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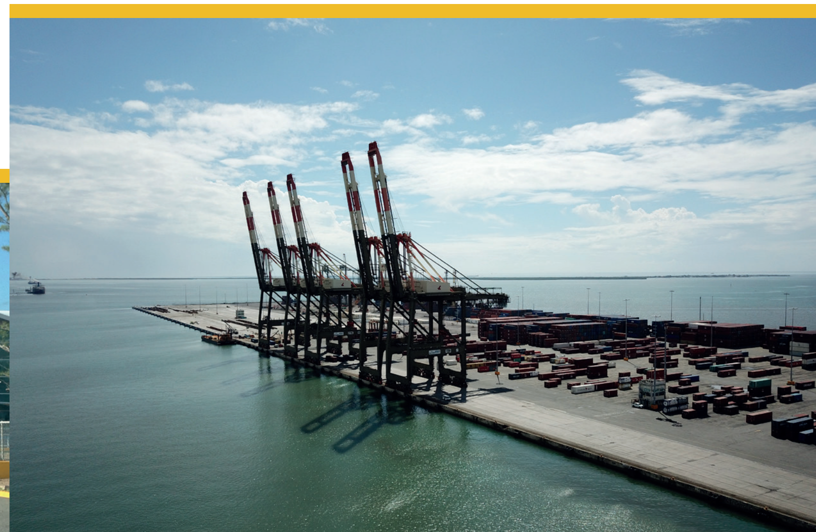
Climate Change Impacts on Coastal Transport Infrastructure in the Caribbean: Enhancing the Adaptive Capacity of Small Island Developing States (SIDS)

Jamaica:
A case study



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For further information about the project and relevant documentation, see SIDSport-ClimateAdapt.unctad.org.

For further information about UNCTAD's related work, please contact the UNCTAD Secretariat's Policy and Legislation Section at policy.legislation@unctad.org or consult the website at unctad.org/ttl/legal.

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Executive Summary

Jamaica, and other Small Island Developing States (SIDS) in the Caribbean, are especially vulnerable to climate change. This is due to:

- The location of the Caribbean – within the "hurricane alley" of the Atlantic;
- The geographic nature of the islands – typically characterised by small land masses with mountainous inland areas and narrow coastal plains, combined with large population concentrations and infrastructure located in these narrow coastal areas;
- A limited economic base and dependency on natural resources – this results in a very limited financial, technical and institutional capacity for adaptation.

Because of this heightened vulnerability [as further detailed in Chapters 1 and 2 of this report], development of climate change adaptation strategies and policies are of paramount importance to Jamaica at this time in its planning framework. No longer can Jamaica, or any of the other Caribbean SIDS, afford to ignore the looming impacts of climate change on their respective nations.

An examination of the cost of the impacts of climate change on Jamaica was examined in Chapter 2 of the report. The analysis revealed that the current cumulative loss of GDP due to damage associated with natural disasters was estimated to be in the order of $120 billion (roughly 7% of GDP). This is a significant number, which is even more grave given the already slow growth and fragility of Jamaica's economy. When this is coupled with potential climate change induced impacts, such as an increase in the number of extreme hurricanes, the figure is even more worrisome as it is likely to rise. Estimates indicate that it could reach as high as 56 per cent of GDP by 2025 if climate predictions are accurate.

Transportation Sector – Overview and Project Scope

The transportation sector is crucial to Jamaica's economic development; any major disruptions can seriously affect the economic flow and operations of the country. This is because the transport sector acts as a conduit, linking production and service areas to the end users. This link is especially vital in small islands such as Jamaica, where the country's population, by virtue of existing on an island, is cut off geographically from neighbours and trading partners in the Caribbean and North and South America. To address this need, Jamaica has developed a multi-modal transportation system comprising of air, land (road and rail), and maritime transportation. Of all these modes, the United Nations Conference on Trade and Development (UNCTAD) has focused on the ports and airports sectors as being critically important for development. UNCTAD, in recognizing this dependency of SIDS on their port and airport infrastructure, has noted:

> *"access to well-functioning and reliable transportation systems, in particular maritime and air transport systems, is vital [for SIDS]. Seaports and airports are the lifelines sustaining the survival of these States, especially since they are highly dependent on transport-intensive imports for much of their consumption needs, for example food and energy. While maritime transport accounts for nearly 80 per cent of world merchandise trade by volume, this share is higher for SIDS. Although maritime transport is the predominant mode used to carry cargo and freight, air transport is relied upon primarily for passenger and tourist transport and domestic inter-island shipping and mobility."* – UNCTAD Trade & Development Commission. Multi-Year Meeting on Transport, Trade Logistics and Trade Facilitation. Third session. Geneva. November 24–26 2014. Item 3 :- Small island developing States: Challenges in transport and trade logistics. (TD/B/C.I/MEM.7/8)

Ports and airports are therefore critical to Jamaica's economy. They are required to provide necessary food imports into the country, as Jamaica cannot produce enough to feed its people and meet other vital consumer needs, such as oil and gas to power its electricity producing plants and cars, among other things. Additionally, ports and airports are gateways to bring persons to the island for tourism, which is a major foreign exchange earner. It is noted (World Travel & Tourism Council – Jamaica Economic Impact 2015) that the direct contribution of the travel and tourism sector to the island's GDP in 2015 was 8.5%, and this was projected to increase to 11.6% by 2025. When the wider effects from investment, the supply chain and induced income impacts are factored in, these numbers rise to 28% and 37.5% respectively, further underscoring the importance of the transportation sector to the Jamaican economy.

Project Objective and Outline

The criticality and importance of the transportation sector in Jamaica is undeniable, as is the particular vulnerability of those same transportation facilities along the coastline. It is therefore crucial that climate change impacts for these facilities be properly understood, and that adaptation strategies and a comprehensive procedure for their strategic implementation be developed in tandem. In recognizing this need, the United Nations launched a capacity building project on "Climate change impacts on coastal transport infrastructure in the Caribbean: Enhancing the adaptive capacity of Small Island Developing States (SIDS)", which is being implemented by the United Nations Conference on Trade and Development (UNCTAD).

The underlying purpose of this initiative, which draws on UNCTAD's earlier relevant work in the field, is to strengthen the capacity of policy makers, transport planners and transport infrastructure managers in SIDS to (a) understand the full range of climate change impacts on coastal transport infrastructure, in particular seaports and airports; and (b) take appropriate adaptation response measures. This report represents the case study for Jamaica. In support of the objectives of the project, the following steps will be undertaken within the body of this report.

1. In Chapter 2, Jamaica as a nation is described for the general reader in terms of its geography, its population, its economy and its social issues. It is felt that this is a necessary component of framing the overall project within a context specific to Jamaica.
2. A thorough review of the State of Jamaica's climate is then undertaken in Chapter 3 to develop an understanding of the current climate conditions in the island, the climate trends as they have existed up to this point, and the future climate projections based on current climatic modelling.
3. Four key transportation facilities (SIA, NMIA, HFCP, KCT) have been selected and are detailed in Chapter 4, to ascertain the criticality of each to the nation. The facilities themselves will be studied to understand their operations and throughput. This defines for the project the criticality of the facilities to the country and forms a basis to hypothesize what could result from a disruption in services due to climate change.
4. In Chapter 5 the facility vulnerability to climate stressors is assessed taking into account the methodology (which was developed in tandem with this report) of determining facility operational thresholds. This is done in an attempt to quantify the amount of disruptions and the costs associated with each particular climate stressor.
5. Potential Adaptation Strategies are then presented on a facility basis as well as on a national level for a more general sense.

Jamaica's Climate

Current Climate Conditions

Analysis of historical data collected on various meteorological parameters governing Jamaica's climate suggests the following:

- Surface temperature in Jamaica is largely controlled by the variation of solar insolation. Average annual temperatures range from 24°C in the winter months to 27°C in the summer months.
- The rainfall pattern is bimodal with early rainfall peaking in May and late season rainfall peaking in October. For all seasons, the maximum rainfall is located in the parish of Portland, close to the border with St. Thomas. The main drivers of the rainfall pattern are the North Atlantic High (NAH) Pressure system, sea surface temperatures, easterly waves, and the Trade Winds.
- The data suggests that Jamaica receives an estimated average of 1825 kWH/m^2 per year of direct solar radiation. The south receives marginally more radiation than the north and the far eastern tip of Jamaica receives more than anywhere else. The annual variation suggests that for the given locations radiation peaks around June.
- Winds are strongest in Portland and St. Thomas, Manchester and St. Elizabeth. The strongest influence are the prevailing winds from the East or North East.
- Data paucity hampers the in-depth analysis of other meteorological variables, particularly analysis of their spatial variation.
- Relative humidity does not vary significantly throughout the year. For morning hours, the average humidity at the airport stations is higher and ranges from 72-80%. In the afternoon it is lower (59-65%).
- Sunshine hours vary little throughout the year, ranging between 7 and 9 hours per day. The average evaporation at Manley International Airport is 7.23 mm/day and 5.50 mm/day at Sangster International Airport.
- There appears to have been a lull in hurricane activity near Jamaica between 1952 and 1973 and much increased activity since 2001.

Historical Climate Trends

Analysis of historical climate data also reveal certain trends which are summarized following:

- There is an upward (linear) trend in temperatures which are consistent with global rates. Minimum temperatures are increasing faster than maximum temperatures. Mean temperatures are increasing at a rate of 0.16°C/decade.
- There is significant year-to-year variability in rainfall due to the influence of various phenomena (El Niño etc.) which results in no clear trend and an insignificant upward trend. The intensity and occurrence of extreme rainfall events have been increasing between 1940 – 2010.

- There is a regional increase in sea level rise of 0.18 ±0.01 mm/year between 1950 and 2010 which is consistent with the global mean, although there is a higher rate of increase in the later years: up to 3.2 mm/year between 1993 and 2010.
- There has been a dramatic increase in frequency of Atlantic hurricanes since 1995. There has also been an increase in category 4 and 5 hurricanes; rainfall intensity associated peak wind intensities and mean rainfall for the same period.

Climate Projections

Some of the work conducted by the Climate Studies Group, Mona, University of the West Indies (UWI-Mona) has been in predicting future climate under various Regional Climate Models (RCM) which are similar to Global Climate Models (GCM) but scaled to suitably fit the Caribbean and the island of Jamaica. Key projections are summarized following:

- Temperatures increase across all seasons of the year, irrespective of scenario, through the end of the century. The mean temperature increase (in °C) from the GCMs will be 0.75-1.04°C by the 2030s and 0.87-1.74°C by the 2050s. However, RCMs suggest higher magnitude increases for the downscaled grid boxes. Mean daily maximum temperature each month at the Norman Manley International Airport (NMIA) station is expected to increase by 0.8-1.3°C by early to mid-century. The annual frequency of warm days in any given month at the NMIA station may increase by 4-19 days by mid-century.
- GCM's suggest that mid 2030's will be up to 4% drier while the 2050's will be up to 10% drier, while by the end of the century the county as a whole may be up to 21% drier for the most severe scenario. Similarly, RCM projections reflect the onset of a drying trend from the mid-2030's, which continues through to the end of the century. However, the decreases are higher for the grid boxes in the RCM than for the GCM projections for the entire country. There is some spatial variation across the country with the south and east showing greater decreases than the north and west.
- For Jamaica, projected sea level rise (SLR) for the north coast is 0.43-0.67m by the end of the century with a maximum rise of 1.05m. SLR rates are similar for the south coast.
- There seems to be a shift towards stronger storms by the end of the century: maximum wind speed increases of +2 to +11% and rainfall rates increasing +20% to +30% for the hurricane's core. Although there is no statistically significant increase in the frequency of all hurricanes, it is predicted that there will be an 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

Climate Projections effect on Transport

Of the climate projections highlighted above, the temperatures and sea level rise are of the greatest immediate concern. Extremely hot temperatures cause excessive strain on HVAC systems, which affect operations and functionality of the facilities. Further, these extreme temperatures can affect asphalt both on the linking roadways and on the airport tarmacs. Sea level rise is also a grave concern as all the transport facilities under this study are located in low-lying coastal areas subject to inundation by rising waters. Increasing and stronger storms are also concerning as they cause large disruptions in the service operations of both the airports and seaports and can also cause significant damage to the facilities and equipment.

Criticality of Transport Facilities

The four transport facilities selected for analysis within this project are the two international airports, the largest cargo handling port in the island and the port with the most cruise ship arrivals:

- The Sangster International Airport
- The Norman Manley International Airport
- The Historic Falmouth Cruise Port
- The Kingston Container Terminal

The Sangster International Airport (SIA)

The importance of the SIA as the gateway to Jamaica's north coast cannot be overstated as the bulk of tourists visiting the island arrive through this airport. According to the airport's website: *Of the approximately 1.7 million annual visitors to Jamaica, 72% use SIA as their primary airport.* The Airports Authority of Jamaica (AAJ) also shows that 72% of visitors to the island came through the SIA in the financial year 2013/14. The AAJ data further indicates that this percentage share of the passengers entering the island has been on the rise since the 2008/09 financial year. This not only shows that the SIA is the most important airport in the island for visiting passenger traffic, but it also indicates that it is becoming more important as the share of the total national traffic is growing. Although the SIA does not heavily compete in the freight movement: cargo and mail, the movement of cargo and mail is increasing at a faster rate than the passenger movement. Regardless of the rate of increase, the data available clearly indicates that SIA features a large throughput of passengers and cargo that has steadily increased over the past 6 years. Further, because of its location on the north coast, close to hotels and tourist attractions the airport serves as a critical tourist gateway into the island, without which arriving passengers would have to travel long hours from NMIA to reach their north coast destinations.

The Norman Manley International Airport (NMIA)

As the "premier gateway to the nation's capital", NMIA plays a critical role in the economic development of Jamaica. The airport caters to over 1.5 million total passengers per year on average and handles over 9 million kilos of the island's airfreight (roughly 70% of total air freight traffic to the island). NMIA tends to provide air service primarily for visiting friends and relatives (VFR) and business travellers, rather than pleasure-seeking tourists. Surveys have indicated that over a million Jamaican-born persons live outside of Jamaica in the United States (75.5%), the United Kingdom (13.5%) and Canada (11%). The VFR traffic at NMIA reflects the demographic characteristics of this diaspora. NMIA is a draw for business travellers because of the proximity to Kingston. The city plays a central role in Jamaica's economy as the administrative capital and commercial and financial hub. The city is also home to several multinational organizations with regional headquarters, head offices of banks and consultancies, universities and sites of archaeological and historical interest. The criticality of air traffic access to the island's capital for the facilitation of business cannot be overstated.

Airport Comparison

The SIA and the NMIA are Jamaica's only two international airports; with similar histories and similar challenges they have a lot in common. Both international airports have existed in their respective locations in some form for over 60 years. Both airports currently occupy large extents of land (between 350 – 400 acres in each case) and feature all necessary elements of a functioning international airport. Throughout their histories, upgrades on both airports has been an almost ongoing process, and plans for improvements continue, with both airports having significant capital improvement programmes including the lengthening of their runways (when funds become available).

However, there are distinct differences between the two airports. Reports issued by the Airports Authority of Jamaica (AAJ) indicated that between the financial years 2008/09 to 2013/14, the percentage share of total passenger traffic to the island controlled by the SIA ranged from a low of 66.5% to a maximum of 72% with an average percentage share of 69%. NMIA contributed the remaining 31% on average over the period to total passenger traffic. The data regarding freight performance for the same period as recorded by the AAJ, shows that the NMIA has a higher market share in this field than SIA averaging 71% of total market share over the period and SIA controlling only 29%. The information is also found in the tables below.

The key points and trends revealed from the AAJ data can be summarized as follows:

- The SIA is steadily increasing its percentage share in both the freight market and the passenger market. Conversely the NMIA is losing percentage share in both markets.
- The SIA and the NMIA are dominant in two clearly distinct areas – the SIA has consistently controlled more than two thirds of the island's passenger traffic, while the NMIA has controlled over 70% of the freight traffic in the island for all years of record save one.
- The SIA and the NMIA differ in terms of the makeup of their passengers – the NMIA caters primarily to Jamaicans living abroad and to business travellers, while the SIA is the gateway to the north coast predominantly utilised by tourists vacationing in the island.

This analysis clearly highlights the complementarity of the two assets, which are both vital to the island in different ways. However, because the strengths of the facilities are so vastly different it raises questions about each facility's readiness to absorb the other's load in the event of a closure of either. For instance, in the event of a failure of SIA, NMIA would have to manage those passengers coming into the island, which are roughly 4 times its usual load (over the period of a year). It is unlikely that NMIA could adequately cope with the surge in passenger traffic in this eventuality; and conversely, it is also unlikely that SIA could manage the surge in freight traffic should NMIA close for any reason. This again reinforces the criticality of each airport in the management of passengers and freight entering the island.

The Historic Falmouth Cruise Port (HFCP)

Because of its excellent location and its ability to host larger cruise ship vessels, the HFCP is a critical player in the island's cruise ship industry. Additionally, the number of calls has continuously increased since the port's opening in 2011, which bodes well for anticipated growth.

Data obtained from Port Authority of Jamaica (PAJ) publications revealed that since it's opening in 2011 the Falmouth Pier has consistently had more passengers arriving on its docks than any of the other cruise ship piers in Jamaica. This is partly because it is able to dock larger ships with larger passenger capacities, but is also related to the popularity of the HFCP. It is likely also a function of the fact that the port lies between Montego Bay and Ocho Rios, allowing visitors a greater range of attraction options. The data also shows that the HFCP facility is responsible for approximately half (48% on average) of the total cruise ship passenger arrivals to the island. This elucidates the criticality and importance of the HFCP to the island's cruise ship industry. Damage of the port facility causing non-functionality for whatever reason would thus have massive effects on Jamaica's 'stop-over' tourism trade. Total cruise ship arrivals account for a significant part of total tourist arrivals into the island; in 2014, that percentage was 41%. This highlights the relative importance of cruise ship tourism in the island's overall tourism economy. As the cruise ship port with the most arrivals and calls, the data further underscores the importance of the HFCP to the island's economy.

Even locally the presence of the port is a significant economic contributor. Figures received from The Falmouth Jamaica Land Co. Ltd. revealed that approximately nine hundred (900) staff are employed within the 'plaza' of the pier i.e. within the shops and restaurants etc. This figure does not include tour operators etc. which are outside companies using the pier for excursion pickups, and so the overall number of persons who depend on the pier for their livelihood is even higher than stated above. In the small town of Falmouth, with a population under 9,000 persons, this is a very important employment centre (roughly 10% of the population) to the people of the town.

The Kingston Container Terminal (KCT)[1]

Data extracted from the database of the Port Authority of Jamaica (PAJ) on the KCT for the past five (5) years: 2011 – 2015 revealed that roughly 1500 vessels visited the KCT each year over the period. Of this amount, the vast majority (approximately 96%) were cargo vessels. The data showed that close to a million metric tonnes of cargo are brought into the island on an annual basis through this port alone. Other documents revealed data related to the 2008-2009 shipping season. During that period: *"the KCT received 2470 vessel calls and handled a total of almost 16.3 million metric tons of cargo. Fees produced by the KCT… during the 2008-2009 shipping season, generated a net income of $8.5 billion for KCT."* [– World Port Source]. It is worth noting that the bulk of the KCT business is transhipment and not domestic importation. *"Of the total amount handled by the port in the 2008-2009 shipping season, about 1.4 million TEUs (86%) were transhipments. Domestic containerized cargo represented 12% of the total 1.7 million."* [– World Port Source]

The transhipment services to the region – the Caribbean, North, Central and South American markets, are a vital component of the KCT business. The Economic Commission for Latin America and the Caribbean (ECLAC) updates every year its ranking of container port throughput, which shows the cargo volume in containers in 120 ports of the region, based on data obtained directly from port authorities and terminal operators. In 2015, the regional activity grew 1.7%, with a total volume of approximately 48 million TEU. ECLAC ranked the KCT as 8th in Latin America and the Caribbean.

The critical importance of the port is thus multi-fold:

- It controls the largest share of the country's imports and exports.
- It is a major contributor to the region's (Latin America and Caribbean) transhipment activities.
- It is a major revenue earner as well as a large employer of persons in the island, and thus contributor to the island's economy, through direct earnings and taxes.

The domestic cargo market should also not be underestimated as large amounts of produce and commodities are brought into the island through the port. Through the KCT and other ports, Jamaica mainly imports oil and ethanol (to satisfy the island's energy needs); wheat and rice (as the primary food imports); as well as lye, electronic appliances, vehicles and metals, all of which are inputs for manufacturing, agriculture and local businesses. Should operations at the KCT be forced to cease for any reason such as a natural disaster, Jamaica's economy and its people would be severely affected.

[1] Throughout the document, Kingston Container Terminal refers to the port facility whereas Kingston Freeport Terminal Limited (KFT or KFTL) will refer to the current (since 2015) managing company of the facility.

Vulnerability of Transport Facilities

The extensive studies reported in Chapter 3 of this report indicate clearly that: Climate projections specific to the island indicate climate change will likely occur. Key projections of climatic changes for the island of Jamaica along with their likely effects are summarized below:

Table 0.1 Forecasted changes in climate and their effects on transport facilities

Parameter	Change	Period	Effect
Higher Temperatures	Increase by 0.87-1.74°C	2050s	- Strain on HVAC systems - Weaken asphalt - Strain on personnel working outdoors
More Warm Days	Increase by 4-19 days	2050s	
More Droughts	10% drier	2050s	- Limits water supply and related functionality - Detracts tourists
Higher Sea Level	Increase by 0.43-0.67m	2100s	- Increased risk of inundation of facility runways, container bays and access roads
More Intense Storms	Wind Speed: +2 to +11% Rainfall: +20% to +30%	2100s	- More incidents of higher category storms - More likely to have facility shutdown due to storms.

Of all the climate changes which will occur, the climate stressor that is perhaps of most concern to facility managers is the threat of more intense hurricanes. The wave action; storm surge; and flooding linked to hurricanes has in the past resulted in large disruptions in the service operations of both the airports and seaports and has also caused significant damage to the facilities and equipment. The effects of climate change on these parameters will increase their damaging effects which is an alarming thought.

All the transportation facilities in this study border the sea, and KCT is almost completely surrounded by water. Therefore, the vulnerability of the sites to sea level rise, or inundation of the facility and access roads because of storm surge, is quite clear.

Possible Adaptation Strategies

The analysis so far suggests some actions that can be taken by the facilities to safeguard against the impending climate changes which could include:

Facility	Potential Adaptation Strategy	Effect
SIA	- Raise Runway - Extend Runway	- combat SLR and storm surges - combat warmer temperatures affecting lift
NMIA	- Extend Runway - Raise low-lying areas	- combat warmer temperatures affecting lift - combat SLR and storm surges
HFCP	- Combine efforts with local government to improve infrastructure in Falmouth	- improve resilience of access roads - improve tourist experience
KCT	- Invest in better reinforcement for cranes - Deploy booms in Hunts Bay	- combat higher wind speeds - control debris outflow

All of the improvement strategies recommended will decrease the vulnerability of the facilities in question. However, to make really effective change, especially for the seaports, coordination with agencies outside of the facility will be required. Additionally, national level strategies are also required for cohesive and long-term planning, especially for those issues being affected on a larger scale.

In this context, with a view to the development of effective adaptation measures, it is important to note that the Jamaican Government, in 2015, has adopted a comprehensive and cross-cutting Climate Change Policy Framework for Jamaica which expressly recognizes the importance of climate change adaptation for seaports and airports.

Contents

1. Introduction

1.1 Project Background

The potentially negative impact of climate change on the development of nations has become a more recognized phenomenon over the past decade. It was concluded in 2007, by the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report (AR4), that climate change would impede the ability of many nations to achieve sustainable development by the mid-century and could become a risk that would steadily intensify, particularly under more extreme global warming scenarios. Article 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC) furthers this idea and goes on to list those groups of countries that require special consideration for climate change adaptation assistance "*...especially: (a) small island countries, (b) countries with low-lying coastal areas,… (d) countries with areas prone to natural disasters….*" The nations of the Caribbean Community (CARICOM) bear these characteristics, which makes them exceptionally vulnerable to climate change for several reasons:

- The Caribbean's location in the "hurricane alley" of the Atlantic (Figure 1.1) makes the region especially vulnerable to hurricanes;
- The geographic nature of the islands, which is typically small land masses with mountainous inland areas and narrow coastal plains, combined with large population concentrations and infrastructure located in these narrow coastal areas;
- A limited economic base and dependency on natural resources, which translate to limited financial, technical and institutional capacity for adaptation.

Figure 1.1 World map with the warm waters of "Hurricane Alley" depicted in yellow. Caribbean highlighted in red

The nations of CARICOM are thus expected to be among the most impacted by climate change in the coming years. Caribbean coastal communities in particular, will be severely threatened by the direct and indirect impacts of climate change such as increased sea-surface temperatures, sea level rise (SLR), coastal erosion, more extreme events and the loss of aesthetics, which are projected to accelerate in the coming decades and compound the existing threats to natural systems and society. Dulal et al. (2009) conclude that:

> *"If the Caribbean countries fail to adapt, they are likely to take direct and substantial economic hits to their most important industry sectors such as tourism - which depends on the attractiveness of their natural coastal environments - and agriculture (including fisheries), which are highly climate sensitive sectors. ... and significant losses ... will not only increase unemployment but have debilitating social and cultural consequences to communities."*
> – Dulal et al, 2009. "Social Equity Considerations in the Implementation of Caribbean Climate Change Adaptation Policies".

Development of adaptation strategies and policies are thus of paramount importance to the CARICOM nations at this time in their planning framework. No longer can these countries afford to ignore the looming impacts of climate change on their respective nations.

As a first step in developing adequate policies, the Ministry of Land, Water, Environment and Climate Change (MLWECC) of Jamaica (which had existed under the 2011-2016 government administration) issued a Climate Change Policy Framework for Jamaica which was released in September 2015. The document identified as one of the government's highest priorities "*building resilience to the impacts of climate change*" [Minister of LWECC, 2011 - 2016]. The policy framework was intended to encourage relevant sectors to develop, in a streamlined manner which the MLWECC would oversee, their plans for addressing climate change adaptation and mitigation. The relevant sectors requiring attention were identified in the document as follows: *"The main sectors for the development of climate change strategies and action plans are tourism, agriculture, fisheries, forestry, water, energy, industry, human settlements and coastal resources, marine resources, human health, transportation, waste management, education, finance and disaster risk reduction and response management."* – Climate Change Policy Framework for Jamaica. This list highlights the vast reaching effects of climate change impacts on industries and sectors which are inextricably linked to each other and to the operations of the country as a whole. It further points out those sectors that are considered to be the most vulnerable to impacts because of their importance to the country's economy and its operations.

1.1.1 Transportation Sector – Overview and Project Scope

As implied in the framework quote above, any major disruptions to the transportation sector can seriously affect the economic flow and operations of the country. This is because the transportation networks within a country link factors of production and services to consumers "*to create a more efficient division of production, leverage geographical comparative advantage, and provide the means to expand economies of scale and scope*" (The Public-Private Infrastructure Advisory Facility (PPIAF)). Therefore, the transportation sector is crucial to economic development because it acts as a conduit, linking production and service areas to the end users. This link is especially crucial in Small Island Developing States (SIDS) such as Jamaica, where the country's population, by virtue of existing on an island, is cut off geographically from neighbours and trading partners in the Caribbean and North and South America. To address this need, Jamaica has developed a multi-modal transportation system comprising of air, land (road and rail), and maritime transportation, some of which are highlighted in Figure 1.2. below. Of all these modes, the United Nations Conference on Trade and Development (UNCTAD) has focused on the ports and airports as being critically vital for development. UNCTAD, in recognizing this dependency of SIDS on their port and airport infrastructure, has noted:

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The potential adverse implications of climate induced disruption and delays for Jamaica's external trade are also explicitly acknowledged in the Climate Change Policy Framework for Jamaica, which was adopted in 2015. There, it is noted: *"Any interruption in operations at seaports, airports, other points of entry and related infrastructure resulting from climate change may potentially cause import and export delays, loss and damage to goods and other challenges in global supply chains which have severe negative implications for international trade."* – Climate Change Policy Framework for Jamaica.

Ports and airports are therefore vital to Jamaica's economy. They are required to provide necessary food imports into the country, Jamaica cannot produce enough to feed its people and meet other vital consumer needs, such as oil and gas to power our electric plants and cars among other things. Additionally, ports and airports are gateways to bring persons to the island for tourism, which is a major foreign exchange earner. It is noted (World Travel & Tourism Council – Jamaica Economic Impact 2015) that the direct contribution of the travel and tourism sector to the island's GDP in 2015 was 8.5%, and this was projected to increase to 11.6% by 2025. When the wider effects from investment, the supply chain and induced income impacts are factored in, these numbers rise to 28% and 37.5% respectively, further underscoring the importance of this overall sector to the Jamaican economy.

Jamaica is home to two (2) international airports that facilitate air transport out of, and into the island from several countries, as well as transport across the island. The Norman Manley International Airport (NMIA) in Kingston is the access point to the island's capital. The Sangster International Airport (SIA) is in Montego Bay, commonly called the 'second city' as it is the economic hub of the north coast of Jamaica. Both airport facilities, which will be discussed in detail in later chapters, are critical to the island's development because of their significant contribution to the tourism industry as well as the cargo and air freight they facilitate to be brought into the island. Further, their locations at almost opposite ends of the island are ideal for purposes of island coverage; i.e. SIA provides access to the north coast and NMIA provides access to the south coast of the island. Recently, with the opening of the new North-South Highway creating 40 minute transit times between Kingston and Ocho Rios, it is anticipated that some north coast residents will now arrive and depart from NMIA, and some south coast residents will use SIA.

To connect the airports to each other and to other major towns across the island, the roadways and highways are used. The road network in Jamaica consists of almost 21,000 kilometres of roads, of which over 15,000 kilometres is paved. The letter/numbering scheme used covers toll highways (T), freeways, primary (or A) roads, secondary (or B) roads, parochial roads and unclassified roads. The primary and secondary roads, designated as 'A' and 'B' are shown in Figure 1.2. The maintenance responsibility for these roads vary, with some roadways falling under the portfolio of the Ministry of Transport (MoT), while some others fall to the private highway companies who have signed contracts with the Government of Jamaica (GoJ) for construction and maintenance of these highways. Conversely, the parochial roads and unclassified roads are a local responsibility, with the respective Parish Councils bearing the responsibility for their maintenance and upkeep. Because of the vastness of the road network system in the island, spanning both the hilly interior areas and the coastal roads, it is almost impossible to assess the vulnerability of each road. The entire road network was therefore not included in the project scope. Rather only the primary access roads to the major facilities were considered, whereby impacts to these access roads would affect the facilities and/or their operations.

Jamaica's maritime sector is inclusive of the container market – which brings in a large amount of Jamaica's imports; the cruise ship market – which brings in tourists to visit the island and contributes to the tourism sector; and the pleasure boating market - which is the smallest percentage of the maritime industry. To better understand the impact on the maritime industry in its entirety, a representative container port was chosen under the study, the Kingston Container Terminal (KCT), as well as a cruise ship terminal, the Historic Falmouth Cruise Port (HFCP), Jamaica's newest cruise ship terminal. Both facilities are highlighted in Figure 1.2 below, and both fall under the jurisdiction of the Port Authority of Jamaica (PAJ). Pleasure boating was not considered under this project because of its small market impact.

Figure 1.2 Map of Jamaica showing two international airports (denoted by airplanes), major roadways (denoted by yellow lines) and two ports (denoted by small red triangles)

1.2 Project Objectives and Report Outline

The criticality and importance of the transportation sector in SIDS is undeniable, as is the particular vulnerability of those same transportation facilities along the coastline. It is therefore crucial that climate change impacts for these facilities be properly understood, and that adaptation strategies and a comprehensive procedure for their strategic implementation be developed in tandem.

In recognizing this need, the United Nations launched a capacity building project on "Climate change impacts on coastal transport infrastructure in the Caribbean: Enhancing the adaptive capacity of Small Island Developing States (SIDS)", which is being implemented by the United Nations Conference on Trade and Development (UNCTAD).

The underlying purpose of this initiative, which draws on UNCTAD's earlier relevant work in the field[2], is to strengthen the capacity of policy makers, transport planners and transport infrastructure managers in SIDS to: (a) understand climate change impacts on coastal transport infrastructure, in particular seaports and airports; and (b) take appropriate adaptation response measures.

This report represents the case study for Jamaica. In support of the objectives of the project, the following steps will be undertaken within the body of this report.

1. In Chapter 2, Jamaica as a nation is described for the general reader in terms of its geography, its population, its economy and its social issues. It is felt that this is a necessary component of framing the overall project within a context specific to Jamaica.
2. A thorough review of the State of Jamaica's climate is then undertaken in Chapter 3 to develop an understanding of the current climate conditions in the island, the climate trends as they have existed up to this point, and the future climate projections based on current climatic modelling.
3. Four key transportation facilities (SIA, NMIA, HFCP, KCT) have been selected and are detailed in Chapter 4, to ascertain the criticality of each to the nation. The facilities themselves will be studied to understand their operations and throughput. This defines for the project the criticality of the facilities to the country and forms a basis to hypothesize what could result from a disruption in services due to climate change.
4. In Chapter 5 the facility vulnerability to climate stressors is assessed, taking into account the methodology (which was developed in tandem with this report) of determining facility operational thresholds. This is done to quantify the amount of disruptions and the costs associated with each particular climate stressor.
5. Potential Adaptation Strategies are then presented on a facility basis as well as on a national level for a more general sense.

[2] UNCTAD has been working on the implications of climate change for maritime transportation, since 2008. The particular focus of this work is on impacts and adaptation needs of seaports and other coastal transport infrastructure. For further information, see the UNCTAD website at http://unctad.org/en/Pages/DTL/TTL/Legal/Climate-Change-and-Maritime-Transport.aspx

2. Profile of Jamaica

2.1 Jamaica's Geography

Jamaica is the fourth-largest island country situated in the Caribbean Sea and the third-largest island of the Greater Antilles. Located in the west-central Caribbean, it lies approximately 145 kilometres south of Cuba and 191 kilometres west of Hispaniola, between latitudes 17° and 19°N, and longitudes 76° and 79°W, almost in the centre of the Caribbean Sea. A map of Jamaica showing its location relative to the rest of the Caribbean is shown in the insert of Figure 2.1 below.

The island, 10,990 square kilometres in area, is approximately 234 kilometres long and 80 kilometres wide. Volcanic in origin, Jamaica can be divided into three landform regions: the eastern mountains, the central valleys and plateaus, and the coastal plains. These landforms are organized into a mostly mountainous interior, with a narrow, discontinuous coastal plain around the edges. There are elevation differences from the 0m shoreline to 2,256m at its highest point on the Blue Mountain Peak. Other mountain ranges of note include the John Crow, Dry Harbour and the southern Manchester Plateau. The bulk of the land is agricultural land (41.4%) and forest (31.1%).

Figure 2.1 Map of Jamaica showing major cities. Insert shows Jamaica relative to the rest of the Caribbean

The island is ringed by numerous bays, small cays and islands, and attractive white-sand beaches which are a large draw to the island for tourists. Also of note are the rivers in the island, of which there are over a hundred. However most of the island's rivers are small, unexplored and not navigable; many are mostly underground rivers and run through the limestone region. The Black River is the largest (widest) river with widths ranging from 38km to 73km at parts of the Black River morass and is navigable in certain sections. The Rio Minho is the longest river in Jamaica at 92.8km.

To better promote conservation and sustainable management and use of the island's limited natural resources, for the benefit of local communities, the Forest Conservation Fund was established. Under the initiatives related to this fund, eleven (11) protected areas have been designated, these are:

- Negril Marine Park
- Black River Morass
- Royal Palm Reserve
- Dolphin Head Reserve
- Ocho Rios Marine Park
- Cockpit Country Reserve
- Port Antonio Marine Park
- Montego Bay Marine Park
- Palisadoes-Port Royal Protected Area
- Portland Bight Protected Area
- Blue & John Crow Mountains National Park

It is worthwhile to note that both international airports under this study are located in designated protected areas [Montego Bay Marine Park – SIA, and the Palisadoes/Port Royal Protected Area – NMIA]. Also of note is the fact that a logistics hub was being considered in Jamaica within another protected area, the Portland Bight Protected area. Although that project now seems to have been shelved, it was a topic of much media coverage and social debate; weighing the benefits of a logistics hub to the island against preserving the country's limited resources.

2.2 Jamaica's Demographics

2.2.1 Population, Qualification and Labour Force

Jamaica is the third most populous Anglophone country in the Americas with an approximate population of 2.7 million people according to the Statistical Institute of Jamaica's (STATIN) 2014 end of year estimate. There is no significant dichotomy between the numbers of males and females, with the population being split almost 50/50 between the sexes as shown in Table 2.1 below.

Table 2.1 Population divided by sex, growth rate, births, deaths and marriages in Jamaica

	2008	2009	2010	2011	2012	2013	2014
Total Population		2,686,105	2,695,543	2,704,133	2,711,476	2,717,862	2,723,246
Female		1,358,277	1,362,390	1,366,354	1,369,776	1,373,002	1,375,203
Male		1,327,828	1,333,153	1,337,779	1,341,700	1,344,860	1,348,043
Female/Male Ratio		50.6/49.4	50.5/49.5	50.5/49.6	50.5/49.7	50.5/49.8	50.5/49.9
Population Growth Rate			0.35%	0.32%	0.27%	0.24%	0.20%
Births	43,112	42,782	40,508	39,673	39,553	36,746	
Deaths	19,966	18,855	21,503	16,926	16,998	15,427	
Emigration	-13,741	-14,515	-9,718	-14,488	-15,000	-14,744	

As shown in the table, although the island's population has increased over the period of record, it has done so at a very small rate of growth (<0.35%) and further, the population growth rate is seen to be decreasing. This decreasing population growth rate is partially influenced by the decreasing birth rate but is also strongly influenced by the rate of emigration, which has been fluctuating over the years but is overall increasing. Emigration is a particularly worrisome issue because of its implications, discussed in almost every national plan, including Vision 2030:

> *"One profound impact of the economic, social, environmental and governance challenges [of the country] has been the sustained outward migration of many Jamaicans, including the highly educated, who have made other countries the places of choice to live and unfold their talents."* – Vision 2030: National Development Plan.

The issue from a socio-economic perspective is that the emigration numbers are typically related to the well-accomplished, trained, qualified and professional persons who seek employment outside of Jamaica to better match their qualifications. These persons are usually educated (at least up to the secondary level) in Jamaica, at a cost which the government contributes to and sees no return on its investment when these persons leave. This "brain drain" phenomenon has been a huge issue in the country for decades.

> *"Jamaica has one of the highest rates of migration of persons with tertiary education among Commonwealth countries, according to figures made public (…) at a conference in Kingston looking at the effects of migration. Dr Cyrus Rustomjee, director of economic affairs at the Commonwealth Secretariat, told the conference that data from a 2007 study showed that 85 per cent of Jamaicans who have migrated are tertiary graduates."* – Jamaica Observer Article. (2012)

As reported in the most recent census, completed in 2012: 69% of Jamaica's work force had received no training whatsoever, while only 24% were equipped with either a vocational certificate or degree, and the others had received on-the-job training or apprenticeship [Source: STATIN]. The small percentage of qualified individuals joining the local labour force will affect not only the country's capacity for development, growth and innovation but will also increase the need for hiring foreign consultants and bringing in foreign technologies for specific jobs and projects in Jamaica.

Interestingly, despite having a predominantly un-trained work force, the bulk of employed persons are employed in the services sector, according to the CIA WorldFactbook 2006 estimate, the labour force breakdown by sector is: Agriculture 17%, Industry 19% and Services 64%.

As shown in Table 2.2 below, approximately 50% of Jamaica's total population comprises the labour force, of which roughly 86% are employed, according to Jan 2014 estimates published on the STATIN website. Of those unemployed persons, roughly 9% are seeking jobs. Only 2 years of data have been published, so it is not possible from this data base to calculate trends in the employment and job seeking rates. Nevertheless, it is worth noting that over the brief period of record, the unemployment rate and job seeking rate were trending downward, reflecting worldwide patterns of recovery after the global downturn in 2008.

Table 2.2 Main Labour Force Indicators for Jan 2013 and Jan 2014. Source: STATIN.

ITEM	Jan 2013	Jan 2014
Labour Force	1,297,600	1,305,500
Employed Labour Force	1,110,000	1,130,500
Unemployed Labour Force	187,600	175,000
Employment Rate	85.5%	86.6%
Unemployment Rate	14.5%	13.4%
Job Seeking Rate	9.50%	8.90%
Total Population	2,711,500	2,718,800
Labour Force as a % of Total Pop.	47.9%	48.0%

Sectoral employment is also of interest, particularly within the context of this report, as the data implies that at least 25% of the sectors may be dependent on the transportation of goods, services and people. The table below shows the January 2016 figures of employment by industry group. As shown, the transport sector is directly (6%) and indirectly (~8%) a source of employment in the country. The indirect source is tourism (hotels & restaurant services) which employs both skilled and unskilled workers in the country and for which transport is an essential component.

Table 2.3 Employed Labour Force for Jan 2016 divided by Industry Group. Source: STATIN.

Industry	Jan 2016	Percentage of total labour force
Agriculture, Hunting, Forestry & Fishing	194,000	17%
Mining & Quarrying	6,400	1%
Manufacturing	73,700	6%
Electricity, Gas and Water Supply	8,400	1%
Construction	86,000	7%
Wholesale & Retail Repair of Motor Vehicle & Equipment	251,100	20%
Hotels & Restaurants Services	87,700	8%
Transport, Storage and Communication	73,600	6%
Financial Intermediation	31,200	2%
Real Estate, Renting & Business Activities	66,600	6%
Public Administration & Defence; Compulsory Social Security	52,900	5%
Education	73,300	6%
Health & Social Work	36,200	3%
Other Community, Social and Personal Service Activities	64,400	5%
Private Households with Employed Persons	54,500	5%
Total Employed Labour Force	**1,163,600**	**100%**

2.2.2 Social Issues

As discussed earlier, the emigration of qualified persons is a major social issue faced by Jamaica. Additionally, this emigration results in the creation of an extensive Jamaican diaspora. There are many Jamaicans living outside of Jamaica, with estimates placed at approximately 1.5 million or more persons (including over 150,000 Jamaicans in the United Kingdom (UK Office for National Statistics, 2011), over 250,000 in Canada (Statistics Canada, 2011), over a million in the United States and approximately 60,000 living elsewhere in the Caribbean) according to Wikipedia. The Jamaican diaspora has been essential to the survival of the country as highlighted in quote below taken from a June 2015 piece "What would we be without our Diaspora?" in a local newspaper:

> *"Remittances from overseas nationals represent the largest inflow of foreign exchange for some of the smallest and most vulnerable Caribbean states. The contribution of the diaspora goes beyond remittances to include being a source of employment, investment, tourism, market for exports, and their nationals are active goodwill ambassadors. Nearly every school, church, hospital, and charitable organisation benefits from donations in cash and kind. When the nationals return home they usually bring valuable skills and habits developed in a more modern society. Many families are dependent on remittances, which function as a type of informal social security system, especially for children and senior citizens. The diaspora is the ever-reliable shock absorber in times of trouble, including rebuilding after a natural disaster such as a hurricane. In crises, Caribbean people overseas often increase their regular subvention by drawing down on their savings."* – Jamaica Observer Article.

The relevance of the Jamaican diaspora in the context of this report is multi-fold. Firstly, they are a large market for transportation usage into and out of the island, the airports cater to them specifically, particularly the airport in Kingston because they represent such a substantial market share. Secondly, their significant contribution to the local economy as highlighted above cannot be overstated and makes them a powerful body in appeals to and negotiations with the government for various policies to be implemented. Thirdly, they are an important source of funding in the event of the occurrence of natural disasters and other such hazards related to climate change.

In addition to emigration and unemployment, another socio-economic issue facing Jamaica currently is urban densification. Large amounts of persons move from the rural areas to the urban areas seeking better opportunities at an urbanization rate of roughly 1% per annum (CIA WorldFactbook).

Figure 2.2 Map of Jamaica [©Google Earth] showing densely urbanized areas as grey patches in contrast to the green hills.

As the Google Earth satellite imagery shown in Figure 2.2 highlights, there are densely packed areas of urbanization in the Kingston and St. Andrew zones and stretching into St. Catherine – these are shown as grey and not green in the satellite imagery. 2012 census figures made available by STATIN indicate that 44% of Jamaica's total population reside in these urban areas, the highlighted ovals on the figure. The area most under threat from urban densification is Jamaica's most populated city – Kingston, the country's capital. In the Americas, Kingston is the largest predominantly English-speaking city south of the United States, and has become a business hub in the region for this reason.

The urban densification coupled with the mass emigration of qualified persons from the island as previously discussed translates to a densely-populated capital city typically with underqualified persons. Because of the inability of this sector of the society to get and sustain employment, Kingston has large 'ghetto' areas or slums where the poor of the society live. The findings of the 2012 Jamaica Survey of Living Conditions (JSLC) corroborates this, showing that poverty increased in most urban areas but dropped in most of the rural areas. The survey findings showed that *"The all-Jamaica individual poverty prevalence increased by 2.3 percentage points relative to 2010 to reach 19.9 per cent,"*. This indicates that approximately one-fifth of the Jamaican population live below the poverty line and as such does not earn enough to meet basic needs. This not only hinders the country's development on a per capita level but also affects the application and effectiveness of policies and funding. The government may be obliged to focus on poverty alleviation policies rather than other initiatives, such as climate change adaptation policies, which although warranted are not as immediate a priority for the people of the country as poverty alleviation.

As pertains in most ghettos or slums worldwide, the youth tend to become frustrated with their financial situations and apparent inability to advance themselves and in several cases, turn to illicit criminal activities such as theft, gang dealings or the selling of drugs as a means of upward mobility. At larger scales this leads to drug trafficking rings and contributions to the 'drugs for guns' trade which is at the heart of a lot of the violence that occurs in the island. Another form of crime offering easy money to the youth of the country in recent years is the 'lottery scamming' rings which has been on the increase in the island and particularly in the Montego Bay area. These crime rings, whether their trade is drugs or lottery scams, have helped to drive the island's homicide rate to its current high level, which is the highest in five years.

"The Jamaica Constabulary Force said the country had at least 1,192 slayings in 2015, a roughly 20 percent increase from the previous year. There were 1,005 killings in 2014, the lowest annual total since 2003 in this country that has long struggled with violent crime. Jamaica had about 45 slayings per 100,000 people in 2015, keeping it ranked among the most violent countries in the world. In recent years, the UN listed the island as having the world's sixth-worst homicide rate. The World Bank ranked Jamaica in the top five in 2013. […] Fighting between gangs has long been blamed for the majority of Jamaica's homicides." – Jamaica Observer Article. (January, 2016); exact data can be also found in the annual report of the Jamaica Constabulary Force (Jamaica Constabulary Force, 2016)

Although not directly impacted by the transportation sector, save for the consideration of the narrow roadways or alleyways upon which many violent acts are committed; the violence in Jamaica must be considered in setting the frame of reference for this study, as it would impact the tourism sector and the rate of foreign direct investment (FDI). As we have seen in many other contexts, the transportation sector and the tourism sector in Jamaica are inextricably linked. High rates of crime and violence in the country, especially in the two major cities where the airports are located, will deter tourists from coming to the island and, as mentioned, could slow the inflow of FDI's. That in turn will reduce demand for the international airports and cruise terminals which will ultimately result in less profit for the facilities and less funding available for climate change adaptation.

The social issues discussed here: poverty, violence, drug trafficking, emigration, urban densification and high unemployment are important in understanding the social context in which Jamaica exists. Further, these issues must be understood in a wider sense to better appreciate the complexity of problems affecting the economy and productive sectors of the country such as the transportation sector and the tourism sector.

2.3 Jamaica's Economy

Jamaica unfortunately has one of the slowest growing economies when compared to other developing countries in the world according to World Bank data, consistently demonstrating a typical pattern of underperformance.

"This chronic pattern of underperformance has left in its wake a high level of public debt, unemployment, and deterioration in physical infrastructure and in the delivery of social services (such as health, education and the justice system). These inherited conditions underpin significant and persistent levels of poverty as well as the continued existence of marginalized, vulnerable, and volatile communities throughout the country." – Planning Institute of Jamaica (2012). A Growth-Inducement Strategy for Jamaica in the Short and Medium Term

Analysis conducted by the Planning Institute of Jamaica (PIOJ) found that Jamaica's weak performance in terms of economic growth can be explained

"as the direct consequence of specific, identifiable, and quantifiable conditions operating in the economy and through the process of capital investment. In particular, these conditions are: the chronic state of fiscal imbalance, underutilization of productive capacity, economic waste of capital and concentration of capital investment in highly capital-intensive sectors and economic enclaves. These conditions, in turn, are associated with a number of dysfunctional pathologies and systemic constraints, operating as both cause and effect in a complex mutual interaction with the investment process. At the top of this list, as determined by [the PIOJ's] assessment based on world-wide surveys done by international agencies, are the following factors: crime and violence, corruption, taxation, supply of electricity, finance and macroeconomic instability." – Planning Institute of Jamaica (2012). A Growth-Inducement Strategy for Jamaica in the Short and Medium Term.

The constraints listed in the PIOJ analysis, along with various supply-side factors in the business environment and additional factors related to the internal operations of firms, are considered to be crucial. It is the interaction and combination of these various factors that determine the prevailing low level of international competitiveness of the Jamaican economy. Any policy seeking to address the problem of economic growth and development in the Jamaican economy must tackle and hopefully alter the complex set of structural and behavioural conditions described above which have severely limited the capacity of Jamaican businesses.

Throughout the past 30 – 40 years, several government administrations and agencies, both domestic and international, have attempted to formulate strategies to induce economic growth for the country as well as foreign investment. One such strategy is the "Vision 2030 Jamaica – National Development Plan" which focused on the long-term development of the Jamaican economy with a vision of making Jamaica "the place of choice to live, work, raise families and do business" and enabling Jamaica to achieve developed country status by 2030. However, this document better outlined overall goals than it did actual plans for achieving them.

As a more definite strategy for growth, the previous GoJ administration[3] embarked on: "*a four-year Extended Fund Facility (EFF) by the International Monetary Fund (IMF) providing a support package of US$ 932 million; World Bank Group and the Inter-American Development Bank (IDB) programs providing US$ 510 million each to facilitate the GoJ's economic reform agenda to stabilize the economy, reduce debt and create the conditions for growth and resilience. In addition, the International Finance Corporation (IFC) and Multilateral Investment Guarantee Agency (MIGA) will continue to support private sector development*." The reform program has been bearing fruit, and positive changes in the country's credit rating, business ranking and investor confidence have been recorded.

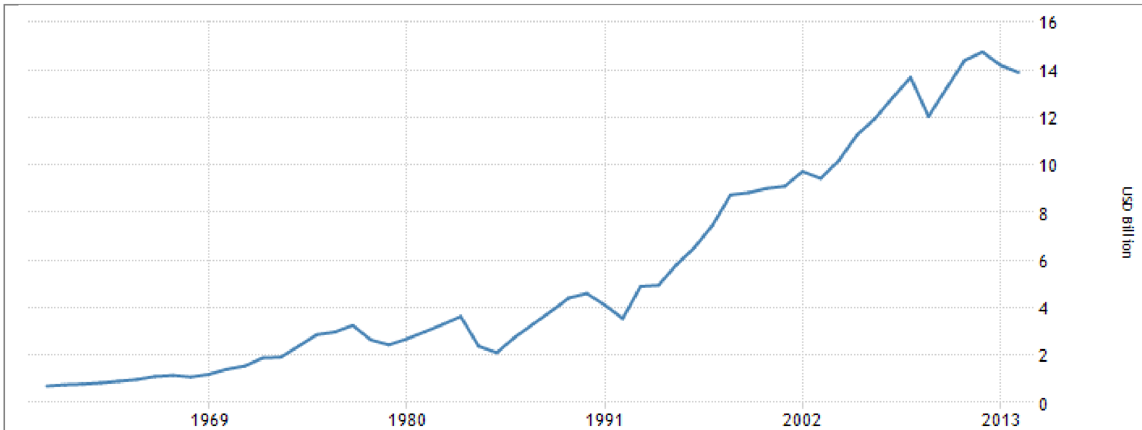
The role of the transportation sector in promoting economic growth and competitiveness is not easily quantifiable. It can be stated with certainty that the transportation sector plays an important role in building economic competitiveness for exports of locally grown and manufactured goods both nationally, regionally and globally. It further facilitates the exchange of business ideas and opportunities with the passage of business travellers and entrepreneurs; provides necessary tools of production through the importation of equipment; and is also a source of both direct and indirect employment in the country, which also aids the country's economy. The sectors' contributions to economic growth is therefore unquestionable but nevertheless difficult to quantify in a monetary manner.

[3] This report was written between 2016 and 2017. During the course of the project, there was a change in administration during February 2016 from the then People's National Party (PNP) to the current Jamaica Labour Party (JLP) government. Therefore, reference to the "previous administration" refers to the PNP whereas reference to the "current administration" refers to the JLP, unless stated otherwise.

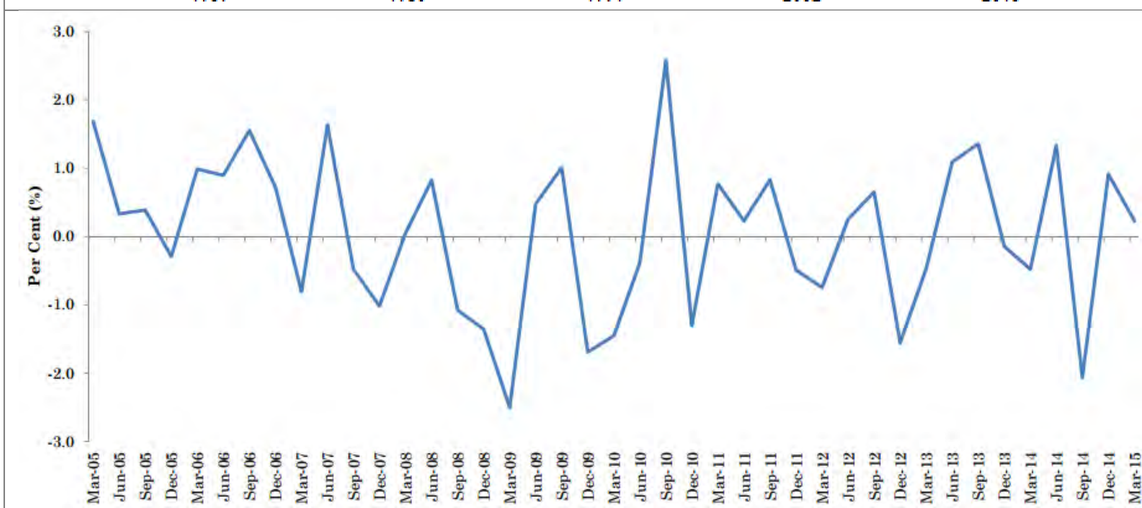
2.3.1 Economic Indicators

Gross Domestic Product (GDP)

The gross domestic product (GDP) is one of the primary indicators used to gauge the health of an economy. Over the last ten (10) years, GDP for Jamaica has ranged between 12.0 - 14.75 billion US dollars, an amount that is very small (roughly 0.02%) when compared to the world economy. According to World Bank data, GDP in Jamaica averaged 5.51 USD Billion from 1960 until 2014, reaching an all-time high of 14.75 USD Billion in 2012 and a record low of 0.70 USD Billion in 1960. The changes over that period are shown in Figure 2.3(a) below. Jamaica's economic growth, as reflected by its GDP increase, has been effectively stagnant for many years (shown in Figure 2.3(b)), indicating a real per capita GDP increase of just one percent annually, averaged over the past 30 years. Further, over the past decade, GDP has been effectively stagnant, with fluctuations of approximately +/- 2%.



(a) GDP in Jamaica from 1960 to 2014. [Source: www.tradingeconomics.com | World Bank]



(b) GDP Quarterly Growth Rates between March 2005 – March 2015. [Source: Bank of Jamaica]

Figure 2.3 Figures describing Gross Domestic Product (GDP) in Jamaica

Jamaica's economy faces many challenges to growth, some of which have been discussed already. Others, such as the significant shadow economy and loose tax regulations are also major challenges to fulsome tax revenue collection. A factor that deserves special mention is the existing debt-to-GDP ratio of about 130%. The attendant debt servicing cost consumes a large portion of the government's budget, over 60%, according to articles in one of the local newspapers – the Jamaica Gleaner. This limits the government's ability to fund much needed critical infrastructure and social programs that are required to drive growth. Coupled with the funding requirements for reconstruction following major natural disasters such as hurricanes and tropical storms, there is a major constraint on funds that are available to be used for development. Excessive bureaucracy, high energy costs and a slow, inefficient legal/judicial system are further hampering the inflow of foreign direct investments and private initiative.

The WorldFactbook, prepared and maintained by the Central Intelligence Agency (CIA) of the United States, lists the following as 2015 estimates of the GDP composition by sector of origin:

Agriculture	7.0%
Industry	21.4%
Services	71.6%

As can be seen, the Services Sector is the most important sector of the economy and accounts for over 70% of the Gross Domestic Product (GDP). While most of the foreign exchange earned by the country is through tourism, remittances and bauxite, which collectively account for approximately 30% of GDP according to the CIA WorldFactbook, other industries such as banking, agriculture, sports, construction, manufacturing, and real estate all serve to play their roles in the development of the economy of Jamaica. Of the three most influential industries (remittances, tourism and bauxite/alumina), the bauxite/alumina sector was most affected by the global downturn while the tourism industry and remittance flow remained resilient. While highlighting the fragility of the nation's economy, this also points to the importance of tourism to the national economy, and by extension those facilities through which the tourism sector is supported, i.e. international airports and seaports. The sustainability of the transportation sector is therefore even more vital to the economy and to the country as a whole.

Inflation

Inflation [the rate at which the general level of prices for goods and services is rising and, consequently, the purchasing power of currency is falling] has historically been a problematic issue in Jamaica. According to data recorded and available from STATIN, and shown in Figure 2.4 below, the inflation rate in Jamaica averaged 10.02 percent from 2002 until 2016, reaching an all-time high of 26.49 percent in August of 2008 and a record low of 1.80 percent in September of 2015. Inflation rate in Jamaica is reported by the Statistical Institute of Jamaica.

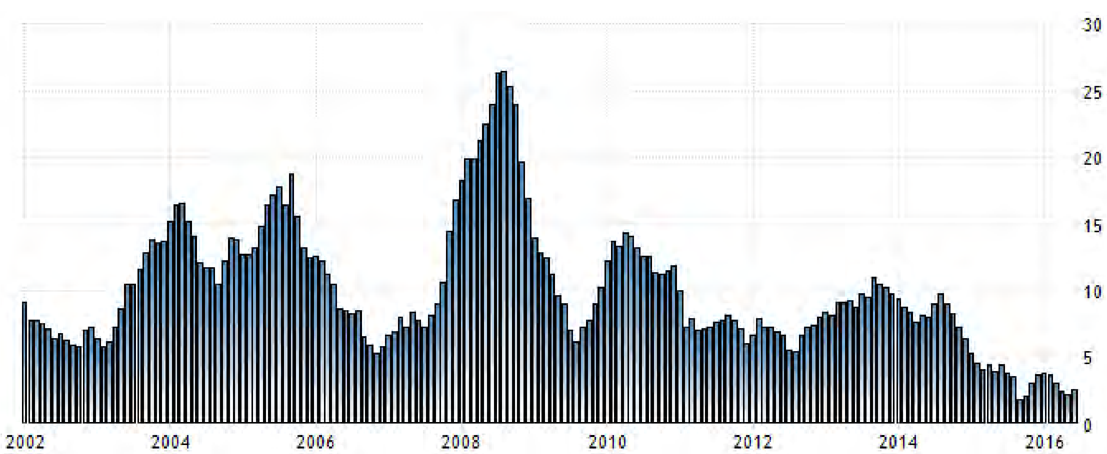


Figure 2.4 Inflation rate in Jamaica as recorded by the Statistical Institute of Jamaica.

[Source: www.tradingeconomics.com]

A 2015 study aimed at assessing the problem of inflation in Jamaica was carried out and reported on with the aid of a news release made available from the STATIN. The study concluded that the cost of electricity was a main factor driving the high rates of inflation in Jamaica. This is primarily because Jamaica does not produce any oil or gas for electricity production and imports, through its seaports, all of the petroleum products that it consumes. Almost all businesses, manufacturing or otherwise, rely on electricity for the running of their operations and therefore every business sector is susceptible to increases in the global oil and gas markets. Locally manufactured goods and local services are therefore particularly subject to rapid increases in costs. This is inclusive of the transportation sector. All the facilities in this study use large amounts of electricity to maintain their operational status and will be severely affected by inflation in this manner.

Logistics Performance Index

Jamaica's Logistics Performance Index (LPI) is the weighted average of the island's scores on the following six key dimensions:

- Efficiency of the clearance process by border control agencies, including customs;
- Quality of trade and transport related infrastructure;
- Ease of arranging competitively priced shipments;
- Competence and quality of logistics;
- Ability to track and trace consignments;
- Timeliness of shipments in reaching destination within the scheduled delivery time.

This LPI therefore indicates the relative ease and efficiency with which products can be moved into, and distributed within a country. The LPI is given in the range from 1 (low) to 5 (high); and is assessed bi-annually by the World Bank.

During the 2007 – 2016 assessment period, Jamaica's scores have consistently been between 2.2 and 2.9 as shown in Table 2.4 below.

There were some countries in the Caribbean region for which data was available, these were: The Bahamas, Cuba, Guyana and Haiti, and the data is shown below in Table 2.4 and Figure 2.5 for comparison to Jamaica. As shown, the Bahamas has consistently had the highest LPI score while the values for Jamaica are typically within the average for countries in the region.

Table 2.4 Logistics Performance Index (LPI) Average Scores for Caribbean countries which were ranked

Year of Assessment	*The Bahamas*	*Cuba*	*Guyana*	*Haiti*	*Jamaica*
2016	2.75	2.35	2.67	1.72	**2.40**
2014	2.91	2.18	2.46	2.27	**2.84**
2012	2.75	2.20	2.33	2.03	**2.42**
2010	2.75	2.07	2.27	2.59	**2.53**
2007			2.05	2.21	**2.25**

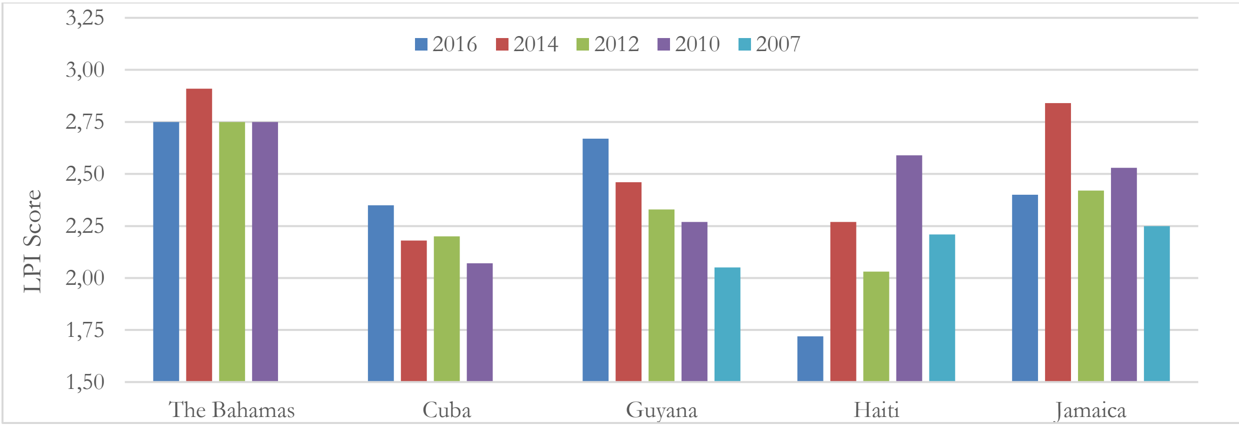


Figure 2.5 Comparative column chart showing Caribbean LPI average scores. [Source: data.worldbank.org]

The index for Jamaica peaked in 2014, perhaps because of the initiative arising at that time to create a logistics hub in the island. This proposed project received negative public feedback because of apparent environmental impacts and was shelved. Nevertheless, the drop in Jamaica's rankings, from 70 (2014) to 119 (2016) out of 180 countries for its logistics readiness, is a negative image for the country, and could impact investor confidence. Generally, investors may be reading the variability in Jamaica's LPI scores cautiously, especially when compared to the stable Bahamas and the consistently increasing scores of Guyana and Cuba.

2.3.2 Jamaica's Economy and Climate Change

Given the slow growth and fragility of Jamaica's economy, the impact of climate change, natural disasters or any other disruption in services is likely to have large and far reaching effects. Although it is very difficult to separate the financial effects of climate change on a sector by sector basis, such as the transportation sector, it is nevertheless clear to see that climate change, particularly related to natural disasters, has the potential to be devastating to the country's economy as a whole. The 2011 - 2016 Minister of Finance, Dr the Hon. Peter Phillips, indicated this at a climate change workshop in July of 2012. He is quoted as saying that data from the Planning Institute of Jamaica (PIOJ) indicates that damage associated with natural disasters (hurricanes, floods and droughts) has cost the country an annual average of two (2) per cent of GDP since 2001 and could reach fifty-six (56) per cent of GDP by 2025. In this regard, he is quoted as saying:

> *"The cumulative loss entailed from this damage is estimated at close to $120 billion. This is money, which would otherwise be spent on developmental tasks rather than simply protecting or relieving the effects of climate-related events,"* – Dr Peter Phillips (July 26, 2012). Climate Change Workshop. Source: Jamaica Information Service

The figure quoted by the then minister is roughly equivalent to 7% of GDP for that year (2012), which is far more than the country can afford given its limited resources.

As Dr Phillips said, the bulk of the funds are spent in "protecting or relieving the effects of climate-related events". Protection likely includes the construction of coastal structures such as sea walls or revetments to safeguard coastal infrastructure such as roadways, from wave effects and storm surge (including sea level rise). "Relieving the effects" could include temporary housing for those that were displaced, provision of aid, infrastructure clean up and in some extreme cases, rebuilding of damaged infrastructure, among other trickle-down effects. It is worthy of note that adaptation strategies or procedures were not considered as a cost by the minister at the time.

2.4 Summary - Jamaica's Profile

Jamaica is the fourth-largest island country in the Caribbean. The island features a predominantly mountainous interior with a narrow, discontinuous coastal plain around the edges. The major cities and population centres, as well as the transportation facilities of this study, are located on this coastline characterized by cliffs, bays and beaches.

The island is located almost in the centre of the Caribbean Sea. Due to this prime location – with close proximity to the Americas, Jamaica is advantageously positioned to become a gateway between the USA and the Caribbean and Latin Americas. This is further boosted by Jamaica being the third most populous Anglophone country in the Americas with an approximate population of 2.7 million people.

Unfortunately, the country has not used its geographic location to its full potential. In addition, the country struggles with a host of social issues - mass emigration of the population in general and of educated persons in particular, high unemployment, urban densification, poverty, violence, gangs, drug trafficking among others – which not only create a negative perception of the island but also stifle economic growth.

The country's economy consistently under-performs and has not been able to develop much economic competitiveness within the region. The lack of growth is felt to result from *the chronic state of fiscal imbalance, underutilization of productive capacity, economic waste of capital and concentration of capital investment in highly capital-intensive sectors and economic enclaves. These conditions, in turn, are associated with a number of dysfunctional pathologies and systemic constraints, operating as both cause and effect in a complex mutual interaction with the investment process. At the top of this list, […] are the following factors: crime and violence, corruption, taxation, supply of electricity, finance and macroeconomic instability.* [Planning Institute of Jamaica (2012)] Several economic indicators: GDP, Inflation and LPI, were examined to better understand the economic context of the island to better frame the focus on the transportation sector.

The cost of the impacts of climate change was also examined. The current cumulative loss of GDP due to damage associated with natural disasters was estimated to be in the order of $120 billion (roughly 7% of GDP). This is a significant number which is made even more worrying given the already slow growth and fragility of the economy. When coupled with the effects of climate change induced impacts such as an increase in extreme hurricanes (Cat 4 and Cat 5), the figure is even more of concern as it is likely to rise. Estimates indicate that it could reach as high as 56 per cent of GDP by 2025 if climate predictions are accurate.

3. The Climate of Jamaica

3.1 Current Climatic Conditions in Jamaica

The Climate Studies Group of the University of the West Indies, Mona (CSGM) has done extensive work in compiling and summarizing climate data for Jamaica, which had been collected by the Meteorological Service of Jamaica (Met Office). The Met Office has unfortunately, due to a variety of circumstances, not always been able to provide data across the entire island for various climate variables. The lack of quality data has meant that the CSGM has had to rely on the use of relatively short data spans to establish climate patterns. In this chapter we describe for Jamaica the average values of many climate variables - temperature, rainfall, radiation, wind and others - as data affords and as provided by the CSGM. In most cases, island averages are given.

3.1.1 Temperature

Land surface temperatures in Jamaica tend to vary monthly, due primarily to the variations in solar insolation reaching the island, i.e. how the earth is orbiting the sun. The average monthly variations in temperature for selected stations in Jamaica from 1992 to 2008 are presented below in Table 3.1. Also shown below (Figure 3.1) is a plot of the average variations for Jamaica (as highlighted in the table) as well as the variations for the two airport stations.

Table 3.1 Average monthly temperature values at 11 stations in Jamaica from 1992-2008. (Data Source: Meteorological Service of Jamaica)

Station	Parish	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bodles	St. Catherine	25.4	25.0	25.3	26.2	26.9	27.5	27.8	27.8	28.0	27.1	26.4	25.7
Case	Portland	24.7	24.6	25.2	25.8	26.5	27.3	27.5	27.5	27.3	26.8	26.0	25.4
Discovery Bay	St. Ann	24.9	25.0	25.1	26.0	26.6	27.3	26.6	27.8	27.8	27.4	26.4	25.6
Sangster	Montego Bay	25.7	25.8	26.3	27.1	27.7	28.5	28.9	28.9	28.6	28.1	27.4	26.4
Duckenfield	St. Thomas	24.8	24.9	25.2	26.0	26.8	27.6	27.8	27.6	27.2	26.7	26.4	25.6
From	Westmoreland	25.0	24.8	25.2	26.1	26.8	27.4	27.6	27.9	27.7	27.4	26.6	25.7
Hampshire	Trelawny	23.2	22.9	23.1	23.5	24.5	24.9	25.5	25.9	25.5	25.2	24.4	23.7
Mason River	Clarendon	20.4	20.3	20.8	21.5	22.1	22.8	23.1	23.2	22.8	22.7	22.2	21.5
Norman Manley	Kingston	26.9	26.9	27.1	27.8	28.4	29.2	29.6	29.4	29.3	28.7	28.2	27.5
Orange River	St. Mary	22.0	22.5	22.8	23.6	24.4	24.8	25.3	25.4	25.2	24.9	23.7	22.9
Worthy Park	St. Catherine	22.1	22.1	22.7	23.6	24.4	24.9	25.2	25.3	25.2	24.8	23.6	22.9
Average across all stations in Jamaica		**24.1**	**24.1**	**24.4**	**25.2**	**25.9**	**26.6**	**26.8**	**27.0**	**26.8**	**26.3**	**25.6**	**24.8**

Using the average values obtained over this 17-year period, it is noticeable that the maximum annual temperature variation for any one station is only three and a half degrees. The general pattern shown across the island is one of cool winters (December to March) and the hottest months in late summer (July to September).

There is insufficient temperature data to enable analysis of spatial variations in temperature across the entire island, however the hilly interior of the island tends to be significantly cooler than the coastal communities due to the variations associated with altitude. Mason River, in the northern hilly regions of Clarendon is the coolest site, while Norman Manley International Airport registered temperatures higher than all other stations.

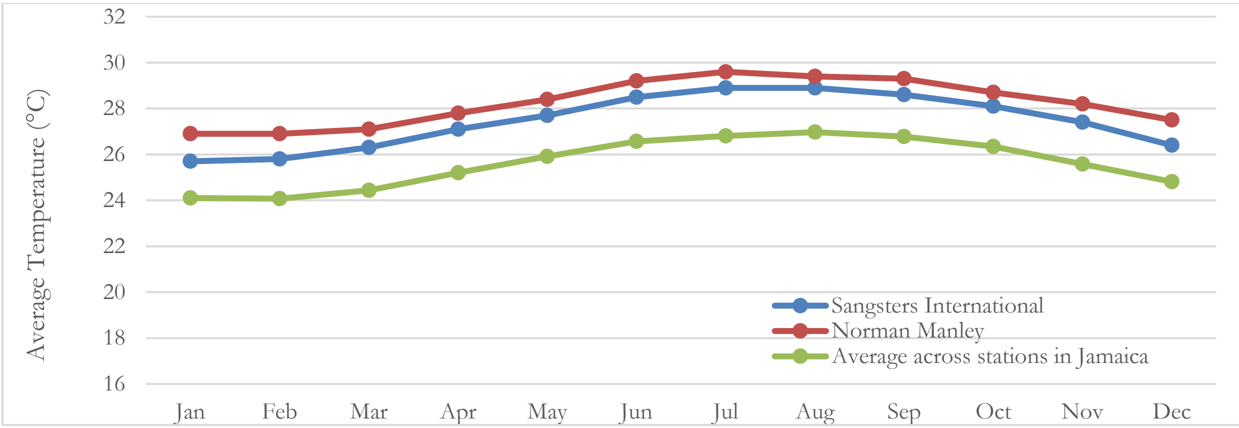


Figure 3.1 Temperature climatology (1992-2008) of Jamaica (green), Norman Manley International Airport (red) and Sangster International Airport (blue). [Data source: Meteorological Service of Jamaica.]

3.1.2 Rainfall

Rainfall trends for the island are shown below in Figure 3.2. The figure highlights the main dry season which occurs from December through April. The wet season is described as 'bi-modal' (double peaked) with an early rainfall season occurring in May-June and a late rainfall season (August to November). The brief dry period (July) which interrupts the wet seasons is often referred to as the midsummer drought (MSD). The late wet season rainfall peak is larger than that for the early wet season, though rainfall totals vary from year to year due to the influence of global climatic fluctuations, e.g. the impact of El Niño (Chen and Taylor, 2002). As depicted in the figure, the bimodal pattern is a consequence of global climatic mechanisms, including the movement of the North Atlantic High (NAH), the appearance of warm sea surface temperatures (SST's), a decrease in vertical wind shear, the location of the Inter-Tropical Convergence Zone (ITCZ) and the onset of tropical and easterly atmospheric waves (CSGM 2012).

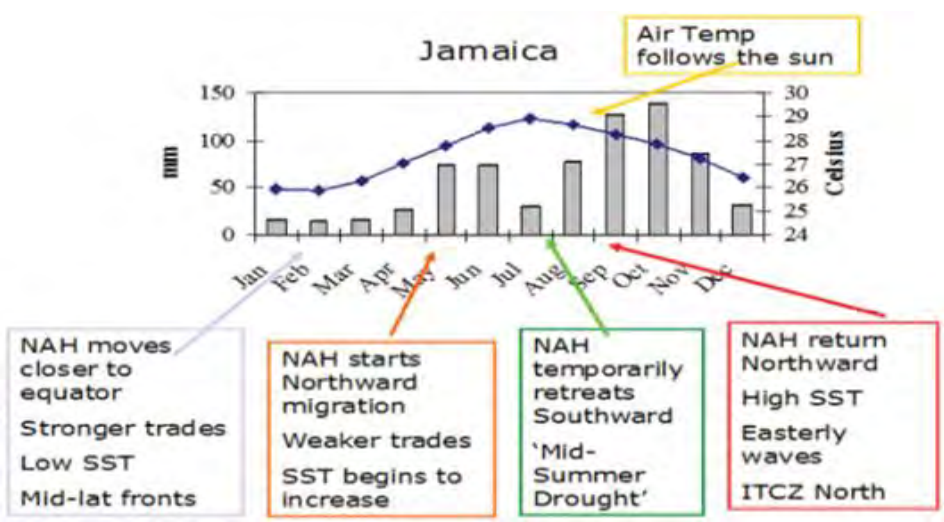


Figure 3.2 Rainfall and temperature climatologies of Jamaica. Bars denote rainfall and the line denotes temperatures. Schematic also shows timeline of large scale systems that affect the climate of the island throughout the year (©CSGM, 2012)

Spatial Variation

The average rainfall values vary significantly between parishes, with the general consensus being that North-East Jamaica receives the most rain in the island, while the southern plains of the island tend to be much drier.

As an illustration of the spatial variation in rainfall, the CSGM used a Kriging interpolation technique to interpolate rainfall station data to fixed grid points and then contour the gridded data to show variations of average rainfall over Jamaica. This is possible for rainfall (as opposed to temperature) because of the significantly larger number of station data points. Figure 3.3 shows the patterns of average annual rainfall and of rainfall from November to January (NDJ), February to April (FMA), May to July (MJJ) and August to October (ASO) calculated using data from 1992-2010.

As expected, the maximum rainfall is located in the Blue Mountains within the parish of Portland. Although the centre of maximum rainfall is only approximate (due to the scarcity of stations in the border region with St. Thomas), it is still clear that Portland is the wettest parish.

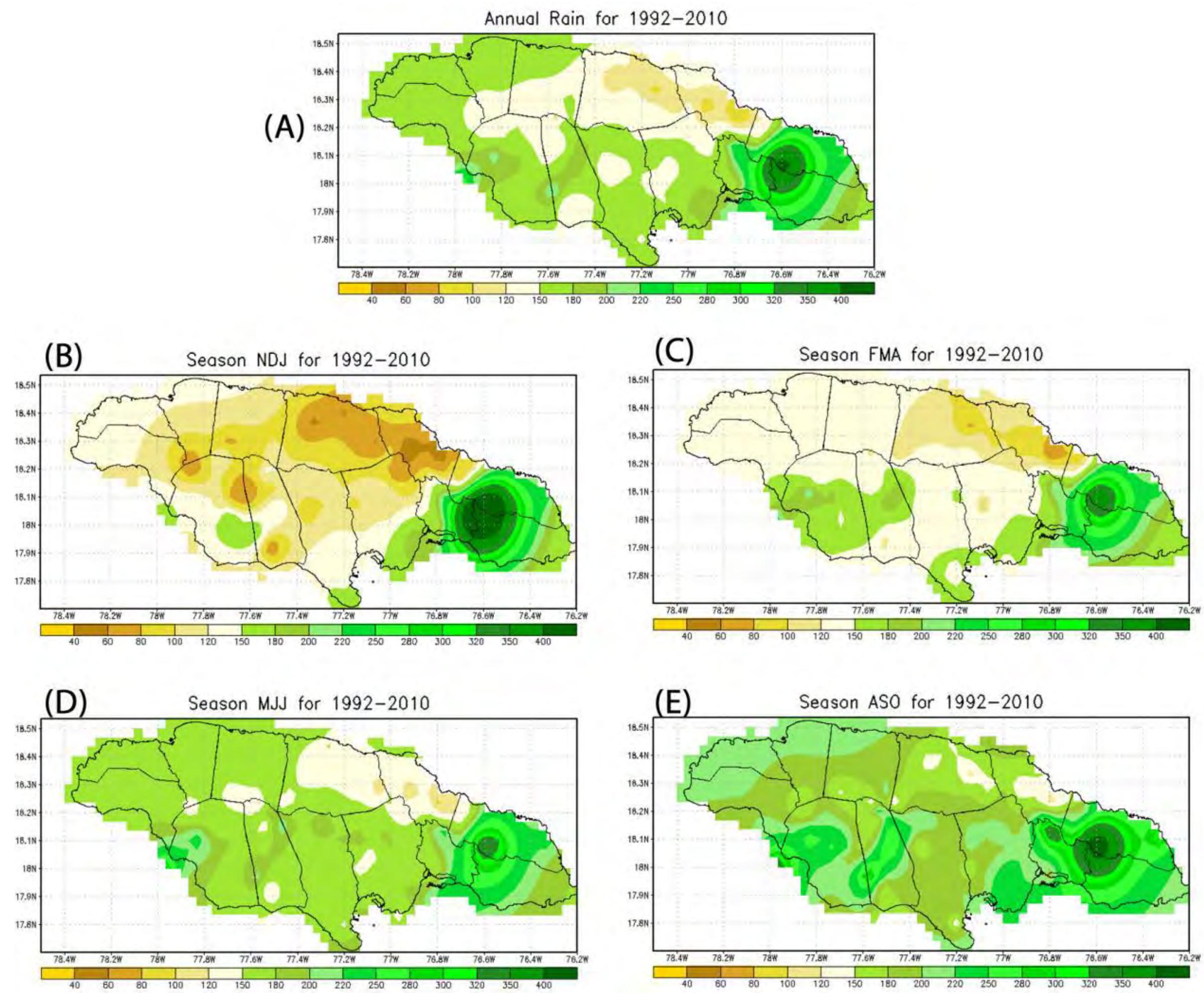


Figure 3.3 Map of rainfall means over Jamaica for (A) Annual, (B) November-December-January (C) February-March-April (D) May-June-July and (E) August-September-October.

3.1.3 Solar Radiation

There are twelve (12) stations across the island of Jamaica where solar radiation instruments are recording data. These pyranometers have been set up by the Meteorological Service of Jamaica and the Department of Physics in each parish except Portland and St. James. The data recorded and shown in Table 3.2 below speaks to both annual variability and spatial variability. The annual variation is linked to the temperature variations. Data shows that through the year, minimum solar radiation is seen in the cooler months of December through to February while maximum solar radiation is recorded in April through to August. Spatial variability is approximately divided horizontally across the island with the southern parishes experiencing more radiation than the northern parishes with St. Thomas, on the south-eastern tip experiencing the most of any other parish.

Table 3.2 Mean daily global radiation in MJ/m²/day at several radiation stations in Jamaica. [Source: Alternative Energy Research Group, UWI (2012)]

PARISH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Manchester	14.6	15.1	18	18.9		19.6	20.4			16.7	15.6	15.1
Trelawny	13.1	13.7	17.4	17.3	17.5	22	17.7	17.7	16.3	14.8	13.3	14.8
St. Elizabeth	16.2	17.1	18.6	18.8	20.9	26.1	24.6	25.4	18.7	16.5	16.1	14.5
St. Catherine	15.2	16.8	19.5	21.5	21.2	19.7	20.8	20.4	19	18	16.2	15.5
St. Ann	12.9	14.9	19.6	21.3	21	21.1	21.6	18.6	18.7	16	14.1	12.9
St. Thomas	16.5	15.8	21.1	22.9	21.9	22.4	22.3	21.1	21.4	17.6	18.4	16.4
Kingston	15.9	18	20.3	20.7	20	19.5	19.9	21.4	19	17.3	15.8	15.4
St. Andrew	14.4	17	19.5	19.5	20	20.5	19.5	18.7	17.8	15.4	15.7	15.2
Westmoreland	15.8	17.5	18.4	19.7	18.4	19.9	18.7	17.8	18.6	16.1	15.2	14.7
St. Mary	15.9	13	13	18.7	18	19	17.9	19.5	17.8	15.9	16.1	15.5
Montego Bay	14.5	15.5	19	20.9	20.6	20	20.5	19.3	16.8	15.9	14.9	13.8
Hanover	13.1	15.6	20.7	22.3	19.8	17.2	17.2	17.2	17.1	16.1	12.2	13.2

Unlike solar radiation, the hours of sunshine incident upon the island vary little throughout the year. The hours of sunlight range between seven (7) and nine (9) per day, regardless of location or the time of year. Variations are slight, and the most notable annual variation relates to the rainfall patterns with more sunlight hours in the dry season and less in the main rainy season. This pattern is to be expected as it is directly related to cloudiness during those months. Spatially this is also a factor, as mountainous areas, which are typically covered by clouds, experience less sunshine hours than coastal areas.

3.1.4 Wind Speed and Humidity

Unfortunately, there is limited data readily available on winds. Although winds have been modelled over the island (Chen et al., 1990) data is only regularly collected at the two international airports. Wind mapping exercises are likely to have been conducted at other times and locations, by private enterprises collecting data, but only the airport data are available to the public. Therefore, only airport data are discussed here. Climate data recorded from the meteorological station at the Norman Manley International Airport (NMIA) is shown in Figure 3.4. Analysis of that data shows that winds were typically from the east-north-east (67.5°) to south-east (135°) directional sector, as dictated by the influential Trade Wind patterns. Average and maximum values for the summer and winter months are shown on the graph. Generally, the rainfall patterns observed were inversely related to the wind speed patterns; i.e. when there is low rainfall there are higher winds. Conversely, the relative humidity tends to mirror the rainfall pattern. It is highest in the wettest months and lower during the dry periods. The data from NMIA suggests that humidity attains maximum values of 90% in the wettest seasons. Average humidity at the airport stations is higher during morning hours, ranging from 72-80%, and lower in the afternoon at 59-65%.

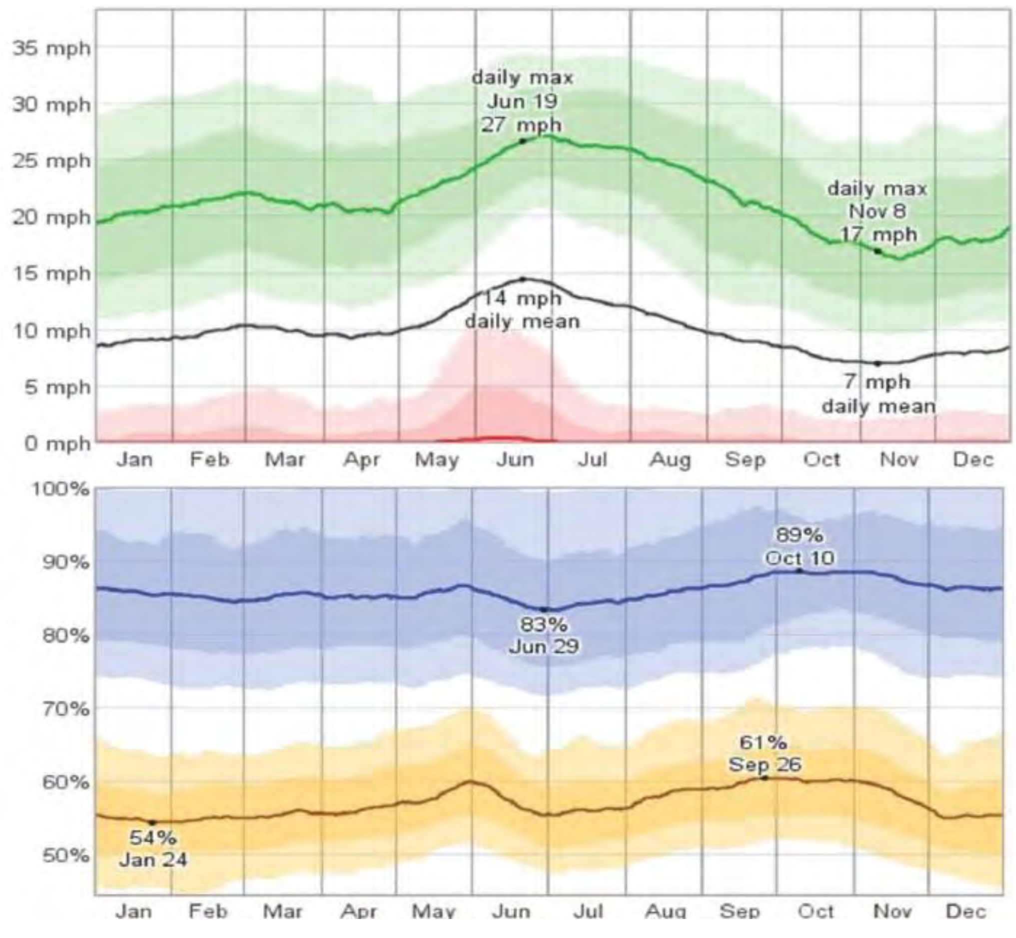


Figure 3.4 Climate data for Norman Manley Airport station – Wind Speeds and Relative Humidity
Top: The average daily minimum (red), maximum (green), and average (black) wind speed with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).
Bottom: The average daily high (blue) and low (brown) relative humidity with percentile bands (inner bands from 25th to 75th percentile, outer bands from 10th to 90th percentile).
Base period: 1974-2012. Source: http://weatherspark.com

3.1.5 Hurricanes

Jamaica lies in the North Atlantic hurricane belt. This means that every year between the months of June and November, the country is vulnerable to tropical cyclones that form between latitudes 10° and 20° north of the Equator and usually move on a westerly track across the northern Atlantic. The most intense of these tropical cyclones are known as hurricanes, which have the most damaging effects on both inland and coastal regions. A tropical cyclone is classified as a hurricane only after it has attained one-minute maximum sustained near-surface (10m above ground level) winds of 33m/s or more. Below this, these cyclones are referred to as tropical storms. The Saffir-Simpson Scale is commonly used to classify hurricanes into five different ranges based on the maximum wind speed attained.

History

An analysis of historical hurricane data was carried out on the Kingston area and the Montego Bay area (as that would cover opposite ends of the island) using an in-house computer program, HurWave and the methods and parameters therein, Banton (2002). As part of the analysis, historical hurricane information from the National Hurricane Centre (NHC) database was reviewed (for storms between 1850 and 2013). All hurricanes passing within a 300km radius of the proposed site were selected from the NHC's database.

The results of the analysis showed that since the year 1850, between 135 to 144 tropical storms and hurricanes have passed within a 300km radius of the sites. This number can be broken down per the categories described by the Saffir Simpson scale as shown in Figure 3.5. The figure shows that the area is more frequently hit by tropical storms, however it is also significantly affected by major hurricanes.

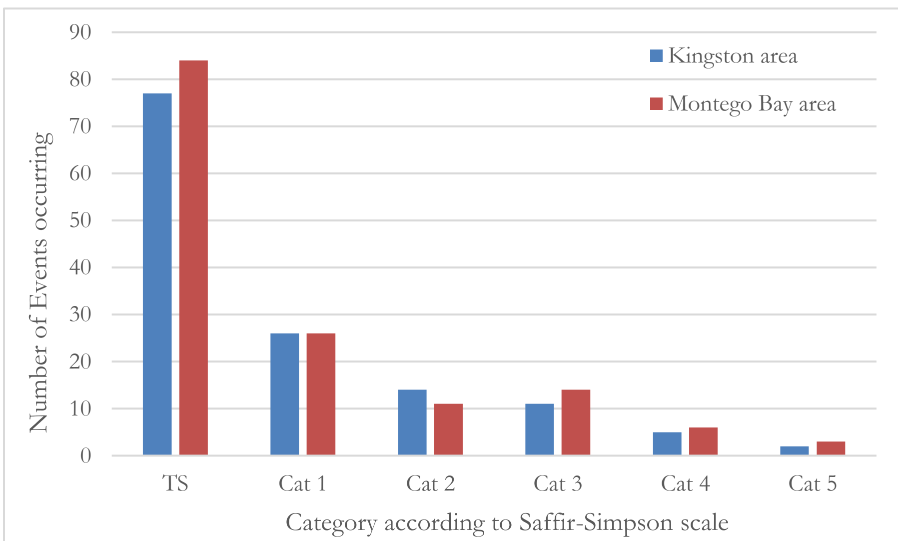


Figure 3.5 Distribution of Saffir-Simpson storm categories of storms passing within 300km of the airports

Figure 3.6 shown below indicates the temporal distribution of storm occurrence over the past 163 years. That figure indicates that, for the number of storms passing within 300 km of each airport facility, typically one event occurs in any given year. However, it can also be seen that there are certain peak times such as the 1930's and the 2000's where hurricane activity was greater, indicating that hurricane frequency is not uniformly distributed.

It is further worth noting that there were no Category 5 storms recorded before 1980 (Hurricane Allen); no recorded Category 4 storms before 1915 in the Kingston area, and none before 1932 in the Montego Bay area. These findings show that the Category 4 storms have only been incident on the island within the last 90 years of record and Category 5 storms within the last 30 years of record.

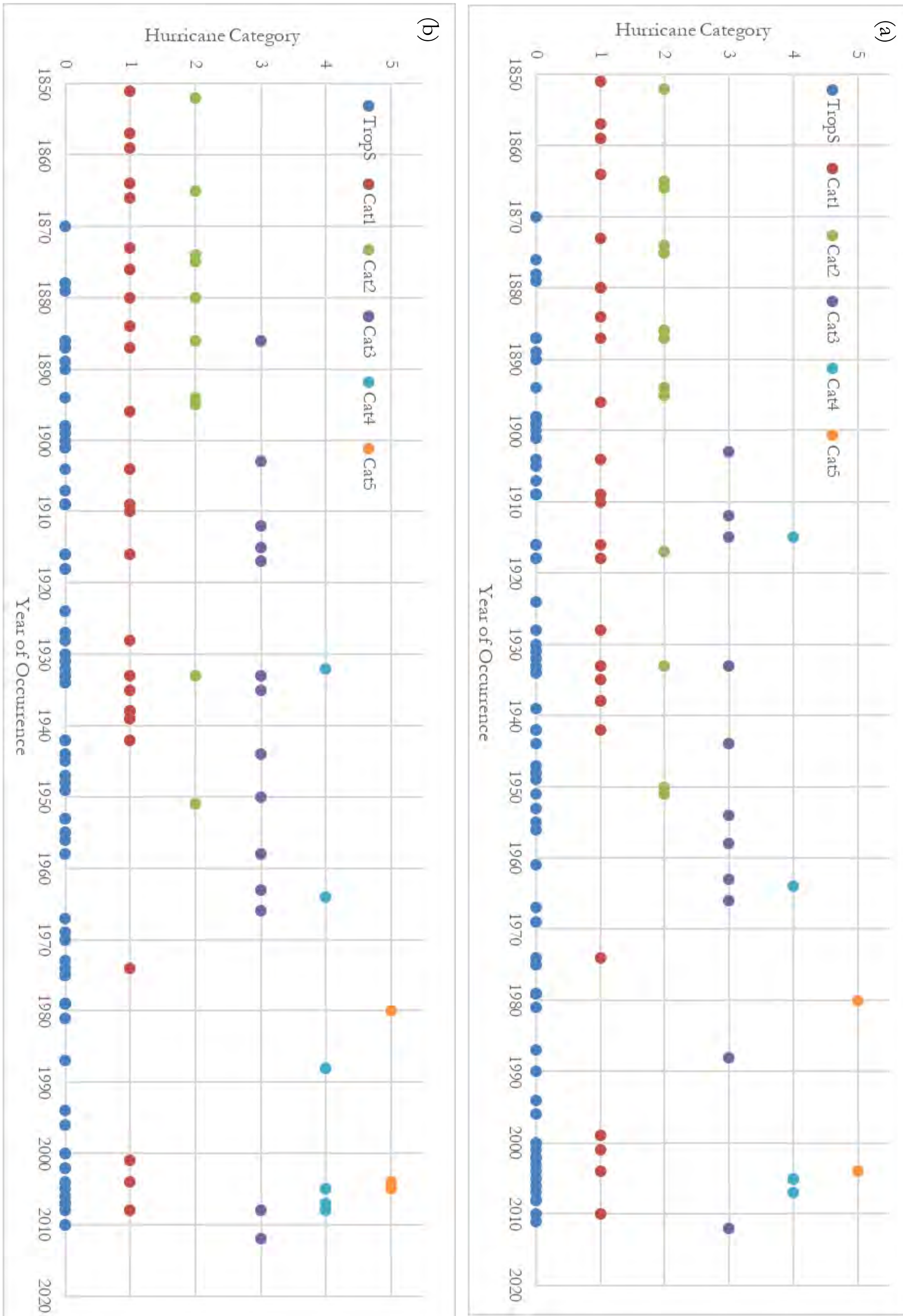


Figure 3.6 Temporal distribution of storm occurrences for storms that have passed with 300km of (a) the Kingston area and (b) the Montego Bay area

Not all the 135 to 144 tropical storms and hurricanes which passed within a 300km radius of the sites had the same impact however. Below is a list of those storms which had a more significant effect on the island per the 'Discover Jamaica' website[4]:

- 1944 - An un-named hurricane destroyed 40 percent of the coconut crop.
- 1951 - Hurricane Charlie hit Jamaica leaving 154 dead, 20,000 homeless, and causing approximately 16 million pounds sterling in damages.
- 1953 - A Tropical Storm affected the northwest coast of the island.
- 1954 - Hurricane Hazel caused widespread rains in eastern Jamaica.
- 1955 - Hurricane Janet unleashed island-wide rains that caused flooding.
- 1958 - Tropical Storm Gerda caused flooding on the north coast.
- 1963 - Hurricane Flora affecting the eastern section of the island causing several deaths.
- 1964 - Hurricane Cleo affected north-eastern coast of the island.
- 1966 - Hurricane Inez affected north-eastern coast of island.
- 1967 - Hurricane Beulah hit Jamaica. St. Thomas was the hardest hit parish.
- 1969 - A Tropical Storm caused extensive damage in eastern and northern parishes.
- 1970 - Tropical Storm Alma caused widespread showers in eastern parishes.
- 1973 - Tropical Storm Gilda caused extensive damage and resulted in the death of six persons.
- 1974 - Hurricane Carmen affected the south coast.
- 1974 - A Frontal System caused flooding on north coast, resulting in extensive damage.
- 1975 - Tropical Storm Eloise caused damage to crops.
- 1978 - A Tropical Depression affected western parishes causing extremely heavy rainfall.
- 1978 - Hurricane David caused flooding in eastern section of the island.
- 1980 - Hurricane Allen missed Jamaica but winds and heavy rains generated by the hurricane ravaged the island causing the deaths of six persons and leaving hundreds homeless.
- 1981 - Hurricane Katrina caused torrential rains island-wide and flooding in the east.
- 1988 - Hurricane Gilbert smashed into Jamaica devastating the agricultural sector, leaving hundreds homeless, and causing billions of dollars in damage. This was the most destructive storm in the history of Jamaica and the most severe storm since Hurricane Charlie in 1951.
- 2004- Hurricane Ivan caused damage across the island, with southern parishes suffering the greatest damage. Storm surges of 3-4 metres were observed in some locations and caused extensive damage to natural coastal systems and housing. This phenomenon was responsible for several deaths.
- 2007- Hurricane Dean rains caused flooding and landslides on the eastern and north-eastern side of the island, blocking several roads. At least two direct deaths were confirmed. Over 1,500 roofs were lost, and 1,582 of the 3,127 damaged homes were uninhabitable.
- 2012- Hurricane Sandy caused millions of dollars in damage and immense dislocation in the eastern parishes of St Mary, Portland and St Thomas.

The vulnerability to the island's population and infrastructure to hurricanes and the associated flooding and wind damage cannot be overstated.

[4] http://www.discoverjamaica.com/gleaner/discover/weather/weather.htm

3.2 Jamaica's Climate Trends and Future Projections

3.2.1 Climate Change Drivers

Historically, the climate in the country has been thought of as being constant as discussed in the preceding section. However, there are some deviations from the typical or average weather behaviour over a given time period which is typically termed 'climate variability'. There are some primary global drivers of climate variability in Jamaica; these are the El Niño phenomenon and sea surface temperatures, the North Atlantic Oscillation (NAO), Atlantic Multi-Decadal Oscillation (AMO) and Caribbean Low Level Jet (CLLJ).

The details of these climate phenomena are quite detailed and will not be discussed here. The table below does however summarize the association between these patterns and their effects in the Caribbean, as well as provide references for further research.

Table 3.3 Some ocean – atmosphere linkages associated with Caribbean rainfall variability and trends. [Source: State of Jamaica Climate 2012]

Ocean-Atmosphere Pattern	Comments	Caribbean	Some References
El Niño	• Warmer than normal eastern Pacific sea surface temperatures	• Caribbean drier and hotter than normal during year of onset • Diminished tropical Atlantic hurricane activity • December to March rainfall below normal in the south Caribbean and above normal in the north Caribbean; Jamaica is in the transition zone • May-July rainfall over Caribbean above normal in the year following onset	Gray 1994 Chen et al., 1997 Giannini et al., 2000 Chen and Taylor, 2002 Taylor et al, 2002 Martis et al., 2002 Spence et al., 2004 Ashby et al., 2005 Stephenson et al, 2007 Jury et al., 2007
La Niña	• Cooler than normal eastern Pacific sea surface temperatures	• On average opposite effect with respect to an El Niño	See El Niño References
Atlantic warm pool	• Warmer than normal Atlantic ocean temperatures	• Caribbean wetter than normal	Wang and Enfield, 2001 Taylor et al, 2002 Wang and Enfield, 2012
North Atlantic Oscillation (NAO)	• Opposing pressure variations between Iceland and Azores • Modulates the behaviour of El Niño	• Positive NAO phase implies a stronger than normal NAH and amplifies the drying during a warm ENSO • Negative NAO phase amplifies the precipitation in the early rainfall season in the year after an El Niño	Giannini et al., 2001 Charlery et al. 2006 Jury et al., 2007 Jury, 2009
Atlantic Multidecadal Oscillation (AMO)		• Positive AMO amplifies tropical Atlantic hurricane activity	Goldenburg et al., 2001
Caribbean low level jet	• Wind intensification south of Jamaica below 600 hPa • Primary peak in July • Secondary peak in February	• Stronger than normal low level jet associated with drier Caribbean	Munoz et al., 2008 Whyte et al., 2008 Wang, 2007

3.2.2 Climate models

Climate models are used to simulate the large scale atmospheric systems in existence and in so doing develop a better understanding of the complexities of the Earth's climate as well as how the Earth's climate is likely to change in the future. Climate models – of which there are two types: Global Climate Models (GCM's) and Regional Climate Models (RCM's) – incorporate the best scientific understanding of the physical processes of the atmosphere, oceans, and the earth's surface using comprehensive mathematical descriptions. GCM's simulate climate across the globe on coarse scales, generally of a few hundred kilometres, and represent for regions like the Caribbean, a first guess of their future climate. They therefore lay the foundation for decision making concerning climate change and its potential impacts. Regional climate models (RCM's) are then used to downscale GCM output to obtain higher resolution results for a specific region.

To make any kind of estimate on the future, some assumptions must be made, particularly as it concerns greenhouse gas (GHG) emissions into the atmosphere. Future concentrations of GHG's will depend on multiple factors, which may include changes in population, economic growth, energy use and technology. The Special Report on Emissions Scenarios (SRES) represent possible pathways for future GHG emissions premised on different storylines of change in the global development factors noted above (Nakicenovic et al. 2000). Forty different scenarios or storylines have been proffered, divided into four families (A1, A2, B1 and B2), with each family having an accompanying narrative describing the relationships between GHG emission levels and the driving factors, i.e. demographic, social and economic and technological developments. None of the scenarios, however, assumes any future policies that explicitly address climate change, so they represent a range of plausible possible futures, i.e. low emission to high emission futures. The storylines combine two sets of divergent tendencies: one set varying between strong economic values and strong environmental values, the other set between increasing globalization and increasing regionalization. The storylines and scenario families are summarized as follows (Nakicenovic et al., 2000):

- A1: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1: convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Emission scenarios of Greenhouse Gases (GHG's) are used to drive General Circulation Models, which simulate the physics and chemistry of the atmosphere and the land-sea interactions that drive climate processes, to produce representations/predictions of future climate, generally through the end of the century. General Circulation Models are run by large modelling centres across the globe which have the computational power to do so. The modality is usually to run General Circulation Models over multiple scenarios since every scenario is plausible. This allows for a range of values for the future projected climate. For regions like the Caribbean, results are also often taken from an ensemble of General Circulation Model runs over one or more scenarios. The biases of any one General Circulation Model are therefore minimized in the results presented.

Global climate modelling results are used as input into the General Circulation Models which provide projections for the Caribbean and specifically Jamaica. The projections are compiled primarily from three sources:

- The IPCC AR4 report
- The UNDP Climate Change Country Profiles
- The CARIBSAVE Climate Change Risk Atlas for Jamaica.

Although useful, Global Climate Models (GCMs) tend not to provide sufficient information at the scale of individual small island states such as Jamaica, due to their coarse resolution. Though Jamaica would possibly be seen by a GCM it would be represented by at most two grid boxes. Therefore, to achieve information at the 'small island scale', Regional Climate Models (RCM's) are used. RCM's are also comprehensive physical models of atmospheric, oceanic and land processes but with higher resolutions (e.g. 50 km or less) and which are run over limited areas using GCM output as boundary conditions. RCM Projections provide projections for Jamaica, and are compiled from two sources:

- Climate Studies Group, Mona (CSGM) PRECIS analyses
- The CARIBSAVE Climate Change Risk Atlas for Jamaica.

In both cases the data comes from the PRECIS regional model run as a part of the PRECIS-Caribbean Initiative (Taylor et al., 2007). This is a collaborative research effort involving Cuba, Jamaica, Barbados and Belize to produce downscaled climate scenarios for the Caribbean using an RCM. The PRECIS (Providing Regional Climates for Impact Studies) RCM was run at 25 km and 50 km resolution over limited domains covering all or part of the Caribbean, Central America, Florida and the northern territories of South America as well as portions of the Atlantic and Pacific oceans, for both present day (1961-1990) and future (2071-2100) periods. The PRECIS RCM was forced with output from the HadCM3 GCM (Jones et al. 2004) and the ECHAM GCM (Jones et al. 2003), for both a relatively high GHG emissions scenario (A2) and a relatively low GHG emissions scenario (B2) to provide a range of projections. The projections are only presented for the end of the century (2080's) and are for the B2 (low) and A2 (high) SRES Emission scenarios. [Details of the PRECIS-Caribbean initiative and the validation of the PRECIS model for present day Caribbean climate are given in Taylor et al. (2007) and Campbell et al. (2010), respectively.] Because of the resolution of the PRECIS model (50 km), data for Jamaica exists for 12 grid boxes located over the island, as shown in Figure 3.7. When these are compared to one general grid box for the GCM, the benefits of using a higher resolution RCM are obvious.

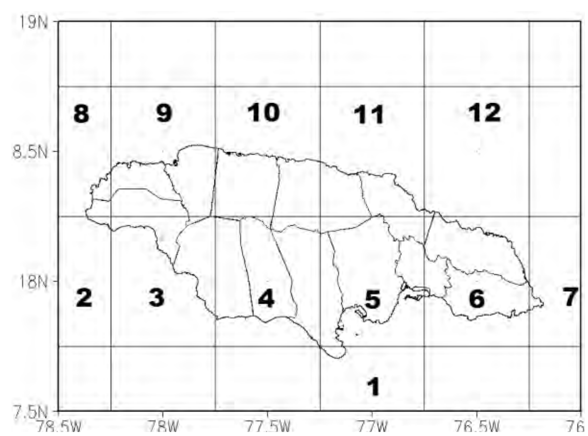


Figure 3.7 PRECIS RCM grid box representation at a resolution of 50 Km over Jamaica.

3.2.3 Temperature

There is a warming trend in Jamaican temperature data, evident from data collected at the airport stations. From 1992 to present the trend at the airport stations is approximately +0.1 degrees Celsius/decade. This is less than the all island value quoted in the CARIBSAVE Risk Atlas which indicates a statistically significant annual trend of 0.27 degrees Celsius/decade. CARIBSAVE values show that the annual and seasonal rate of temperature increase ranges from 0.20 – 0.31 °C per decade. They also suggest that observed increases have been most rapid in June-July-August (JJA) (at a rate of 0.31˚C per decade).

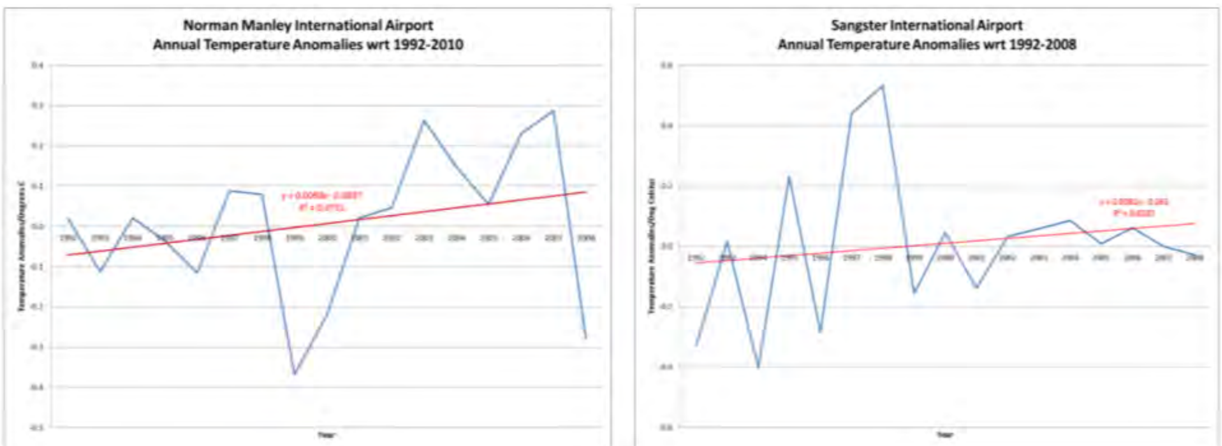


Figure 3.8 Annual temperature anomalies for Norman Manley (left panel) and Sangster (right panel) International Airports with respect to 1992-2010 for Norman Manley and 1992-2008 for Sangster. Units are degrees Celsius [Data Source: Meteorological Service of Jamaica]

It is not only mean temperatures that have been increasing. Data for Jamaica shows that the frequency of very hot days and nights has increased by 6% (an additional 22 days per year) every decade. The frequency of hot nights has increased particularly rapidly in June-July-August, an increase in frequency of 9.8% or an additional 3 hot nights per month per decade. As for the Caribbean, the frequency of 'cold' nights has decreased at a rate of 4% fewer 'cold' nights i.e. 14 fewer cold nights in every year per decade.

Table 3.4 Observed trends in extreme temperature for Jamaica for the period spanning 1960 – 2006. [Data Source: CARIBSAVE Risk Atlas (2011)]

	Variable	Annual	DJF	MAM	JJA	SON
Temperature	Hot Days (TX90p) *frequency / decade*	6.03	6.26	5.63	6.19	7.87
	Hot Nights (TN90p) *frequency / decade*	5.89	1.48	3.63	9.76	4.59
	Cold Nights (TN10p) *frequency / decade*	-4.03	-3.76	-2.81	-5.31	-7.58

Jamaica's mean annual temperature is projected to increase across all models in a 15 GCM ensemble and across all scenarios by 1.1 to 3.2 ˚C degrees by the 2090's. The range of increase is 0.7 to 1.8˚C by the 2050's and 1.0 to 3.0˚C by the 2080's. Projected mean temperatures increase most rapidly over Jamaica in JJA. Further, the frequency of 'hot' Jamaican days and nights should continue to increase, reaching 30-98% of days annually by the 2090's. It is to be noted that the rate of increase varies substantially between models for each scenario. 'Hot' days/nights are projected to increase most rapidly in JJA and SON, occurring on 60 to 100% of days/nights in JJA and SON by the 2080's. 'Cold' days/nights are projected to diminish in frequency, occurring on a maximum of 2% of days/nights by the 2080's. Cold days/nights decrease in frequency most rapidly in JJA.

The RCM generally indicates much more rapid increases in temperature over Jamaica than any of the models in the GCM ensemble when similar scenarios are compared. RCM projections indicate increases of 2.9°C - 3.4°C by the 2080's compared with GCM ensemble projections of 2.0 - 3.0°C. The increased rate of warming is due to the improved spatial resolution which allows the land mass of Jamaica and its impacts on climate, to be represented. Land surfaces warm more rapidly than the ocean. The results suggest that southern Jamaica warms faster than northern Jamaica. Greatest warming will occur in JJA (up to 5 degrees warmer than present).

Table 3.5 Projected change in monthly temperature (°C), comparing baseline to the period 2071-2099. The projected changes are shown for the SRES emissions scenarios A2 and B2, over the western, central and eastern sections of Jamaica, as well as an overall average. [Data Source: Climate Studies Group, Mona (2012)]

MTH	WEST		CENTRE		EAST		JAMAICA	
	A2	B2	A2	B2	A2	B2	A2	B2
JAN	3.0	2.3	3.0	2.2	3.6	2.2	3.0	2.2
FEB	3.0	2.1	3.1	2.1	4.3	2.4	3.1	2.1
MAR	3.0	2.2	3.1	2.4	4.4	3.4	3.2	2.4
APR	2.9	2.1	3.0	2.3	3.9	2.8	3.1	2.2
MAY	3.3	2.3	3.5	2.5	4.4	2.8	3.5	2.4
JUN	3.7	2.6	4.0	2.8	5.0	3.0	3.9	2.7
JUL	3.7	2.8	4.1	3.0	4.9	3.0	4.0	2.9
AUG	3.1	2.7	3.6	2.8	4.8	2.9	3.5	2.7
SEP	2.9	2.6	3.6	2.8	4.8	3.0	3.3	2.7
OCT	2.9	2.5	3.6	2.7	4.8	2.7	3.4	2.6
NOV	2.8	2.4	3.3	2.5	3.7	2.3	3.1	2.4
DEC	2.9	2.4	3.1	2.4	3.3	2.3	3.0	2.3

3.2.4 Rainfall

The mean Jamaica rainfall record shows no statistically significant trend. This is not surprising given the large inter-annual variability in rainfall. However, if a linear trend is fitted to data from individual stations across Jamaica, areas of increasing rainfall over the 1992-2010 period may be identified over the centre of the island and areas of decreasing rainfall over the eastern and western parishes.

Table 3.6 Observed mean and trends in precipitation. [Data Source: CARIBSAVE Risk Atlas (2011)]

Time	Mean (1970 -1999) mm per month	Trend (1960-2006) % per decade
Annual	155.2	-1.6
DJF	107.2	0.2
MAM	142.4	1.3
JJA	141.0	-4.4
SON	227.6	-2.0

Trends in rainfall extremes have largely been negative (decreasing) over the recent past. On an annual basis, statistically significant decreases have been observed in the proportion of total rainfall that occurs in 'heavy' events at a rate of -8.3% per decade over the observed period 1973-2008. There have also been decreases in 1-day and 5-day maxima. These 'trends' should however be interpreted cautiously given the relatively short period over which they are calculated, and the large inter-annual variability in rainfall and its extremes.

Table 3.7 Observed trends in extreme precipitation for Jamaica for the period spanning 1973-2008. [Data Source: CARIBSAVE Risk Atlas (2011)]

	Variable	Annual	DJF	MAM	JJA	SON
Precipitation	% Rainfall in Heavy Rainfall Events (R95pct) *% / decade*	-8.32	No Data	No Data	No Data	No Data
	Maximum 1-day Rainfall (RX1day) *mm/decade*	-23.58	-28.70	-13.30	-0.03	-2.92
	Maximum 5-day Rainfall (RX5day) *mm/decade*	-48.56	-32.94	-18.26	-32.64	-24.88

GCM projections of future rainfall for Jamaica span both overall increases and decreases, but most models project decreases, especially by the end of the century. Projected rainfall changes range from -44% to +18% by the 2050's and -55% to +18% by the 2080's. The overall decrease in annual rainfall is strongly impacted by decreased JJA (early wet season) and SON (late wet season) rainfall. The drying will firmly establish itself somewhere in the middle of the current century. Until then, inter-annual variability will be a strong part of the rainfall pattern, i.e. superimposed upon the drying trend. There is a tendency for decreases in rainfall extremes particularly in MAM. By the 2080's the range of changes is -19 to +9% for the proportion of rainfall during heavy events and -29 mm to +25 mm for 5-day maximum rainfall.

The PRECIS projections of rainfall for Jamaica are strongly influenced by which driving GCM provides boundary conditions. When driven by the ECHAM4 (Max Planck Institute of Meteorology, Germany) GCM, PRECIS projections suggest a moderate decrease in MAM and JJA rainfall, but very little change in total annual rainfall (-14%). When driven by HadCM3 (Hadley Centre, UK), the projections indicate dramatic decreases in annual rainfall (-41%), and more severe decreases in JJA and SON by the 2080's. These HadCM3-driven projections correspond with those that are at the most extreme end of the range of GCM projections. Though the entire island dries out, the most severe drying seems to occur in the west and least severe in Portland. From May onward, irrespective of scenario, it is drying which is projected for the entire island. The months of September through November seem to dry out the most. January through April seem to be least affected. In both scenarios for the HadCM3, rainfall is projected to increase slightly in April.

Table 3.8 Projected percentage change in rainfall, averaged over Jamaica, for the 2080s for annual change and seasonal change. The projected changes for each season and for the annual mean are shown for an RCM driven by ECHAM4 (left column) and HadCM3 (right column) for the SRES emissions scenario A2.

Projected changes by the 2080s A2 Change in %		
	Echam4	HadCM3
Annual	-14	-41
DJF	9	-42
MAM	-23	-36
JJA	-35	-31
SON	-6	-53

3.2.5 Solar Radiation

The observed number of sunshine hours indicates statistically significant increases in sunshine hours in March-April-May (MAM) and June-July-August (JJA) for Jamaica over recent years (1983-2001).

Most models project an increase in sunshine hours over Jamaica by the end of the century. This likely reflects reductions in average cloud cover fractions as the country tends towards drier conditions. Under the A2 scenario, the changes in annual average sunshine hours span -0.2 to +0.9 hours per day, with largest increases in JJA (-0.9 to +1.9 hours per day by the 2080s).

The HadCM3 driven RCM projections indicate particularly large increases (+1.4 hours per day by 2080s under A2) in mean annual sunshine hours by the end of the century, and that these increases lie beyond the envelope of changes indicated by GCMs.

3.2.6 Wind Speed and Humidity

Significant increases over the period have been noted in the annual and seasonal values of wind speed around Jamaica in all seasons over the period 1960-2006. The increasing trend in mean annual marine wind speed is 0.26 ms^{-1} per decade.

The GCM projections generally indicate an increase in mean wind speeds over Jamaica. Changes in annual average wind speeds range between -0.1 and +0.5 ms-1 by the 2080's across all models and emission scenarios. The greatest increases occur in MAM and JJA and range between -0.5 and +1.3 ms^{-1} and -0.2 to 1.2 ms^{-1} respectively by the 2080s.

PRECIS projections for change in wind speed lie in the lower end of the range of changes indicated by the GCM ensemble, indicating small decreases in mean wind speed over Jamaica by the 2080's under the A2 scenario. The largest decreases in wind speeds in these models occur in SON at -0.3 to -0.5 ms^{-1}.

There is no significant trend in Relative Humidity (RH) over Jamaica. The small trends noted are generally positive and increasing except for the March – May and September – November seasons.

Though relative humidity data is not available for all models in the 15-model ensemble, projections from those models for which the data are available tend towards small increases in relative humidity, particularly in DJF and MAM. Care must be taken in interpreting the relative humidity data since many of the GCM's do not explicitly represent Jamaica and therefore only see ocean. Relative humidity over land and ocean can differ significantly.

RCM simulations indicate decreases in RH over Jamaica in all seasons, with changes in annual average RH of -1.1 to -1.7% by the 2080's under the A2 scenario. The largest decreases in RH occur in JJA.

3.2.7 Hurricanes

Tropical cyclone activity in the Caribbean and wider North Atlantic Basin has shown a dramatic increase since 1995. This increase, however, has been attributed to the region being in the positive (warm) phase of the Atlantic multi-decadal oscillation (AMO) and not necessarily to global warming (Goldenburg et al., 2001). Additionally, El Niño and La Niña events influence the location and activity of tropical storms across the globe.

Attempts to link warmer sea surface temperatures (SSTs) with the increased number of hurricanes have proven to be inconclusive (Peilke et al., 2005). Webster et al. (2005) found that, while SSTs in tropical oceans have increased by approximately 0.5˚C between 1970 and 2004, only the North Atlantic Ocean shows a statistically significant increase in the total number of hurricanes since 1995. Both frequency and duration display increasing trends significant at the 99% confidence level. Webster et al. (2005) also noted an almost doubling of the category 4 and 5 hurricanes in the same time period for all ocean basins. While the number of intense hurricanes has been rising, the maximum intensity of hurricanes has remained fairly constant over the 35-year period.

Several recent studies have indicated that the frequency of storms may decrease in a warmer climate. In several of these studies, intensity of hurricanes still increases despite decreases in frequency (CARIBSAVE Climate Change Risk Atlas – Jamaica (2011)). This is supported by a simulation of current and future Category 3-5 storms based on downscaling of an ensemble mean of 18 global climate change models. The results show a doubling of the frequency of category 4 and 5 storms by the end of the 21st century, despite a decrease in the overall frequency of tropical cyclones (Bender et al., 2010).

> *"Changes to the frequency or magnitude of storm surge experienced at coastal locations in Jamaica are likely to occur as a result of the combined effects of: (a) Increased mean sea level in the region …. (b) Changes in storm surge height, or frequency of occurrence, resulting from changes in the severity or frequency of storms. (c) Physical characteristics of the region (bathymetry and topography) …. There is a high degree of uncertainty in projecting potential changes in sea level and hurricane intensity that might be experienced in the region under (global) warming scenarios. This creates difficulties in estimating future changes in storm surge height or frequency."* – CARIBSAVE Climate Change Risk Atlas – Jamaica (2011)

3.2.8 Sea Levels

Global sea level rise over the 20th century is estimated to have been 0.17 ± 0.05 m. Satellite altimeter measurements also show a rate of sea-level rise of about 3 mm/year since the early 1990's (Bindoff, 2007). However recent findings indicate that the estimates may be too conservative and sea level may be rising at a more rapid rate.

> "*The IPCC's AR4 report summarised a range of SLR (Sea Level Rise) projections under each of its standard scenarios, for which the combined range spans 0.18-0.59 m by 2100 relative to 1980-1999 levels. These estimates have since been challenged for being too conservative and a number of studies … have provided evidence to suggest that their uncertainty range should include a much larger upper limit… Recent studies that observed acceleration in ice discharge … and observed rates of SLR in response to global warming … suggest that ice sheets respond highly non-linearly to atmospheric warming. We might therefore expect continued acceleration of the large ice sheets resulting in considerably more rapid rates of SLR.*" – CARIBSAVE Climate Change Risk Atlas.

From estimates of observed sea level rise between 1950 and 2000 by Church et al. (2004), the rise in sea level in the Caribbean appeared to be near the global mean. Table 3.9 shows the rates of sea level rise for a number of locations in the Caribbean, all the values suggest an upward trend.

Table 3.9 Observed sea level rise rates for the Caribbean basin (State of the Jamaica Climate, CSGM 2012)

Tidal Gauge Station	Observed Trend (mm/yr)	Observation Period
Bermuda	2.04 ± 0.47	1932 - 2006
San Juan, Puerto Rico	1.65 ± 0.52	1962 - 2006
Guantanamo Bay, Cuba	1.64 ± 0.80	1973 - 1971
Miami Beach, Florida	2.39 ± 0.43	1931 - 1981
Vaca Key, Florida	2.78 ± 0.60	1971 - 2006

3.3 Summary - Jamaica's Climate

3.3.1 Current Climate Conditions

Analysis of historical data collected on various meteorological parameters governing Jamaica's climate suggests the following:

- Surface temperature in Jamaica is largely controlled by the variation of solar insolation. Average annual temperatures range from 24°C in the winter months to 27°C in the summer months.
- The rainfall pattern is bimodal with early rainfall peaking in May and late season rainfall peaking in October. For all seasons, the maximum rainfall is located in the parish of Portland, close to the border with St. Thomas. The main drivers of the rainfall pattern are the North Atlantic High (NAH) Pressure system, sea surface temperatures, easterly waves, and the Trade Winds.
- The data suggests that Jamaica receives an estimated average of 1825 kWH/m^2 per year of direct solar radiation. The south receives marginally more radiation than the north and the far eastern tip of Jamaica receives more than anywhere else. The annual variation suggests that for the given locations radiation peaks around June.
- Winds are strongest in Portland and St. Thomas, Manchester and St. Elizabeth. The strongest influence is the prevailing wind from the East or North East.
- Data paucity hampers the in-depth analysis of other meteorological variables, particularly analysis of their spatial variation.
- Relative humidity does not vary significantly throughout the year. For morning hours, the average humidity at the airport stations is higher and ranges from 72-80%. In the afternoon it is lower (59-65%).
- Sunshine hours vary little throughout the year, ranging between 7 and 9 hours per day. The average evaporation at Manley International Airport is 7.23 mm/day and 5.50 mm/day at Sangster International Airport.
- There appears to have been a lull in hurricane activity near Jamaica between 1952 and 1973 and much increased activity since 2001.

3.3.2 Historical Climate Trends

Analysis of historical climate data also reveal certain trends which are summarized following:

- There is an upward (linear) trend in temperatures which are consistent with global rates. Minimum temperatures are increasing faster than maximum temperatures. Mean temperatures increasing at a rate of 0.16°C/decade.
- There is significant year to year variability in rainfall due to the influence of various phenomenon (El Niño etc.) that results in no clear trend and an insignificant upward trend. The intensity and occurrence of extreme rainfall events have been increasing between 1940 – 2010.

- There is a regional increase in sea level rise of 0.18 ±0.01 mm/year between 1950 and 2010 which is consistent with the global mean, although there is a higher rate of increase in the later years: up to 3.2 mm/year between 1993 and 2010.
- There has been a dramatic increase in frequency of Atlantic hurricanes since 1995. There has also been an increase in category 4 and 5 hurricanes; rainfall intensity associated peak wind intensities and mean rainfall for the same period.

3.3.3 Climate Projections

Some of the work conducted by the Climate Studies Group, Mona University of the West Indies (UWI-Mona) has been in predicting future climate under various Regional Climate Models (RCM) which are similar to Global Climate Models (GCM) but scaled to suitably fit the Caribbean and the island of Jamaica. Key projections are summarized following:

- Temperatures increase across all seasons of the year, irrespective of scenario, through the end of the century. The mean temperature increase (in °C) from the GCMs will be 0.75-1.04°C by the 2030s and 0.87-1.74°C by the 2050s. However, RCMs suggest higher magnitude increases for the downscaled grid boxes. Mean daily maximum temperature each month at the Norman Manley International Airport (NMIA) station is expected to increase by 0.8-1.3°C by early to mid-century. The annual frequency of warm days in any given month at the NMIA station may increase by 4-19 days by mid-century.
- GCMs suggest that mid 2030s will be up to 4% drier while the 2050s will be up to 10% drier, while by the end of the century the county as a whole may be up to 21% drier for the most severe scenario. Similarly, RCM projections reflect the onset of a drying trend from the mid-2030's, which continues through to the end of the century. However, the decreases are higher for the grid boxes in the RCM than for the GCM projections for the entire country. There is some spatial variation across the country with the south and east showing greater decreases than the north and west.
- For Jamaica, projected SLR for the north coast is 0.43-0.67m by the end of the century with a maximum rise of 1.05m. SLR rates are similar for the south coast.
- There seems to be a shift towards stronger storms by the end of the century: maximum wind speed increases of +2 to +11% and rainfall rates increasing +20% to +30% for the hurricane's core. Although there is no statistically significant increase in the frequency of all hurricanes, it is predicted that there will be an 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

3.3.4 Climate Projections effect on Transport

Of the climate projections highlighted above, the temperatures and sea level rise are of the greatest immediate concern. Extremely hot temperatures cause excessive strain on HVAC systems which affect operations and functionality of the facilities. Further, these extreme temperatures can affect asphalt both on the linking roadways and on the airport tarmacs. Sea level rise is also a grave concern as all the transport facilities under this study are located in low-lying coastal areas that are subject to inundation by rising waters. Increasing and stronger storms are also of concern, as they have the potential to cause large disruptions in the service operations of both the airports and seaports and can also cause significant damage to the facilities and equipment.

4. Critical Transport Infrastructure

As discussed earlier in Section 1.1.1, Jamaica's multi-modal transportation system is comprised of air, land, and maritime elements as outlined below.

According to Vision 2030 Jamaica. Transport Sector Plan 2009-2030. Transport Task Force July 2009: *Jamaica's transport system includes:*

(i) a total of 15,394 km of road network (844 km of arterial roads, 717 km of secondary roads, 3,225 km of tertiary roads, 282 km of urban roads, 10,326 km of parochial roads and 800 bridges). Source: Transport Policy.;

(ii) an airport infrastructure of two international airports and four domestic aerodromes;

(iii) a railway network covering approximately 331 km of track as well as six privately owned mining railways lines; and

(iv) a maritime transport infrastructure of fourteen seaports.

All of these various elements in the sector play critically important roles in the development of Jamaica's economy through the importation and subsequent distribution of goods (food and energy) as well as through the direct contribution to vital economic sectors of the country.

> *During the period 2004-2008, Transport, Storage and Communication (TS&C) contributed on average 11.5% to Jamaica's Gross Domestic Product (GDP). [Based on Contribution to Total Goods and Services Production in Basic Values at constant (2003) prices (PIOJ)] In 2008, transport (road, railway, water and air including services allied to transport) and storage contributed 5.6% to total GDP. [Based on Contribution to Total Goods and Services Production in Basic Values at constant (2003) prices (PIOJ)] The overall transport sector (including land, sea and air transport) is the largest consumer of petroleum in the Jamaican economy, accounting for 37% of the total quantity of petroleum consumption in 2008. [Economic and Social Survey of Jamaica, 2008].* – Vision 2030 Jamaica. Transport Sector Plan 2009-2030. Transport Task Force July 2009.

The transport sector therefore represents a critical component of Jamaica's economy given its impact on national development. One of the most fundamental attributes of the sector is the ability to move persons, goods and services between spatial locations at the local, regional and international levels. The efficient management of the sector can therefore provide tremendous economic and social gains to a country through indirect and direct employment as well as induced development which ultimately leads to wealth creation and growth.

To harness the potential for growth, the Ministry of Transport within the Government of Jamaica undertook a strategic analysis of the sector, a key component of which was SWOT analysis which sought to identify the main strengths, weaknesses, opportunities and threats for the sector. For the transport sector in Jamaica the identification of strengths and weaknesses represents the internal assessment of the sector while the consideration of opportunities and threats represents the analysis of the external environment for the sector. The SWOT analysis was then used to form the basis for identifying goals, objectives and strategies for the Vision 2030 Transport Sector Plan; to apply the strengths and address the weaknesses of the sector, and capitalize on the opportunities and mitigate the threats to the long-term development of the sector. The results of the SWOT analysis conducted are summarized in Table 4.1 below for the overall transport sector.

Table 4.1 SWOT Analysis of Overall Transportation Sector

DIMENSION	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
LOCATION	• Geographic location of Jamaica is asset for marine and air transport sub-sectors	• Poor strategic route development plan to utilize Jamaica's location in the air sector	• The potential for establishment of Jamaica as a major logistics junction for land, air and marine transport sub-sectors	• Small islands are particularly vulnerable to climate change • Location in region prone to natural hazards including hurricanes
FACILITATION	• Jamaica is a world brand tourist and shipping location • Facilitation convention for maritime cargo to be signed	• Highly bureaucratic systems • Poor quality service to transport sector by some public service entities • Complicated fee structure • Tedious immigration and customs procedures	• Existence of best practices for transport sector in other countries that may be applied to Jamaica	• Competition from other countries in the region in provision of transport services
ECONOMIC	• Performance and growth of maritime subsector	• High costs of doing business in transport sector • High energy costs and dependence on imported petroleum	• Continued interest of private sector for investment in sector • Development of South-South trade	• Rising capital and operating costs • Global economic downturn which may reduce the demand for transport services
MODERNIZ-ATION	• All transport sub-sectors are have modernized elements	• Lack of adequate investment	• Availability of modern technology to establish a more efficient and financially beneficial sector	• Rising capital and operating costs
FACILITIES	• The marine and air facilities are at globally high standards	• Existing facilities do not have the needed capacity for projected growth	• Potential growth of the sector provides basis for establishing responsive infrastructure	• Competing destinations for investment in transport facilities
EDUCATION AND HUMAN RESOURCES	• Jamaica has a number of technical educational institutions including Caribbean Maritime Institute • Jamaica has the largest English speaking workforce in the region	• Relatively weak consultation culture • Lack of adequate multi-lingual skills • People are not being adequately trained for the job market in transport sector	• Examples of consultative culture and integrated approaches to human resource development which can be applied to Jamaica	• Brain drain of skilled persons including from transport sector
REGULATION	• Existence of established regulatory agencies	• Regulatory standards not good across all sectors	• Opportunity to integrate economic, social and environmental strategies through regulations	• Changes in international regulatory requirements

Due primarily to Jamaica's location in the northern Caribbean as an English-speaking island geographically close to the United States, the country is advantageously placed to become a gateway between the USA and the Caribbean and Latin Americas. Development plans such as these were outlined in the article on the webpages of the Ministry of Transport (MoT): *Jamaica Poised to Develop as A Transport Hub Through Multi-Modal Transport System*. The article summarized statements from Transport and Mining Minister Lester 'Mike' Henry as he addressed the UN Economic Commission for Europe's 70th Anniversary Meeting of the Inland Transport Committee in Geneva.

> *"Minister Henry told the gathering […] that Jamaica is committed to achieving its Sustainable Development Goals through enhanced connectivity within and between territories for the safe, efficient and cost-effective movement of people, goods and services in a" just- in- time world". He said new models of connectivity must be pursued and implemented ... He also told the gathering that designing connected cities around state of the art infrastructure, is fundamental to our present and future agendas for improved mobility of people goods and services for sustainable development."* http://www.mtw.gov.jm/index.php/news/31-2017/350-jamaica-poised-to-develop-as-a-transport-hub-through-multi-modal-transport-system Copyright© 2017 Ministry of Transport and Mining.

Therefore, the ports and airports are not only valuable in their own right, they are also vital to the strategic development of the nation. The importance of adaptation of these facilities to both climatic and non-climatic stressors should therefore be of paramount concern to our government in its planning for the future safeguarding of these critical facilities.

Airports and seaports are potentially vulnerable to hurricanes, precipitation increase, temperature increase and storm surge due to sea level rise. Specifically, this includes wind damage to assets, redirection of flights or vessels, flooding of airfields, docks and access roads causing delays, scour of embankments and earthworks, reduced equipment performance, increased energy use and demand, and potential closures and failures due to storm surge. All of this damage to infrastructure or disruption of service is quite costly. Further, a disruption in any of the transportation facilities can often have massive trickle-down effects: profit/loss because of failure to deliver cargo on time, additional incurred expenses depending on the nature of the delay, perceived poor level of service and company reputation/customer relations managing angry travellers among many others. All disruptions in the transportation services and facilities should therefore be minimized for the health of the economy.

The airports, seaports and the roads that link them to population centres can be considered particularly vulnerable to those disruptions related to climate change such as sea level rise, storm surge from hurricanes, increased winds, etc. due to their location of the facilities on low-lying areas of the coastline. Because of their special vulnerability to climate change stressors, and because of their undeniable significance to the nation's economy, UNCTAD has focused the project on the island's seaports and airports. In particular, the project is to focus on those facilities which are critically important to the nation's economy and functioning because of their assets and the services they provide and to which facility disruptions would be detrimental to the economy. The transport facilities selected for further analysis are:

- The Sangster International Airport (SIA)
- The Norman Manley International Airport (NMIA)
- The Kingston Container Terminal (KCT)
- The Historic Falmouth Cruise Port (HFCP)

The assets, criticality and vulnerability of each of these facilities will be discussed in greater detail in the subsequent sections.

4.1 Ownership, Operations and Regulatory Framework

The 1974 enactment of the Airports Authority Act transferred to the Airports Authority of Jamaica (AAJ) responsibilities for the ownership, management and commercial functions of the two (2) international airports. In 1997, AAJ's responsibility was expanded to incorporate the four (4) active domestic aerodromes. All the airports owned and operated by the AAJ are therefore:

International Airports	Domestic Airports
Norman Manley International Airport – Kingston	Tinson Pen Aerodrome – Kingston
Sangster International Airport – Montego Bay	Negril Aerodrome – Negril
	Ian Flemming Airport – Ocho Rios
	Ken Jones Aerodrome – Port Antonio

One of the primary responsibilities of the AAJ is to oversee the expansion and modernization of facilities at the island's international and domestic aerodromes. In April 2003, AAJ divested the operational responsibility (but not the ownership), of SIA to MBJ Airports Limited, a private sector operator. In October 2003, NMIA Airports Limited, having been incorporated as a wholly-owned subsidiary of AAJ, commenced operation of the Norman Manley International Airport (NMIA). It is proposed that this airport will also be privatized in due course. It is the responsibility of AAJ to provide oversight and contract administration for the concession agreement which is in place with each of the Airport Operators; MBJ Airports Limited and NMIA Airports Limited. The AAJ's decision to privatize both international airports is a direct result of a Government of Jamaica (GoJ) policy. The policy directive was driven by the need to attract private capital to finance the required levels of expansion and development at the international airports to cope with the projected growth in aircraft and passenger traffic; the policy is also in keeping with international trends. The privatization policy applied solely to international airports; therefore, as a part of its responsibility, AAJ continues with the operation and management of the four domestic aerodromes.

A similar arrangement exists for the seaports. The Port Authority of Jamaica (PAJ) is a statutory corporation established by the "Port Authority Act" of 1972. It is the principal maritime agency responsible for the regulation and development of Jamaica's port and shipping industry. Further, the PAJ is also responsible for the safety of all vessels navigating the ports of entry and regulation of the tariffs charged on goods passing through the public wharves. The PAJ is the landowner for both ports in this study, however the daily operations of the ports are managed by private concessionaires who have acquired the operational responsibility for them. Since 2015, the KCT has fallen under the operational jurisdiction of a consortium: The Kingston Freeport Terminal Limited (KFTL) - jointly owned by the members of the Consortium, Terminal Link [TL] and CMA CGM with equity interests of 40% and 60% respectively. In 2010, a partnership between Royal Caribbean Cruises and the PAJ spurred on the desire to create a new cruise ship port which could successfully handle the larger cruise ships. From this partnership, the Falmouth Jamaica Land Company was formed which operates and manages the HFCP while the PAJ maintains the ownership of the lands.

Both the AAJ and the PAJ are housed under the Ministry of Transport and Mining (MoT), which has regulatory responsibility for the safety of all modes of transportation, whether publicly or privately operated. Other agencies fall under this ministry's purview, such as the National Works Agency (NWA) with maintenance responsibility for all of the island's roadways, among others. The full list of agencies under the ministry portfolio are listed here: http://www.mtw.gov.jm/index.php/agencies.

Although discussed in greater detail in their relevant sections, Figure 4.1 shows a general overview of the ownership and operational framework for the facilities under this study.

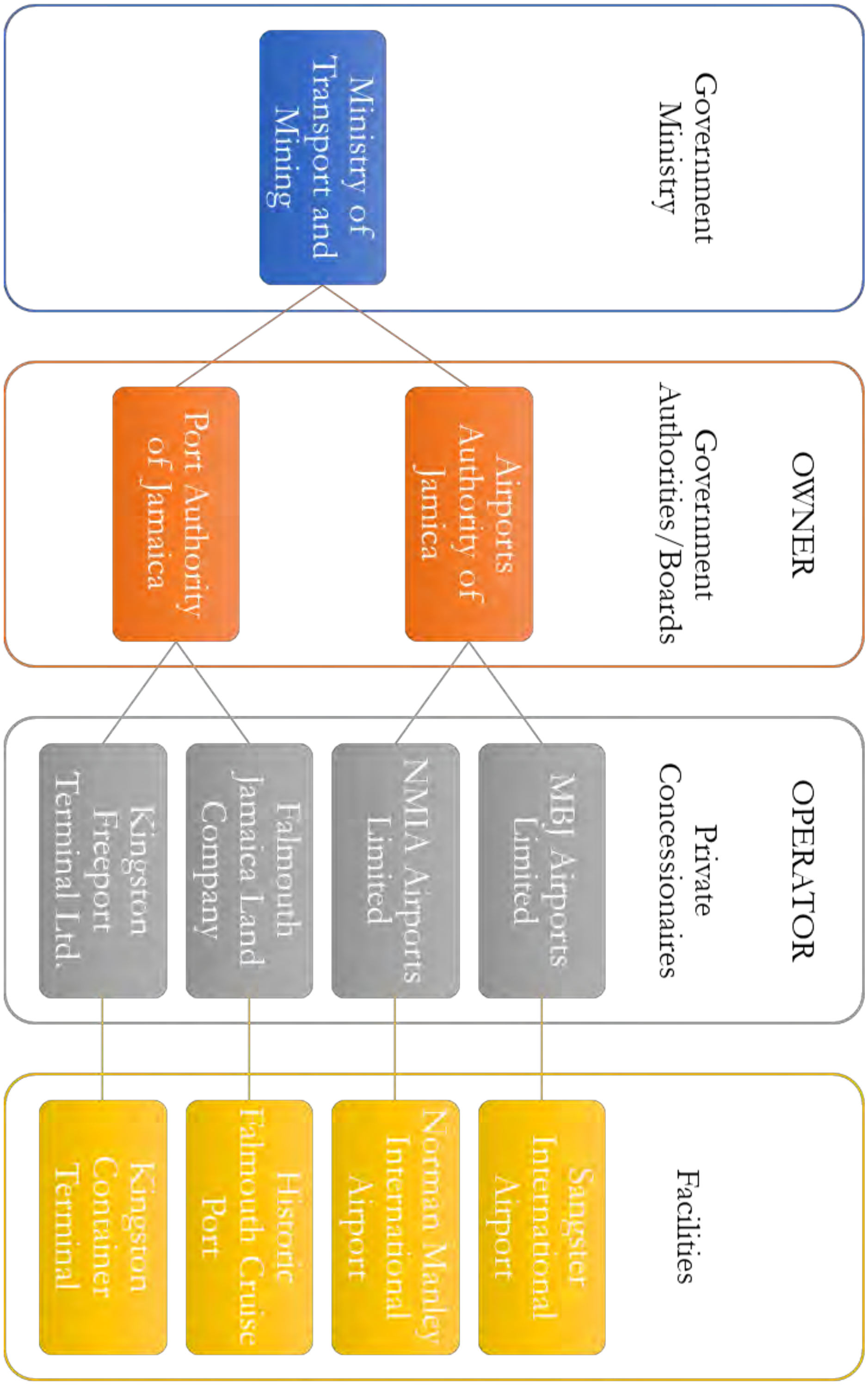


Figure 4.1 Ownership and Operational Framework for facilities of focus

4.1.1 Legislative and Regulatory Framework

Despite their privatisation, all the facilities are still governed by various statutes issued by the Government of Jamaica. It is the combination of the acts, regulations, policies, procedures and CEO's instructions that will together establish the mandatory rules of operation for all the facilities which are the focus of this project. Therefore, should changes in the operations or physical changes in the infrastructure be deemed necessary for better adaptation to climate change, these will have to be agreed to by the respective CEO but governed by the legislation which currently has the legal administrative authority over the facility.

The Jamaica Civil Aviation Authority (JCAA) was established in 1996 to address the safe and orderly development of air transport services in Jamaica. The Authority, which replaced the Civil Aviation Department, was to strengthen safety measures and regulation of the Jamaican air transport sector. The JCAA currently regulates all air navigation activities and matters relating to safety and security in civil aviation in Jamaica and Jamaican airspace, as stipulated by the International Civil Aviation Organization (ICAO). As a member State of the ICAO, Jamaica is required to ensure that civil aviation operations are carried out in accordance with the Standards and Recommended Practices (SARPS) of the 1944 Chicago Convention on International Civil Aviation. The regulatory areas under the responsibility of the JCAA can be categorized into two (2) main areas: flight safety and economic regulation. Flight safety includes the licensing of industry personnel and continued safety and security oversight of all aviation service providers. Economic regulation relates to the regulation of airport services and charges, permits for charter flights and air transport licences to aircraft operators. Additionally, the Authority provides air navigation services incorporating air traffic management, air traffic control training and aeronautical information services, as well as aeronautical communication services through its subsidiary, AEROTEL. AEROTEL was established in August 1978 for the provision of engineering and telecommunication services to the aviation sector. The entity is a subsidiary of the JCAA, and its functions include designing, installing, maintaining and operating aeronautical telecommunication facilities and systems for various entities. These include the JCAA, Meteorological Office, AAJ, Airlines and users of Jamaica's airspace, the Kingston Flight Information Region (FIR). Additionally, the 'Civil Aviation Act' and more specifically the Civil Aviation Regulations of 2004 will have to be consulted for the two international airports under the study. Part XIII of these regulations prescribe the requirements for: (a) the operation of aerodromes; (b) certification of aerodromes and the requirements that apply to operators of certified aerodromes; (c) safety inspections of aerodromes; (d) the management of obstacles and hazards at aerodromes; and (e) the obligations of an aerodrome operator. The Twenty-First Schedule also provides the minimum standards which an aerodrome operator is obliged to meet in operating an aerodrome in Jamaica. Therefore, any physical changes to either of the airport facilities under this project would have to meet or exceed the standards in this act. Or perhaps an amendment to this act would be in order to include adaptation strategies for the future of all the facilities falling under the act.

It should be noted that changes to the NMIA facility of a physical nature would also have to be governed by the 'Protected Areas Policy' as the Palisadoes peninsula, its surrounding waters with mangroves and seagrass meadows and the adjacent Port Royal Cays and coral reefs comprise an ecological complex of significant social and economic value to Jamaica and that area was designated a protected area in September 1998.

The two ports being considered under this project (HFCP and KCT) are also governed by legislative statutes, particularly the 'Port Authority Act' and the 'Harbours Act'. The Port Authority Act authorises the Port Authority to declare harbours, and establish or alter boundaries of harbours. It allows for the prohibition of the discharge of rubbish, earth, stone, ballast, mud, oil, mixtures with oil or its residues, as well as the removal of stones and gravel from reefs, shoals, or cays. The Marine Divisions of the Port Authority regulates the construction of structures on or over the water, or dredging activities. It empowers the Authority to regulate the use of all port facilities in the port including berths and stations. It also allows the Authority to make by-laws for the control and management of the wharves and premises, regulate the loading and discharging of vessels, and carry out the compulsory acquisition of lands for bringing into effect any of the provisions of the Act. The Harbours Act allows the Marine Board to make rules for the regulation and control of any harbour in the island and of the channels and approaches leading thereto and of persons, boats and vessels using such harbour or approaches, and for all purposes connected with any such matters. According to the Act, the duty of the Harbour Master includes all matters relating to maintaining and protecting the harbour and shipping channels.

These two acts are thus of paramount importance in the governance of any changes to the existing port facilities, even the dredging of the channels. Any adaptive measure employed to combat climate change at either port will have to be in sync with the regulatory framework provided by these two acts. As previously mentioned in relation to the airport upgrades, any adaptive concepts or strategies for ports that seem to not be covered within the acts may require the consideration of an amendment to the existing acts to accommodate future issues with the port facilities.

The Climate Change Policy Framework for Jamaica, which was adopted in September 2015, creates an institutional mechanism and structures to facilitate the development, coordination and implementation of policies, sectoral plans, strategies, and legislation to address the impacts of climate change. In this regard, the Policy Framework provides for specific strategies, legislation and policies to be adopted and implemented, including:

- Enactment of framework for climate change mitigation and adaptation;
- Development of a Climate Financing Strategy;
- Development of Research, Technology, Training and Knowledge Management;
- Regional and International Engagement and Participation;
- Promotion of Consultative Processes and Communication to Improve Public Participation in Mitigation and Adaptation Response Measures;
- Strengthening Climate Change Governance Arrangements;
- Development and incorporation of mechanisms and tools to mainstream climate change into ecosystem protection and land-use and physical planning.

4.2 *Sangster International Airport*

4.2.1 History and Description of Assets

Sangster International Airport (SIA) is located on the northwest coast of the island, at Latitude 18° 30' 13" and Longitude 77° 54'48" and is roughly 5 kilometres east of the main city of Montego Bay. The north coast of Jamaica is known as the country's main tourism region and as such the airport is close to a wide range of hotel and resort facilities, as well as other tourist attractions. For these reasons, the airport is the more popular airport for tourists visiting the north coast of Jamaica.

It has been primarily catering to visitors to the island since the completion of its construction in February 1947. *"At the time (…), the town of Montego Bay was more like a playground for the rich and famous, and was considered then, one of the premier vacation spots within the Caribbean, just as it is today."* (https://en.wikipedia.org/wiki/Sangster_International_Airport). The airport, originally named the Montego Bay Airport, was operated by Pan American until September 1949 when the Jamaican government took control of the facility. Since then, the airport has upgraded, expanded, changed names and changed hands.

In 2003, SIA was privatised and turned over by Airports Authority of Jamaica (AAJ) to a consortium. The consortium is referred to as 'MBJ Airports Limited' but the members of the consortium have changed hands several times since its conception. Relations between the new management and unions have been difficult, with a strike in November 2007 and again in November 2009.

The current team, headed by Dr Rafael Echevarne, has been performing well and revealed at a 2015 press conference that the facility falls among the elite group of one fifth of the world's airports that are certified by the International Civil Aviation Organization (ICAO); which means it has been complying with all those standards and recommended practices set forth by the organization. Further, the airport has won the World Travel Awards "Caribbean's Leading Airport" for the years 2005, and 2009 to 2015, further emphasizing its importance as a critical transport facility for the tourism sector.

Facilities and Features

The sole roadway access to the SIA is an offshoot of a roundabout which merges Sunset Blvd., The Queens Dr, and the A1 highway as shown here in Figure 4.2. The airport access is a small roadway accommodating only one lane of traffic in either direction. Although this could potentially cause an issue in the event of an urgent need to evacuate the facility, it has not been an issue to date.

Figure 4.2 Google Earth imagery showing SIA entrance

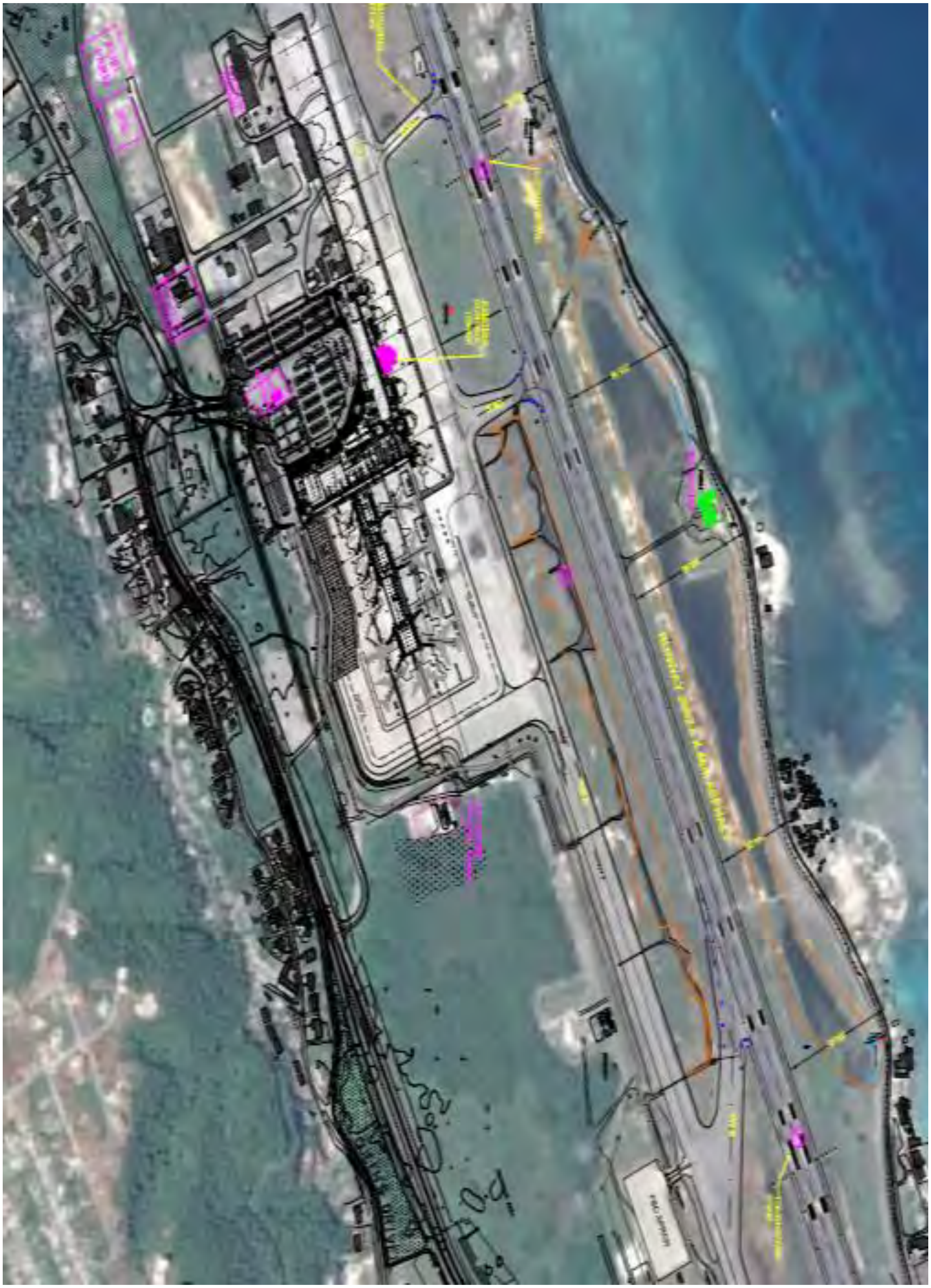


Figure 4.3 Facility overview map of the Sangster International Airport

The overview of the facility is shown in Figure 4.3 above. As shown on the drawing, the sole runway is 2662.4m long by 46m wide and there are 3 taxiways that lead to the runway. The runway maintains a constant elevation of 1.37m above MSL along its entire length, except at its easternmost end where the elevation drops to 1.18m. To the north of the runway there are some low-lying retention ponds, followed by the northern boundary of the airport. Just beyond this boundary is a narrow parochial roadway (Kent Avenue) and the coastline. Currently, the runway is on average 195m away from the coastline, 144m at its closest and 222m at its farthest.

The domestic terminal is to the west of the facility and the international terminal is to the east of that. The entire airport features 19 gates for airplanes of different sizes. The terminal buildings are all located to the south of the runway. The terminal building, in addition to housing administrative functions, is home to 59 stores that are inclusive of: 8 duty free stores, 28 souvenir stores and 23 food and beverage locations. The terminal map is shown below in Figure 4.4. The vast majority of these stores are small in terms of both size and sales.

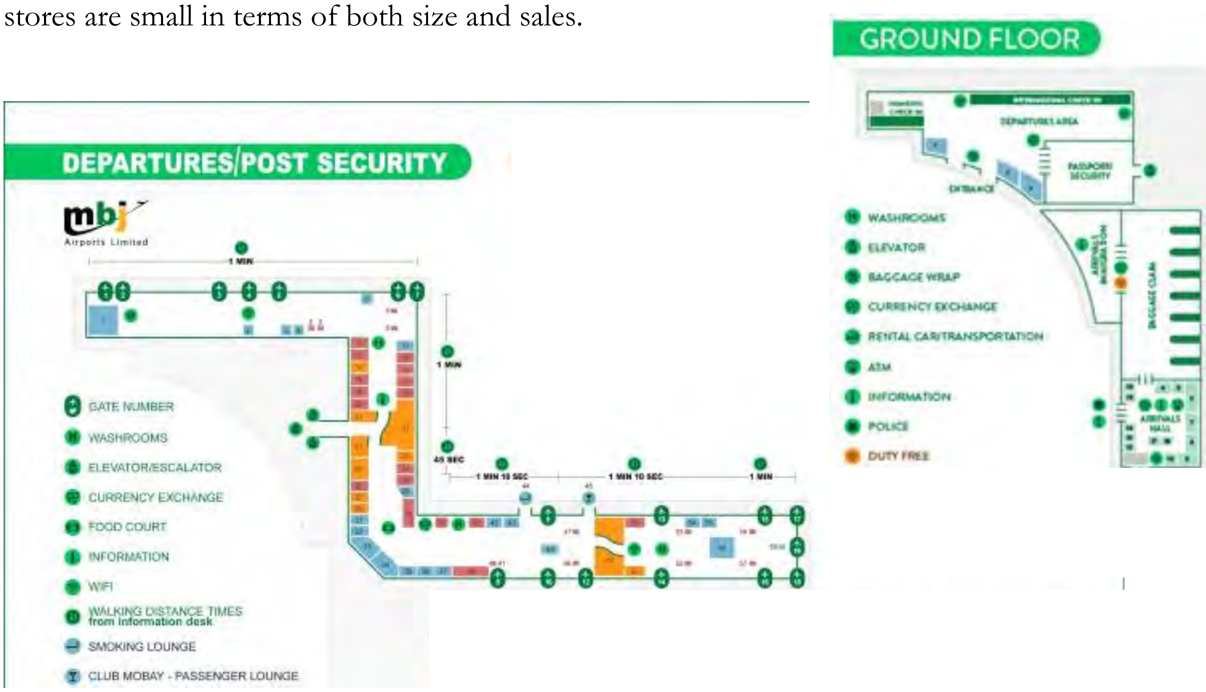


Figure 4.4 Terminal Map of Departure Lounge at SIA. Ground Floor and arrivals areas are shown in insert.

The only control tower had previously been located in the main terminal building, but recently this facility was relocated to the east of the international gates, both the previous and current locations of the control towers are shown in Figure 4.3.

The electrical power at SIA consists of a high voltage ring distribution system supplied by Jamaica Public Service Company (JPS) through the 510 and 610 feeders sharing the load. With any disruptions in one of the feeders, the other picks up the rest of the load in the building through a switching process and vice versa. Additionally, there are four standby generators, two (1500 KVA, 1000 KVA) per feeder used as a backup supply with automatic power transfer located in the main substation across from the area housing the maintenance facilities. There are also fuel farms, and a JPS sub-station on the facility, these locations are all highlighted in pink in the image above. It is worth noting that there has never been a problem with electricity at the facility and all the backups have functioned well when there has been any issue.

The Emergency Response Service (ERS) is comprised of 37 firefighter personnel specially trained to respond to emergencies common to airport environments. All emergency responses therefore come from the Fire Station on site, which is the only building to the north of the runway. The location of the fire station is shown in green in the image above. The retention ponds have been bridged with a makeshift roadway to allow the trucks and personnel access to cross if the runway is clear. However, the low-lying elevation of both the building and roadway is cause for some concern.

Plans for improvement

Originally named 'Montego Bay Airport', the SIA started as a small aerodrome. From 1955 when the new terminal building was constructed, construction and upgrading at the facility has been continuous. Since January 2001, plans have been executed to expand the airport to a 'world-class' airport. The new eastern concourse of the SIA was officially opened in December 2005. MBJ Airports Limited also commissioned a new customs hall, arrivals lobby, and transportation centre in March 2007. Since then, further expansion and renovation projects such as the relocation of the immigrations hall and duty-free mall have been launched and were completed in September 2008; all projects which allowed the facility to increase its handling capacity. At a press conference in October of 2015 the CEO, Dr Echevarne disclosed that work was then underway to improve the airport in preparation for the upcoming winter season, to avoid a repeat of the glitches experienced during the corresponding period in the previous year. Dr Echevarne is quoted as saying:

> *"Basically we are taking into consideration all the issues that we had to go through last year. We are improving the facilities by ensuring that we have the proper air conditioning in place. We are also going to be providing assistance to customs and immigration to ensure that passengers actually have a smooth as possible journey through the airport when they arrive. We are also going to be providing remote parking stands for the additional aircraft that are coming and the busing of those passengers from the aircraft to the terminal building and hopefully we can work together… with all stakeholders… to go through the winter season without a problem."* [Jamaica Observer, 2015]

It is worth noting that both this statement and all subsequent interviews with staff members at SIA indicated no planned improvements to raise the runway itself. There was some indication of long term plans to lengthen the runway to accommodate larger planes, but these plans had been temporarily shelved due to lack of funding.

4.2.2 Criticality

The importance of the SIA as the gateway to Jamaica's north coast cannot be overstated as the bulk of tourists visiting the island arrive through this airport. According to the airport's website: *Of the approximately 1.7 million annual visitors to Jamaica, 72% use SIA as their primary airport.* The Airports Authority of Jamaica (AAJ) also shows that 72% of visitors to the island came through the SIA in the financial year 2013/14. The AAJ data further indicates that this percentage share of the passengers entering the island has been on the rise since the 2008/09 financial year. This not only shows that the SIA is the most important airport in the island for passenger traffic, but it also indicates that it is becoming more important as the share of the total national traffic is growing. This is discussed further in Section 4.4.

Data from the SIA from 2010 to 2015 show that on average 3.5 million persons traversed through the airport every year. The numbers indicate a steady increase each year from 3.2 million passengers in 2010 to 3.8 million in 2015. The total aircraft movements and the total cargo and mail showed similar trends as that of the total passenger count, with steady increases each year since 2010 as shown in Table 4.3 and Table 4.4

Table 4.2 Total Passengers per year since 2010 divided on a monthly basis

Month	*2015*	*2014*	*2013*	*2012*	*2011*	*2010*
Jan	352,346	322,719	307,701	321,620	331,730	317,031
Feb	325,159	294,925	286,620	315,531	304,885	296,578
Mar	384,388	364,140	363,572	363,918	365,267	347,376
Apr	352,353	319,666	319,395	321,020	308,341	305,070
May	303,539	292,345	280,158	268,114	255,356	264,704
June	312,138	308,031	306,851	288,170	269,493	268,834
July	360,943	356,194	337,197	325,143	315,997	313,892
Aug	328,264	329,167	311,564	283,174	282,607	292,945
Sept	213,014	195,008	190,857	185,619	175,987	169,303
Oct	233,736	228,931	211,105	188,594	191,521	189,105
Nov	283,666	284,716	256,292	232,012	233,651	227,812
Dec	351,193	338,265	316,628	288,575	292,932	290,852
TOTALS	**3,800,739**	**3,634,107**	**3,487,940**	**3,381,490**	**3,327,767**	**3,283,502**

Table 4.3 Total Aircraft Movements recorded at SIA for the years 2010 – 2015 shown by month

Month	*2015*	*2014*	*2013*	*2012*	*2011*	*2010*
Jan	4,192	3,770	3,974	4,110	4,107	3,756
Feb	3,778	3,494	3,660	3,916	3,797	3,735
Mar	4,317	4,213	4,245	4,356	4,334	4,310
Apr	3,799	3,558	3,574	3,627	3,599	3,532
May	3,240	3,259	3,073	3,176	2,908	3,128
June	3,310	3,134	3,102	3,102	2,913	3,022
July	3,469	3,527	3,391	3,428	3,244	3,361
Aug	3,097	3,140	3,008	2,861	2,867	3,035
Sept	2,504	2,454	2,210	2,471	2,346	2,349
Oct	2,749	2,784	2,534	2,426	2,534	2,489
Nov	3,456	3,469	3,179	3,179	3,158	2,997
Dec	3,994	3,964	3,534	3,675	3,887	3,655
TOTALS	**41,905**	**40,766**	**39,484**	**40,327**	**39,694**	**39,369**

Table 4.4 Total Cargo and Mail (Kilos '00s) recorded at SIA for the years 2010 – 2015 shown by month

Month	*2015*	*2014*	*2013*	*2012*	*2011*	*2010*
Jan	5,188	4,554	4,235	4,241	3,987	4,043
Feb	5,072	4,440	3,924	4,421	3,691	3,367
Mar	7,084	5,366	4,410	6,064	4,278	4,501
Apr	6,733	6,424	5,182	5,519	4,042	4,234
May	5,978	5,816	4,791	4,703	4,654	4,219
Jun	6,113	6,122	4,954	4,705	4,209	4,263
Jul	5,815	5,747	4,261	4,566	4,070	3,845
Aug	4,513	4,890	4,809	3,883	3,786	5,076
Sept	3,639	4,081	3,983	3,925	3,635	3,589
Oct	4,555	5,332	4,817	4,090	3,828	4,026
Nov	4,714	5,189	5,791	3,703	3,249	3,818
Dec	5,567	4,626	4,530	3,850	4,606	4,160
TOTALS	**64,971**	**62,587**	**55,686**	**53,671**	**48,034**	**49,140**

Comparing Table 4.4 with the previous Table 4.2 reveals that the movement of cargo and mail is increasing at a faster rate than the passenger movement. In both 2012 and 2014 the number of thousands of kilos of cargo and mail increased by over 11% from their previous years, and the percentage increase in cargo and mail movement increased by an average of 5.9% over the 6 year period. By contrast, the number of passengers increased by an average of 3% over the same period, with the highest percentage change occurring in 2015 at 4.6%. This trend may affect the strategic planning of the airport and more resources could be geared towards air cargo if the trend continues. The trend is shown graphically in Figure 4.5 below where the blue line (cargo and mail) has a much steeper upward incline than the red line (passengers), although importantly, both trend upwards.

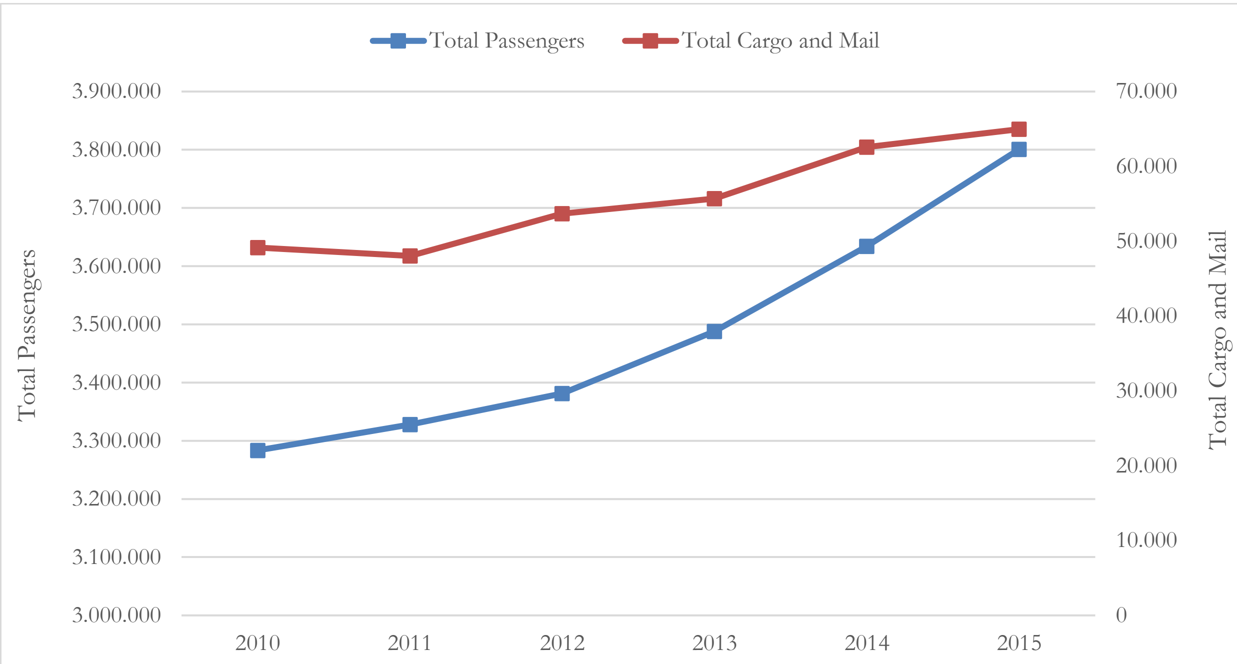


Figure 4.5 Total passengers (red line) compared with total cargo and mail (blue line) per year since 2010.

Regardless of the rate of increase, the data available clearly indicates that SIA features a large throughput of passengers and cargo that has steadily increased over the past 6 years for all the parameters indicated here. Further, because of its location on the north coast, close to hotels and tourist attractions the airport serves as a critical tourist gateway into the island, without which arriving passengers would have to travel long hours from NMIA to reach their north coast destinations.

4.3 Norman Manley International Airport

4.3.1 History and Description of Assets

The Norman Manley International Airport (NMIA) is located on the Palisadoes peninsula, approximately twenty minutes from Jamaica's business centre: Kingston, at Latitude 17° 56' 16" and Longitude 76° 46'46". The airport is considered to be the premier gateway to the nation's capital, Kingston, providing air service primarily for business travel to and from Jamaica and for the movement of air cargo, as well as for visiting friends and relatives (VFR) located in the south, central and eastern parishes of the island.

The NMIA was established in 1948 as the Palisadoes Airport. It is currently operated by NMIA Airports Ltd. which is a wholly owned subsidiary of Airports Authority of Jamaica (AAJ) and which was incorporated in 2003. The Airport is operated under a 30-year Concession Agreement with AAJ, and is held to specific performance targets under this agreement. Recently the GoJ sought to identify a private operator for the airport, however a January 2016 news release from the AAJ indicated that no bids were received by the submission deadline of December 30, 2015. However, the AAJ chairman also indicated in the same news release that NMIA is delivering strong operating and financial performance and will continue with the ongoing capital development programme. Further, according to the release, with NMIA's positive financial performance, it is able to service its debts and is not a charge on the national budget.

Facilities and Features

Figure 4.6 Aerial view of terminal building, control tower and gates.

The Airport encompasses approximately 230 hectares of land and is generally surrounded by Kingston Harbour to the north and the Caribbean Sea to the east and the south. The Airport's property boundary and existing facilities are shown in Figure 4.7. NMIA has one runway, Runway 12-30 which is 2,716 metres long by 46 metres wide and situated to the south side of the terminal and aircraft apron. The runway is classified as a Code 4E with a precision approach, and is equipped with a Category I Instrument Landing System (ILS). The critical aircraft for this runway is a B747-400 series aircraft. In addition, the runway has four (4) taxiways for planes to approach the gate area. The level along the runway centre line is 2.38 m above the mean sea level, and 1.95 m at the edge of the runway shoulders.

The Airport's passenger terminal complex is located just north of the runway and consists of a three-storey main passenger terminal building, two passenger aircraft parking aprons, ground support equipment parking and staging areas, and administrative offices, comprising of a total covered area of about 10,000 square metres.

A major expansion of the terminal facility was completed in 2008, with additional upgrades to the arrivals terminal in 2009. Airport ancillary and support facilities include cargo facilities, aircraft maintenance building, fire-fighting facilities, fuel storage facilities, flight catering, airline support facilities, airport maintenance, general aviation and an air traffic control tower. Air cargo facilities are located east of the existing commercial pier in a cargo pier, and cover about 4,450 m². Additionally, there is a separate Cargo and Logistics Centre that contains about 5,100 m² of leasable space, with a much greater potential to be expanded. These facilities have the capability to include apron areas, warehousing, and express cargo facilities.

Figure 4.7 Existing Airport Layout

The airport can only be accessed by one road: the Norman Manley Highway, known to most by its unofficial name "the Palisadoes road". The roughly 5 km strip of highway from the Harbour View roundabout to the Airport roundabout recently underwent works (completed in 2013) which raised the road by approximately 2m and added a boulder revetment over a four-kilometre stretch to buttress it against incoming wave action from hurricanes. The passage of Hurricanes Ivan in 2004 and Dean in 2007, both to the south of Jamaica, resulted in the erosion, inundation and blockage of this roadway with sediment and debris. This led to the complete shutdown of the NMIA for approximately two (2) days and contributed to the inability of Port Royal residents to drive to the mainland. The subsequent sea defence works were done to address this critical vulnerability of the road to passing storms and related wave action.

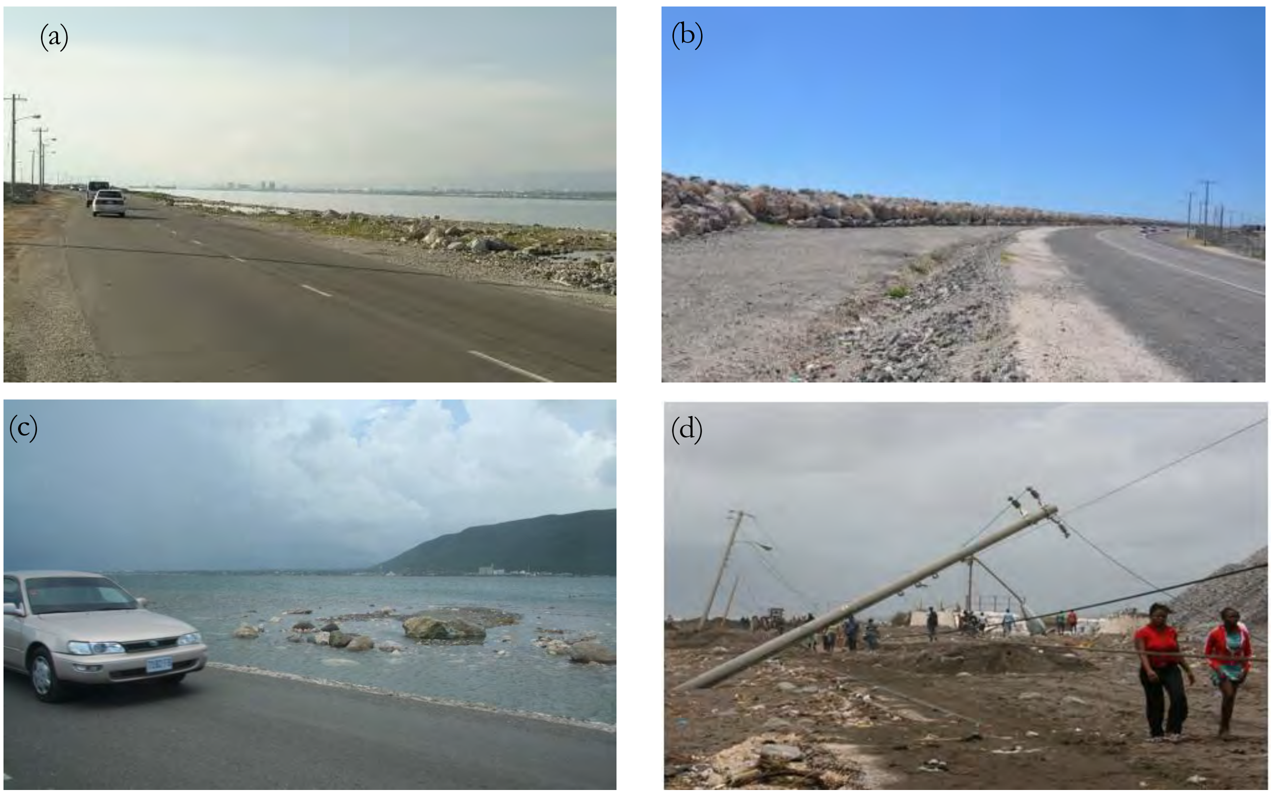


Figure 4.8 Various photos of the Palisadoes Roadway: (a) Before and (b) After the construction of the revetment; (b) right after Hurricane Ivan; and (d) after Hurricane Dean (road not shown as it is covered by washed up sand).

<u>Plans for Improvement</u>

In the Jamaica Information Memorandum issued regarding the NMIA for probable concessionaires to operate the airport facility programme, the proposed capital improvement program was outlined. The mandatory capital improvements included:

- **Airfield**.
    - Development of an ICAO compliant runway strip and runway end safety area (RESA) at each runway end without reducing current runway declared distances.
    - Extension of the runway by an additional 500 metres, into Kingston Harbour.
    - ICAO compliant taxiway separations for Code E operations. To be completed by 2020.

- **Terminal Building**.
    - Replace complete baggage claim system in the Arrivals Terminal.
    - Reduce terminal energy costs, for example through the replacement of A/C units in tenants' offices with a chilled water HVAC system.
    - Review/upgrade fire detection system (install sprinkler systems and extinguishers).
- **Ancillary Services**.
    - Relocate electrical west substations.
    - Upgrade incinerator system.
    - Relocate cargo road.
    - Change out /upgrade water mains from the Port Royal Road.

These planned improvements fall under a Master Plan for the facility, which outlined a 20 Year programme of works (2004 – 2024). Within this, Phase 1a was completed in March 2012 at a cost of US$119m and focused primarily on the terminal facility. Phase 1b will run from 2012 – 2017 and will be aimed at improving efficiency and reducing risk (e.g. installation of sprinkler systems). In addition, it is anticipated that under the Phase 1b programme, the Arrivals Hall will be improved. Phase 2 is expected to include a Public-Private-Partnership (PPP) and through this a capital development programme. The extension of the runway by 500m is also expected to be achieved under this latter phase.

In 2016, the NMIA commissioned Environmental Solutions Ltd. (ESL) to conduct a study on the "Potential Impacts of Climate Change on the Norman Manley International Airport." The study was not intended to be a forecasting tool for the NMIA. Rather, the consultants focused on potential climate change impacts that could possibly occur within the next 25 years and determined what, if any, effect there may be on any capital projects already planned for the airport. The findings are quoted below:

> Of all the [capital expenditure] CapEx projects identified in the NMIA Master Plan (2013) and the Jamaica Information Memorandum (2014), the RESA (Runway End Safety Areas) and Runway extension may be affected by the impacts of climate change. However, due to the existing height of the runway it is possible that it may be impacted by climate change whether or not the runway extension is carried out. The level along the runway centre line is 2.38 m above the mean sea level, and 1.95 m at the edge of the runway shoulders. The estimates for SLR vary but using any of the predicted heights, the NMIA will be affected because of its current height which is lower along the edge of the runway shoulder.
>
> In light of this specific project and the other proposed projects which will result in building the climate resilience of the NMIA, it is essential that NMIA develop viable climate change risk management plans that incorporate a "trigger point approach" to long term climate change planning. Trigger Points refer to temperature or sea level above or below which an impact occurs or becomes significant. Thresholds/ trigger points can be determined using past experience, or from company policies, procedures or operating standards for machinery.
>
> NMIA intends to develop a business continuity plan for the airport this year which will incorporate climate risks. Additionally, there is a climate change project also planned to start this year. Each of these can be incorporated or used along with the climate change risk management plans suggested above.
>
> In summary, the desk based assessment indicates that like much of Jamaica's critical infrastructure located along the coastline, the NMIA is vulnerable to the impacts of climate change. However, several of the planned CapEx projects will build the airport's climate resilience thus reducing its vulnerability.

4.3.2 Criticality

As the "premier gateway to the nation's capital", NMIA plays a critical role in the economic development of Jamaica. The airport caters to over 1.5 million total passengers per year on average and handles over 9 million kilos of the island's airfreight (roughly 70% of total air freight traffic to the island). The passenger number is split between enplanements and deplanements in a roughly 50:50 ratio, with some small numbers transiting through the airport. The breakdown of passengers into these groupings is shown below. Of note is the column displaying the percentage change in numbers. This percentage change was positive over the 20-year span from 1992 to 2012 except for 2 distinct periods. The first being the 2002-2003 period where the fallout from the September 11 bombings in 2001 seriously affected flight traffic because of fears as well as enhanced security measures which some viewed as a hindrance to travel. The second period was 2008-2009, 2011, this period is thought to be related to the global financial crisis which affected airline traffic significantly.

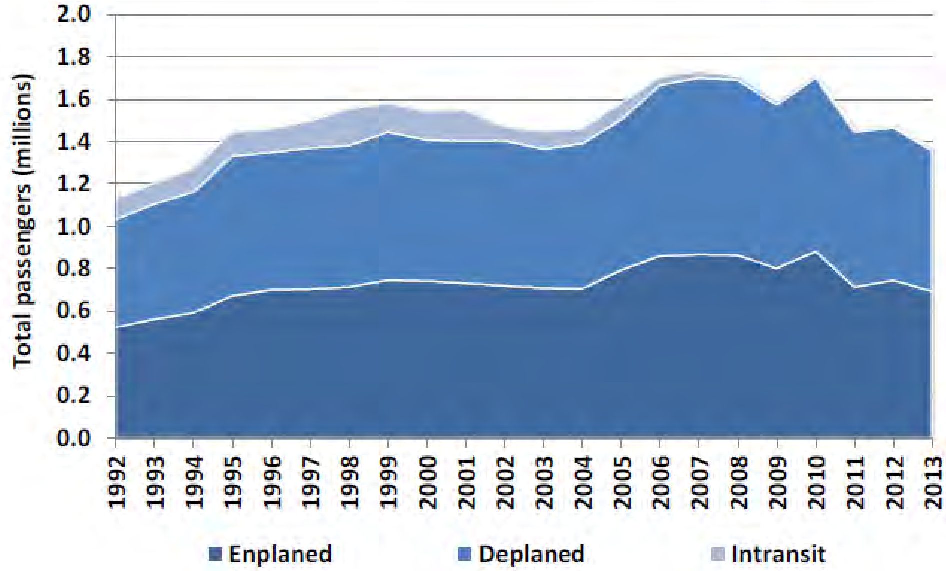


Table 4.5 Historical trends in total passengers at NMIA. Corresponding figures shown in table.
Source: Norman Manley International Airport Records

Year	Enplaned	Deplaned	In-transit	Total	Percent change
1992	524,019	509,078	93,304	1,126,401	--%
1993	561,721	544,395	98,070	1,204,186	6.9
1994	592,953	570,553	115,465	1,278,971	6.2
1995	671,169	660,609	112,348	1,444,126	12.9
1996	699,541	650,138	110,217	1,459,896	1.1
1997	703,516	665,944	127,800	1,497,260	2.6
1998	713,183	669,146	173,922	1,556,251	3.9
1999	745,373	700,884	135,916	1,582,173	1.7
2000	740,883	667,584	135,109	1,543,576	-2.4
2001	731,112	672,039	147,228	1,550,379	0.4
2002	718,971	686,224	63,352	1,468,547	-5.3
2003	707,309	657,855	83,958	1,449,122	-1.3
2004	704,663	686,653	69,394	1,460,710	0.8
2005	792,545	711,509	79,962	1,584,016	8.4
2006	859,038	809,559	39,917	1,708,514	7.9
2007	866,570	835,540	30,243	1,732,353	1.4
2008	862,954	827,714	18,422	1,709,090	-1.3
2009	801,121	774,076	18,675	1,593,872	-6.7
2010	881,083	822,178	13,402	1,716,663	7.7
2011	712,695	734,022	10,382	1,457,099	-15.1
2012	745,125	720,447	11,324	1,476,896	1.4
2013	693,275	664,757	14,570	1,372,602	-7.1

Air cargo and air mail are also big revenue earners for NMIA, albeit with a greater fluctuation on earnings. Figure 4.9 and Figure 4.10 present NMIA's historical volume of air cargo and air mail from 2003 through 2013. It is worth noting that during this time, total air cargo tonnage at the airport decreased by an average of 4.1% per year. This downward trend is thought to have been affected by the global financial crisis, although there are likely other factors involved.

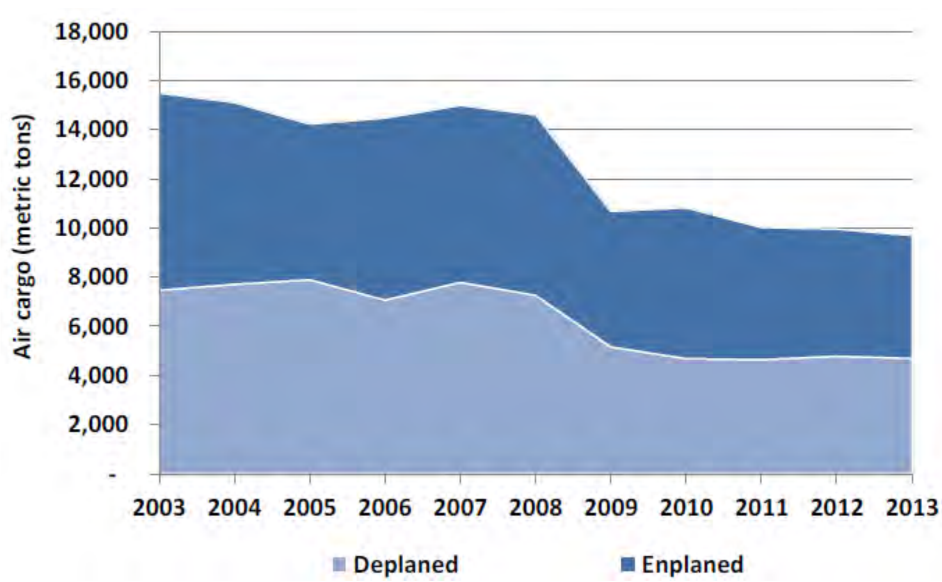


Figure 4.9 Air cargo in metric tons through the period (2003 – 2013) going through the NMIA. Source: Norman Manley International Airport Records

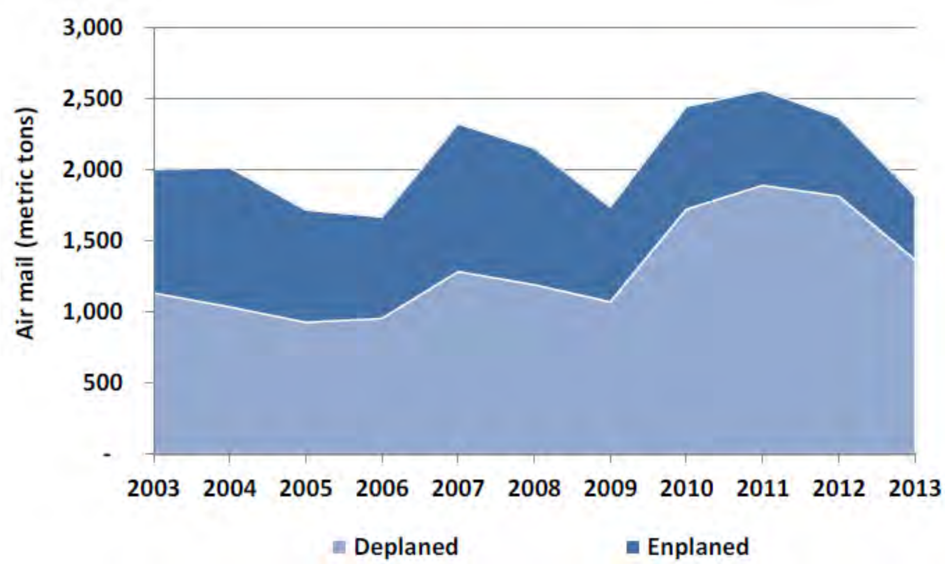


Figure 4.10 Air cargo in metric tons through the period (2003 – 2013) going through the NMIA. Source: Norman Manley International Airport Records

NMIA tends to provide air service primarily for visiting friends and relatives (VFR) and business travellers. Surveys have indicated that over a million Jamaican-born persons live outside of Jamaica in the United States (75.5%), the United Kingdom (13.5%) and Canada (11%). The VFR traffic at NMIA reflects the demographic characteristics of this diaspora. As shown in Figure 4.11, the 10 busiest origin and destination (O&D) passenger markets at NMIA reflect (1) the Jamaican diaspora in New York, South Florida (Fort Lauderdale and Miami), Toronto, and London who drive NMIA's VFR passenger traffic. Business travellers, the second largest group using the airport, are also reflected in the chart, which shows business and visitor passenger traffic to other islands in the Caribbean.

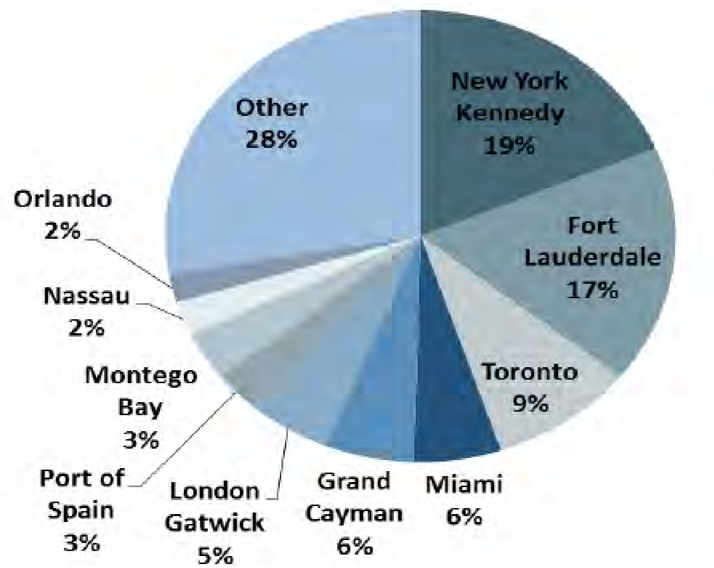


Figure 4.11 Busiest origin and destination (O&D) passenger markets in 2013 at NMIA. Source Consultants/IFC, based on Sabre Airline Solutions Ltd, online database, accessed April 2014.

The predominance of VFR and business passenger traffic is further highlighted in Table 4.6. It is seen that there is a good mix of Caribbean carriers, and foreign flag airlines.

Table 4.6 Passenger Airlines Serving NMIA in 2014. Sources: NMIA records and OAG Worldwide Aviation database accessed June 2014.

Airline	Headquartered in:
Aerogaviota	Cuba
Air Canada	Montreal, Canada
American Airline s	Miami, USA
British Airways	England
Caribbean Airlines	Trinidad & Tobago
Cayman Airways	Cayman Islands
Copa Airlines	Panama
Delta Air Lines	Atlanta, USA
Fly Jamaica	Jamaica
Insel Air	Curaçao
Intercaribbean Airways	Turks and Caicos Islands
JetBlue Airways	New York, USA
Spirit Airlines	Fort Lauderdale, USA
Sunwing Airlines	Toronto, Canada
Westjet	Calgary, Canada

NMIA is a draw for business travellers because of the proximity to Kingston. The city plays a central role in Jamaica's economy as the administrative capital and commercial and financial hub. The city is also home to several multinational organizations with regional headquarters, head offices of banks and consultancies, universities and sites of archaeological and historical interest. The criticality of air traffic access to the island's capital for the facilitation of business cannot be overstated.

To further corroborate this, an economic impact assessment done in 2010 by the commercial department of NMI Airports Ltd., indicated the economic activities generated by NMIA (including direct, indirect and induced effects) accounted for 10% of GDP. The methodology used by the in-house department to determine this figure was not made available for review and so is unknown and unverified, but the findings are nevertheless informative.

The area serviced by the airport was once just the south, central and eastern parishes of Jamaica, but this seems to have been expanded because of improvement in the ease of access due to major highway projects. The new North-South Highway now provides a significantly faster and more direct route from the south coast to the north, central and eastern parishes. This will provide linkages to the island's north coast tourism destinations and the tourist passenger traffic not currently served by NMIA, thus increasing the airport's demand. There is a possibility therefore that the airport will begin to see increased revenues and growth due to: these new highway linkages, possible runway extensions, and increased business and visitor travel to Kingston. The critical importance of the NMIA in the minds of 'Kingstonians' and Jamaicans is huge, and as they face a positive outlook this importance will hopefully continue to grow.

4.4 Comparison of Airports

(a)

(b)

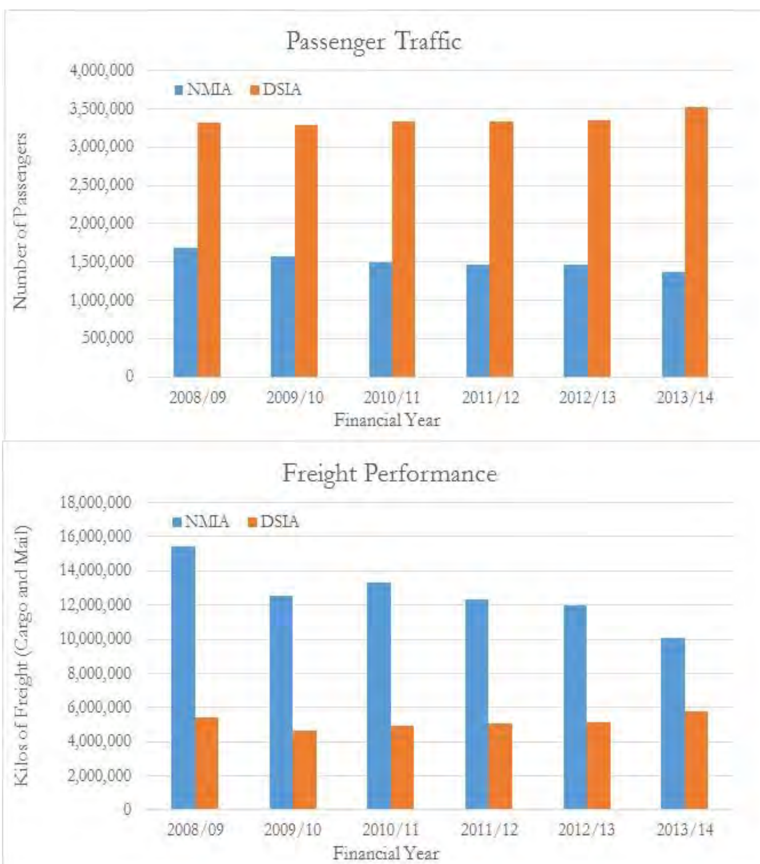


Figure 4.12 Comparisons between SIA and NMIA in terms of (a) passenger traffic, and (b) freight performance

The SIA and the NMIA are Jamaica's only two international airports; with similar histories and similar challenges they have a lot in common, however there are distinct differences between the two airports as shown in the graphs. Reports issued by the Airports Authority of Jamaica (AAJ) indicated that between the financial years 2008/09 to 2013/14, the percentage share of total passenger traffic to the island controlled by the SIA ranged from a low of 66.5% (in 2008/2009) to a maximum of 72% (in 2013/14) with an average percentage share of 69%. NMIA contributed the remaining 31% on average over the period to total passenger traffic. The 70/30 ratio of passengers travelling through SIA/NMIA is shown here in Figure 4.12 (a). Shown in Figure 4.12 (b) is the share of both airports in freight performance for the same period as recorded by the AAJ. This data shows that the NMIA has a higher market share in this field than SIA averaging 71% of total market share over the period and SIA controlling only 29%. The information is also found in the tables below.

Table 4.7 Passenger Traffic and Freight Performance at both airports across 6 financial years. Source: AAJ

PASSENGER TRAFFIC						
Financial Year	**NMIA**	**Percentage Share**	**SIA**	**Percentage Share**	**Total**	**Percentage Change**
2008/09	1,676,235	33.5%	3,323,142	66.5%	4,999,377	
2009/10	1,579,122	32.4%	3,292,296	67.6%	4,871,418	-2.56%
2010/11	1,495,406	30.9%	3,339,635	69.1%	4,835,041	-0.75%
2011/12	1,457,840	30.4%	3,338,827	69.6%	4,796,667	-0.79%
2012/13	1,462,072	30.4%	3,351,751	69.6%	4,813,823	0.36%
2013/14	1,370,601	28.0%	3,526,733	72.0%	4,897,334	1.73%
Total	**9,041,276**	**30.9%**	**20,172,384**	**69.1%**	**29,213,660**	
FREIGHT PERFORMANCE						
Financial Year	**NMIA**	**Percentage Share**	**SIA**	**Percentage Share**	**Total**	**Percentage Change**
2008/09	15,444,215	74.1%	5,394,901	25.9%	20,839,116	
2009/10	12,515,693	73.1%	4,616,343	26.9%	17,132,036	-17.79%
2010/11	13,281,921	73.0%	4,918,609	27.0%	18,200,530	6.24%
2011/12	12,336,776	70.8%	5,078,916	29.2%	17,415,692	-4.31%
2012/13	11,991,323	70.0%	5,151,382	30.0%	17,142,705	-1.57%
2013/14	10,041,376	63.6%	5,747,736	36.4%	15,789,112	-7.90%
Total	**75,611,304**	**71.0%**	**30,907,887**	**29.0%**	**106,519,191**	

The overall numbers as well as the percentage share of the market is increasing for SIA, an upward trajectory that is indeed noteworthy. The SIA has captured 5% of the passenger traffic market from the Kingston competitors since the 2008/09 financial year. The difference is even more stark in the freight performance where the SIA share of the freight market steadily rose from 25.9% in the 2008/09 financial year to 36.4% in 2013/14, a jump of over 10%. The SIA is therefore growing in relative importance in the island with the market share of both passenger and cargo traffic increasing during the six (6) year data period.

Although very positive for the SIA, this has had the obvious counter-effect on the NMIA which has seen its market share of both passenger and cargo traffic steadily decreasing during the six (6) year data period, as it has had its markets captured by the SIA. NMIA is still the dominant airport in terms of cargo and freight controlling roughly 70% of the market, and its importance as the gateway to the capital city cannot be understated. The AAJ data does however warrant some internal discussion within the NMIA about why the market share of both passenger and freight traffic has decreased in the manner that it has.

The key points and trends revealed in the figure and tables above can be summarized as follows:

- The SIA is steadily increasing its percentage share in both the freight market and the passenger market. Conversely the NMIA is losing percentage share in both markets.
- The SIA and the NMIA are dominant in two clearly distinct areas – the SIA has consistently controlled more than two thirds of the island's passenger traffic, while the NMIA has controlled over 70% of the freight traffic in the island for all years of record save one.
- The SIA and the NMIA differ in terms of the makeup of their passengers – the NMIA caters primarily to Jamaicans living abroad and to business travellers, while the SIA is the gateway to the north coast predominantly utilised by tourists vacationing in the island.

This analysis clearly highlights the complementarity of the two assets, which are both vital to the island in different ways. However, because the strengths of the facilities are so vastly different it raises questions about each facility's readiness to absorb the other's load in the event of a closure of either. For instance, in the event of a failure of SIA, NMIA would have to manage those passengers coming into the island, which are roughly 4 times its usual load (over the period of a year). It is unlikely that NMIA could adequately cope with the surge in passenger traffic in this eventuality; and conversely, it is also unlikely that SIA could manage the surge in freight traffic should NMIA close for any reason. This again reinforces the criticality of each airport in the management of passengers and freight entering the island.

4.5 Historic Falmouth Cruise Port

4.5.1 Description of Assets

The Historic Falmouth Cruise Port (HFCP) opened its doors for docking in March 2011, making it the newest facility to serve the Jamaican cruise industry (Figure 4.13). HFCP is operated by the Falmouth Jamaica Land Company, which was formed under a partnership between Royal Caribbean Cruise Lines (RCCL) and the Port Authority of Jamaica (PAJ). The Falmouth Jamaica Land Company leases the port and facilities from the Port Authority of Jamaica, which was responsible for the construction and development of the port in 2009-2010.

As described previously, the north coast of Jamaica is the area of the island that caters to tourists. Not only is the HFCP located on the north coast to make use of the attractions, but it is quite conveniently located between Montego Bay (34km to the west) and Ocho Rios (67km to the east). "*Guests arriving into Falmouth will be able to choose between the shore excursion options in both Ocho Rios and Montego Bay since the new port is [roughly] the same distance from both of these towns*" – Cruise Falmouth Jamaica. It is of interest to note that the HFCP facility will be the only Jamaican cruise port that will allow the berthing of two GENESIS/OASIS class vessels, with a passenger capacity each of over 6,000 once planned expansion works are completed.

<u>Facilities and Features</u>

The HFCP facility is approximately 114,500 square metres in total stretching from its berth to its inland boundaries. This total square footage also includes parking areas, warehouse and maintenance areas as well as administration buildings and the retail facilities available. The overview of the facility is shown in Figure 4.13 below.

Figure 4.13 Facility layout map of the Historic Falmouth Cruise Port, Falmouth, Jamaica.

As shown on the drawing, the port is trapezoidal in shape with the berthing of the ships accommodated on the west and east boundaries, with a visitors' centre in the middle that has retail facilities and other conveniences available. The main pier is also comprised of pneumatic berthing fenders, mooring bollards, lighting, water supply lines and safety equipment. The initial Environmental Impact Assessment Report (EIA) that was submitted for the pier shows that the deck level of all pier structures should have been set at approximately +3.00m above Chart datum. However, no elevation data was received at the time of preparation of this report to confirm that the elevation specification was adhered to. Extending approximately 60m out from the extremity of the pier, two mooring dolphins have been installed. These dolphins are accessed from the main pier by steel truss walkways. The dolphins are isolated structures, approximately 8m x 8m in dimension, comprised of a suspended deck on driven steel raking piles. The dolphins support quick release mooring hooks, lighting, aids to navigation, and safety equipment as necessary. The berths are similar in length: 340m on the western boundary and 335 metres on the eastern boundary, but the available draughts are different. The area on the west is deeper than that on the east, which means that the western side of the berthing facility can accommodate larger ships. The largest ships that can currently be accommodated at the facility are the Oasis Class of Royal Caribbean ships, which are 6,000+ passenger capacity ships. This class features the Oasis, Allure and Harmony ships, all of which can be berthed at the western side of the facility as pictured in Figure 4.14. The eastern side of the facility can accommodate the Freedom Class of Royal Caribbean ships which are 4000 passenger capacity ships. It is however noted that the PAJ presently has an application in to the National Environment and Planning Agency (NEPA) to deepen the eastern berth so that it will be able to accommodate the largest class of vessels operated by RCCL.

Figure 4.14 Photo showing the Falmouth Cruise Port with ships docked at both its western and eastern berths.

As their website notes, "*With over 120,000 Square Feet of leasable retail space, the Port of Falmouth has a variety of retail and duty-free shops, restaurants, and excursion options, with something for everyone.*" – [Historic Falmouth Cruise Port]. There are seventy-six (76) retail spaces set up at this facility, ranging in size from the small kiosk of which there are thirteen (13), to the large restaurants such as Margaritaville. The stores/restaurants etc. on the main port are only made available to those persons coming off the ship and persons cannot drive into the facility to make use of the offerings. This restriction addresses security considerations for the operation of such a port.

The sole roadway access to the HFCP is off Trelawny Street in the town of Falmouth. Unfortunately, because of the location of the port, it is impossible to access without driving through the small town, which oftentimes features roadways that are narrow, full of potholes and susceptible to flooding due to poor drainage in the town of Falmouth.

Plans for improvement

President and CEO of the Port Authority of Jamaica Professor Gordon Shirley is reported to have said in April 2015 that plans were at that time being finalised for the expansion of the Falmouth Cruise Shipping Pier. "*Shirley said that the RCCL has indicated that the two existing berths, designed to accommodate 6,000 and 4,000 passenger vessels respectively, "won't cut it"*." – Observer, Hines (2015). This is likely in anticipation of hosting vessels larger than the RCCL's Oasis class, which is currently the largest vessel that can be accommodated. Professor Shirley said: "*We really have to have the second berth developed to take the very largest ships, …, I am telling you this that you will know that we have some work to do on the berths again and that will also be coming soon*." This is in keeping with the plans to deepen the eastern berth.

4.5.2 Criticality

Because of its excellent location and its ability to host larger cruise ship vessels, the HFCP is a critical player in the island's cruise ship industry. Additionally, the number of calls has continuously increased since the port's opening in 2011 as shown in Table 4.8, which bodes well for anticipated and continued growth. It should be noted that although the number of calls increased in 2015, the total guest count fell. This indicates that the ships docking at the port were not travelling at their full capacity (roughly 4000 guests per call). Nevertheless, the tracked growth is still impressive, as data received from the facility showed that the number of guests disembarking at the HFCP was in excess of 750,000 persons in 2015, which is 300,000 more persons than it initially received in its opening year of 2011.

It is worth noting that data obtained from PAJ publications and shown below in Table 4.8 and Figure 4.15 (a) and (b), revealed that since it's opening in 2011 the Falmouth Pier has consistently had more passengers arriving on its docks than any of the other cruise ship piers in Jamaica. This is partly due to the fact that it is able to dock larger ships with larger passenger capacities, but is also related to the overwhelming popularity of the HFCP. It is likely also a function of the fact that the port lies between Montego Bay and Ocho Rios, allowing visitors a greater range of attraction options.

Table 4.8 PAJ reported data on Cruise Ship Calls and Arriving Passengers during the period 2011-2015 for the three cruise ship ports in Jamaica

	Cruise Ship Calls				Arriving Passengers			
	Ocho Rios	Montego Bay	Falmouth Pier	TOTAL	Ocho Rios	Montego Bay	Falmouth Pier	TOTAL
2011	156	101	111	368	425,304	250,731	460,520	1,136,555
2012	138	108	135	381	392,235	339,481	586,581	1,318,297
2013	126	81	154	361	384,550	239,363	646,452	1,270,365
2014	131	86	187	404	407,637	239,771	772,241	1,419,649
2015	135	129	190	454	439,682	370,074	752,205	1,561,961

As the data shows, the HFCP facility is responsible for approximately half (48% on average) of the total cruise ship passenger arrivals to the island; with the combined efforts of the Ocho Rios port and the Montego Bay port accounting for the other half of arriving passengers.

The data, as presented in the tables and figures, clearly shows the criticality and importance of the HFCP to the island's cruise ship industry. Damage of the port facility causing non-functionality for whatever reason would thus have massive effects on Jamaica's 'stop-over' tourism trade.

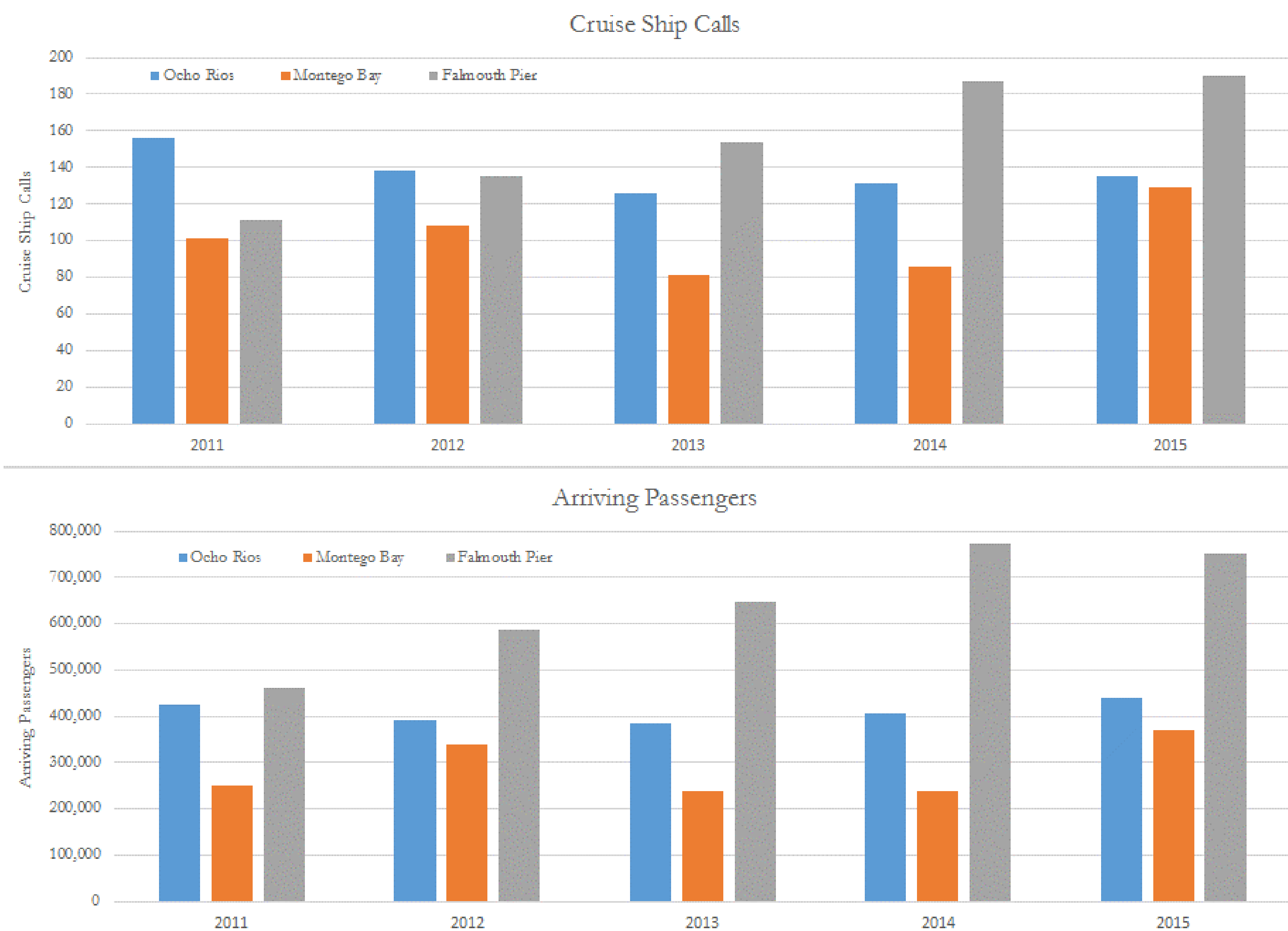
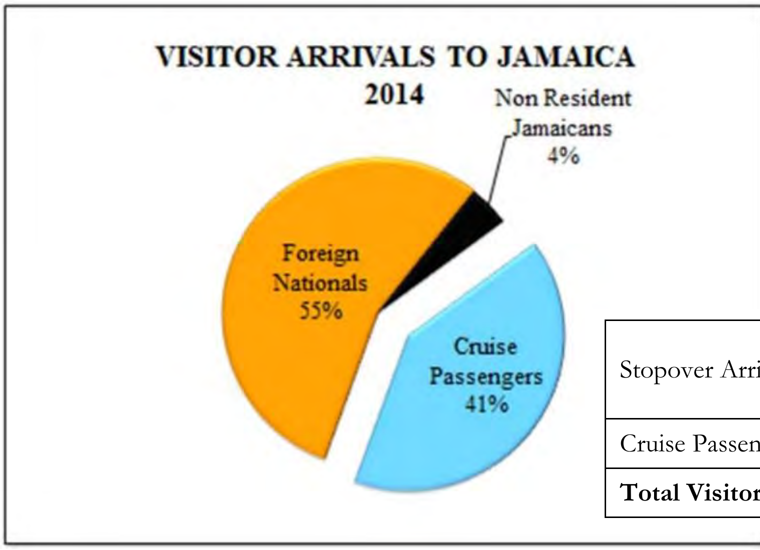


Figure 4.15 Graphs showing (a) Cruise Ship calls and (b) Arriving Passengers for the three major cruise ship ports in Jamaica: Ocho Rios (blue), Montego Bay (orange) and Falmouth (gray).

Total cruise ship arrivals account for a significant part of total tourist arrivals into the island. In 2014, that percentage was 41% as shown in the figure and table below copied from the Jamaica Tourist Board's 'Annual Travel Statistics 2014'.



Stopover Arrivals	Foreign Nationals	1,929,454
	Non-resident Jamaicans	150,727
Cruise Passenger Arrivals		1,423,797
Total Visitor Arrivals		**3,503,978**

Figure 4.16 Breakdown of visitor arrivals in 2014. Source: Annual Travel Statistics 2014 – Jamaica Tourist Board

These figures highlight the relative importance of cruise ship tourism in the island's overall tourism economy. As the cruise ship port with the most arrivals and calls, the data further underscores the importance of the HFCP to the island's economy.

Further, there are hopes that because of Falmouth's capacity, those numbers will continue to rise with the arrival of larger and larger ships.

> *" 'Harmony of the Seas', the largest cruise ship in the world, made its inaugural call to Jamaica on November 22 (2016), docking at the Falmouth port in Trelawny. […] Minister (of Tourism, Edmund) Bartlett, who led a delegation on board to meet with Captain Johnny Faevelen and several members of his crew, described the visit of 'Harmony of the Seas' as a historic moment for Jamaica's cruise-ship industry. "This is an important addition to our cruise itinerary," Bartlett told JIS News. "This is the biggest sister in the Royal Caribbean fleet of luxury vessels, which includes 'Oasis of the Seas' and 'Allure of the Seas'. To have all three coming here speaks volumes as to how we are viewed by that prestigious cruise line and to the kind of confidence they have in the port of Falmouth," he noted. Bartlett further pointed out that Falmouth being the largest port in the Caribbean and able to accommodate vessels of the size of 'Harmony of the Seas' bodes well for Jamaica as a port of call and also the future of the cruise industry."* – Jamaica Observer News Article, 'World's largest cruise ship docks at Falmouth port'. Wednesday, November 23, 2016.

Even locally the presence of the port is a significant economic contributor. Figures received from The Falmouth Jamaica Land Co. Ltd. revealed that approximately nine hundred (900) staff are employed within the 'plaza' of the pier i.e. within the shops and restaurants etc. This figure does not include tour operators etc. which are outside companies using the pier for excursion pickups, and so the overall number of persons who depend on the pier for their livelihood is even higher. In the small town of Falmouth, with a population under 9,000 persons, this is a very important employment centre (roughly 10% of the population) to the people of the town.

4.6 Kingston Container Terminal

4.6.1 History and Description of Assets

Kingston Harbour is the seventh largest natural harbour in the world and is approximately 16 kilometres long by 3.2 kilometres wide. This picturesque harbour is almost completely landlocked and as such provides an excellent anchorage facility. The harbour became an important trading and docking point for ships because of its geographic benefits and the city of Kingston was established on the banks of the harbour early in the 18th century as a trading post. The city has continued to expand and develop as the island's business centre since that point. Additional interesting information on the history of the Port of Kingston is included in Appendix 2a for reference. Because of its natural sheltering characteristics and deep channels, the harbour is a logical home for many docks. Jamaica's largest port, Kingston Container Terminal (KCT) is a prominent feature on the western end of the harbour at Latitude 17° 58' 58" and Longitude 76° 49'56".

KCT can be thought of as one of the island's prime assets. Initially developed in response to the containerization of cargo, the terminal has grown in step with the expansion of the transhipment of containerized cargo in the hemisphere. Recognizing its potential for continued growth in light of the Panama Canal expansion, the CMA CGM Group signed (on April 7th, 2015) an agreement with the Port Authority of Jamaica granting the Kingston Freeport Terminal Limited (KFTL) - jointly owned by the members of the Consortium, Terminal Link [TL] and CMA CGM with equity interests of 40% and 60% respectively, the concession of KCT for 30 years. The Agreement has given the KFTL group a 30-year term concession with the right to finance, expand, operate, maintain and transfer the KCT at the end of the concession period. The Agreement will also see the group dredging the access channel to the Kingston Harbour and the basin of the KCT to allow for the handling of the larger vessels that will transit the Panama Canal after its expansion. The transfer of the operating control to the group took place at the beginning of 2016.

Figure 4.17 Image of KCT showing terminals, cranes and wharves.

Facilities and Features

In 1972, the Government of Jamaica took the decision to build a modern container terminal. The then chairman of the Port Authority of Jamaica (PAJ) was given the responsibility of acquiring land for the terminal, carrying out dredging of channels and obtaining financing for the design and construction. The modern Kingston Container Terminal (KCT) began operations at Port Bustamante in 1975 with only two berths and two container-stacking cranes. Extensive expansion in 1976 increased the facility to include two additional berths, and the 1980s saw more expansion of facilities and equipment. This progress continued in the 1990's, which saw the PAJ embarking on a major expansion programme of the KCT capacity at a site known as Gordon Cay lying adjacent to the existing Container Terminal. There was a phased approach to the incorporation of the Cay and at the end of the works in November 2001 there had been a total of 1630 metres of berth added under all three phases. This expansion and development programme continued in 2004/2005, which included the development of the West Berth and Hunts Bay areas. The many construction and expansion projects undergone at the KCT over the years indicates a willingness to adapt to the changing market and lends credence to their vision "*To be Port of Choice for the 21st Century and beyond*".

Currently the KCT consists of three terminals as shown in below. The North, South and West Terminals have a current rated capacity of 2.8 Million TEUs. The berth face, channel and turning basin have been dredged to an existing depth of 13 metres. The list of current equipment available at the port is included in the appendices.

There are further expansion plans for the port, which will lift the capacity of the terminal to 3.2 million TEU's. In order to facilitate this expansion, more lands will be brought into use. This expansion is hoped will optimise and expand Kingston's container terminal capacity in Jamaica, as the port must stay competitive to handle larger ships now passing through the expanded Panama Canal.

Electricity generation for this facility is provided primarily by the Jamaica Public Service (JPS), which guarantees a dedicated supply operating to a 99.7% reliability level. They are able to do this as the supply to KCT draws on the Hunts Bay station and the Duhaney Substation. Potable water is obtained from the National Water Commission (NWC), and is used at the terminal itself and for the supply of berthed vessels. KCT also maintains a backup water supply in the form of a 300,000-gallon tank. Sewage disposal for the terminal is handled through the NWC sewerage facility.

Plans for improvement

The expansion of the Panama Canal, expected to be completed in 2017, will allow for the passage of larger vessels through the region. Located close to the entrance of the canal, at the cross roads of the North/South and East/West lines, the new KCT terminal will offer a deeper draught facility where those larger vessels carrying 12 thousand TEUs and that are up to 366 meters long with a draft up to 15.2 meters will be accommodated. The additional equipment planned for implementation will allow for the development of transhipment operations via secondary shipping lines in the regional area.

Figure 4.18 Facility overview of the Kingston Container Terminal. Also showing future expansion area in light blue.

To ensure that the Port of Kingston will continue to grow, expand and maintain its competitive position in the region, some terms for capital development were incorporated into the concessionaire's agreement. Under the agreement the concessionaire is expected to invest approximately US$509M over two phases of the concession with the possibility of a third phase to be negotiated. Specifically, the new consortium is expected to conduct:

- Capital dredging to a draught of 15.5 metres;
- Strengthening of the existing quay walls to accommodate the larger vessels and equipment;
- Optimization of existing facilities - berths and addition of new equipment.

The expansion effort will also include paving and expanding the container stacking area to 28.8 hectares and adding more reefer plugs at the Port of Kingston's West Berth as well as the acquisition of a more powerful tugboat. It is noteworthy that no information is available on whether or not climate change or climate change adaptation has been considered in the expansion project. With a grand expected total of 2,400 meters of wharf, an 80 ha surface and 15.5 meters' draught after the works have been completed, KCT will increase its annual capacity up to 3.6 million TEU containers from its current capacity of 2.8 million TEUs. It will be equipped with new equipment and optimized operations that will hopefully turn Kingston into one of the Caribbean's top five ports. Further, to make the KCT a more productive multi-modal logistics and distribution hub, there is a plan to increase logistics services. The goals for Port of Kingston's Logistics and Distribution Hub facilities include making facilities available for the breakdown and repackaging of cargo, the light manufacturing and assembly of goods, and marketing for a wide range of goods.

4.6.2 Criticality

Data extracted from the PAJ's database on the KCT for the past five (5) years: 2011 – 2015, and shown in Table 4.9 below, revealed that roughly 1500 vessels visited the KCT each year over the period. Of this amount, the vast majority (approximately 96%) were cargo vessels.

PAJ data also showed that 2011 was a very good year, recording maximum cargo amounts over the period as shown in Table 4.9 (a) and (b) below. After that year the cargo volumes dropped significantly, reaching a low in 2013, and have remained relatively constant throughout the period of record. The sharp decline observed in container throughput after 2011 is primarily due to losing some major shipping lines, such as Maersk, but was also affected by the overall deceleration in Latin America and the Caribbean's foreign trade.

In addition to the sharp drop-off on the graph, the disparities between discharged and loaded cargo is also worth noting. For the transhipment cargo handled the ratio of discharged cargo to loaded cargo is almost 50/50 with slightly more cargo being loaded than being discharged; specifically, 46% of the total cargo handled was discharged versus 54% which was loaded. This is in stark contrast to the domestic cargo which had 80% of its total cargo handled being discharged and the remaining 20% being loaded. This shows that 4 times as many goods are being imported than are being exported, this further highlights the criticality of the KCT for imports, close to a million metric tonnes of cargo are brought into the island on an annual basis through this port alone.

Other documents revealed data related to the 2008-2009 shipping season. During that period: *"the KCT received 2470 vessel calls and handled a total of almost 16.3 million metric tons of cargo. Fees produced by the KCT… during the 2008-2009 shipping season, generated a net income of $8.5 billion for KCT."* [– World Port Source].

Table 4.9 Vessel visits and Cargo Handled (both transhipment and domestic) at the KCT from 2011-2015

	Total Vessel Visits	Cargo Vessel Visits	Transhipment Cargo Handled			Domestic Cargo Handled		
			Discharged	Loaded	Total	Discharged	Loaded	Total
	(number)	(number)	(metric tonnes)	(metric tonnes)	(metric tonnes)	(metric tonnes)	(metric tonnes)	(metric tonnes)
2011	1502	1447	6,434,949	6,641,778	13,076,727	1,157,672	690,559	1,848,231
2012	1535	1439	3,994,778	4,250,749	8,245,527	803,916	114,294	918,210
2013	1447	1402	3,025,634	4,086,505	7,112,139	767,977	137,872	905,849
2014	1506	1444	3,505,828	4,437,164	7,942,992	898,610	187,119	1,085,729
2015	1464	1396	3,220,200	4,059,522	7,279,722	885,110	166,523	1,051,633

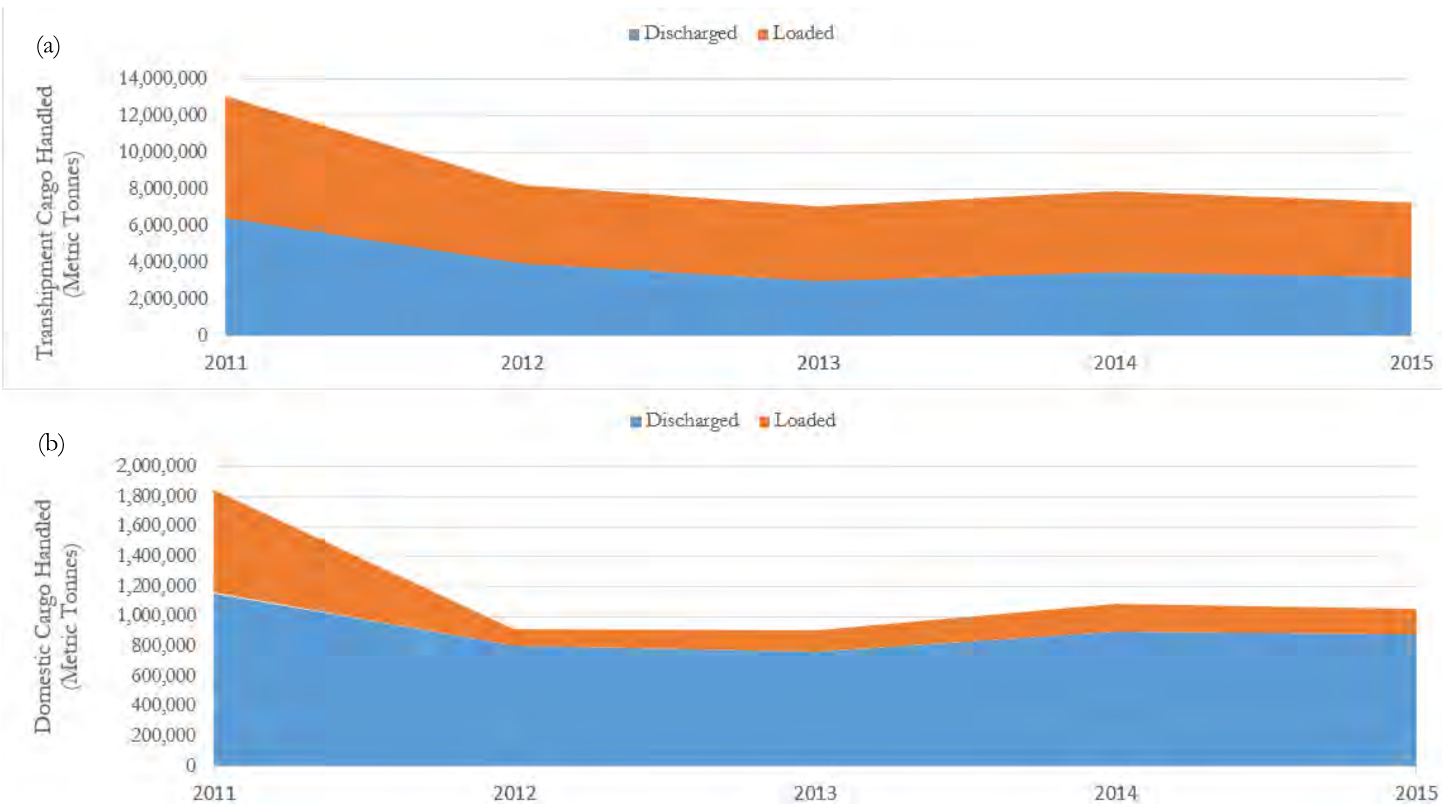


Figure 4.19 Graphs showing Discharged and Loaded cargo handled at KCT over the past 5 years both (a) for Transhipment and (b) Domestically

It is worth noting that the bulk of the KCT business is transhipment and not domestic importation. *"Of the total amount handled by the port in the 2008-2009 shipping season, about 1.4 million TEUs (86%) were transhipments. Domestic containerized cargo represented 12% of the total 1.7 million."* [– World Port Source]

The transhipment services to the region – the Caribbean, North, Central and South American markets, are a vital component of the KCT business. The Economic Commission for Latin America and the Caribbean (ECLAC) updates every year its ranking of container port throughput, which shows the cargo volume in containers in 120 ports of the region, based on data obtained directly from port authorities and terminal operators. In 2015, the regional activity grew 1.7%, with a total volume of approximately 48 million TEU. ECLAC ranked the KCT as 8th in Latin America and the Caribbean.

Figure 4.20 The Top twenty ports in Latin America and the Caribbean in 2015 (based on throughput).

The critical importance of the port is thus multi-fold:

- It controls the largest share of the country's imports and exports.
- It is a major revenue earner, and thus contributor to the island's economy, through direct earnings and taxes.
- It is a significant contributor to the region's (Latin America and the Caribbean) transhipment activities.
- It is a large employer of persons in the island. KCT had 834 employees as of June 2016, and will likely add technical staff who were previously employed to the Shipping Association of Jamaica to its staff as part of the concessionaire agreement.

The domestic cargo market should also not be underestimated as large amounts of produce and commodities are brought into the island through the port. Through the KCT and other ports, Jamaica mainly imports oil and ethanol (to satisfy the island's energy needs); wheat and rice (as the primary food imports); as well as lye, electronic appliances, vehicles and metals, all of which are inputs for manufacturing, agriculture and local businesses. Jamaica's main imports partner is the United States (42 percent of total imports) while other imports partners include Venezuela, Trinidad & Tobago, China, Brazil, Japan, Canada, the United Kingdom and Mexico.

Dr Fritz Pinnock, the executive director at Caribbean Maritime Institute explains in a Jamaica Observer article, that the "trans-shipment type operation" sees main line ships discharging large numbers of containers at the KCT which connects to small feeder ships serving the Caribbean, North, Central and South American markets. These feeder ships will later return the empty containers to the hub port (KCT), which will then be repositioned primarily for reloading. Dr. Pinnock further explains that since the global recession of 2008, the concept of trans-shipment has lost its attractiveness to global shipping lines, as nine out of every ten containers coming into Jamaica have no matching exports. Hence, the cost of import has to bear the empty container return, making the average freight cost 30 per cent higher than the average for the rest of the world. For this reason, there are efforts being made, through the concessionaire as mentioned previously, as well as through other government initiatives to transform the economy from a "trans-shipment type operation" to a gateway port. A gateway port is an extensive port facility integrated into a major logistics park. This now becomes an economic driver that can attract development of other logistics zones. This means that Jamaica now has to reinvent itself in order to benefit from the global logistics chain. This will require Jamaica to expand and develop the current trans-shipment port to include value-added activities, as opposed to exchanging full containers for empties, which yields very little revenue. Based on this expectation the critical importance of the KCT as a logistics hub port is likely to increase.

4.7 Summary of Transport Infrastructure

As described, the four transport facilities selected for analysis within this project are the two international airports, the largest cargo handling port in the island and the port with the most cruise ship arrivals:

- The Sangster International Airport
- The Norman Manley International Airport
- The Kingston Container Terminal
- The Historic Falmouth Cruise Port

Both international airports have existed in their respective locations in some form for over 60 years. Both airports currently occupy large extents of land (between 350 – 400 acres in each case) and feature all necessary elements of a functioning airport as described in their relevant sections. Throughout their histories, upgrades on both airports has been an almost ongoing process, and plans for improvements continue, with both airports having significant capital improvement programmes including the lengthening of their runways (when funds become available).

The cargo port in the study came into existence just over 40 years ago and like the airports, has experienced continuous growth and expansion throughout its history. Recently a concession agreement was signed which transferred the ownership of the KCT to a private group. As part of their concessionaire agreement the new consortium is expected to conduct: capital dredging, strengthening of the existing quay walls, optimization of existing facilities and addition of new equipment.

The newest facility of all those discussed is the HFCP which was constructed in 2010 and opened for business in 2011, a mere 6 years ago. It has had very little need for improvement during that period, although the facility continues to be affected by the infrastructural shortcomings in the town of Falmouth. These include issues relating to the condition of roadways in and out of the town, as well as poor drainage of many of the roads and areas within the town. Although the facility is still in new and excellent condition, there are presently plans to dredge the east berth in order to accommodate the largest class of cruise vessels presently operating on the seas.

The importance of the transportation facilities is not determined by their assets, either existing or planned. Rather the criticality of each asset was discussed in terms of their throughput. Generally, those facilities on the north coast contribute greatly to the tourism industry, Jamaica's highest grossing sector of the economy. HFCP has the most arriving passengers of all cruise ship terminals in the island, averaging roughly 650,000 passengers a year. SIA serves as the most popular airport for tourists coming to the island, managing over 3 million passengers a year on average. Disruptions in services to either of these facilities will close much needed gateways for tourists into the island, and the resulting effect on GDP would likely be equally devastating.

Conversely, data shows that traffic to the NMIA is primarily for visiting friends and relatives and business travellers, as well as large air cargo and air mail volumes. The KCT has 96% of its total vessel visits as cargo vessels and is Jamaica's largest container terminal, dealing primarily with transhipment of cargo but also managing roughly 1 million metric tonnes of domestic cargo a year. ECLAC ranked the KCT as 8th in Latin America and the Caribbean in terms of cargo throughput. These two south coast facilities are therefore absolutely critical to Jamaica's commerce and trade, as well as to the importation of several necessary goods. It is to be expected that several sectors would be impacted by any disruptions in these facilities, should these two portals into the island's capital be damaged.

5. Asset Vulnerability to Climate Stressors

Vulnerability can be defined as "*the quality or state of being exposed to the possibility of being attacked or harmed, either physically or emotionally*." In relation to hazards and disasters, vulnerability is a concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them. "*The concept of vulnerability expresses the multi-dimensionality of disasters by focusing attention on the totality of relationships in a given social situation which constitute a condition that, in combination with environmental forces, produces a disaster*" (Bankoff, 2004). In the context of this report, the asset vulnerability to climate stressors speaks specifically to the exposure of the transport facilities to damage or closure caused by environmental effects that are related to climatic changes.

5.1 Climate Stressors

As mentioned previously in Section 3.3.3, the CSGM has made some key projections for the island of Jamaica which include the following climate stress factors:

Temperature Increase

Temperatures are expected to increase across the entire island in every season of the year. The mean temperature increase from the GCMs will be 0.75-1.04°C by the 2030s and 0.87-1.74°C by the 2050s. The annual frequency of warm days in any given month is also expected to rise by between 4-19 days by mid-century. Extremely hot temperatures cause excessive strain on HVAC systems, which affect operations and functionality of the facilities. Further, these extreme temperatures can weaken the integrity of the asphalt both on the linking roadways and on the airport tarmacs.

More Severe Droughts

GCMs suggest that the mid 2030s will be up to 4% drier while the 2050s will be up to 10% drier, and by the end of the century the country may be up to 21% drier for the most severe scenario. RCM projections are similar and show some spatial variation across the country with the south and east showing greater decreases than the north and west. Droughts will further constrain the already limited water supply to metropolitan areas (Kingston and Montego Bay) and affect the staff and functionality of facilities in those areas. Further, when coupled with high temperatures, droughts will affect the country's marketability to tourists, as they will be more likely to fly or cruise to cooler places with more lush environs. This would affect the business of those facilities catering to tourists.

Sea level Rise

For Jamaica, projected Sea Level Rise (SLR) for the island is expected to be in the range of 0.43-0.67m by the end of the century with a maximum rise of 1.05m. Sea level rise is a grave concern as all the transport facilities considered, as well as connecting roadways and infrastructure under this study, are located in low-lying coastal areas subject to inundation by rising waters.

More Intense Storms

Climate predictions forecast a shift towards stronger storms by the end of the century: maximum wind speed increases of +2 to +11% and rainfall rates increasing +20% to +30% for the hurricane's core. Although there is no significant increase in the frequency of all hurricanes foreseen, it is predicted that there will be an 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

Of major importance when analysing the primarily accepted scenario for climate change related impacts, is that there will be a need to plan for more extreme storm events, even if overall storm occurrences will not increase over what presently prevails. This "message" is startlingly demonstrated in a previous section of this report, which shows that over the period of hurricane record (from 1850 to date) Category 4 storms did not appear on the event horizon for Kingston before 1915 and for Montego Bay before 1932. Furthermore, Category 5 storms only appeared at these locations after 1980.

Based on interviews with management at the four facilities considered, and from an appreciation of the characteristics of the facilities themselves, it is clear that worsening storms are a particularly frightening concept for facility management. The wave action; storm surge; and flooding linked to hurricanes tend to result in large disruptions in the service operations of both the airports and seaports and can also cause significant damage to the facilities and equipment. The effects of climate change on these parameters will be to increase their damaging effects.

5.2 Operational Threshold Methodology for assessing vulnerability

An optimal process for determining the vulnerability of the specific facilities to the aforementioned climate stressors is outlined below in a step-by-step format.

1. Acquisition of available operational climatic thresholds from airports and seaports. These thresholds should be related to climatic factors for which time series can be easily obtained.
2. Collation from the available data of a time series (relevant to the critical asset operational life time) of temperature, precipitation, waves/storm surge and wind at the asset sites.
3. Comparison of Step 1 data and Step 2 data to record potential times of intersection and overlap which would equate to disruption (and possible damages) at the site.
4. Identification of data bases containing time series of projections on temperature, precipitation, waves/storm surge and winds for different scenarios.
5. Estimation of ranges of inundation due to Sea Level Rise predicted by suitable morpho-dynamic model ensembles. [Ideally, forcing will be under MSLRs projected for the same periods and scenarios as the other climatic factors identified in Step 4].
6. Comparison of future projections with the existing operational thresholds for the critical assets. These are going to be related to impacts by (a) changes in the means and (b) changes in extremes.

It should be noted that this methodology/approach was agreed upon during an UNCTAD Technical Expert Group meeting (June 2016) seminar in Geneva as that which would best enable a rapid, low-cost assessment of vulnerabilities with a view to identifying priorities for adaptation planning.

5.2.1 Limitations to the methodology

The methodology outlined above was not very successful in actual practice due primarily to difficulties in obtaining data. The specific limitations confronted when attempting to apply the methodology are outlined below.

Difficulty in acquiring data.

Site visits were conducted to each facility under the study at which time contacts with operational management were made and interviews conducted. To prepare for the visits and interviews, contacts at the facilities were first emailed data collection sheets. Even with the notice provided, the facility managers were not able to provide a lot of the data required. The reasons for this varied and are summarised following:

It does not appear that data is exchanged when there are shifts in management / ownership. The SIA was privatised and turned over to a consortium in 2003 by AAJ, but since then the members of the consortium have changed hands several times. The current team has been in place since 2009 and have no data available before that time. All records of operations etc. start in 2010. Because there has been no major storm or weather event since that time there are no records of facility disruptions, although there are some members of staff who have been at the SIA long enough to witness storms and who could provide anecdotal information. There are no official records of facility disruptions as none were passed on from previous management. This seems to be a problem at other facilities as well (except HFCP which has been under one ownership), where surveys that have been conducted or other data collected under one administration, is not transferred to the next.

Relevant data was not easily obtained. Most of the facilities in this study have been wholly or partially privatised, and therefore not a lot of information is public. Further, some facilities such as the two international airports, are in direct competition and may have related concerns regarding releasing their data. Further, it appears that facility information is not readily available and unearthing records could have been a time-consuming task which facility operators may not have been able to undertake in the time available.

There is not a major emphasis placed on collecting and collating meteorological data. Meteorological (met) offices are at both international airports and wind gauges should be at both ports. However, it seems as if this data is not stored for record keeping purposes. Rather the value of establishing large (and long) databases of weather and climate information seems to not be a priority for facility managers, and the benefits of such a database should be further impressed upon them.

The lack of data made the application of the agreed upon methodology very difficult. Although records exist of major storms and weather systems which could have interrupted operations at the facilities, there are no actual records of facility disruptions due to weather, or if they exist they were not made available. There was no data made available on thresholds describing when operations are disrupted. There were no actual figures made available on the economic implications of disruptions; neither were there any figures for repair and replacement costs. These constraints severely limited the application of the methodology outlined above and should be given consideration. Nevertheless, an effort was made to ascertain the vulnerability of the facilities, the results of which are shown below.

Difficulty in establishing operational thresholds

In summary, and based on observations made during interviews, facilities seem to not necessarily be aware of those factors which limit their functionality. As a result, it does not appear that in general sufficient operational protocols are in place. For most facilities, there does not appear to be a 'cut-off' temperature at which there are known operational problems or beyond which staff would not be required to work outside etc. This exists for other parameters as well, such as rainfall. Even in the event of storms, some facilities take a "wait and see" approach to see what will occur rather than initiating a prescribed set of early response actions.

All the facilities appear to have well thought out shut-down procedures, but most do not have operational thresholds which would trigger a shut-down. Instead, it appears as if the decision to shut down is very subjective and highly variable.

Investigation revealed that KCT had a threshold related to wind, above which the cranes would be tied down; however, no other facility nor any other parameter was available. As operational thresholds formed the basis of the methodology, lack of this information severely constrained the application of the methodology.

Difficulty in estimating 'down time' costs

A fundamental concept in the methodology is using past 'shut-down' or 'down time' experiences and related costs to project future costs in the event that these experiences happen more frequently. However, whether it is from a lack of knowledge or an unwillingness to share data (see above), most facilities could not provide costs of impacts. Neither opportunity costs of lost business, nor repair and replacement costs related to damage from storms was available.

5.3 Operational Thresholds for determining Future Disruptions

Aspects of the procedure described above were incorporated into analysis of potential facility disruptions. For each facility, specific thresholds were identified to best determine the climatic conditions under which operations of the facility would be affected.

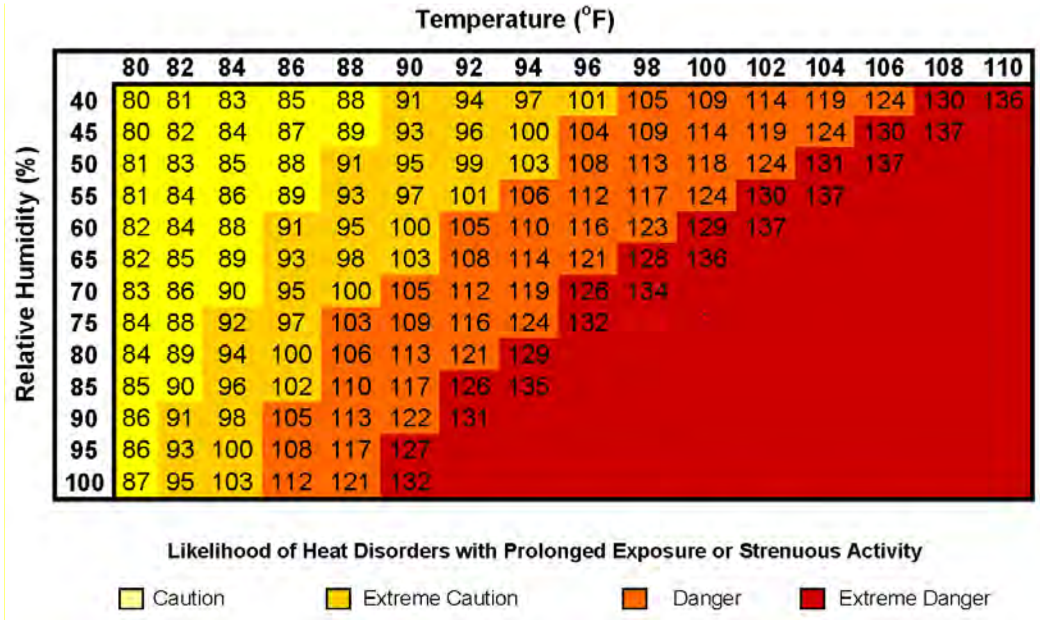
The analysis was focused on those climatic variables which are likely to change such as temperature, tropical storms and sea level, among others. The objective of the approach has been to project threshold exceedance in the future and, thus, estimate the potential impacts of such events on the facilities.

5.3.1 Extreme Heat

Employee Health and Safety

An average person's ability to work safely outdoors depends on the Heat Index – a function of air temperature and humidity which describes how hot an environment really feels.

> *The Heat Index is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature. … The National Weather Service [of the US] will initiate alert procedures when the Heat Index is expected to exceed 105°-110°F (depending on local climate) for at least 2 consecutive days. The National Weather Service [of the US] also offers a Heat Index chart for area with high heat but low relative humidity. Since heat index values were devised for shady, light wind conditions, exposure to full sunshine can increase heat index values by up to 15°F. Also, strong winds, particularly with very hot, dry air, can be extremely hazardous.* Heat Index Bulletin – The National Weather Service of the National Oceanic and Atmospheric Administration (NOAA). [http://www.nws.noaa.gov/om/heat/heat_index.shtml]



RH (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Figure 5.1 Heat Index Graph. Prepared by NOAA's National Weather Service.

The Heat Index chart shown above in Figure 5.1 shows the likelihood of heat disorders with prolonged exposure or strenuous activity i.e. employees working outdoors. The red area without numbers indicates extreme danger. As an example, if the air temperature is 88°F (31°C) and the relative humidity is 85%, the heat index--how hot it feels--is 110°F (43.3°C) and someone working outside is in the 'danger zone' for suffering from a heat disorder.

Analysis of this table revealed the following operational thresholds:

- Heat Index over 30.8 °C (87.5 °F) with relative humidity 80% is "high" risk
- Heat Index over 32.9 °C (90.7 °F) with relative humidity 80% is "very high" risk

As shown in Figure 3.4, humidity across the island varies by location, time of day and time of year. It is on average 83% in the summer months. Also, Figure 3.1 shows that the month of July is already averaging temperatures of 29.6°C and with the mean temperature increase (in °C) projected (from the GCMs) to be 0.75-1.04°C by the 2030s and 0.87-1.74°C by the 2050s, it is easy to see how workers at the island's transport facilities will be in the danger, and extreme danger, zones of the Heat Index graph.

Aircraft Lift

Airports are generally vulnerable to the impact of temperature rise because hotter temperatures will require a longer runway for aircraft to achieve the same levels of lift. The data and table below show the effect of temperature increase on runway length requirements for the two largest aircraft that travel to the two Jamaican international airports (777, 747), and for the aircraft that transits these ports most frequently (737).

Table 5.1 Base Data and Assumptions in Temperature Rise Analysis

Aircraft Considered	Assumptions
NMIA – Boeing 777	Maximum Aircraft Take-off Weight
SIA – Boeing 747	Sea Level Elevation
Both Airports – Boeing 737	Dry Runway

Average Base Temperature
NMIA – 31.9°C
SIA – 28.9°C

Air Conditioning Off
Zero Wind
Zero Runway Gradient
Optimal flap settings

Table 5.2 Aircraft Minimum Take-off Lengths

Airplane Model	Mean Maximum Daily Temperature of the Warmest Month			
	STD 15ºC (59ºF)	STD+15ºC 30ºC (86ºF)	STD+25ºC 40ºC (104ºF)	STD+35ºC 50ºC (122ºF)
Boeing 747	10,200 ft. (3110 m)	10,700 ft. (3,262 m)	12,400 ft. (3,780 m)	15,500 ft. (4,724.4 m)
Boeing 777	8,000 ft. (2,439 m)	8,400 ft. (2561 m)	n/a	n/a
Boeing 737	7,800 ft. (2,2377 m)	8,100 ft. (2,469 m)	10,100 ft. (3,078 m)	15,000 ft. (4,572 m)

Source: Airplane Characteristics for Airport Planning, Boeing 2012
STD = Standard Day

The data suggests that both SIA and NMIA will have to increase runway lengths by approximately 500m in order to accommodate their most frequently arriving aircraft, the 737, given annually increasing temperatures. Further, SIA will need to increase its runway length by 600 m in the near term to accommodate 747 aircraft. Fortunately, the 777 requires much shorter runway take-off lengths than its larger counterparts. This issue supports the present capital expansion plans for SIA, which call for the extension of the runway to accommodate larger aircraft. It is hoped that this expansion may be contained in an easterly direction to avoid a requirement for serious investigations relating to the impacts of such a venture on the adjacent beaches. It is unknown whether or not NMIA has similar plans at this time, but it would be similarly advised.

Tarmac Exposure

Yet another problem faced by airports with regard to extremely hot temperatures, is that on very hot days the tarmac cover layer can become soft. This is exacerbated by the fact that temperatures on a dark tarmac can be typically 20ºC to 30ºC above air temperatures on a hot day. Many asphalt mixes will melt or become soft at 50ºC, unless treated with special polymer modified binders, which can raise the melting point to 80ºC. It is not known whether this issue is on the "radar" of the operations mangers of the airport facilities, however it needs to be.

Energy Costs

The costs associated with running facilities of the size of those studied herein are quite high. Specifically, energy costs associated with the Heating, Ventilating and Cooling (HVAC) systems can be quite exorbitant. Higher temperatures put extra pressure on the HVAC system to maintain a cool, habitable interior space. A direct relationship can be assumed between energy costs and warming i.e. the higher the temperature, the higher the energy costs and the more strain on the HVAC system.

5.3.2 Wind Speed

High velocity winds will affect the functioning of transport facilities in many ways, including the ease and comfort of persons moving about. However, it will specifically limit the operations of airports in that aircraft may not be able to safely take off and/or land in high winds. For seaports, the wind speed could limit the ability to berth ships due not only to the force of the wind itself but also because high waves are often generated in windy conditions. For these reasons the following operational thresholds are recommended for airports and seaports respectively:

Table 5.3 Operational Threshold limits for Wind Speed

Operational Condition	Associated Operational Threshold Value
Aircraft unable to safely take off and/or land	Commercial airports: sustained winds of 20 m/s
	General Aviation airports: 11.2 m/s
Ships unable to safely berth	With winds of 12.8-18 m/s, discretion is applied (25 – 35 knots)
	Winds ≥18 m/s (35 knots) force operational shutdown

Climate projections are currently unable to accurately predict how daily winds will be affected by Climate change. However, projections do indicate that winds associated with storms will become more intense, with maximum wind speed increases of +2 to +11% associated with stronger storms by the end of the century. This will likely result in an increased time of operational shutdowns associated with storms as a result of winds.

5.3.3 Precipitation

Precipitation can severely limit the visibility at any major transport facility. However, whereas pilots and airport staff have machines and computer systems guiding them, crane operators at commercial port facilities typically use only eyesight to conduct their work duties. There is no set operational threshold for low visibility due to increased precipitation, as visibility can be impacted by a myriad of factors. However, it is nevertheless concerning that crane operations could have to more regularly cease operations as a result of increased rainfall due to increased storminess.

5.3.4 Sea Level Rise

The Sea Level is expected to rise (depending on the scenario adopted) by approximately 1m by the end of the century. All the transport facilities, as well as connecting roadways and infrastructure, under this study are located in low-lying coastal areas subject to inundation by rising waters. Should components of operation such as the airport runways, the container yard for storage, or the shops and restaurants visited by the cruise tourists fall below this level they will be inundated with water. Further, the water level also rises due to surges during storms. As storm intensities are projected to increase, the vulnerability of the facilities to water inundation will worsen.

5.4 Vulnerability Overview by Facility

The overall vulnerabilities of each of the facilities considered are summarised herein.

5.4.1 Sangster International Airport (SIA)

The SIA handles the largest number of arrivals and departures of any airport in Jamaica and is the premier gateway for leisure visitors to the island. It is ranked within the top 20% of airports worldwide, and is a critical facility to the underpinning of the tourism sector and its earnings potential for the island. The airport is well run and has been the subject of ongoing upgrading and renovations, which have resulted in its ability to handle an increasing number of passengers.

There is not a lot of information related to historically significant weather events which have had some impact on the operations of the SIA. It was anecdotally reported that during the passage of a hurricane there has been a shutdown of the facility, with reopening occurring after clean-up had taken place such as debris removed from runway. However, the length of time for which the facility was closed, and the extent of damage related to particular events remains unknown.

Despite the lack of available data, climate related vulnerabilities can still be identified. The most noticeable is the fact that the runway is low lying and will be increasingly subject to flooding in the event of global sea level rise (SLR), and storm surge resulting from more intense hurricane events. Survey information indicates that the runway is at approximately 1.2-1.4m above MSL. Recent work done for a section of shoreline to the immediate east of SIA predicted that for the 1 in 50-year hurricane (approximately equivalent to a Category 3 – 4) the water level at the shoreline (high tides, storm surge, global sea level rise) will be 2.15m above MSL. If some freeboard is applied, then a finished ground elevation of +2.5m relative to MSL would therefore be appropriate.

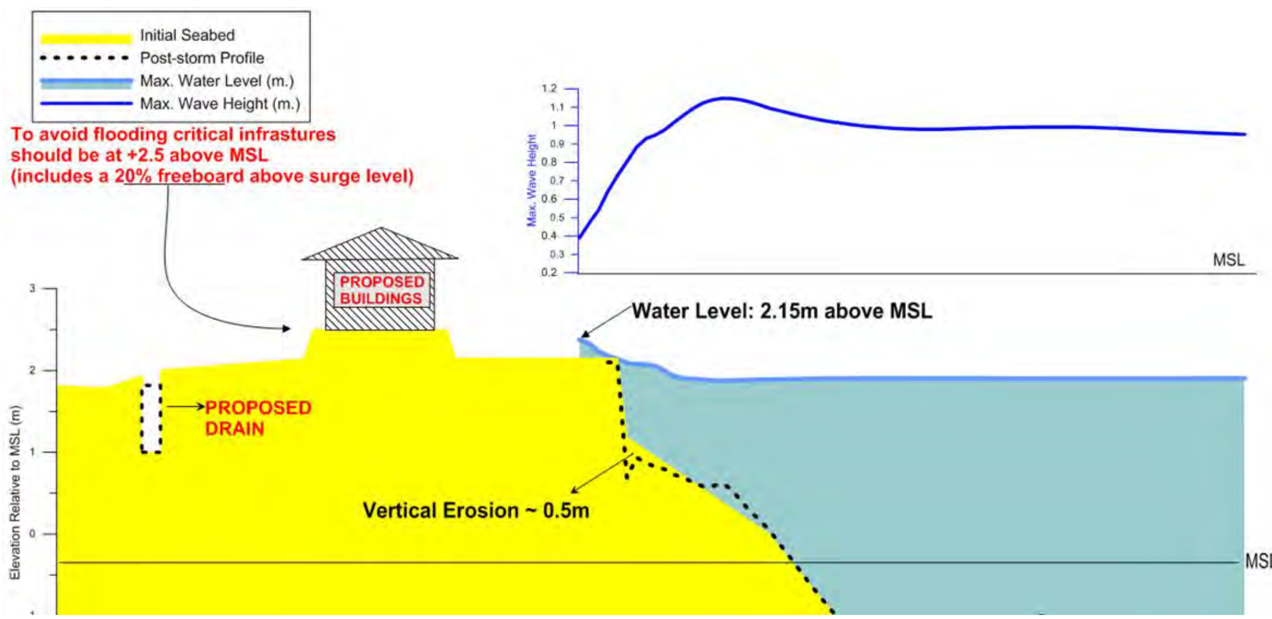


Figure 4.3 Water Level Predictions for the Shoreline East of SIA

It is therefore strongly recommended that the management of SIA put this issue squarely on their management and upgrading timeline.

5.4.2 Norman Manley International Airport (NMIA)

The NMIA is a critical facility in the context of providing business travellers and visiting friends and relatives, access to and egress from, the nation's capital city. While it does not accommodate the sheer number of travellers that pass through SIA, it is nonetheless as important to the advancement of Jamaica's economy. As with the SIA, it is well run and has been the subject of continual improvement.

Historical Disruptions

The NMIA facility has over the years, been affected by many hurricanes and tropical systems; the following weather-related events stand out for this facility:

- Hurricane Ivan in 2004, which forced the closure of the Manley Highway (Palisadoes Road) for a two-day period, thereby preventing people from easily accessing the airport.
- Hurricane Dean in 2007, which essentially was a repeat of the Hurricane Ivan damage, as Dean followed a similar track to Ivan.
- Hurricane Sandy in 2012, which also resulted in some downtime at the airport, although it did not result in a closure of the access road.

In addition, in recent years the area west of the Administration building has been subject to flooding of drains and parking areas. This effect has primarily been observed in the summer months between July and November. The flooding appears to have been forced by tidal action causing a backwater effect in the drainage system of the area.

Figure 5.2 Flooding of area behind Administration Building

While not causing a shutdown of facilities, the 0.08m to 0.13m of standing water in the Administration Building parking lot and fuel farm areas did cause disruptions to the movement of airport personnel who were working in the area. The figure here shows the area described with the flooding in evidence.

From previous investigations done into water level fluctuations in the Caribbean at stations ranging from Key West in the Florida Cays south-east to Puerto Rico, there is evidence of a thermal expansion phenomenon in the Caribbean Sea, which occurs typically in the summer months. This phenomenon resulted in the increase of mean water levels at the Key West station by as much as 0.127m (5"). It is to be noted that between December and June the mean water levels are below the long term average of MSL. This phenomenon was first observed at NMIA in 2008 and then again within the past two years. It is likely that climate change and global sea level rise has made this more noticeable.

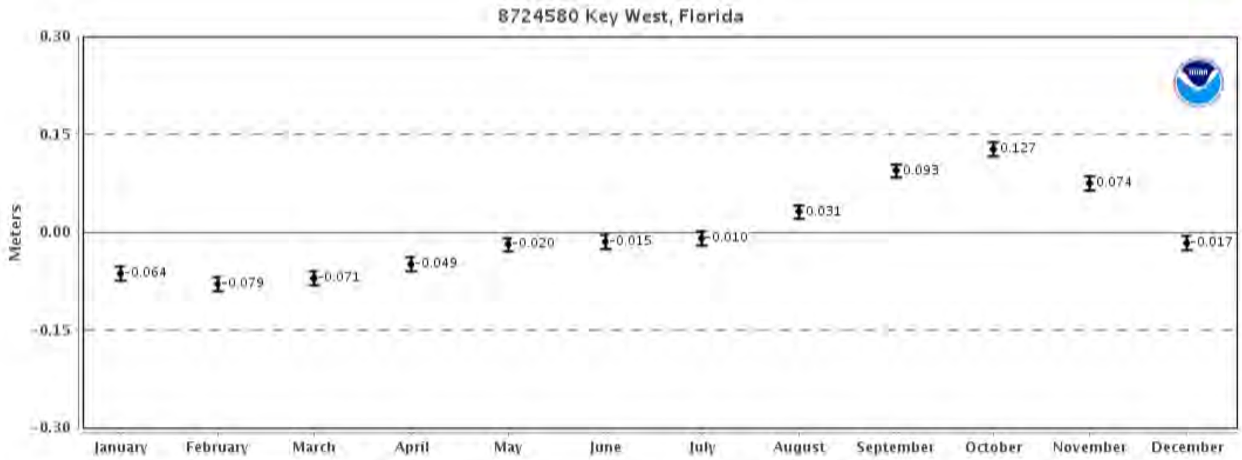


Figure 5.3 Thermal Expansion Observations for Key West, Florida

NMIA also had an unusual incident in May 2015, when for the first time a large flock of pelicans were observed to be congregating off the western end of the runway. This posed a serious threat to aircraft on a flight path to approach the runway. It is not known what had triggered this occurrence.

Finally, the only other weather-related event of note that has posed a threat to aircraft landings and take-offs has been the occurrence of Sahara dust in May. In addition to reduced visibility, the Sahara dust has the potential to result in respiratory problems for airport staff.

Vulnerability

NMIA is better suited to withstand the effects and impacts of climate change, and in particular sea level rise, than SIA, as it is located within Kingston Harbour and is adjacent to extensive stands of mangrove, which have been shown to reduce the impacts of storm surge. In addition, the runway elevation is typically in excess of 2.5m and this would make it initially resistant to sea level rise impacts. Previously, the major area of vulnerability for this facility lay in the approach linking road. However, with the relatively recent sea defence works that have been implemented, this risk has been considerably reduced. Notwithstanding this however, it is important to note that these new sea defence works have not yet been tested by the likes of a Category 4 hurricane such as Ivan or Dean. These structures have been designed to withstand the 1 in 50-year return period hurricane, which would be equivalent to a Category 3 – 4. New drainage improvements on the runway have also added to the flood proofing of this facility.

In summary, this facility has the capability to withstand many of the climate change effects related to storms that are anticipated, and it is expected that recovery and return to normalcy after a hurricane event should be achievable within a day or two.

5.4.3 Historic Falmouth Cruise Port (HFCP)

This facility is relatively new (6 years old) and has been subject to the latest design standards and codes. As outlined previously, it has, in its short lifespan, become the premier cruise terminal in Jamaica, handling half of all the cruise arrivals. Expansion (sea bed deepening) plans for the east berth imply that this level of importance will likely increase soon as this facility will shortly be able to accommodate over 12,000 visitors on a single day.

This facility has had no shut down incidents since its opening date, neither were there any other interruptions in facility operation reported by the manager.

Threats and vulnerabilities for this facility still exist however, and would be primarily from the passage of hurricane events. In discussions with the port management and PAJ representatives it was revealed that, in the event of a hurricane the Harbour Master will instruct any vessels at port to leave Jamaican waters; any cruise ship vessels approaching port would be steered away from this port, and indeed from making landfall at any Jamaican port. In this regard the primary driver to recovery of operations is likely to be the general state of readiness of the country, and specifically the north coast attractions, to receive visitors. It will also be important for the operators of this facility to ensure, perhaps on a five-year inspection cycle, that the retail buildings are fully storm proofed. In addition, given the poor state of roadways and drains for the town of Falmouth, it is to be expected that the ability for visitors to leave this port after docking could be impaired following a hurricane, when roads and drains will be damaged and/or blocked, flooding will be evident and debris will likely cover the roads.

The location of the facility in the town of Falmouth further increases the vulnerability of HFCP. Low-lying access roads to the port through the town could become impassable in years to come due to inundation from SLR. This would hinder the tourists from leaving the port to pursue their leisure activities and thus have downstream economic impacts on tourism revenue. The poor drainage in the town which is already struggling with backing up of water from salt water intrusion up the drainage pipes will be worsened in the event of SLR; an additional deterrent for those tourists wishing to walk around the historic town of Falmouth.

Swell waves (or long-period waves) could become more frequent with a changing climate, and this may affect those vessels docked at the pier. However, most vessels are equipped with enough mooring points to secure themselves against the pier, and this reinforcement can be increased in swell wave scenarios. Therefore, although this is a concern worth noting, it is not necessarily unmanageable.

5.4.4 Kingston Container Terminal (KCT)

The KCT has been in place for several years and has been subject to ongoing upgrading of equipment and land space. It is a critical facility for the import and export of goods to and from Jamaica and its contribution to the Jamaican economy is of paramount importance. Present expansion plans, which would see the facility able to handle larger vessels, will add to this importance in the years to come.

The KCT facility is judged to be vulnerable primarily to hurricane events especially those which track close to, or over, the island. There are four main sources of vulnerability from storms:

- <u>Strong winds</u> - In general, once wind speeds exceed 25–35 knots, the Port Manager will require that operations cease, and that all cranes be tied down. These wind speeds are equivalent to a Tropical Depression (28-33 knots) or a Tropical Storm (34–64 knots); hurricane force winds are ≥ 64 knots. With the CSGM predicting more intense storms, it is likely that the vulnerability of the port equipment to winds will increase. Perhaps research into better reinforcement of the cranes to increase their wind resistant threshold is warranted.
- <u>High waves</u> – Storms typically translate to higher, more energetic waves in the port. If the wave height reaches a point where it is unsafe for persons or cargo on board a vessel, the Harbour Master will take control and instruct all vessels to leave Jamaican waters; or approaching vessels are instructed not to dock.
- <u>Strong Rainfall / Gully Outflow</u> – Because of its location close to the mouths of the Sandy Gully and Rio Cobre, debris from these water sources has been washed into the port during times of

heavy rainfall. This has, in the past, halted operations at the port, and has required that specific interventions must be employed, using tugs and manpower, to clear away these debris jams. In the event of more intense rainfall events, the amount of debris washed down could possibly increase and could result in a longer downtime and greater effort to remove the debris to continue operations.

- Storm Surge / Inundation of Access Road – Due to its location being fronted by the Kingston Harbour and neighbouring Hunt's Bay on its north-western side the access roads are vulnerable to flooding. In its history, there have been occasions when flooding of the access road has impaired access to the facility by staff which would affect its overall functionality. The low-lying access road is therefore further vulnerable to SLR because of the same threat of inundation.

In the event of an approaching storm, the Manager relies extensively on meteorological forecasts to decide on the point of shutdown, or not, for the facility; and that shutdown is at the manager's discretion.

5.5 Results of Recent Storm Surge Modelling of Transport Facilities

Recently, inundation maps were prepared for the critical transportation assets (Monioudi et al., under review), using the dynamic Lisflood-ACC (LFP) model. The results of modelling show that because the SIA runway is low lying (approximately 1.2m - 1.4m above MSL), it will be increasingly subject to inundation during extreme events. In particular, the modelling results show that even for the AOSIS advocated scenario (a 1.5°C warming cap) which is at this point projected to be exceeded in the early 2030's, the 100-year Extreme Sea Level (ESL_{100}) will cause significant flooding of the airport. By 2050, similar damages are projected for the 50-year event (ESL_{50}).

NMIA, located within Kingston Harbour, is adjacent to mangroves and salt marshes that are able to reduce storm event impacts and has a typical runway elevation in excess of 2.5m above mean sea level, making it less prone to marine inundation. The modelling confirms that only some small areas of the airport are vulnerable to marine inundation.

By 2030, some areas of the KCT seaport are projected to be flooded under the ESL_{100}, whereas by 2100 (and under RCP8.5), much larger areas will be affected. Its access roads are also projected to be vulnerable to flooding. KCT has been previously vulnerable to extreme events, including strong winds (> 13-18 m/s), energetic harbour waves and terrestrial flash floods that can drive large volumes of land-borne debris into the harbour.

Finally, modelling results suggest that the HFCP cruise port will be only very moderately affected until the 2080's, even by events with return periods between 1/200 and 1/1000. As a result of this, inundation images from this modelling have not been presented here. However, it appears that the low-lying access roads will be increasingly vulnerable to flooding. According to port officials, this is already a problem, as is berthing under certain wind and wave conditions.

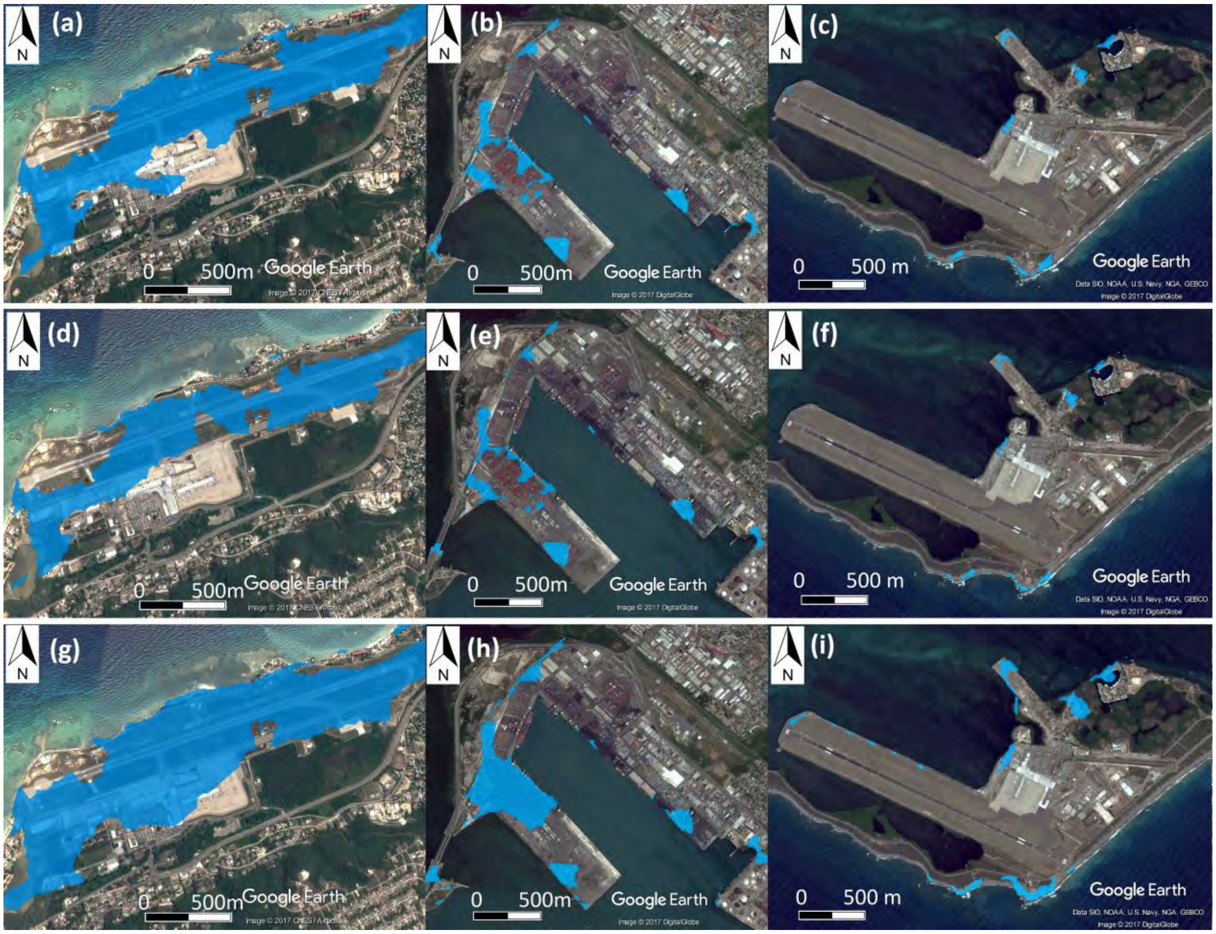


Figure 5.4 Inundation maps of: (a, d, g) SIA; (b,e,h) KCT and (c, f, i) NMIA for a Caribbean hurricane with the characteristics of Tomas (Tomas) superimposed on (a ,b, c) and a 100-year ESL (ESL100) (2030 AOSIS scenario); (d, e, f) a 50-year ESL (ESL50) 2050 (RCP4.5); and (g, h, i) a 100-year ESL (ESL100) (2100, RCP8.5)

6. Potential Adaptation Strategies

According to the European Commission's Climate Action, adaptation to climate change means:

> *"anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause, or taking advantage of opportunities that may arise. It has been shown that well planned, early adaptation action saves money and lives later."* [https://ec.europa.eu/clima/policies/adaptation_en]

In the specific case of the transportation facilities studied herein, all of which are along the low-lying coastline, examples of adaptation measures could include:

- Adapting building codes to account for anticipated future climate conditions and extreme weather events [to increase structural resilience of terminal buildings];
- Building flood defences and/or bunds and raising the levels of runways and container terminals [to promote flood-proofing of these critical components of the transport facilities and thereby permit a longer useful time-span of operations];
- Setting aside land space to facilitate movement landward [to allow managed retreat of operations in the event where loss of land and incursion by the sea may be inevitable];
- Planting of mangroves and other marine-related flora, which would dampen the impact of high waves and storm surge [to reduce the impact of storm surge and high water levels on the associated critical facilities; this is an adaptation strategy that could be considered for the SIA];
- Reinforcing cranes and other equipment to resist higher wind speeds [to assist in the rapid return to productivity following an extreme storm event];
- Employing the use of solar panels, wind turbines etc. to help reduce energy costs associated with rising temperatures [and to assist in the rapid start-up of operations following a storm or natural disaster].

It should be noted that some of these approaches are considered 'hard-engineering' while some are considered 'soft' and/or management approaches. Generally, 'hard-engineering' approaches involve the design and construction of a structure or reinforcement of an existing one. The construction of the revetment along the Palisadoes roadway is an example of a hard-engineering approach to climate change adaptation, whereas the planting of mangroves along another section of the roadway would be considered a 'soft' approach. Hard approaches are generally more rigid and better at defending against extreme events as well as SLR in the long term. However softer approaches tend to be beneficial on a much broader scale: e.g. creating habitat for fishes, filtering water etc. Hard approaches are also permanently fixed i.e. built to a specific size/height, and so should levels exceed that fixed point they would be breached. Soft approaches on the other hand, tend to grow and adapt to their environment, if successful. Any solution, whether hard or soft, will come at a significant cost and should be properly thought-out and designed by a qualified engineer who will require long-term data on the climate which is being designed for. Therefore, data collection will have to be an integral part of any engineering study required by any meaningful adaptation approach.

Adaptation strategies are needed at all levels of administration: at the facility level, the community level and the national level, and in some cases even at the international level. Proper strategy development is needed to plan for the wide range of possibilities that could occur. Further, there is an important need for stakeholders, policymakers, regulators and facility operators to liaise and collaborate, with a willingness to share data and methodologies, in the hopes of creating a better understanding of the problems and to develop possible solutions with regard to climate change.

6.1 Facility-level Adaptation Strategies, Requirements and Capacity

6.1.1 Sangster International Airport (SIA)

The SIA will need to establish general and specific adaptation strategies to combat the anticipated effects of climate change. The airport has already equipped itself with back-up generators and water storage tanks but there is still much more that is desired from a capital improvement perspective. In particular, the premier strategy would have to include changes to the existing runway.

The runway should be raised by a minimum of approximately 1m to provide additional resilience against global sea level rise, thermal expansion of the Caribbean Sea and storm surge from hurricanes. It is of interest and much concern that the raising of the runway was not mentioned by the operators of the airport, and indeed does not appear to be on their planning horizon. It is anticipated that this is an action which may be taken with minimal environmental disturbance, but one which will have to be carefully planned and executed in order to minimise logistical impacts. Rationalisation of such an action with the ground elevations of the surrounding facility will also have to be carefully thought out.

A second area of specific adaptation will be the extension of the runway, which should be extended to the west (i.e. seaward). Note that this action will serve a commercial purpose, as it will allow larger aircraft to land and take off from this facility. From a climate change perspective, it will also address the need for a longer taxiway to counter the effects of warmer temperatures and decreased air densities. Such an extension will require significant environmental studies, to ensure that the planned works do not adversely affect the seabed or cause erosion of the neighbouring famous beaches of Montego Bay, and/or the flow of traffic in from the Rose Hall tourist area.

Both of these specific adaptation strategies may be achieved with existing resources in the Montego Bay area, however a significant amount of planning must be brought to bear for these works to be accomplished in a seamless manner and with as little facility down-time as possible.

It would be of further added benefit if a water level recorder was installed at the airport and adequate data storage was in place to track and record the local climate parameters of interest (water level, wind speed and direction, rainfall etc.). Accurate data records at the airport over the long term are essential to monitor trends and will help to feed into the climate projection models to get more specific forecasts.

6.1.2 Norman Manley International Airport (NMIA)

The NMIA has already been the subject of extensive adaptive strategies. The Palisadoes Road has been raised by approximately 2m and a sea defence system that should protect this roadway from Category 3 – 4 hurricanes has also been implemented. In addition, and as with the SIA, the management of this facility have put in place many safeguards against fire, and have assured the continuation of water supply and electricity generation in emergency situations. It is also of interest to note that the existing elevation of the runway and terminal areas for this facility in general provide a generous time schedule for accommodation of climate change impacts.

The major adaptation strategy required (and which is already in the planning process for commercial reasons) for this facility would be the extension of the runway into the harbour by roughly 500m and the inclusion of a Runway End Safety Area (RESA) in the extension. This action will address commercial needs (ability to accommodate larger aircraft) as well as climate change concerns regarding the onset of warmer temperatures. The strategy for lengthening the runway may be achieved using facilities that are available in the greater Kingston area. It will require, however, careful planning, design, environmental and permitting considerations and implementation.

Raising the land area westward of the NMIA Administration Building and in the vicinity of the fuel farm could also be considered, to better mitigate against global sea level rise and thermal expansion of the Caribbean Sea (a phenomenon that is presently occurring in July to November of most years).

6.1.3 Kingston Container Terminal (KCT)

The KCT appears to have a well-developed response plan to deal with the approach of hurricanes. This consists of the diversion of vessels away from Jamaican waters and the tying down of gantry cranes to limit damage to equipment. There is an operational threshold for winds (regardless of whether or not they are associated with a storm) above which the cranes are tied down, but research into better reinforcements could potentially increase these thresholds and is worth investigating further.

The secondary source of facility shutdown, which relates to the wash out of debris into the western basin of Kingston Harbour, is as a result of outpouring from the Sandy Gully and the Rio Cobre River. This is a problem that may be expected to become less frequent but more problematic when it does occur, given the predictions for longer periods of drought but more intense rainfall when it does rain. To address this, there could be some consideration for the implementation of trash booms placed across the exit of Hunts Bay, or a dredged hole at the outlet of that Bay, to impound debris before it gets into Kingston Harbour.

This is however, a problem which extends beyond the immediate facility and which requires a multi-stakeholder approach to its solution. This issue is a societal one, which is related to people living on the banks of Kingston's gullies, the inability of solid waste trucks to get into those areas, and the development of a culture whereby gullies are used for waste disposal.

6.1.4 Historic Falmouth Cruise Port (HFCP)

Adaptation requirements for this facility are considered to be minimal, as it is a new facility, and one that has been designed to modern codes and standards. Adaptation efforts associated with this facility relate more to the upgrading of roadways and drains in the town of Falmouth, than they do to the facility itself.

In this regard, and of a related note, the town of Falmouth is of great historical value and requires much preservation and upgrading. It is necessary to improve the main roads and drains in the town, to provide all-weather access and egress from this town. Main drains and outfalls should be designed to accommodate at a minimum the 1 in 25-year return period event; and secondary drains should be designed to accommodate the 1 in 10-year event. This will, however, be a challenging design given the relatively flat land gradients in this town.

In carrying out the works to improve Falmouth, consideration should also be made of increased wind speeds, sea level rise, and potential torrential rainfall, all resulting from climate change impacts. It is therefore noted that the management of the Falmouth port will not have the mandate, or the capacity to carry out the required works. Essentially, these must be carried out as multi-agency projects.

6.2 National-level Strategies and Requirements

Each of the facilities considered under this study exist within the Jamaican context and as such are challenged with the same national-level struggles such as poverty, crime etc. (as outlined in Section 2). Therefore, to properly adapt to impending climate change, holistic, national-level approaches are required.

Some national level strategies which could aid in adaptation cover a wide range of sectors and are outlined here.

1. All the facilities will further strain their HVAC systems when the temperature rises and there are more warmer days. This will result in further electricity consumption and fossil fuel use which further contributes to climate change. To address this cyclical pattern, the government should encourage the facilities to install and make use of other power sources such as photo-voltaic (PV) cells (solar energy) or wind turbines (wind energy). The government of Jamaica has made some steps in this regard on a national level with the construction of wind farms, the implementation of an LNG terminal and through other mechanisms. However, on a facility level, the government could encourage the use of alternative energy through tax breaks on the purchase of the PV units or through other incentives.
2. Some roadways in Jamaica date back several decades and have not been built with proper drainage or even to current design code. Some roads, which are main connecting roads between facilities are themselves the drainage conduits and are always scoured in times of heavy rainfall. On a national level, the government needs to re-examine its road network and make dramatic improvements to storm water drainage and road height, to decrease vulnerability to SLR, storm surge and more dramatic rainfall events. Staff, tourists and all persons using the facility rely on road use to access the transport facilities and the vulnerability of these access roads are therefore directly related to the vulnerability of the facilities themselves.
3. The Meteorological Office of Jamaica (Met. Office) has the mandate for meteorological data collection across the island. However, perhaps because of lack of funding, it does not have extensive storage capacity, neither are instruments deployed as widely (geographically) as they could be. A national initiative to increase the capacity of the Met Office, both in terms of data collecting equipment as well as storage volume, would be worthwhile. Records on sea level rise, rainfall over the years and many other parameters are lacking and this data gap hinders proper analysis by the CSGM.
4. Gullies in Jamaica are severely polluted, oftentimes with disastrous environmental consequences, such as waste outpouring into the Kingston Harbour and interfering with ships, as well as polluted waters affecting the swimming areas and coral reefs used recreationally. This can only be addressed on a national level. Strengthening the existing solid waste collection mechanisms would provide better alternatives for waste disposal. A public education campaign on the downstream effects of dumping in gullies would perhaps sufficiently retard this practice.
5. Generally, the government of Jamaica may need to make more of an effort to put climate change and the seriousness of its impacts in the forefront of the minds of its citizens. More public education campaigns, marketing and other public awareness efforts are required to raise awareness about the need for climate change adaptation among average Jamaicans.

7. Summary and Conclusions

7.1 Geographical Vulnerability

Jamaica is particularly vulnerable to climate change impacts due to:

- Its location within the Caribbean – which is itself within the "hurricane alley" of the Atlantic;
- The geographic nature of the island – characterised by a relatively small land mass with mountainous inland areas and narrow coastal plains, combined with large population concentrations and infrastructure located in these narrow coastal areas;
- A limited economic base and dependency on natural resources – this results in a very limited financial, technical and institutional capacity for adaptation.

Because of this heightened vulnerability, development of climate change adaptation strategies and policies are of paramount importance to Jamaica currently in its planning framework. No longer can Jamaica afford to ignore the looming impacts of climate change on their respective nations.

An examination of the cost of the impacts of climate change on Jamaica revealed that the current cumulative loss of GDP due to damage associated with natural disasters, was estimated to be in the order of $120 billion (roughly 7% of GDP). This is a significant number, which is even more grave given the already slow growth and fragility of Jamaica's economy. When this is coupled with potential climate change induced impacts, such as an anticipated increase in the number of extreme hurricanes, the figure is even more worrisome as it is likely to rise. Estimates indicate that it could reach as high as 56 per cent of GDP by 2025 if climate predictions are accurate.

7.2 Transportation Sector – Overview and Project Scope

The transportation sector is crucial to Jamaica's economic development, and major disruptions can seriously affect the economic flow and operations of the country. This is primarily since the transport sector acts as a conduit, linking production and service areas to end users. This link is especially vital in small islands such as Jamaica, where the country's population, by virtue of being on an island, is cut off geographically from neighbours and trading partners in the Caribbean and North and South America. To address this need, Jamaica has developed a multi-modal transportation system comprising of air, land (road and rail), and maritime transportation. Of all these modes, the United Nations Conference on Trade and Development (UNCTAD) has focused on the ports and airports sectors as being critically important for development. UNCTAD, in recognizing this dependency of SIDS on their port and airport infrastructure, has noted:

> *"access to well-functioning and reliable transportation systems, in particular maritime and air transport systems, is vital [for SIDS]. Seaports and airports are the lifelines sustaining the survival of these States, especially since they are highly dependent on transport-intensive imports for much of their consumption needs, for example food and energy. While maritime transport accounts for nearly 80 per cent of world merchandise trade by volume, this share is higher for SIDS. Although maritime transport is the predominant mode used to carry cargo and freight, air transport is relied upon primarily for passenger and tourist transport and domestic inter-island shipping and mobility."* – UNCTAD Trade & Development Commission. Multi-Year Meeting on Transport, Trade Logistics and Trade Facilitation. Third session. Geneva. November 24–26 2014. Item 3 :- Small island developing States: Challenges in transport and trade logistics. (TD/B/C.I/MEM.7/8)

Ports and airports are therefore critical to Jamaica's economy. They are required to provide necessary food imports into the country, as Jamaica cannot produce enough to feed its people and meet other vital consumer needs, such as oil and gas to power its electricity producing plants and cars, among other things. Additionally, ports and airports are gateways for people entering the island for tourism, which is a major foreign exchange earner. It is noted (World Travel & Tourism Council – Jamaica Economic Impact 2015) that the direct contribution of the travel and tourism sector to the island's GDP in 2015 was 8.5%, and this was projected to increase to 11.6% by 2025. When the wider effects from investment, the supply chain and induced income impacts are factored in, these numbers rise to 28% and 37.5% respectively, further underscoring the importance of the transportation sector to the Jamaican economy.

7.3 Project Objective and Outline

The criticality and importance of the transportation sector to Jamaica is without question, as is the vulnerability of those same facilities, which are to be found along the coastline. It is therefore crucial that all potential climate change impacts for these facilities be properly understood, and that adaptation strategies and a comprehensive procedure for their strategic implementation be developed in tandem. In recognizing this need, the United Nations launched a capacity building project on "Climate change impacts on coastal transport infrastructure in the Caribbean: Enhancing the adaptive capacity of Small Island Developing States (SIDS)", which is being implemented by the United Nations Conference on Trade and Development (UNCTAD).

The purpose of this initiative, which draws on UNCTAD's earlier relevant work in the field, is to strengthen the capacity of policy makers, transport planners and transport infrastructure managers in SIDS to (a) understand the full range of climate change impacts on coastal transport infrastructure, seaports and airports; and (b) take appropriate adaptation response measures. This report represents the case study for Jamaica. In support of the objectives of the project, the following steps have been incorporated in the preparation of this report.

1. In Chapter 2, Jamaica as a nation is described for the general reader in terms of its geography, its population, its economy and its social issues. It is felt that this is a necessary component of framing the overall project within a context specific to Jamaica.
2. A thorough review of the State of Jamaica's climate was undertaken in Chapter 3 to develop an understanding of the current climate conditions in the island, the climate trends as they have existed up to this point, and the future climate projections based on current climatic modelling.
3. Four key transportation facilities (SIA, NMIA, HFCP, KCT) have been selected and are detailed in Chapter 4, to ascertain the criticality of each to the nation. The facilities themselves have been studied to properly understand their operations and throughput. This defines for the project the criticality of the facilities to the country and forms a basis to hypothesize what could result from a disruption in services due to climate change.
4. In Chapter 5 the facility vulnerability to climate stressors has been assessed taking into account the methodology (which was developed in tandem with this report) of determining facility operational thresholds. This was done in an attempt to quantify the amount of disruptions and the costs associated with each particular climate stressor.
5. Potential Adaptation Strategies were then presented on a facility basis as well as on a national level for a more general sense.

7.4 Jamaica's Climate

7.4.1 Current Climate Conditions

Analysis of historical data collected on various meteorological parameters governing Jamaica's climate suggests the following:

- Surface temperature in Jamaica is largely controlled by the variation of solar insolation. Average annual temperatures range from 24°C in the winter months to 27°C in the summer months.
- The rainfall pattern is bimodal with early rainfall peaking in May and late season rainfall peaking in October. For all seasons, the maximum rainfall occurs in the parish of Portland, close to the border with St. Thomas. The main drivers of the rainfall pattern are the North Atlantic High (NAH) Pressure system, sea surface temperatures, easterly waves, and the Trade Winds.
- The data suggests that Jamaica receives an estimated average of 1825 kWH/m^2 per year of direct solar radiation. The south receives marginally more radiation than the north and the far eastern tip of Jamaica receives more than anywhere else. The annual variation suggests that for the given locations radiation peaks around June.
- Winds are strongest in Portland and St. Thomas, Manchester and St. Elizabeth. The strongest influence are the prevailing winds from the East or North East.
- Data paucity hampers the in-depth analysis of other meteorological variables, particularly analysis of their spatial variation.
- Relative humidity does not vary significantly throughout the year. For morning hours, the average humidity at the airport stations is higher and ranges from 72-80%. In the afternoon it is lower (59-65%).
- Sunshine hours vary little throughout the year, ranging between 7 and 9 hours per day. The average evaporation at Manley International Airport is 7.23 mm/day and 5.50 mm/day at Sangster International Airport.
- There appears to have been a lull in hurricane activity near Jamaica between 1952 and 1973 and much increased activity since 2001.

7.4.2 Historical Climate Trends

Analysis of historical climate data also reveal certain trends which are summarized following:

- There is an upward (linear) trend in temperatures which are consistent with global rates. Minimum temperatures are increasing faster than maximum temperatures. Mean temperatures are increasing at a rate of 0.16°C/decade.
- There is significant year-to-year variability in rainfall due to the influence of various phenomena (El Niño etc.) which results in no clear trend and an insignificant upward trend. The intensity and occurrence of extreme rainfall events have been increasing between 1940 – 2010.

- There is a regional increase in sea level rise of 0.18 ±0.01 mm/year between 1950 and 2010 which is consistent with the global mean, although there is a higher rate of increase in the later years: up to 3.2 mm/year between 1993 and 2010.
- There has been a dramatic increase in frequency of Atlantic hurricanes since 1995. There has also been an increase in category 4 and 5 hurricanes; rainfall intensity associated peak wind intensities and mean rainfall for the same period.

7.4.3 Climate Projections

Some of the work conducted by the Climate Studies Group, Mona, University of the West Indies (UWI-Mona) has been in predicting future climate under various Regional Climate Models (RCM). These are similar to Global Climate Models (GCM) but scaled to suitably fit the Caribbean and the island of Jamaica. Key projections from these analyses are summarized following:

- Temperatures increase across all seasons of the year, irrespective of scenario, through the end of the century. The mean temperature increase (in °C) from the GCMs will be 0.75-1.04°C by the 2030s and 0.87-1.74°C by the 2050s. However, RCMs suggest higher magnitude increases for the downscaled grid boxes. Mean daily maximum temperature each month at the Norman Manley International Airport (NMIA) station is expected to increase by 0.8-1.3°C by early to mid-century. The annual frequency of warm days in any given month at the NMIA station may increase by 4-19 days by mid-century.
- GCM's suggest that mid 2030's will be up to 4% drier while the 2050's will be up to 10% drier, while by the end of the century the overall county may be up to 21% drier for the most severe scenario. Similarly, RCM projections reflect the onset of a drying trend from the mid-2030's, which continues through to the end of the century. However, the decreases are higher for the grid boxes in the RCM than for the GCM projections for the entire country. There is some spatial variation across the country with the south and east showing greater decreases than the north and west.
- For Jamaica, projected SLR for the north coast is 0.43-0.67m by the end of the century with a maximum rise of 1.05m. SLR rates are similar for the south coast.
- There seems to be a shift towards stronger storms by the end of the century: maximum wind speed increases of +2 to +11% and rainfall rates increasing +20% to +30% for the hurricane's core. Although there is no statistically significant increase in the frequency of all hurricanes, it is predicted that there will be an 80% increase in the frequency of Saffir-Simpson category 4 and 5 Atlantic hurricanes over the next 80 years using the A1B scenario.

7.4.4 Climate Projections effect on Transport

Of the climate projections highlighted above, the temperatures and sea level rise are of the greatest immediate concern. Extremely hot temperatures cause excessive strain on HVAC systems, which affect operations and functionality of the facilities. Further, these extreme temperatures can affect asphalt both on the linking roadways and on the airport tarmacs. Sea level rise is also a grave concern as all the transport facilities under this study are in low-lying coastal areas subject to inundation by rising waters. An increasing number of more intense storms are also of concern as they cause large disruptions in the service operations of both the airports and seaports and can also cause significant damage to the facilities and equipment.

7.5 Criticality of Transport Facilities

The four transport facilities selected for analysis within this project were the two international airports, the largest cargo handling port in the island and the port with the most cruise ship arrivals:

- The Sangster International Airport
- The Norman Manley International Airport
- The Historic Falmouth Cruise Port
- The Kingston Container Terminal

7.5.1 The Sangster International Airport (SIA)

The importance of the SIA as the gateway to Jamaica's north coast cannot be overstated as the bulk of tourists visiting the island arrive through this airport. According to the airport's website: *Of the approximately 1.7 million annual visitors to Jamaica, 72% use SIA as their primary airport.* The Airports Authority of Jamaica (AAJ) also shows that 72% of visitors to the island came through the SIA in the financial year 2013/14. The AAJ data further indicates that this percentage share of the passengers entering the island has been on the rise since the 2008/09 financial year. This not only shows that the SIA is the most important airport in the island for visiting passenger traffic, but it also indicates that it is becoming more important as the share of the total national traffic is growing. Although the SIA does not heavily compete in the freight movement: cargo and mail, the movement of cargo and mail is increasing at a faster rate than the passenger movement. Regardless of the rate of increase, the data available clearly indicates that SIA features a large throughput of passengers and cargo that has steadily increased over the past 6 years. Further, because of its location on the north coast, close to hotels and tourist attractions the airport serves as a critical tourist gateway into the island, without which arriving passengers would have to travel long hours from NMIA to reach their north coast destinations.

7.5.2 The Norman Manley International Airport (NMIA)

As the "premier gateway to the nation's capital", NMIA plays a critical role in the economic development of Jamaica. The airport caters to over 1.5 million total passengers per year on average and handles over 9 million kilos of the island's airfreight (roughly 70% of total air freight traffic to the island). NMIA tends to provide air service primarily for visiting friends and relatives (VFR) and business travellers, rather than pleasure-seeking tourists. Surveys have indicated that over a million Jamaican-born persons live outside of Jamaica in the United States (75.5%), the United Kingdom (13.5%) and Canada (11%). The VFR traffic at NMIA reflects the demographic characteristics of this diaspora. NMIA is a draw for business travellers because of the proximity to Kingston. The city plays a central role in Jamaica's economy as the administrative capital and commercial and financial hub. The city is also home to several multinational organizations with regional headquarters, head offices of banks and consultancies, universities and sites of archaeological and historical interest. The criticality of air traffic access to the island's capital for the facilitation of business cannot be overstated.

7.5.3 Airport Comparison

The SIA and the NMIA are Jamaica's only two international airports; with similar histories and similar challenges they have a lot in common. Both international airports have existed in their respective locations in some form for over 60 years. Both airports currently occupy large extents of land (between 350 – 400 acres in each case) and feature all necessary elements of a functioning international airport. Throughout their histories, upgrades on both airports has been an almost ongoing process, and plans for improvements continue, with both airports having significant capital improvement programmes including the lengthening of their runways (when funds become available).

However, there are distinct differences between the two airports. Reports issued by the Airports Authority of Jamaica (AAJ) indicated that between the financial years 2008/09 to 2013/14, the percentage share of total passenger traffic to the island controlled by the SIA ranged from a low of 66.5% to a maximum of 72% with an average percentage share of 69%. NMIA contributed the remaining 31% on average over the period to total passenger traffic. The data regarding freight performance for the same period as recorded by the AAJ, shows that the NMIA has a higher market share in this field than SIA averaging 71% of total market share over the period and SIA controlling only 29%. The information is also found in the tables below.

The key points and trends revealed from the AAJ data can be summarized as follows:

- The SIA is steadily increasing its percentage share in both the freight market and the passenger market. Conversely the NMIA is losing percentage share in both markets.
- The SIA and the NMIA are dominant in two clearly distinct areas – the SIA has consistently controlled more than two thirds of the island's passenger traffic, while the NMIA has controlled over 70% of the freight traffic in the island for all years of record save one.
- The SIA and the NMIA differ in terms of the makeup of their passengers – the NMIA caters primarily to Jamaicans living abroad and to business travellers, while the SIA is the gateway to the north coast predominantly utilised by tourists vacationing in the island.

This analysis clearly highlights the complementarity of the two assets, which are both vital to the island in different ways. However, because the strengths of the facilities are so vastly different it raises questions about each facility's readiness to absorb the other's load in the event of a closure of either. For instance, in the event of a failure of SIA, NMIA would have to manage those passengers coming into the island, which are roughly 4 times its usual load (over the period of a year). It is unlikely that NMIA could adequately cope with the surge in passenger traffic in this eventuality; and conversely, it is also unlikely that SIA could manage the surge in freight traffic should NMIA close for any reason. This again reinforces the criticality of each airport in the management of passengers and freight entering the island.

7.5.4 The Historic Falmouth Cruise Port (HFCP)

Because of its excellent location and its ability to host larger cruise ship vessels, the HFCP is a critical player in the island's cruise ship industry. Additionally, the number of calls has continuously increased since the port's opening in 2011, which bodes well for anticipated growth.

Data obtained from Port Authority of Jamaica (PAJ) publications revealed that since it's opening in 2011 the Falmouth Pier has consistently had more passengers arriving on its docks than any of the other cruise ship piers in Jamaica. This is partly because it can dock larger ships with larger passenger capacities, but is also related to the popularity of the HFCP. It is likely also a function of the fact that the port lies between Montego Bay and Ocho Rios, allowing visitors a greater range of attraction options. The data also shows that the HFCP facility is responsible for approximately half (48% on average) of the total cruise ship passenger arrivals to the island. This elucidates the criticality and importance of the HFCP to the island's cruise ship industry. Damage of the port facility causing non-functionality for whatever reason would thus have massive effects on Jamaica's 'stop-over' tourism trade. Total cruise ship arrivals account for a significant part of total tourist arrivals into the island; in 2014, that percentage was 41%. This highlights the relative importance of cruise ship tourism in the island's overall tourism economy. As the cruise ship port with the most arrivals and calls, the data further underscores the importance of the HFCP to the island's economy.

Even locally the presence of the port is a significant economic contributor. Figures received from The Falmouth Jamaica Land Co. Ltd. revealed that approximately nine hundred (900) staff are employed within the 'plaza' of the pier i.e. within the shops and restaurants etc. This figure does not include tour operators etc. which are outside companies using the pier for excursion pickups, and so the overall number of persons who depend on the pier for their livelihood is even higher than stated above. In the small town of Falmouth, with a population under 9,000 persons, this is a very important employment centre (roughly 10% of the population) to the people of the town.

7.5.5 The Kingston Container Terminal (KCT)[5]

Data extracted from the database of the Port Authority of Jamaica (PAJ) on the KCT for the past five (5) years: 2011 – 2015 revealed that roughly 1500 vessels visited the KCT each year over the period. Of this amount, the vast majority (approximately 96%) were cargo vessels. The data showed that close to a million metric tonnes of cargo are brought into the island on an annual basis through this port alone. Other documents revealed data related to the 2008-2009 shipping season. During that period: *"the KCT received 2470 vessel calls and handled a total of almost 16.3 million metric tons of cargo. Fees produced by the KCT… during the 2008-2009 shipping season, generated a net income of $8.5 billion for KCT."* [– World Port Source]. It is worth noting that the bulk of the KCT business is transhipment and not domestic importation. *"Of the total amount handled by the port in the 2008-2009 shipping season, about 1.4 million TEUs (86%) were transhipments. Domestic containerized cargo represented 12% of the total 1.7 million."* [– World Port Source]

The transhipment services to the region – the Caribbean, North, Central and South American markets, are a vital component of the KCT business. The Economic Commission for Latin America and the Caribbean (ECLAC) updates every year its ranking of container port throughput, which shows the cargo volume in containers in 120 ports of the region, based on data obtained directly from port authorities and terminal operators. In 2015, the regional activity grew 1.7%, with a total volume of approximately 48 million TEU. ECLAC ranked the KCT as 8th in Latin America and the Caribbean.

The critical importance of the port is thus multi-fold:

- It controls the largest share of the country's imports and exports.
- It is a major contributor to the region's (Latin America and Caribbean) transhipment activities.
- It is a major revenue earner as well as a large employer of persons in the island, and thus contributor to the island's economy, through direct earnings and taxes.

The domestic cargo market should also not be underestimated as large amounts of produce and commodities are brought into the island through the port. Through the KCT and other ports, Jamaica mainly imports oil and ethanol (to satisfy the island's energy needs); wheat and rice (as the primary food imports); as well as lye, electronic appliances, vehicles and metals, all of which are inputs for manufacturing, agriculture and local businesses. Should operations at the KCT be forced to cease for any reason such as a natural disaster, Jamaica's economy and its people would be severely affected.

[5] Throughout the document, Kingston Container Terminal refers to the port facility whereas Kingston Freeport Terminal Limited (KFT or KFTL) will refer to the current (since 2015) managing company of the facility.

7.6 Vulnerability of Transport Facilities

The extensive studies reported in Chapter 3 of this report indicate clearly that: Climate projections specific to the island indicate climate change will likely occur. Key projections of climatic changes for the island of Jamaica along with their likely effects are summarized below:

Table 7.1 Forecasted changes in climate and their effects on transport facilities

Parameter	Change	Period	Effect
Higher Temperatures	Increase by 0.87-1.74°C	2050s	- Strain on HVAC systems - Weaken asphalt - Strain on personnel working outdoors
More Warm Days	Increase by 4-19 days	2050s	
More Droughts	10% drier	2050s	- Limits water supply and related functionality - Detracts tourists
Higher Sea Level	Increase by 0.43-0.67m	2100s	- Increased risk of inundation of facility runways, container bays and access roads
More Intense Storms	Wind Speed: +2 to +11% Rainfall: +20% to +30%	2100s	- More incidents of higher category storms - More likely to have facility shutdown due to storms.

Of all the climate changes which will occur, the climate stressor that is perhaps of most concern to facility managers is the threat of more intense hurricanes. The associated wave action; storm surge; and flooding linked to hurricanes has in the past resulted in large disruptions in the service operations of both the airports and seaports and has also caused significant damage to the facilities and equipment. The effects of climate change on these parameters will likely increase their potential for damage, which is an alarming consideration.

All the transportation facilities in this study border the sea, and KCT is almost completely surrounded by water. Therefore, the vulnerability of the sites to sea level rise, or inundation of the facility and access roads because of storm surge, is obvious.

7.7 Possible Adaptation Strategies

The analysis so far suggests some actions that can be taken by the facilities to safeguard against the impending climate changes which could include:

Facility	Potential Adaptation Strategy	Effect
SIA	- Raise or bund Runway - Extend Runway	- combat SLR and storm surges - combat warmer temperatures affecting lift
NMIA	- Extend Runway - Raise low-lying / RESA areas	- combat warmer temperatures affecting lift - combat SLR and storm surges
HFCP	- Combine efforts with local government to improve infrastructure in Falmouth	- improve resilience of access roads - improve tourist experience
KCT	- Invest in better reinforcement for cranes - Deploy booms in Hunts Bay	- combat higher wind speeds - control debris outflow

All the improvement strategies recommended are expected to decrease the vulnerability of the facilities in question. However, to make effective change, especially for the seaports, coordination with agencies outside of the facility will be required. Additionally, national-level strategies are also required for cohesive and long-term planning, especially for those issues being affected on a larger social and geographical scale.

In this context, with a view to the development of effective adaptation measures, it is important to note that the Jamaican Government, in 2015, has adopted a comprehensive and cross-cutting Climate Change Policy Framework for Jamaica which expressly recognizes the importance of climate change adaptation for seaports and airports.

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APPENDICES

Appendix 1 – Facility Data Norman Manley International Airport

<u>Airport Data</u>

Airport Name	Norman Manley International	
Location of Aerodrome	3 ml SW of Harbour View and 2 ml NE of Port Royal	
Reference Point (WGS 84)	N17º 56.0' W 076º 47.3'	
Geometric Centre	1357.80 m West of THR 30 (on RWY centre line)	
Aerodrome Elevation and Geoid Undulation	3.04m 19.27m	
Thresholds Elevation and Geoid Undulation	<u>RWY 12</u> 2.34m 18.41m	<u>RWY 30</u> 5.31m 21.09m
Elevation of Runway End	2.34m	5.31m
Touchdown Zone Elevation	2.40m	3.02m
Reference Temperature	31^0 C	
Aerodrome Beacon	Coordinates	N17º 52.0' W077º 40.0'
	Intensity 1000 Candelas	White 550 Green 110
	Characteristics	Alternating Flashing White and Green every 5 seconds
	Operating Hours	H24 - IMC – Instrument meteorological conditions

Runway Data

Runway Designation		**12**	**30**
True & Magnetic Bearings (WGS 84)		112° GEO 117° MAG	292° GEO 297° MAG
Runway Dimension	Length	2716m	2716m
	Width	46m	46m
Runway Slope	Longitudinal	1% U	1% D
	Transverse	0.1%	0.1%
Surface Type		Asphaltic concrete	Asphaltic concrete
Type of Runway		Code 4E	Code 4E
Precision Approach Obstacle Free Zone		In place	In place
Runway Strip			
Dimension	Length	2716m	2716m
	Width	300m	300m
Type of surface		Asphalt for RWY Grass for verges	Asphalt for RWY Grass for verges

Taxiways

Taxiway Data						
Taxiway	A	B	C	D	E	F
Taxiway Code	4E	4E	4E	4E	4E	4E
Length	2539m	308m	301m	401m	210m	610m
Surface Type	Asphaltic concrete	Asphaltic concrete	Asphaltic concrete	Asphaltic concrete	Asphaltic concrete	Asphaltic concrete
Pavement Width	23m	23m	23m	23m	23m	23m
Shoulder Width	10.50m	10.50m	10.50m	10.50m	10.50m	not provided

Facility Information

Surface Type	Concrete
Number of aircraft gates	14
Number of remote stands	5
Number of provisional stands	6

	Gate Number	Aircraft Type	Wing Span (m)	Overall length (m)
AIRCRAFT TYPE FOR WHICH STANDS ARE DESIGNED NOTE: AIRCRAFT OF SMALLER WING SPAN AND OVERALL LENGTH CAN BE ACCOMMODATED	1,2,3,4	B767-200	47.6	48.51
	5 and 6	B747-400	64.5	70.67
	7	B767-200	47.6	48.51
	8,9	A300-600	44.8	54.08
	11,12,14	B767-200	47.6	48.51
	15	B747-400	64.5	70.67
	Stand Number			
	16,17	A310	43.9	46.66
	18,19	Lear 60	13.4	17.89
	20	Canadair Challenger	28.5	20.85
	Provisional Stand Number			
	16A	B747-400	64.5	70.67

Appendix 2a – History of the Port of Kingston.

(The following was extracted from "KINGSTON Portrait of a City" with the kind permission of its author, Anthony Johnson. The book was sponsored by the Shipping Association of Jamaica and published in 1993. The copyright for this information is owned by The Shipping Association of Jamaica)

The history of Kingston shows that the great harbour of Kingston, has created significant wealth over the years, quite apart from whatever economic regime may have been operating on the mainland. The Port of Kingston has always been the hub of trade with several periods governing its development:

1. **1692-1713** - **The early freebooters**
   British Governments, Jamaican Governors, pirates, buccaneers and privateers plundered and brought fortunes to Kingston to finance imports from North America and Britain.
2. **1713-1759 -The Asiento Trade**
   When the British got exclusive right to supply Spanish America with some products, Jamaican planters objected to the competition, but trade developed earning vast sums for the port and created fortunes in Britain.
3. **1766-1822** - **Kingston as a Freeport**
   During this period, Kingston was said to be among the principal ports in the Western Hemisphere, and the main source of coins for the British Empire.
4. **1860-1912** - **Opening of Central America**
   When it was decided to cut a canal across the Isthmus of Central America, Kingston became a primary source of supply of labour for the canals, railways, and the introduction of banana cultivation by American companies who found Jamaica too small for their operations. This trade brought new influences into Jamaica – George Stiebel from Venezuela and Cecil Lindo from Costa Rica.
5. **1939-1944** – **WWII**
   With the closure of the Atlantic merchant shipping lanes, Kingston port flowered into a range of activities as a new coastal trade was renewed among Jamaican ports; and small boats started trading with other Caribbean ports as new sources of goods were sought.

When in 1938, the country's workers rebelled at the sub-human conditions of their daily lives, it was the waterfront workers who marched to the offices of Alexander Bustamante (now one of Jamaica's National Heroes) and begged him to form a union.

When Bustamante was arrested in 1938, the waterfront workers went on strike until he was released. This act of defiance by the waterfront men was new, and out of it was born the spirit of the new Jamaica, which resulted in Independence for Jamaica in August 1962.

THE SHIPPING ASSOCIATION OF JAMAICA

Captain S.D. List, a Danish captain and businessman, presented the idea of a shipper's association to all the wharf owners. They recognized that chaos could result if the management of the wharves was not geared to respond constructively to the new labour situation, and it was on this basis that the major shipping interest founded the Shipping Association of Jamaica in January 1939. It operated from the offices of Jamaica Fruit & Shipping, with Adam Pullar, a former Customs officer as the first manager; Capt. List was the first Chairman.

The SAJ then started the joint employment of labour for all wharf companies, bringing wharf workers into permanent employment. The initial negotiations with the BITU were acrimonious, long and sometimes dangerous. But out of them, wharf workers were able to pioneer in receiving several benefits today accepted as normal.

As the joint employment system developed, other unions joined the BITU at the bargaining table, first the Trades Union Congress, then the National Workers Union (the latter formed by Norman Manley, another of Jamaica's National Heroes) and once again there was the threat of chaos. This led to the formation in 1952, of Jamaica's first Joint Industrial Council, a development which has since has been patterned nationally, whereby a permanent council of representatives of the affected firms and the Unions meet on a regular basis to discuss and decide on issues affecting labour relations and eventually set the framework for labour contract. The innovation, started in Kingston, is most extensively used in the sugar and banana industries, which adopted the model.

The SAJ is one of four agencies responsible for the Port's operations as a modern commercial facility. The others are:

The Port Authority of Jamaica (a Government Agency) is responsible for the general operation and policy concerning shipping and navigation.

The Harbour Department, headed by the Harbour Master is in charge of all navigational aids, the condition of the channel, and the emergency services in the Harbour.

The Pilotage Department (under the Port Authority) provides the compulsory pilotage service required of all ships, except military vessels, which enter any Harbour in Jamaica.

After Hurricane Charlie in 1951, and the development of the Kingston Industrial Estate in 1952, business in Kingston boomed, especially imports, which benefited from the vast earnings of the new bauxite industry.

But downtown Kingston, laid out with narrow streets by Goffe in 1692 could not absorb the traffic. The waterfront became a nightmare of mule-drawn drays, handcarts, motor trucks, and vans of all sizes, together with passengers of ships coming to have a peek at the City. Overcrowding was endemic, movements were slow, spoilage, spillage and slippage were the norm rather than the exception, and clearly something new was required.

It was clear that a solution had to be found as the 15 wharves were in a state of chaos. Moses Matalon, a young Jamaican engineer, suggested removal to the Hunts Bay section in the Western Harbour, bounded by a swamp, then used as a dump for the City's refuse. Negotiations started about 1955 and resulted in the creation of the area known as Newport West, which in 1970, became Port Bustamante. This was soon hailed by the international community as the first private sector development in the Western Hemisphere since the War.

It provided:

- 8,000 feet of deep-water frontage
- Seven deep-water berths
- Four Hundred acres of new land to house the warehousing, offices and factories needed
- to service, and be serviced, by a great Port.

The owners of the 15 abandoned wharves were consolidated in two groups – Kingston Wharves headed by Grace, Kennedy; and Western Terminals which included the Lascelles and Matalon interests. The Government acquired 176 acres of the dumped land as its fee, and this section provided two new useful facilities at Newport West: The Container Port, using the new gantry crane mass movement system in a duty-free customs area and the Kingston Freezone which houses export manufacturing operations.

The first major innovation at the new Port, was the development of a Roll-on/Roll-off facility by Western Terminals at Berth No.1, which greatly increased the capacity of the port to speedily handle cargo.

On the 14th February, 1966, the world's largest cruise ship, SS "United States" docked at Western Terminals to officially open the new port, and for the first time in almost 300 years, the Parish of Kingston would no longer have the major port of the Anglophone Caribbean. In moving too Newport West, the port had moved to Western St. Andrew.

Appendix 2b - List of equipment at the Kingston Container terminal:

- 13 Ship-to-Shore Gantry Cranes including 4 Super Post Panamax Cranes with computer-aided management for both operations and maintenance (5 Gantry Cranes were recently de-commissioned and these are to be replaced)
- 30 stevedoring chassis (to move containers from one terminal to another
- 28 yard tractors
- 30 yard trailers
- 3 mobile cranes for hire
- 2, 4000 HP tugboats
- 1, 6000 HP tugboat (being acquired)
- 14 empty stackers
- 73 straddle carriers
- 24 trailer trains
- 4 train tractors
- 9 forklifts
- 744 reefer outlets (440/480v, Universal Type) with stand-by

The North Terminal:

- 535 metres of berth
- 47 hectares of yard space for stacking containers;
- 4 super-Post Panamax ship-to-shore gantry cranes

The South Terminal (Gordon Cay):

- 1,300 metres of berth
- 5 post-Panamax gantry cranes
- 6 super post-Panamax ship-to-shore gantry cranes
- 82 hectares (25 unpaved) of container storage space

The West Terminal:

- 475 metres of berth
- Extension of 65 hectares of container yard
- 4 Super-Post-Panamax ship-to-shore gantry cranes (delivered, and commissioned into service)