COASTAL ZONE ADAPTATION IN TRINIDAD AND TOBAGO: A REVIEW OF LITERATURE

Carianne Johnson and Udayangani Kulatunga*

Centre for Disaster Resilience, School of the Built Environment, University of Salford, United Kingdom.

ABSTRACT

Empirical evidence supports that anthropogenic activities have brought about significant changes in our climate. In the instance of Small Island Developing States (SIDS) there is a potentially significant impact from the effects of climate change as the majority of the population resides within the coastal zone, thereby increasing potential loss of life and damage to property during climate related events. Determining vulnerability can provide an assessment of the factors that place communities at risk to the potential loss of life and property and assist in the creation of solutions towards increased resilience and adaptation.

This paper explores the literature on the coastal zone vulnerabilities of Trinidad and Tobago with particular focus on the Caroni River Basin, the most populated basin on the island. In addition to the population growth in the coastal zone, key sectors of subsistent agriculture, fisheries, cottage industries, oil refineries and manufacturing are located within the coastal zone. Therefore, this paper also highlights the myriad of vulnerabilities of Caribbean SIDS and outlines environmentally sensitive design solutions for coastal zone adaptation.

***Keywords**: Caribbean SIDS; Vulnerabilities; Climate Change Adaptation; Trinidad and Tobago.*

1. INTRODUCTION

Empirical evidence supports that anthropogenic activities have brought about significant changes in our climate. Global results of these activities include the melting of the solar ice caps, sea level rises, increased magnitude of storms, and warmer temperatures in our urban centres. In the instance of Small Island Developing States (SIDS) where the majority of the population resides within the coastal zone, the potential of loss of life and damage to property increases greatly. In Small Island Developing States (SIDS) more than 70% of the population live within 100 km of the shoreline (Creel, 2003) and population figures are expected to rise exponentially as more people move from to cities to increase their access to economic activity and government services.

Expanding coastal cities in SIDS are now resulting in the challenge of finding sufficient land to meet the needs of inhabitants, ensure their safety and prevent potential loss of property assets due to flooding and coastal erosion. In the midst of these challenges, the issue of vulnerability becomes more relevant and the limited geographical area and access to information and economic resources are central to the discussion. In Caribbean SIDS, there are gaps in information sharing which has limited the region's ability to develop a comprehensive response to climate change. Each country within the Caricom network has been keen to develop its own appropriate response, and to create a detailed regional course of action, including contingency planning, where larger islands can assist the citizenry of smaller islands.

Determining vulnerability can provide a method of assessment of the factors that place communities at risk to the potential loss of life and property. A vulnerability index is an attempt to attain a measurement of vulnerability, based on the particular demographic factors that impact the capacity of the area to become resilient. Due to the underlying qualitative nature of demographic research, these numerical indexes have inherent flaws, as averages or estimations can never completely relate the entire story of a community. They do, however, provide a guide to the conditions that may impact the vulnerability of a

*Corresponding Author: E-mail - u.kulatunga@salford.ac.lk

given community and should be used in conjunction with visual observation and expert interviews. Comprehensive assessment of the community can then determine the solutions towards increased resilience and adaptation.

This paper explores the coastal zone vulnerabilities of Trinidad and Tobago with particular focus on the Caroni River Basin, the most populated basin on the island. Although Trinidad and Tobago is seen as the most affluent nation in the Caribbean, its various vulnerabilities are not uncommon to SIDS in the region. Through a comprehensive literature review, this paper highlights the inherent vulnerabilities of Caribbean SIDS and recommends the development of a comprehensive coastal adaptation strategy that includes *e*nvironmentally sensitive design solutions from built environment disciplines.

2. CLIMATE CHANGE IMPACT ON COASTAL ZONES

Coastal zones can be roughly defined as the area within 200 kilometers of the shoreline (Creel, 2003). During the period of 1961 to 2003, the observed sea level rise was about 1.6 mm/year with contributing factors including ocean thermal expansion and the melting of glaciers, ice sheets and ice caps (Church *et al.*, 2007). By 2100, the global sea level rise is expected to be between 0.5m to 2.0 m (Nicholls *et al.*, 2011). SIDS, where there is an inherent vulnerability to sea-level rise, could be severely impacted by a rise of 1m (Nicholls *et al*., 2011).

The warming of the earth's temperatures is also likely to cause changes in precipitation. "A more active hydrologic cycle" is a result of an increased atmospheric water holding capacity (Easterling, 2002). This increase of the water vapour holding capacity will not only result in increased precipitation during storms, but could also contribute to larger storm surges and surface waves. It is noted that warming of the climate may not necessarily increase the frequency of these storms, but an increase in storm severity will have a significant impact on coastal regions (Church *et al.*, 2007).

As a Caribbean SIDS, Trinidad and Tobago has distinct physical and demographic characteristics that contribute to its vulnerability, particularly the high concentration of infrastructure and industry in the coastal zones. Shown in Figure 1, the centers of industry (oil, manufacturing) are in coastal zones and the impacts of climate change could therefore weaken the viability of these industries. In terms of the infrastructure, by 2100 Trinidad and Tobago could experience damage to a significant part of its GDP in terms of the damage to infrastructure at a cost of $1,892,000 (Bueno *et al*., 2008).

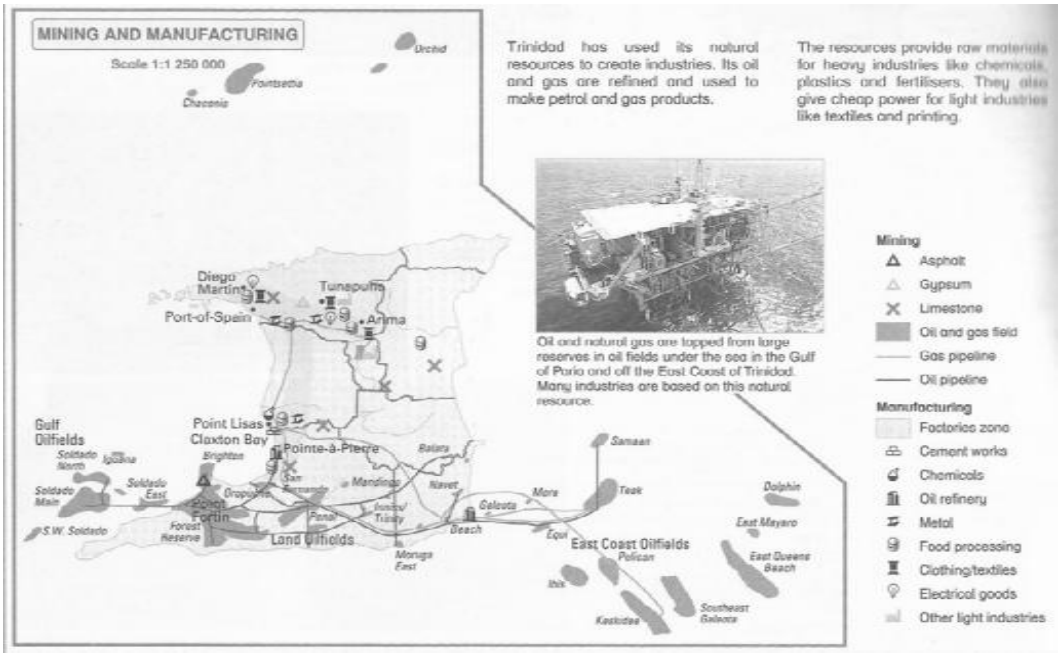

Figure 1: Coastal Industries in Trinidad and Tobago
Source: Morrissey (2007)

In Trinidad and Tobago, the Caroni basin has been identified as the most vulnerable to the impact of climate change. The Caroni basin is the largest on the island; it is a densely populated area with the growth of development encroaching on mangroves and swamp land. Concurrent development in the surrounding hills exacerbates the effect of flooding in this basin and leads to the potential damage of property and infrastructure. In addition, this area also has the largest concentration of arable land on the island, which often experiences the loss of crops due to frequent water logging of farms. Currently, flooding often impedes access to the capital city of Port of Spain, forcing the closure of government offices.

3. VULNERABILITY

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2007). This definition describes vulnerability as a function of exposure, sensitivity and adaptive capacity where exposure is the extent to which a system is exposed to an extreme event, sensitivity is how affected the particular system is to this event and adaptive capacity is the ability of the system to adapt to the effects of the extreme event (Engle, 2011). SIDS are particularly vulnerable to the impacts of climate change as the majority of industry, development and infrastructure are centralized in these hazardous zones.

However, the links between coastal management, sustainable livelihoods, and the value in building resilience to climate change effects continue to provide a significant challenge for SIDS. Higher income nations are able to develop adaptive measures at a faster rate than the middle to low income nations (Berrang *et al.*, 2010). SIDS are more likely to develop reactive measures to climate change impacts as their understanding and resources to address climate change is largely limited (Amundsen *et al.*, 2010). Developing adaptive measures to climate change is an increasing challenge for SIDS as policy and development trends are centred on building economic capacity. This challenge of coastal zone management in SIDS must be met with a combination of proper assessment and adaptive measures.

3.1. VULNERABILITY INDEXES

Scientists have made attempts to determine the vulnerability of coastal areas through a variety of means, the most significant method in terms of calculating the vulnerable physical characteristics of coastal regions is the Coastal Vulnerability Index (CVI) (Birdwell, 1994). It classifies vulnerability based on a numerical analysis of the tide range, average wave height, geomorphology, coastal slope, relative sea-level change and shoreline accretion. This index, however, does not account for the socio-economic vulnerabilities of coastal communities. Concurrently, the Social Vulnerability Index solely explores the demographic factors that may make communities vulnerable to the impacts of climate change (Cutter, 2006). There has even been an attempt to integrate the two vulnerability indexes to attempt to determine the risk to communities. The basis of analysing the vulnerability of coastal communities must comprehensively outline the built environment vulnerabilities and review the economic vulnerabilities in the global context.

Unfortunately, the SIDS are at increasing risk of the impacts of climate change due to their inherent physical, social and economic characteristics. As a result of the available land in SIDS, the urban and peri-urban and rural communities are all located in low elevation coastal zones. In 2000, 67% of the population in SIDS lived along coastal zones (McGranahan *et al*., 2007). The risks to emergency response management are greater in coastal urban centres where limited service infrastructure is prone to frequent interruptions, particularly in electricity and water. Based on current projections, it is estimated that by 2050, the sea level would be an additional 8.9cm high and by the year 2100, this would be 18cm (Bueno *et al*., 2008).

3.2. PHYSICAL VULNERABILITY IN SIDS

In low lying areas where the geological subsidence is an integral part of development, sea level rise and frequent flooding can lead to groundwater saline intrusion; impact the tidal range, increase the volume of sediment in bays and estuaries, and change the details of the shoreline (Doornkamp, 1998). The cost of providing protection from the sea level rise could be approximately 0.02% of the Gross Domestic Product (GDP) (Nicholls *et al*., 2011) and higher in nations where the infrastructure has yet to be upgraded.

Increased flooding can severely reduce the service life of the existing infrastructure resulting in early deterioration or complete failure (Mills and Andrey, 2002). Although infrastructure can be built to withstand certain environmental occurrences, the aspect of climate change that promises an increased threat of these environmental hazards, makes building for expected conditions an increasingly difficult task (Mills and Andrey, 2002). Mills and Andrey note that 'gradual changes in sea level may be expected to damage or render inaccessible, low-lying coastal infrastructure including road and railway beds, port and airport facilities, tunnels and underground rail / subway / transit corridors' (2002). Increased precipitation can also directly impact the frequency of slope failures and landslides while flooding can exacerbate issues related to riverine and urban storm water management.

3.3. SOCIAL VULNERABILITY IN SIDS

It is noted that connectivity is key to disaster response and adaptation (Dunno, 2011). Limited infrastructure disconnects rural coastal communities in SIDS from their urban centres. The higher transportation costs to these areas also restricts access to external markets and the flow and quality of access to information (Pelling and Uitto, 2001). Isolation from global networks and limited access to services insulate these rural communities and increases their vulnerability (Dunno, 2011). In the SIDS there are discussions around increasing ICT technology to provide stronger emergency management frameworks, but with the vulnerability of the existing infrastructure, these systems are still largely unreliable.

3.4. ECONOMIC VULNERABILITY IN SIDS

Small economies, that are heavily dependent on access to natural resources, are another feature of SIDS. In the Caribbean, the gross domestic product is dependent largely on fisheries, agriculture and tourism. Economic vulnerability increases as a result of natural disasters, since it impacts on the country's gross domestic product, thereby hindering economic growth (Dunno, 2011). In light of the globalized diversified markets, Caribbean economies have remained specialized in areas of tourism, offshore finance and agriculture (Pelling and Uitto, 2001). Since the population has historically relied on certain industries, the transition towards economic diversity is slow. As a result, these islands are also dependent on imports. Limited exportation impedes economic growth and decreases the country's ability to access international funding, which in turn limits its ability to invest in social development and efficient infrastructure (Dunno, 2011).

In light of globalized economies and connectivity of world markets, an economic crisis in one country can quickly impact the GDP of others. Economic vulnerability is becoming an increasing concern as countries' economies are more open and vulnerable to international markets. For example, high food imports make developing countries less food secure when coastal regions are under threat of the impacts of climate change (Broad and Cavanagh, 2011). In the Caribbean, the vulnerabilities are more significant, as noted by Achim Steiner, as 99 percent of Caribbean tourism is along the coastline (Caribbean 360, 2014).

Due to these pressing changes, Trinidad and Tobago developed adaptation strategies centered on data collection, policy development and environmental protection-seen as an integral part of coastal adaptation. To date, these strategies are mainly focused on building capacity through citizen awareness programmes and disaster preparedness policies. The work towards adaptation, however, falls short in the active protection of natural coastal resources, managing coastal development and strengthening the capacity of industries in the coastal areas. The need to protect coastal resources and assets while developing comprehensive measures to manage growth, provides the framework for sustainable

development; yet adaptation is the missing link. Case studies of the most effective ways to approach adaptation can provide guidance and strengthen Trinidad and Tobago's ability to address the impact of climate change.

4. LESSONS FOR CLIMATE WISE URBAN DESIGN

Based on the increasing vulnerabilities to climate change adaptation, countries must consider climate wise strategies to reduce vulnerabilities (Tong, 2012) to their coastal built environment. Strategies that warrant further investigation for use in Trinidad and Tobago are 'Elevated' and 'Floatable' developments 'Living Shorelines' and 'Green Infrastructure' (Tong, 2012; Erdle *et al.*, 2006; Benedict and McMahon, 2002).

'Floatable' development, also known as 'Aquatecture', allows for structures to float on the surface, reducing the vulnerability during instances of flooding or varying tides (Tong, 2012). The creation of floatable cities has even been explored to address the need for housing for growing populations in coastal zones. It also encouraged the revival of 'Chinampas' (floating gardens) as the practical need for agricultural landscapes in these aqua-communities.

'Elevated' developments are constructed at predetermined heights (Tong, 2012). This form of development was historically used for residential structures in rural, low-lying communities of Trinidad and Tobago and provides lessons for commercial development. The usability of elevated commercial structures and/or elevated connectors between existing buildings is also an option.

'Living shorelines' is the process of restoring coastal natural environments to reduce the impact of flooding and erosion (Erdle et al., 2006). This method utilizes environmental engineering strategies to 'rebuild' natural coastal zones and maintain the integrity of shorelines. Environmental engineering is still an emerging field in Trinidad and Tobago and strategies are not widely utilized.

'Green Infrastructure' is defined as an "interconnected network of green space that conserves natural ecosystems values and functions and provides associated benefits to human populations" (Benedict and McMahon, 2002). This network provides connections in three forms: a corridor, patch and matrix. The corridor is an extended connection of green space throughout urban areas, providing a reduction of the urban heat island impact. The patch integrates green spaces within the urban fabric to provide more infiltration of green space in hard surfaces. While the matrix, as its name suggests, is a mix of the aforementioned systems. The particular green space options include, but are not limited to, green roofs, private gardens, public parks, street trees and the retaining or replanting of the natural environment (Gill *et al*., 2007).

5. CONCLUSION

The strategy for determining the best way forward for Trinidad and Tobago through the extension of the region is currently centered on the recommendations for the existing strategies for coastal zone management, although local coastal management documentation reiterates the need for the creation of adaptation strategies to address the adjusting needs to climate change. However, these methods are not clearly defined and the recommendations have suggested that new policies should bolster current development trends. Based on the informal growth of communities in the Caribbean, new policies at the national level will not translate into controlling existing development trends. The general population should be provided with accessible solutions for building in vulnerable areas and reduce the vulnerability of people living in the danger zones of the coastal regions. The solutions developed in this research will be disseminated through the distribution of a pamphlet to local developmental agencies, construction companies and professional organizations within the study area to increase the population's understanding of viable methods to adapt to the impacts of climate change.

The way climate change is understood within the nation's socio-economic structure has a profound impact on assessment and adaptation. Ultimately, proper assessment can lead to a comprehensive adaptation strategy, which will encourage the preservation of natural resources and manage the impact of future development. In light of climate change impacts, environmental management and adaptation is an important consideration (Doornkamp, 1998). As a small island state, Trinidad and Tobago must consider

comprehensive coastal zone adaptation solutions for the population living in such vulnerable areas as the Caroni River Basin.

6. REFERENCES

Amundsen, H., Berglund, F. and Westskog, H., 2010. Overcoming barriers to climate change adaptation - a question of multilevel governance? *Environment and Planning C: Government and Policy*, 28(2), 276-289.

Benedict, M.A. and McMahon, E.T.,2002. Green infrastructure: smart conservation for the 21st century. *Renewable Resources Journal*, 20(3), 12-17.

Berrang, F.L., Ford, J.D. and Paterson, J., 2010. Are we adapting to climate change? *Global environmental change*, 21(1), 25-33.

Birdwell, K.R., 1994. The development of a coastal risk assessment database: vulnerability to sea level rise in the US southeast. *Journal of Coastal Research*, 12, 327-328.

Broad, R. and Cavanagh, J., 2011. Reframing Development in the Age of Vulnerability: from case studies of the Philippines and Trinidad to new measures of rootedness. *Third World Quarterly*, 32(6), 1127-1145.

Bueno, R., Herzfeld, C., Stanton, E. and Ackerman, F., 2008. *The Caribbean and Climate Change: The Costs of Inaction* [online]. USA: Tufts University. Available from: http://sei-us.org/Publications_PDF/SEI-CaribbeanAndClimateChange-08.pdf.

Caribbean 360, 2014. *Caribbean Small Islands will be First in Region to Suffer from Rising Sea Levels – UN*[online]. Barbados, Caribbean 360. Available from: http://www.caribbean360.com/news/caribbean-small-islands-will-be-first-in-region-to-suffer-from-rising-sea-levels-un.

Church, J., Wilson, S., Woodworth, P. and Aarup, T., 2007.Understanding sea level rise and variability.*Eos, Transactions American Geophysical Union*, 88(4), 43-43.

Creel, L., 2003. Ripple Effects: Population and Coastal Regions. Washington, DC: Population Reference Bureau.

Cutter, S.L. and Emrich, C.T., 2006. Moral hazard, social catastrophe: The changing face of vulnerability along the hurricane coasts. *The Annals of the American Academy of Political and Social Science*, 604(1), 102-112.

Doornkamp, J.C., 1998. Coastal flooding, global warming and environmental management. *Journal of Environmental Management*, 52(4), 327-333.

Dunno, C. 2011. *Measuring Social Vulnerability to Natural Hazards: An Examination of the United States Virgin Islands.* Greensboro, North Carolina: University of North Carolina.

Easterling, D., 2002. Observed Climate Change and Transportation.*In: The Potential Impacts of Climate Change on Transportation*, Washington 1-2 October 2002. Washington: DOT Center for Climate Change and Environmental Forecasting, 49-57.

Engle, N.L., 2011. Adaptive capacity and its assessment. *Global Environmental Change*, 21(2), 647-656.

Erdle, S., Davis, J. and Sellner, K. 2006. Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chespeake Bay. *In: The 2006 Living Shoreline Summit*, Virginia 6-7 December 2006. Virginia: Chesapeake Research Consortium.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S., 2007.Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33(1), 115-133.

Intergovernmental Panel on Climate Change (IPCC), 2007.*Fourth Assessment Report: Working Group II*[online]. New York, Cambridge University Press. Available from: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm [Accessed4 October 2012].

McGranahan, G., Balk, D. and Anderson, B., 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization*, 19(1), 17-37.

Mills, B. and Andrey, J., 2002. Climate Change and Transportation: Potential Interactions and Impacts. *In: The Potential Impacts of Climate Change on Transportation*, Washington 1-2 October 2002. Washington: DOT Center for Climate Change and Environmental Forecasting, 77-88.

Morrissey, M., 2007.*Caribbean School Atlas for Social Studies, Geography and History*. 4th ed. Essex: Pearson Education Limited.

Nicholls, R.J., Marinova, N., Lowe, J.A., Brown, S., Vellinga, P., De Gusmao, D., Hinkel, J. and Tol, R.S., 2011. Sea-level rise and its possible impacts given a 'beyond 4 C world'in the twenty-first century.*Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 369 (1934), 161-181.

Pelling, M. and Uitto, J.I., 2001. Small island developing states: natural disaster vulnerability and global change. *Global Environmental Change Part B: Environmental Hazards*, 3(2), 49-62.

Tong, E., 2012. *Climate Induced Sea Level Rise: An Investigation of Adaptation Strategies and Erosion Mitigation in Coastal Regions* [online].Vancouver: University of British Columbia. Available from: https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/52966/items/1.0103544.