ADAPTATION AND MIGATION STRATEGIES; CLIMATE CHANGE AND PUBLIC INFRASTRUCTURES

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CONTENT

INTRODUCTION:

As climate change is likely to play an increasingly important role in the development agenda and activities, an evaluation of its trends, impacts and implications for development management is of significance. Climate change can be addressed through two main approaches: mitigation and adaptation. According to the UNFCCC, climate change mitigation seeks to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Meanwhile, climate change adaptation seeks adjustments in natural or human systems in response to actual or expected climatic stimuli, or their effects, that moderates harm and exploits beneficial opportunities. Both mitigation and adaptation approaches are necessary and interdependent. Thus, a systematic review of climate change implications at early stages is needed to assist policy-makers develop effective and long-term responses to climate change.

There has been coordination of global mitigation efforts occurs through the following structures and mechanisms: United Nations Framework Convention on Climate Change (UNFCCC); Clean Development Mechanism (CDM); United Nations Conference of the Parties (UN COP); and The Subsidiary Body for Scientific and Technological Advice (SBSTA). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4), released in April 2007, notes that "even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential." Both approaches are needed to help ensure environmental and economic sustainability as well as poverty reduction. Consequently, the average global losses due to extreme weather events (e.g. increased frequency and severity of storms) were estimated at US$ 40 billion annually in the 1990s, an almost four-fold increase from that of the 1980s (IPCC, 2001). There seem to be an exponential rise in economic losses due to climate-related disasters (Burton, 1997).

The reality of climate change can no longer be ignored. If the world fails to implement a substantial reduction of global greenhouse gas (GHG) emissions within the next half century then catastrophic impacts are likely (Metz et al 2006; Stern 2006). There is a growing scientific consensus that in order to avoid irreversible change the global GHG emissions in 2050 need to be 60% below the 1990 levels (Preston & Jones 2006).Attempts to mitigate global emissions span a range of scales with a growing attention to the importance of the local emerging recently (Bulkeley 2000; Adger 2001; Bulkeley & Betsill 2003; Bell 2005; Davies 2005; Lindseth 2005; Otto-Zimmermann 2006). The basis of the local argument in climate change mitigation is on the premise to target reduction efforts as majority of greenhouse gas emissions occur at the local level.

Over the past decade there has been a steady increase in commitments to reduce GHG emissions among cities and local governments worldwide. The process of climate change, with its projected changes in temperatures, precipitation patterns, wind conditions and the occurrence of extreme weather events, have clear implications for built infrastructure. A growing body of scientific literature provides evidence that "climate change will continue for many decades, and even centuries, regardless of the success of global initiatives to reduce greenhouse gas emissions" (Natural Resources Canada, 2007, p 4).

In recent years, many government, private sector and Civil Society Organization (CSO's) actors have taken actions to address the cause of climate change. However, limited efforts have been made to address present and future negative impacts and to maximize potential benefits (adaptation). Public infrastructures such as transportation infrastructure, energy utility, water; sewer, communication, coastal and flood defense structure have been of great significance to the smooth functioning of an economy. However, in the occurrence climate change, public infrastructures are at risk. One of the most prominent treats to public infrastructures include extreme event of flooding, gradual inundation, heat stress and permafrost melting.

As the impact continue to be felt amidst other economic, social and environmental stressors, the difficulty of maintaining robust and resilient infrastructure systems increases. The impact of Climate change on public infrastructures has led to destruction/ damage, coastal flooding, inundation from sea level rise (SLR), changes pattern of water availability and higher operating cost. As climate change continues, public infrastructures may become more vulnerable to damage, increasing risks to residents and result to large economic impacts. The increase vulnerability of infrastructures, create additional strains on structures beyond what is expected from normal conditions and use. It has been widely recognized that increased infrastructural damage has been resulted from increased in near-surface permafrost associated with climate change.

Permafrost thaw negatively Impact buildings, roads, rail roads, pipelines, oil and gas infrastructure. Permafrost thaw, inland flooding, extensive erosion caused by sea ice loss, threatens numerous coastal lines and affects most public infrastructures. Low priority on basic maintenance and repairs may leave public infrastructures even more vulnerable to climate change. Climate-related change incurred costs that require maintenance of public infrastructure. However, identifying the threats of climate change on public infrastructures greatly influence our need to maintain, repair and replacement of public infrastructures.

The marginal impact could result to changes in the maintenance cost and period and the need for repair and replacement due to the frequency of damage. (Larsen et al 2008), A typical case is in the state of Alaska where such changes exacerbating existing challenges and introducing new risks for communities, including increased damage to critical infrastructure. As climate change continues, the extent of infrastructure damage, costs to maintenance, replacement and adaptation to build environment are expected to increase. In recent years, Larsen et al. Analysis (Larsen et al 2008), on the damage to infrastructure in Alaska state and broader Arctic region suggested that the largest climate damages result from flooding of roads and permafrost thaw-related damage to buildings.

Adaptation and mitigation to climate change is critical to avoid breakdowns in the essential services delivered by key infrastructures and in ensuring resilience in case of potentially cumulative impacts. A growing literature evidence, seek the need to shift towards a more forward-looking, long-term planning and investment decision-making approach that strengthens adaptive capacity and builds resiliency across different infrastructural sector. These require planning, designing, constructing, maintenance and performance under uncertain circumstances. Proactive adaptation efforts and global action are needed to reduce damages. Failure to take such measures and make the necessary investments would increase costly measures in the future.

Mitigation measures may reduce related expenses and influenced climate change impact on public infrastructures. It is against this background, the objective of this paper is to provide a review of climate related problems, trends and impacts at an early stage, and review the response to climate change in order to integrate climate risk awareness and responsiveness into economic, operational and development planning.

This paper focuses on mitigating strategies public infrastructures. It's comprises of fours (4) parts. The first part is the background/introduction that gives a comprehensive summary of the topic. The second part highlight experimental evidences from recent literature articles and publications on mitigating strategies and public infrastructures with special emphasis on public infrastructure exposure and vulnerability and the role of adaptive capacity in mitigating the impact of climate change on public infrastructures. The third (3) part summarized case studies and lessons learnt to strengthening future adaptive and mitigation strategies. Finally, concluding statement and policy recommendation for more efficient and effective adaptation strategies for public infrastructures.

EXPERIMENTAL EVIDENCE: FROM RECENT LITERATURE ARTICLES:

Climate change will affect many sectors in the economy including the transportation sector, energy, and communication, industrial and agricultural sector to name a few. Climate change has huge implications on public infrastructures :(land transportation, energy, marine, coastal lines, water and waste infrastructures). A huge amount of public funds is invested on land transportation infrastructure mainly in the designing of highway and Roads, Railways, Airports and Bridges. According to (Lemmen & Warren, 2004),the increasing frequency of climate change leads to the softening of road pavement, rutting and thermal expansion of railway infrastructure (Nelson, Anisimov, & Shiklomanov, 2002).

Inmost costal lines, sea level rise (SLR) increasing inundation and damage to bridges and low-lying roads. Moreover, the degradation of Permafrost leads to thawing, sinkholes and potholes affecting roads, bridges, runways and railways (IMG-Golder Corporation, Northern Canada 2012). The increased snow fall led to structural collapse of public and private building structures (Natural Resources Canada, 2007).

Thus, increased precipitation has reduced the structural integrity of many buildings and in some instances, decreased the integrity of engineered beams(Infrastructure Canada, 2006).Water Infrastructures(Dams, Reservoirs Hydroelectricity etc.) is one of most vulnerable infrastructure to climate impacts (Natural Resources Canada, 2004). The failure of such infrastructure is largely due to increase temperatures, sea levels and variability of precipitation patterns evidence from the Canadian experience of insufficient supply, inadequate protection from floods and unacceptable water quality (Simonovic, 2008).

Furthermore, sea levels rise exposes existing marine infrastructure to storm surges, erosion and saltwater intrusion with heavy rains affecting drainage system and increase the risk of flooding for waste water infrastructures such as Culverts, Sewers, Storm Drains and Pipes. In some cases, mitigation results are not enough and adaptation to the new conditions are recommended (Laukkonen et al., 2009). There is a growing interest in exploring linkages between adaptation and mitigation to maximize synergies,minimize trade-offs and increase effectiveness of allocated

resources. Adaptation and mitigation apply to two different spatial scales but balancing between the two will provide realistic solutions (Tol, 2007).

Indeed for sustainable solutions both measures can provide better outcomes (Laukkonen et al., 2009).“Delaying mitigation efforts beyond those in place today is estimated to substantially increase the difficulty of transition to low emissions levels and narrow the range of options consistent with maintaining temperature change below 2°C relative to pre-industrial levels. To stay within “carbon budgets” for the rest of the century, mitigation strategies should focus on energy efficiency, low-carbon electricity, reduced energy use and fuel switching. It is not sufficient enough to concentrate on either mitigation or adaptation, but a combination of both enhance the most sustainable outcomes. Investment in large scale green electricity supply system based on renewable energy sources (Glenn, 2010) reduce climate change improve energy security as well as energy efficiency (Winkler, 2005; Goldemberg, 2007; Laukkonen et al., 2009; Driscoll and Naess, 2010). Adaptation to climate change did not receive much attention in the first years of the international climate change studies, more focus was on mitigation and impacts (Kates 2000).

Quiet recently, adaptation has been covered more extensively and has an important place in the fourth assessment report of the IPCC (2007). The IPCC Third Assessment Working Group II Report, (2001), defined adaptation to climate change as being „„adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts"". This defination in the IPCC Fourth Assessment Report, reiterated the fact that adaptation comprises of actions to reduce vulnerability or enhance resilience (Ad-ger and others 2007).

It's more applicable at the local level and is a long term solution that strengthens communities in building their own coping capacities that shape local climate change policy (Uy et al., 2011). The complexity of understanding adaptation is still frequently discussed in the literature of climate change. The impacts of Climate change, vulnerability, and adaptive capacity will change over time but the adaptation processes needed to support the most vulnerable will be similar. Due to high mitigation cost measures and lack of infrastructure to cope with the effect of climate change, adaptation is seen as the best option for developing countries.

The true vulnerability of people can only be assessed after adaptation has taken place (Kelly and Adger 2000), and in some cases, it might be necessary to „„adapt to the adaptation". Vulnerability is highly contextual and linked to specific hazards and exposure to the impacts of these hazards (Brooks and others 2005; Kelly and Adger2000). Vulnerability and adaptive capacity have been discussed in theoretical climate change adaptation literature for understanding how developing countries should cope and adapt to climate change and variability (Adger2006; Challinor and others 2007; Eakin and Lures" 2006;Mimura and others 2007;). Adequate coping mechanism after adaptive actions will eventually reduce the vulnerability of people.

THE EXPOSURE OF PUBLIC INFRASTRUCTURE EXPOSURE TO CLIMATE CHANGE

Public infrastructures are largely exposed and vulnerable to climate harzard. The vulnerability of infrastructure to climate change is the capacity of the sector to adapt by minimizing adverse impacts and maximizing positive ones (i.e. adaptive capacity).It is evident that the sensitivity of infrastructure to climate hazards is influence by age of the infrastructure, its composition and design. Thus, a better understanding of the sensitivity level to climate hazards is of significant value. Old infrastructures are likely to be more susceptible to the negative impacts of climate change .The high costs associated with aging infrastructure maintenance and replacement will likely to increase in the face of climate change. New infrastructural investment can significantly improve long-term resilience of public infrastructure in the occurrence of climate change.

The exposure of infrastructure to more incremental climatic changes largely depends on the types of material used in their construction. Therefore climate change consideration in the designing of public infrastructure are important not only to improve resilience, but also to contribute positively to reduce the greenhouse gas emission(GHG's).Investments in more resilient designing can help avoid larger future maintenance, repair and replacement cost. Building resilience requires much more than just policy, legal or market responses. A National Adaptation Programs of Action (NAPA) for better understanding of the actual and potential adaptation needs in developing countries has spurred increasing interest in adaptation and development policy(Halsnæs and others 2008; and Michaelowa 2007; O"Brien and others 2008). They are aid national planning, studying vulnerability and developing adaptation strategies (Adger and others 2007; Burton and Lim 2005).

At the Conference of the Parties (COP) 7 in Marrakech, 2001, Climate change mainstreaming related to vulnerability and adaptation were put on the agenda and it was decided that special support be given to a group of Least Developed Countries (LDCs) to develop NAPAs (Burton and Lim 2005). These are likely to contribute in the mainstreaming of climate adaptation in development policies and programs, Recent assessment report from the National Academy of Science and Climate Change Science Program (CCSP)} (U.S. CCSP 2007), on the impacts of climate change on transportation (Transportation research board TRB} 2008) and energy infrastructure have somewhat narrowing scopes, limited to a particular types of public infrastructure.

Even the recent Alaska assessment on public infrastructural impact, (Larsen et al. 2008), none of the assessment focused in identifying public sector enhancements to adaptive capacity. Nevertheless, those assessments provide valuable information. The National Academy of Sciences (2008) reports, on the impact of climate change on public infrastructure focuses on physical infrastructure, maintenance and to some extent its operation. The study highlights that increase in heat waves; Arctic temperature, intense precipitation and hurricane intensity are relevant to transportation infrastructures.

The study concludes that the greatest impacts for North America's transportation systems is flooding of coastal roads, railways, transit system and runways due to global rising sea level, storm surges and land subsidence. The Synthesis Assessment Report (SAP) in Golf Coast highlights the effect of inundation from relative sea level rise and indicates a relative sea level rise (SLR) up to

1.2Cm has resulted to major roads, rail lines and ports at or below 122cm in elevation. The CCSP study, in Central Gulf Coast"s on the potential for short-term flooding associated with storm surge, indicates that more than half of the major highway infrastructures are subject to temporary flooding and almost half of the rail miles, airports and ports are currently subject to periodic flooding. Temperature increased could raise construction, maintenance and Operations cost. In the areas of continuous permafrost, climate change is unlikely to pose an immediate threat to infrastructure if proper permafrost engineering design procedures have been followed.

Two recent assessments in expanding on the issues of infrastructural vulnerability to the Arctic Alaska zones- are the Arctic Climate Impact Assessment and the Arctic study. The first assessment addresses the full range of climate impact on permafrost warming, degradation, coastal erosion and transportation routes. The studies revealed that, the impact on public infrastructures from changes to permafrost is largely due to high temperature vary on the type of permafrost. However, adjustment of Arctic infrastructure through replacement and changing design approaches, to a warmer climate is of vital significance with cost effective designed strategies to address vulnerability.

The Arctic study, conducted at the University of Alaska, on climate change effect on public infrastructure, provides an exception level of details (Larsen et al., 2008). The study revealed that capital maintenance and replacement to estimate marginal economic impact of climate change and timing of expenditure are necessary response to climate vulnerability. A Similar study in Washington revealed that Sea level rise (SLR) could force costly redesign of long term investment in the protection of shore lines. An example is Seattle's Alaskan sea wall and other infrastructures, such as bridges and culverts (Casola et al. 2005). Very few studies have been undertaken on the impact of climate change on telecommunication network infrastructure. But however,

The Australia based Common Wealth Scientific and Industrial Research Organization (CSIRO) qualitative risk assessment in Victoria State in 2006, revealed that more frequent and severe storm associated with climate change represent more significant risk to Victoria's fixed telecommunication network system. The assessment further highlights that exchange station flooding due to extreme rain fall and storm surge are the most significant climate related hazard for Victoria fixed -line network. Other impact identified on landline network and transmission lines are lightening and bush fire that ignite more frequently due to climate change.

THE ROLE OF ADAPTIVE CAPACITY IN MITIGATING IMPACT ON PUBLIC INFRASTRUCTURES

An appropriate climate change mitigation goal is in the range of a 60% reduction of the 1990 GHG emissions by 2050 (Preston & Jones 2006). Local governments should play a critical role in climate change mitigation. .Queens land Studies have revealed that there is little institutional knowledge of climate change at the local and State level.

Findings further suggest that to ensure climate change is recognized as an issue government staff and the general community needs to be adequately educated. Climate change education should be integrated into general environmental education campaigns, having the appropriate resources, technology and regulatory support enhance GHG reductions (Utilizing the capacity to change attitude). In climate change mitigation the establishment of accurate baseline data serve as basis for future analyses, action plans.

Notwithstanding, this data and targets requires constant evaluation. Regular reporting of emissions data and auditing allows transparent and limits data fudging". Moreover, Lack of emissions target set at the State level; impede the ability to evaluate temporal changes in GHG emissions. The present study shows that mitigation can lead to global and regional adaptation savings as well as providing range of local environmental, social and economic benefits.

The willingness to change has a strong potential impact on society and the natural environment. The severity of the issues highlights the need and ethical responsibility to reduce GHG emissions. This was the basis for introducing Article 3 on the UNFCCC on the premise that developed countries created most of the initial emissions and reaped the economic rewards, and they should shoulder the responsibility for fixing the problem (UNFCCC 1994). Much of existing literature on potential impacts of climate change on public infrastructures makes reference to the role of adaptive capacity. The availability of resources, Interdisciplinary research, standards, and legal management instruments impedes the implementation of complex adaptation and mitigation response to climate change. However, the implementation of Policies, regulations, standards and market mechanisms play a key role in adaptive capacity.

Moreover, effective strategy to manage climate risk should focus on the technical, financial socioeconomic and institutional aspects. Modifying designed infrastructures to better suit increased intensity of floods, new building codes, and specific funds in support to maintenance of infrastructure. Abandonment/relocation of infrastructures, awareness raising and capacity building on climate adaptation are vital towards sustainable adaptive capacity.

Larsen et al. (2008), Alaska study on adaptive capacity highlighted infrastructural construction and maintenance to promote full replacement and repair procedures for climate change treats to transport infrastructure. In addition, changing mode of transportation, strategic designed and replacement reduces estimates of damage by up to 30% by 2030 (Larsen et al. 2008).,Participatory initiative, building existing networks of practitioners and strengthen institutional networks partnerships may provide a valuable basis for future policies involving different sectors (similarly to Klopregge and van der Sluijs, 2006). Agencies responsible for public infrastructure management should act strategically in designing replacement infrastructures that better suited the changing climatic condition.

Climate treat to non-energy utility providers has the potential to reduce water supplies. The replacement of pipelines at the end of their life span, Local forest restoration programs, coastal development ,expansion of energy utilities and transportation infrastructure development are of vital significant. The implementation of adaptive measures through system expansion and routine maintenance may not be sufficient to address climate related threats to sewer network due to high uncertainty on climate change potential. A potential adaptive measure to reduce climate change related vulnerability for landlines telecommunications network is the undergrounding of overhead telephone lines.

The undergrounding of power lines also apply to electricity provider. Adaptation to coastal sea rise level (SRL) and storm surge risk involves the construction of new infrastructures. A national economic impact assessment (NEIA) studies, along the Gulf, and Pacific coasts revealed that the construction of sea walls or actively replenishing beach sand helps in mitigating the impact

on coastal line. In addition, Local development decisions on infrastructure, urban development and changes in land-use play a key role in tackling impacts and promoting long-term responses that encourage changing the current development paradigm or approach. Integrating climate change into sustainable development policies and holistic understanding of its impacts foster informed development decisions.To effectively address impact focus should be made in promoting sustainable development paradigm that addresses issues of natural resources depletion, community disintegration, inequalities and poverty: Selecting adaptation choice and creating linkages with diverse mitigation options and identifying societal preferences and capacities to implement identified response.

Mitigation and adaptation measures are the main optimal policy response to climate change. They are mitigation strategies that improve adaptation to warmer climates, create energy savings opportunities and carbon emission reductions. In most developed countries, climate change damages seem to be related to extreme events (sea level rise as). Resources can be used to improve the extreme-climate resilience of infrastructures and mainstreaming of climate change adaptation into long-term landscape planning. According to the World Bank (2006) ,the costs of adapting vulnerable infrastructures to the impacts of climate change is 5- 20 percent increase in investments in 2030.Investtment costs (beach nourishment and sea dykes) and losses due to inundation and flooding are estimated to be US$ 21 – 22 billion in 2030 (UNFCCC, 2007). However, flood management policies, developments of flood plains and increasing investments in flood defenses, could limit the rising costs of flood damage to 9.7 US$ billion. An adaptation response may include better flood protection and stronger land-use planning. A study on costs of flooding in East London revealed that proactive measures for climate change could reduce annual flooding costs by 80 –90 percent, According to Nicholls and Klein (2003), the costs of coastal protection are justified in most European countries. Developing countries are highly vulnerable to sea level rise, although absolute impacts are small findings:

On the basis of reviewed literature, it is clear that actions are needed to help address the challenges posed by climate change to key public infrastructure. Given the diversity of the impacts on various infrastructures, it is difficult to generalize approaches to improve the resiliency .However, a high-level adaptation strategy focusing in conducting risk assessments for infrastructure sectors sensitive to climate change, review and updating existing policies and operational approaches. Mitigation and adaptation policies enable people to manage risk and uncertainty, shape, create and respond to changes throughout their lives. Such Policies should be carefully devised and must be an integral part of a development policy process. Regional impacts and responses are likely to drive the need for international climate policy suggesting potential link between distinct policy areas of development and climate (Corfee-Morlot and Hohne, 2003; Jager et al., 2007).

The development and implementation of Climate Change Action Plan help in reducing impact of extreme events. Several jurisdictions have initiated processes to develop additional adaptation frameworks and/or integrate adaptation more closely into existing action plans. In recent years, discussions around increasing infrastructure resilience have spiked in the United States due to Hurricane Katrina and the ongoing droughts in Midwest and Hurricane. President Obama‟s(June,2013),climate action plans looks at fortifying the country‟s climate resilience, integrate adaptation into national planning process and re-examine policies and programs to promote climate resiliency.

Government of Quebec, (2012), Climate Change Action Plan, for Adaptation (2013–2020) include, „Modify land use and manage risks to reduce vulnerabilities" and "Improve the safety and durability of buildings and infrastructure". Prince Edward Island's Climate Change Strategy (2008) also outlined plans to incorporating climate change considerations into environmental assessments, land use plans, land-use bylaws, road and bridge construction, marinas and other infrastructure. Hazard mapping and monitoring, particularly related to sea-level rise, was also identified in the strategy .Brunswick‟s Climate Change Action Plan (2007–2012) adaptation planning emphasis on coastal regions through incorporation of vulnerability considerations in decision making, and the implementation of a regulatory framework to protect coastal environment, infrastructure and public and private property(Government of New Brunswick, 2012).

There is still lack of case studies of mutually reinforcing policies on the linkages between climate change adaptation, mitigation and sustainable development despite increasing attention researchers.(Swart et al., 2003; Wilbanks, 2005; IPCC, 2007. it's worthwhile investing in physical and institutional assets that reduce climatic vulnerability and increase coping strategies and to what extent policies be proactive or reactive (Smit and others 2000; Smit and Skinner 2002).Disaster Risk Reduction (DRR) should incorporate climate change analysis, as important component to climate change adaptation.

CONCLUSION AND RECOMMENDATIONS

It evident from literature review and case studies, that climate change is real and is being increasingly acknowledged at the local level. Strategies towards adaptation and mitigating the impact on public infrastructures require an integrated approach. Such strategies provide ancillary benefits, at the local level. The dilemma of climate change sometimes brings about great opportunity to changes in public infrastructures and mindset that created this situation. Climate change has potential implication to the effective lifespan of public infrastructure particularly buildings, transportation, marine and water management infrastructure.

The exposure/vulnerability varies greatly in term of the economic costs associated to the impact climate change. These costs are expected to rise in the future. However adaptive measures would limit this cost and strengthen the resiliency of such infrastructure. Integrating adaptation and mitigation planning particularly in energy infrastructure is of great relevance in improving energy efficiency of most public infrastructure. A great deal of research and planning has been carried out in support of policies and regulatory changes. In addition, there have been number of key policy, regulatory and financial instruments in support of deeper integration of climate change considerations into infrastructure decision-making, design and maintenance.

Despite this notable progress many adaptation responses remain underutilized. However, integrated planning may facilitate financial sector adaptation. (Hallegatte 2008). Resources could be more efficiently allocated if infrastructural planning is fully integrated with land use planning. An integrated planning across transportation modes would ensure redundancy during emergency situation. Studies have revealed that climate change my result to technological challenges and as a result more resilient infrastructural capital is needed. Updating building standards required technological

change. There is a need for change in mind set through concerted community education campaign and training, planning and policy and the integration of climate change mitigation strategies, into every aspect of the planning schemes. Scarce resource (water, land and different other scarce resources) should be preserved for future generations and the Sustainable utilization of such resources is critical to facilitate future life on Earth.

Furthermore, mitigation plan should be develop and implemented to mitigate the adverse effect of climate change. Such plan should have the full support of the government, society and global level with a more robust and firm commitment in tackling the impact. Several efforts have been made in updating building standards (Canadian Association Infrastructure Canada 2006). Last but not the least, taking advantage of replacement opportunities has huge implication to maintain public infrastructure. Rebuilding process with a more resilient capital serves as an opportunity to replace damaged infrastructure. Thus, a new policy action is needed for enhancing adaptive capacity. Building codes and standard forms and refinement, developing systems for sharing and communication, climate data projects, public provision of risk information, adopting infrastructural planning to climate change risk, government soft adaptation option (insurance scheme) enhance resilient to future shock.

Finally the use of existing and new technology in higher risk area (Golf coast), adoption of risk base approach to infrastructural planning, expanding regional network and building linkages serves as powerful adaptive and mitigation strategies in the occurrence of an extreme event

SUMMARY OF CASE STUDIES AND LESSONS LEARNT

CASE STUDY	ADAPTIVE/MITIGATING STRATEGIES	LESSONS LEARNT
sea level rise (SLR) Niger Delta	Planting of bamboo tree for erosion control, use of sand bags as bridges, dike (flood control use, use of flood receptor pit as temporary flood water reservoir, community legislation against sand mining and indiscriminate tree felling.	
Alaska infrastructural study on Transportation infrastructures (airports, bridges, harbor s, roads, and railroads)	Quantitative Analysis of (Larsen et al 2008) **Assumptions :** I. climate change With adaptation II. Climate change with No adaptation **Existing Adaptive /mitigation strategies:** • Integrated land use planning • Current Planning, maintenance & replacement system • Adjustment to industry wide range standard. • Up-dating Building Standar	
Philippine case study	Natural disaster-prone countries due to: High incidence typhoons, floods, landslides, droughts, volcanoes, & earthquakes. • Highly vulnerable due to its Geographic location,	System expansion, routine maintenance, Construction of seawalls or actively replenishing beach sand

	Periodic El Niño & La Niña climatic effects & lies along a belt of active volcanoes • World Bank and UN report: About 85.2 % of its US$86 billion annual GDP is endangered as it is located in areas of risk (World Bank 2008). • Since 2000, typhoons are the largest killer in the Philippines (United Nations 2007). In the 20th century(killed 28,812 & caused US$5,653 million worth of damages) • From 1975 to 2002, annual RSL due to warmer ocean waters & melting glaciers affect most province **Response & Mechanism** • Laws .: Philippine Clear Air Act (1999) ; Agriculture & Fisheries Modernization Act (1997) ; Biofuels Act (2006); **Renewable Energy Bill (2008)** & National development plan CDM-Clean development mechanism : Aiming at reducing the GHG's emission & Investment in low cost abatement opportunity • .**The formation of IACCC-(Inter-Agency Committee on Climate Change**) Coordinate climate change related activities& Proposes climate change policies. • **The formation of PTFCC-(Presidential Task Force on Climate Change**	(**mitigate impact on coastal line**.) Integrating climate change into Sustainable Development Policies, Holistic understanding of its impacts • Integrated land use planning, maintenance and replacement System, • Adjustment to range standard and Up-dating building standard • Survey on Pipe Leakage detection: Water Audit & Incentive Program initiated & Replacement of existing infrastructure & Construction of new ones, • Expanding conveyance & Storage capacity, Routine maintenance or construction of new sewer systems • Investment in low cost abatement opportunity & formation Committee and presidential task force to coordinate climate change related activities focusing on adaptation, mitigation. • Selecting adaptation choice and creating linkages with diverse mitigation options • Identifying societal preferences & capacities to implement identified response

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