, disaster risk management efforts are being concentrated on climate change issues, with less community participation carried out on identification of hazards or in developing infrastructure or emergency response plans. American Samoa may not be unique in the Pacific in this respect.

One of the initial thoughts in planning this thesis was whether any cause-effect factors found in the geopolitical histories of Samoa and American Samoa could be seen to have caused specific policy or tactical approaches to the delivery of disaster risk reduction and resilient infrastructure works. Samoa's holistic, community based and timely approach represents both global best-practice and

an acknowledgement of the structure of the communities living there. American Samoa's approach of focussing more specifically on climate change issues may be more of a reaction to intense debate in US political spheres in the 1990s and early 2000s regarding climate change, whether it 'exists' and what its effects may be. This may have skewed American Samoa's thinking on disaster risk reduction generally, although that does not diminish the value of the work carried out on climate change issues, as they are likely to have a large effect on the nature, scale and intensity of storm events in the Pacific in the medium and long-term future.

Despite the skew towards a climate change focus in American Samoa, it appears that there have been no specific cause/effects from geopolitical histories that have impacted the political and tactical approaches taken in the two island states regarding disaster risk reduction.

8.4 Lessons learnt from differing approaches

Apart from the 'development theory' lessons learnt, as outlined above, there are some other factors that have appeared both from the literature review and the specific cases noted in the Samoas. These are:

8.4.1 Carefully plan land use and new infrastructure with natural hazards in mind

When planning new infrastructure, and as demonstrated in ADB's case-studies for planning disaster risk reduction on Pacific Islands (ADB, 2005), designing to adapt for natural hazard events is possible. In the case studies presented, the ADB were able to demonstrate how the incremental cost of adapting to climate change could be calculated. Not all design or funding application processes will need to take this approach, particularly as it would effectively require double-designing and costing aspects of infrastructure (once taking climate change into account, once not, and calculating the cost difference). The point of this issue is that careful planning and design can lead to much more cost effective and

community appropriate works, carried out once, without the often very expensive requirement of retrofitting or repairing damaged infrastructure. Infrastructure is, in terms of community budgets, often extremely expensive, and the costs of repairs can have huge impacts on community and central government budgets.

8.4.2 Planning land use with natural hazards in mind is cost effective

Pacific Forum papers, prepared by SOPAC (Pacific Islands Forum Secretariat, 2009), demonstrated that economically, it is worth carrying out disaster risk reduction works. It is much more economically effective to properly plan works; however even retrofitting works can be economically efficient. This is a factor that will help to justify many sets of works, particularly to International Finance Institutions (the World Bank etc.).

8.4.3 Economic efficiency is not the only measure of the value of disaster risk reduction

It also has to be recognised, however, that in planning potential infrastructure upgrades, there are not just economic issues at work, but community and political ones too. This aspect is recognised in more sophisticated project prioritisation tools such as the New Zealand Transport Agency's project prioritisation tool which grades not just (economic) efficiency, but also the 'strategic fit' and 'effectiveness' of projects on a simple scoring of 'high', 'medium' or 'low'. This can help to justify works to projects that would not otherwise attract a high economic justification, such as the protection of culturally important cemeteries or statues, as seen in the Samoan approach to the prioritisation of future infrastructure upgrades.

8.4.4 Political aspects of choice of infrastructure upgrades

As seen in section 7.5, decisions on infrastructure resilience may be hard to justify solely on economic grounds and therefore can be political in nature. This can lead to a lack of clarity as to why certain decisions are taken. It may be that, with long-term resilient infrastructure issues being taken alongside immediate

community needs, that infrastructure resilience is 'put off' in favour of the politically immediate community needs. This makes the concept of infrastructure resilience not only hard to measure, but also hard to politically justify over short-term needs.

8.5 Summarising lessons learnt

Summarising all lessons learnt, both from the approaches taken in the Samoas and internationally, we see:

8.5.1 Lessons learnt from the Samoas

The following lessons were learnt through this thesis from the Samoan contexts:

A holistic / best practice approach to disaster risk reduction, as outlined for example in the Bettencourt el al (2006) text, provides long-term benefits to communities and economies (see Section 4.5).

Timely action commences initiatives, some of which may be long-term, such as the planting of vegetation. Delay on such initiatives lengthens the period in which communities remain at risk from identified hazards (see Section 3).

As seen in the Samoa example, community involvement in the identification of natural hazards, and in planning disaster risk reduction measures is feasible, even at a whole of Pacific Nation (population around 170,000) level, and may produce robust decision making on disaster planning, both at government and community levels (see Section 4.2).

8.6 Concluding words

This thesis set out to investigate the issue of resilient infrastructure in the Samoas, and to see if geopolitical histories could have informed present infrastructure policies. No explicit cause-and-effect link was found between present policies and histories, although it was found that the approaches taken by

the two administrations are achieving very different results. Samoa has invested effort and some expense in community consultation on hazard identification and disaster risk management issues. This investment has already produced benefits in terms of community readiness to react to hazard events. It is likely that the investment will also produce benefits regarding long term plans for infrastructure management and disaster risk management.

From a development studies point of view, the philosophies of community participation, and of long term sustainable approaches, can be seen to provide real benefits for the communities. Climate change, with the specific effects of sea level rise and climate variability, are causes for concern for Pacific states, however the approach taken by Samoa provides an example of how the administrations, at least of high-island states, may start to address these concerns.

Appendix 1 – Participants / Interviewees

The following are those that participated in the original research of this thesis:

Name	Position	Organisation	Means of introduction	Date / means of interview
Samoa				
Michele Daly	Team Leader, Social Sciences	GNS Science, New Zealand	Introduced by personal contact	Structured face-to-face interview, 4 May 2011
Keith Frentz	Technical Director, Planning	Beca Engineering Consultants	Introduced by Michel Daly	E-mail exchange, 13 May 2011
Jude Kohlhase	Assistance Chief Executive Officer	Planning and Urban Planning Agency, Samoa	Introduced by Keith Frentz	E-mail exchange 31 May 2011
American Samoa				
Gene Brighouse	Superintendent for Fagatele Bay NMS	National Oceanic and Atmospheric Administration	Introduced by Jude Kohlhase	E-mail exchange 10-17 June 2011
Emily Gaskin	Policy Analyst	National Oceanic and Atmospheric Administration	Introduced by Gene Brighouse	E-mail exchange 10-22 June 2011
Kristine Bucchianeri		Department of Commerce	Introduced by Gene Brighouse	E-mail exchange 2-7 March 2012

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