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The Caribbean Disaster
Emergency Management Agency

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THE REGIONAL DISASTER RISK MANAGEMENT FOR SUSTAINABLE TOURISM IN THE CARIBBEAN PROJECT

[THE REGIONAL PUBLIC GOOD]

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Standard for Conducting Hazard Mapping, Vulnerability Assessment and Economic Valuation for Risk Assessment for the Tourism Sector

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CROSQ

CARICOM REGIONAL ORGANISATION FOR STANDARDS AND QUALITY

Standard for Conducting Hazard Mapping, Vulnerability Assessment and Economic Valuation for Risk Assessment for the Tourism Sector

Contents

Foreword

CROSQ, the CARICOM Regional Organisation for Standards and Quality, was established in 2003 by a Caribbean Community (CARICOM) treaty as an Intergovernmental Organisation and the regional centre for promoting efficiency and competitive production in trade and services, through the process of standardisation and the verification of quality.

This Standard was developed under the Project "Regional Disaster Risk Management for Sustainable Tourism in the Caribbean" (ATN/OC-10085-RG). The project was implemented over the period of January 2007 to June 2010, by the Caribbean Disaster Emergency Response Agency (CDERA) with the support of the Inter-American Development Bank (IDB), and in collaboration with the Caribbean Tourism Organization (CTO), the CARICOM Regional Organization for Standards and Quality (CROSQ), and the University of West Indies.

This document was produced according to the ISO standard template "STD template, version 2.1", in conformity with the ISO/IEC Directives, Part 2, 2001.

Symbols and abbreviations

SYMBOLS

D	Consequence (damage or loss)
ε	Protection factor
i	Used as subscript, refers to a vulnerable object
I	Intensity of a hazard
j	Used as subscript, refers to a hazard scenario
P	Probability of occurrence
R	Risk (object or total risk)
T	Return period of a hazard
V	Physical vulnerability of an object
W	Market value of a vulnerable object

ABBREVIATIONS

CDEMA	Caribbean Disaster Emergency Management Agency
CHTA	Caribbean Hotel and Tourism Association
CTO	Caribbean Tourism Organization
DRM	Disaster Risk Management
GDP	Gross Domestic Product
GIS	Geographic Information System
IDB	Inter-American Development Bank
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
NOAA	National Oceanic and Atmospheric Administration
UNWTO	United Nations Word Tourism Organization
UWI	University of the West Indies

Summary

The Caribbean is the most tourism dependent region in the world, and natural hazards cause approximately 300 million US$ of losses to tourism and a similar amount to the connected economies every year. The continuous concentration of assets and the accentuation of the hazard situation due to climate change will lead to an even more critical situation in the future. It is thus imperative for Caribbean tourism to dispose of procedures to assess the risks it is exposed to due to natural hazards.

This Standard defines and describes the procedures for assessing risks due to natural hazards in the tourism sector in the states of the Caribbean Community (CARICOM), following a probabilistic approach. The document is structured into two parts, addressing non-technical (Part A) and technical audiences (Part B).

Part A – Introduction presents an overview of the context of tourism and natural hazards and risks for a non-technical audience. The introduction is composed of the following elements.

- A **rationale for developing this Standard** (→ section 1) is presented, analysing the economic importance of tourism for the Caribbean, its structure and the situation concerning the major natural hazards.
- The **specific vulnerabilities of tourism in the Caribbean** (→ section 2) are analysed addressing the particular characteristics of Caribbean tourism in combination with respect to the hazard situation.
- The **impacts of climate change** on the occurrence and characteristics of natural hazards in the Caribbean (→ section 3) is discussed, as well as its likely consequences for tourism. IPCC's adaptation option and strategy, underlying policy, framework and key constraints, and opportunities to implementation are briefly discussed.
- The general context and meanings of the key terms of **hazard**, **vulnerability** and **risk** are explained and the relative representations on maps are discussed (→ section 4).
- The **concerns addressed by the Standard** (→ section 5) are outlined, emphasizing the key characteristics of the Standard: estimation of specific risks, comparability of risks, standardization of assessment procedures, and standardized representation of results.
- The **current status of risk oriented maps and assessments in the Caribbean** (→ section 6) is reviewed focusing on initiatives of storm-related, flood, and seismic hazard maps, vulnerability assessments, and digital maps produced in the region.
- **Similar initiatives of risk assessment** (→ section 7) on the local, regional and global scale are briefly reviewed.
- Examples of **databases on natural hazards**, events and hazard maps, with regional and world-wide coverage (→ section 8) are presented in order to gain a quick overview of the regional hazard situation in the Caribbean.
- The **linkage of the Standard to the accompanying Strategy** (→ section 9) is discussed, addressing the major connections between the two initiatives.

Part B – Standard presents the Standard itself and is intended for a technical audience that applies the Standard for assessing risks in the tourism sector. The presented procedure is modular and open. Most of the modules can be evaluated individually and, if necessary, elements and procedures of the assessment can be replaced, and additional elements can be added. The assessment can be performed at different map scales – site specific, local, and regional and aims at a quantitative description of risks.

- The **Standard addresses total risks**, its smallest unit is the object risk. The Standard follows a bottom-up strategy, focusing primarily on the assessment of the direct damages and indirect losses of the facilities of tourism and secondarily on larger-scale effects, such as macro-economic effects.

- The **Standard considers the major hazards in the Caribbean**. Of the hydrometeorological (hurricanes, storm surges, wind storms, floods) and geological hazards (volcanic activity, earthquakes, mass movements, tsunamis) mentioned in the accompanying Strategy, assessment procedures are given for hurricanes, storm surges, floods, and earthquakes. Further hazards can be added later on, specifying the necessary data and procedures for their assessment.

- The **general concept of the Standard** is explained (→ section 10), introducing the formula for probabilistic risk quantification and its relative components, the applicability, intended audience, beneficiaries, limitations and uncertainties of the Standard, its review cycles, the terminology used, and the necessity to document natural hazard events as a basis for future analysis.

The Standard reflects the multi-step and multi-disciplinary character of risk assessment, and is structured into five major parts (→ section 11):

- **Definition of objectives and scope** (→ section 12). Initially, the objectives of risk assessment must be defined, addressing motivation, scope, level of detail, scale of assessment, as well as expected results.

- **Analysis of hazards** (→ section 13). The natural hazards are identified according to their importance in the study area and analysed to determine their relative degree of hazard, which can be displayed on maps. Risk analyses are carried out according to risk scenarios, characterised by specific hazard intensities and probabilities of occurrence.

- **Analysis of vulnerabilities** (→ section 14). The elements at risk due to natural hazards are to be identified and their vulnerability and expected damage determined according to the hazard intensity. Elements at risk are installations and essential infrastructures of tourism, people and communities, environmental assets, and connected economic activities.

- **Calculation of risks** (→ section 15). Risks are a consequence of the superposition of hazards on vulnerable objects. They can be calculated and compared to each other, to risks of other nature and compared to predefined levels of risk acceptance and tolerance.

- **Representation of outcomes** (→ section 16). The Standard specifies how the outcomes of risk assessment are to be documented in reports and displayed maps, suggesting layout, scale, colours to be used for the maps of hazards, vulnerable elements and risks.

A quick overview of the situation concerning natural hazards in the nations of the Caribbean can be gained using the supplied tabular summary (→ Annex A). A synthesis of the proposed risk assessment procedure is given (→ Annex B), as well as a short example of risk assessment (→ Annex C). The documentation of natural hazard events and their consequences is an essential prerequisite for conducting risk assessments. The Standard supplies a form for the standardized documentation of natural hazard events for future analysis (→ Annex D). A glossary explains the terms that are used in the document (→ Annex E).

Part A - Introduction

1 Caribbean tourism and natural hazards – Rationale for a standard

The Caribbean is particularly prone to natural hazards, such as hurricanes, earthquakes, floods, volcanic eruptions, drought, and mass movements. Figure 1 illustrates the impacts of natural hazards, in terms of number of people affected, number of people killed, and economic damage caused in the past decades in the Caribbean region. The clear general trend to increasing consequences, which can be observed in the graph, is mainly due to the increasing number of people and assets exposed, particularly in areas which are highly prone to natural hazards.

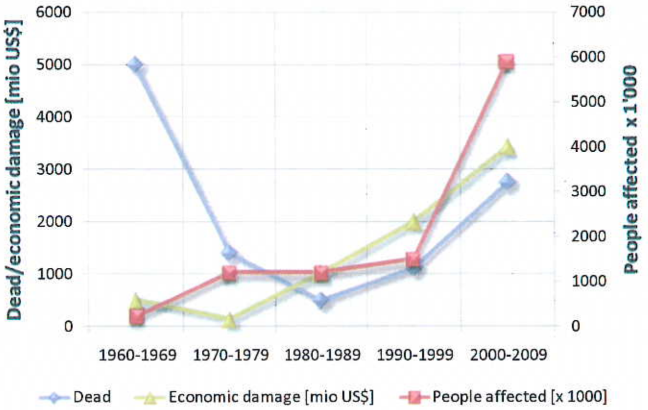


Figure 1 — Evolution of natural hazard impacts in the Caribbean per decade [30].

Since 1980 events of natural hazard such as hurricanes, storm surges, floods and landslides have caused in the Caribbean region US$8 billion in direct damages and possibly a similar or larger amount in indirect losses through, for example, loss of markets due to a reduced number of visitors. Natural hazards have been identified as one of the principal factors that affect the industry.

Tourism in the Caribbean has its roots in the late 18th century, the Bath Hotel was the first to open in 1778 in Nevis. Early tourism was limited to the winter season, less focused on beaches, but rather on the health benefits of the sea. Early tourists were wealthy people, the introduction of regular international flights in the 1960's brought a less exclusive form of tourism, alongside the luxury market. The development of these activities required large investments in infrastructures, not only hotel buildings, but also roads, sea and airports, drinking water and sewage treatment plants, landfills, and energy and communication infrastructure. Mass tourism became important in the 1980's, when multinational organizations such as hotel chains and tour operators began to show serious interest in the region.

From early initiatives to today, tourism has grown to the most important industry in the region, which interferes with nearly any other sector. Today, the Caribbean is the most tourism-dependent region in the world. According to the World Tourism and Travel Council, in 2004, travel and tourism in the Caribbean accounted for 16% employment, 15% Gross Domestic Product (GDP), 22% capital investment, 18% total exports, and 9% government expenditure. The prognosis for the sector is that it could account for an estimated US$10 billion of regional GDP in 2005, increasing this contribution to regional economic growth to approximately US$20 billion by 2015. The Caribbean Tourism Organization reports 22.7 million stop-over tourist arrivals and 19.2 million cruise ship passenger visits in 2007 with an increase of 19.4% and 20.7%, respectively, in the period 2002-2007.

According to the Caribbean Tourism Organization (CTO), the tourism industry can be divided into eight sub-sectors:

- **Accommodation.** Large, medium and small hotels, non-hotel accommodation such as villas, bed and breakfast establishments, and campsites.
- **Food and beverage.** Restaurants, coffee shops, dining rooms, fast food outlets, pubs, lounges, nightclubs, cabarets, catering establishments, and specialty shops.
- **Transportation.** Air carriers, bus and tour companies, cruise lines, car rentals, recreational vehicles, taxis, and gas stations.
- **Attractions.** Museums, galleries, heritage/historical sites and parks, gardens, amusement/recreation parks, interpretive centres, and native/cultural/industrial/eco-tourism.
- **Adventure tourism.** Air carriers, golf/tennis facilities, parks, fishing facilities, cruise lines, hunting facilities, car rentals, adventure tourism, recreational vehicles, marine facilities, and taxis.
- **Events and conferences.** Special events/carnival/cricket, meetings/conferences/conventions, festivals, trade shows/marketplaces, fairs and exhibitions.
- **Travel trade.** Travel agencies, tour wholesalers, tour operators and tour guides.
- **Tourism services.** Government tourism departments, information centres, research services, reservation services, advertising agencies, trade press, marketing, professional associations, consultants, tourism educators, tourism suppliers and retail operations.

The current economic structure of the Caribbean is illustrated in Figure 2, showing the interconnection of tourism and travel with other sectors, such as agriculture, construction, transport, communications, finance, insurance, real estate, and business services. In 2005 tourism accounted for 28% of the Caribbean GDP.

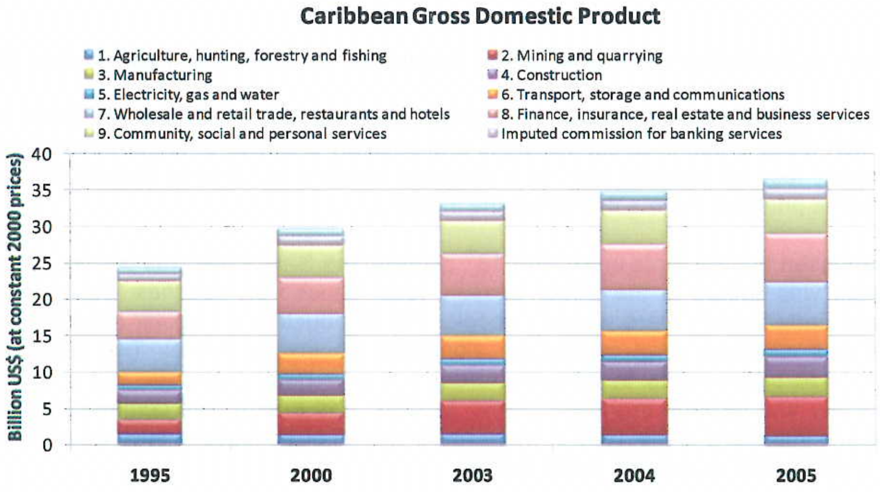


Figure 2 — Gross domestic product of the Caribbean [29].

The major natural hazards in the Caribbean [48] are linked to the formation of tropical cyclones that develop into a number of tropical storms and hurricanes each year with heavy winds and rainfall, causing coastal storm surges and coastal erosion, inland flooding and landslides. The tectonic situation of the Caribbean, located at the boundaries of the tectonic plates of North- and South-America, the Caribbean, Nazca, and Cocos, is responsible for geological hazards with a regional extent: Earthquakes, volcanic activity and tsunamis.

Figure 3 shows the relative occurrence of natural hazard phenomena of a total of 399 events registered in the international hazard database EM-DAT [30] for the period 1950-2008 in the Caribbean. The graph identifies hydrometeorological hazards as the most frequent phenomena. Intense tropical cyclones are generally accompanied by wind storms and storm surges (60%) and cause floods (25%), followed in the statistics by drought (5%). Geological hazards are less frequent: most important are earthquakes (3%), followed by volcanic activity (2%) and landslides (1%). Landslides are often triggered by heavy rainfall, thus directly linked to tropical cyclone activity and floods. Other hazards of natural cause are epidemic (3%) and wild fires (1%). They are not treated in this Standard.

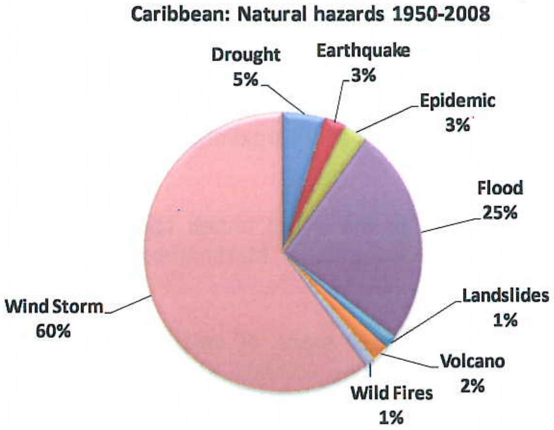


Figure 3 — Relative distribution of natural hazard phenomena in the Caribbean 1950-2008 [30].

A more detailed geographical distribution of the hazard situation in the Caribbean can be drawn from Annex A, which addresses the hazard situation in the Caribbean for hydrometeorological hazards (tropical cyclones, storm surges, tornadoes, and drought) and geological hazards (earthquakes, volcanic activity, tsunamis, and landslides):

Tropical cyclones are important in the whole region, particularly in those areas located at the major hurricane routes, resulting in a tropical cyclone threat of storms of maximum Saffir-Simpson scales (SS) of SS1 to SS4 for a 100-year storm. Hardly touched by this phenomenon is the southern part of the Caribbean (French Guiana, Guyana and Suriname).

In the period 1851-2008 a total of 1010 tropical cyclones (tropical storms and hurricanes) were observed in the Caribbean, 406 in the period 1944-2008 [64]. On the average about six tropical cyclones occur every year, three develop into hurricanes (of which one into a severe hurricane of Saffir-Simpson scale SS3 to SS5), and three remain on the level of a tropical storm. The Eastern Caribbean is less touched by the phenomenon than the Western Caribbean, and particularly the Bahamas. Most affected is the island of Abaco in the Bahamas (18 severe hurricanes since 1851), even though in the last 60 years there were only four. Since 1944 St. Kitts and Cuba were most prone to severe hurricanes (7).

Storm surges are due to a combination of tropical cyclone activity and unfavourable coastal topography and near-coast bathymetry. Less prone to this phenomenon are Trinidad and Tobago, Cuba, Belize, French Guiana, Guyana, Dominican Republic, and Suriname.

Tornadoes are a topic for the whole region, particularly in the northern part of the Caribbean (Dominican Republic, Cuba, Haiti, Jamaica, Cayman Islands, Belize, Puerto Rico, and Bahamas).

Floods are an issue for the whole area, particularly in regions with larger river networks and elevated tropical storm activity (French Guiana, Suriname, Dominican Republic, Belize, Cuba, Guyana, and Haiti).

Drought is a topic in the smaller island states predominantly made of limestone and with reduced vegetation (Cayman Islands, St. Kitts and Nevis, Anguilla, British Virgin Islands, Virgin Islands, Turks and Caicos Islands, Antigua and Barbuda, and Bahamas).

Earthquakes are important for the whole region, particularly where the tectonic situation (at the northern - Puerto Rico and Cayman trenches - and southern borders of the Caribbean tectonic plate) or volcanic activity (volcanoes of the West Indies) trigger the phenomenon (Dominican Republic, St. Kitts and Nevis, Montserrat, Guadeloupe, Anguilla, British Virgin Islands, Virgin Islands, Antigua and Barbuda, Jamaica, Trinidad and Tobago, Puerto Rico, Haiti, Dominica, St. Lucia, Martinique). For the Caribbean earthquakes intensities range, on the Modified Mercalli scale (MMI), from MMI V to MMI IX for an earthquake with a 475-year return period.

The biggest earthquake known in the Eastern Caribbean occurred in 1843 and was felt from St Kitts to Dominica. The English Harbour of Antigua was destroyed, and in Point à Pitre (Guadeloupe), all masonry was destroyed. The fatalities were 5000 in Guadeloupe, 30 in Antigua, 6 in Montserrat and 1 in Dominica. Also Jamaica has a long history of earthquakes. Port Royal (Jamaica) was nearly completely destroyed by an earthquake in 1692, killing more than 200 people. More recently earthquakes occurred in 1902 and in 1993 when earthquakes of 5.3 magnitude caused only minor damage. In 1997 a series of earthquakes affected the southern Caribbean, particularly Trinidad and Tobago. The events caused damage to buildings and other property in Tobago. The damage was estimated at approximately US$ 3 million and about 200 people were affected.

Volcanic activity is an important hazard in the West Indies (St. Kitts and Nevis, Montserrat, Grenada, Dominica, St. Lucia, St. Vincent and the Grenadines, Martinique, Guadeloupe), where several historically active volcanoes are located.

While several islands of the West Indies show signs of volcanic activity, Soufriere Hills (Montserrat) is currently the only erupting volcano. The submarine volcano Kick'em Jenny, located eight kilometres north of Grenada, is the most active in the past century with approximately 11 eruptions since it was identified in 1939. In 1902 Mont Pelé (Martinique) erupted and a pyroclastic flow destroyed the town of St. Pierre, killing its 28000 inhabitants. Volcanic eruptions occurred in 1902/03 on St. Vincent (Soufriere), causing more than 1500 victims. Soufriere erupted again in 1979. Soufriere Hills (Montserrat) began its activity in 1995, and in 1997 a pyroclastic flow caused up to 20 deaths and made most of the island inhabitable, leading to a severe disruption of the economic life of Montserrat.

Tsunamis are a threat to coastal regions, particularly gulfs, bays, and estuaries. Particularly prone are coastlines with low topography and unfavourable geographic orientation towards tsunami-generating areas of elevated seismic or volcanic activity. Caribbean areas which are prone to tsunamis are St. Kitts and Nevis, Montserrat, Anguilla, Antigua and Barbuda, Dominica, St. Lucia, Grenada, and St. Vincent and the Grenadines.

The Leeward earthquakes of 1690 and 1843 generated tsunamis with only minor impact. The Lisbon (Portugal) earthquake of 1755 caused a tsunami which crossed the Atlantic ocean and reached Antigua, causing a flood wave of less than two meters. The earthquake of November 18, 1867 may have caused up to 20 fatalities on the Virgin Islands, even though it is not clear if these victims are to be attributed to a hurricane which occurred a few days before the tsunami. In 1918 a tsunami, generated by a 7.5 magnitude earthquake, caused up to 40 deaths in Puerto Rico. More recently the submarine volcano Kick'em Jenny, located 8 kilometres north of Grenada, generated at least two tsunamis during periods of increased activity in 1939 and 1965.

Landslides are a significant process for the Caribbean region. Only in areas with low relief and limestone bedrock such as the Cayman Islands or the Bahamas can the process be considered irrelevant [25]. Erosional processes such as coastal wave action and stream erosion provide a continuous means for maintaining many slopes at critical inclinations. Tectonic and volcanic activity contributes lithologic and stratigraphic conditions favouring the occurrence of landslides.

Fatalities, injuries and damage to infrastructures are attributable to landslide in the Caribbean. In 1938, three debris flows in two days in Ravines Poisson and Ecrivisse (St. Lucia) killed 60 people and injured 32 others, estimates of the missing ranged as high as 250. In 1985, the catastrophic landslide in the Mameyes district of Ponce (Puerto Rico) claimed the lives of at least 129 people. Smaller landslides causing fewer individual fatalities yield a tragic toll over time. Between 1925 and 1986, 25 people in Dominica lost their lives due to landslides in five separate events [25].

The considerable exposure of the Caribbean to natural hazards, its high economic dependence on tourism and its vast interconnection with other industry sectors present a situation of considerable risk for the Caribbean as a whole. A detailed insight into the risk situation must thus be developed using the structured and modular approach of risk assessment, as proposed by this Standard.

The risks to tourism due to natural hazards can be addressed and quantified by standardized procedures across the Caribbean. Standardized procedures for the assessment of risks due to natural hazards in the region, including hazard mapping, vulnerability and risk assessment, can facilitate the regional approach to disaster risk prevention and response for the sector, and enable comparability of risks and quantification of losses across the region for the tourism sector.

2 Specific vulnerabilities of tourism in the Caribbean

Tourism in the Caribbean has specific vulnerabilities, due to the region's exposure to distinct natural hazards and its specific characteristics, such as the typical location of tourism attractions, infrastructures, and economies that are directly and indirectly linked to tourism. The elevated dependence of the Caribbean on a single economic sector, tourism, makes it particularly vulnerable to episodic disturbances of this sector, caused by natural or other hazards.

The major hazards present in the Caribbean are mainly of hydrometeorological and geological origin. Tropical cyclones cause heavy winds and rainfall. Connected phenomena are inland floods and storm surges. The tectonic set-up of the region causes seismic and volcanic activity. The resulting loads and actions on built structures, facilities and infrastructures, and the impacts on the environment are caused particularly by wind, flooding and ground motion.

Caribbean tourism is mostly coast-oriented, with beach and water activities (boating, diving and fishing), making tourists, people active in tourism, facilities of tourism, and directly related infrastructures particularly vulnerable to ocean- and coast-related hazards, storm surges and tsunamis and related phenomena, such as coastal erosion. Coastal tourism facilities are also at higher risk concerning earthquakes, since often located in coastal areas and founded on loose sandy ground, thus highly susceptible to earthquake-aggravating phenomena such as soil liquefaction.

Climate change is likely to aggravate the hazard situation in the future, given the forecasted impacts for the Caribbean [44]: Sea level rise, increased atmospheric temperatures, and changing pattern and general decrease of precipitations. Sea level rise will increase tourism's vulnerability towards coastal hazards (storm surges, tsunamis, and coastal erosion), changing patterns and net decrease in rainfall will make it more vulnerable to water quantity- and quality-related issues such as drought. A hotter atmosphere will lead to more extreme atmospheric phenomena and increased occurrence of intense tropical cyclones. See section 3 for a more detailed discussion of the challenges for tourism from climate change and proposed mitigation strategies.

3 Impacts of climate change

"Tourism contributes to global warming, and, at the same time, is a victim of climate change", as recognized by the secretary general of the World Tourism Organization (UNWTO) [69]. How is climate change going to alter the hazard situation in the Caribbean? And how is the impact on tourism going to be? Global warming induced climate change is likely to aggravate the situation of hydrometeorological hazards, particularly the occurrences and characteristics of tropical cyclones, storm surges, floods, drought, and other coastal hazards, such as coastal erosion, and of water related and triggered geological hazards, such as landslides.

The 4th IPCC report [44] particularly addresses the impacts of climate change on small island states, the reality of most Caribbean states, as:

- **Sea level rise** is expected to exacerbate flooding, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities.
- **Deterioration in coastal conditions**, for example through erosion of beaches and coral bleaching, is expected to affect local resources.
- By the middle of the 21st century, climate change is expected to cause a **reduction in water resources** in many small islands, to the point where they become insufficient to meet demand during low-rainfall periods.
- With **higher temperatures**, increased invasion by non-native species is expected to occur, imposing a challenge on agriculture and food production.

- Altered frequencies and intensities of **extreme weather** phenomena, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.

The **impacts** that may arise from climate change **for the tourism industry** in such a context can be summarized as [44]:

- Increased temperature leads to reduced energy demand for heating, but increased demand for cooling, and declining air quality in cities.
- Heavy precipitation events cause disruption of settlements, interruption of commerce, transport, increasing pressure on infrastructures, and causing loss of property.
- The areas which are affected by drought will increase. Water shortages will be more frequent.
- Increased tropical cyclone activity leads to disruption by flood and high winds, causing increased loss of property, motivating the withdrawal of risk coverage in vulnerable areas by private insurers.
- Increased incidence of extreme high sea level will motivate relocation of infrastructure to higher elevations (cost of coastal protection versus cost of relocation).

The consequences of climate change for the Caribbean and its tourism industry pose an important challenge for the decades to come. How can tourism react to mitigate the impacts of climate change? IPCC [44] identifies the key adaption strategies and underlying policy frameworks as well as the main constraints and opportunities, as:

- **Adaptation option/strategy.** Tourism should aim at a diversification of its attractions and revenues.
- **Underlying policy framework.** Integrated planning (e. g. carrying capacity; linkages with other sectors); financial incentives, e. g. subsidies and tax credits.
- **Key constraints and opportunities to implementation.** Appeal/marketing of new attractions; constraints are financial and logistical challenges; potential adverse impact on other sectors. Opportunities are revenues from "new" attractions; involvement of wider group of stakeholders.

4 What is risk? The context of hazard, vulnerability and risk

The terms of hazard, vulnerability and risk can be used in differing contexts, and apply to situations of natural, but also technological or industrial threats (safety of nuclear power and chemical plants), from where the discipline of risk analysis actually derives. There exists a widespread confusion on the terms, their definition, description and the various instruments and products in the context of disaster risk management. Using well established definitions avoids misunderstandings. Whenever possible, the definitions by ISDR ([67],[68]), listed in Annex E, are used in this document.

The most important terms in the context of hazard, vulnerability, and risk are shortly explained below [76].

Hazard. "A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage". Each hazard is characterized by its location of occurrence, intensity and probability. Natural hazards are hazards of natural origin. There are a number of ways to display natural hazards on maps.

- **Event maps** are cartographic representations of event registers, showing the records of past natural hazard events and their key characteristics, such as type of phenomena, location and date of occurrence. Event maps give a first overview of the hazard situation in an area, and are the basis for the elaboration of other hazard maps.
- **Hazard indication maps** (or hazard index or danger maps) show the spatial extent of a phenomenon, indicating the areas possibly affected by an extreme event. They provide an overview of the hazard

situation, in terms of the area where a phenomenon, such as flood, might occur. This type of hazard representation is often used as a basis for planning purposes.

- **Hazard maps** show the spatial extent, type of hazard and degree of hazard (magnitude and frequency of a hazard process). They serve as a management tool for land use planning (usually at the local or municipality level), for planning structural and non-structural protection measures, emergency planning, and monitoring. Hazard maps are the basis for quantitative risk assessment.

Vulnerability. "The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard." There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for sustainable environmental management. Vulnerability can vary significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. Physical vulnerability is the degree of loss resulting from a hazard process and is usually expressed in terms of percentage, ranging from 0% (no damage) to 100% (complete damage).

Vulnerability maps can show various aspects of vulnerability, such as population density, overall living condition (e. g. poverty, income, employment, health, and education), water and sanitation, and condition of structures. They are used as a tool for emergency and priority setting, and land use planning. Vulnerability maps are necessary for quantitative risk assessment.

Risk. "The combination of the probability of a hazard event and its negative consequences." The term risk has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in “the risk of an accident”; whereas in technical settings the emphasis is usually placed on the consequences, in terms of potential losses for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks.

There are several additional terms that are often used in the context of risk. Acceptable and tolerable risks are the risks, a community is willing to accept or tolerate. Risk management is a procedure to identify and assess risks. Disaster risk reduction is a set of measures that aim at the reduction of risks. Residual risk is the risk that remains after the implementation of risk reduction measures.

Risk maps show areas of comparable risk. Outcomes of risk analyses may be expressed in a qualitative (e. g. low, medium, high), or a quantitative classification way (damage per area, damage per year, number of fatalities per area per year).

Damages and losses. The consequences that the occurrence of hazards cause on vulnerable objects can be described in terms of damages and losses. According to the ECLAC handbook [28] the consequences are described as direct damages, indirect losses, and macroeconomic effects. Direct damages are directly connected to the occurrence of a natural hazard and are damages to the building stock, infrastructures and the environment. Indirect losses are the consequences which may be noticeable only after days or weeks after the occurrence of an event. They are social and economic consequences, such as a decrease in economic activity due to reduced tourist arrivals or generally a reduced functioning of the economic sectors that are touched. The macroeconomic effects aim at the larger picture of the effects of natural hazards, addressing issues such as the decrease in GDP or other large-scale indicators of the economic conditions of a country or region. The extent of damage and loss is controlled by the magnitude of the damaging process and the vulnerability of the elements at risk, thus relating risks to hazards and vulnerability.

Resilience. The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Resilient tourism suffers only for a relative short period of time from the consequences of the occurrences of natural hazards. The capability to quickly find back to normality depends on the availability of the necessary operative and organizational resources before, during and after a hazardous event.

5 Concerns addressed by the Standard

Natural hazards cause direct damages and indirect losses to tourism, the most important economy of the Caribbean and connected sectors. The impacts of natural hazards on tourism can be addressed by risk assessment, a structured approach that helps to identify objects at risk and determine the expected impacts in terms of people and values at risk. The Standard addresses the following concerns in risk assessment for tourism in the Caribbean.

- **Estimation of specific risks.** The tourism sector in the Caribbean needs to gain knowledge of what kind of risks due to natural hazards it is exposed to, and to what extent. The Standard focuses on natural hazards and tourism, considering direct damages and indirect losses to values and lives at risk.

- **Comparability of risks.** Identified and assessed risks must be comparable throughout the region in order to give a homogenous view of the risk situation. The Standard presents procedures to evaluate risks, resulting in comparable findings.

- **Standardization of assessment procedures.** Standardized and comparable results depend on defined procedures for the assessment of hazards, vulnerabilities and risks. The Standard presents the necessary information on how to conduct the partial aspects of risk assessment.

- **Standardized representation of results.** The Standard gives guidelines on how the outcomes of risk assessment are to be represented on maps and documented in reports.

6 Current status of risk oriented maps and assessments in the Caribbean

Many initiatives have been conducted in the past in the area of risk oriented mapping and assessments in the Caribbean. CDERA conducted in 2003 an assessment on the status of hazard maps, vulnerability analyses and digital maps in 20 countries of the Caribbean ([20],[21]). These efforts partly present the basis for conducting risk assessments and are reviewed. A document with an example of good practice concludes the review.

The analysis were carried out on the situations of Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, The British Virgin Islands, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, Haiti, Martinique, Suriname and Puerto Rico.

Hazard maps. Two approaches to hazard mapping have been carried out in the Caribbean: at a region-wide and local scale. Region-wide analyses and mappings were applied to hazards with a regional extent and effect, such as wind, storm surge and earthquakes. Local analyses and mappings were carried out for less extent hazards, such as floods, landslides, volcanic activity and coastal erosion.

The current state concerning the most common hazards, such as storm related hazards (wind and storm surges), floods and earthquakes are described in more detail below. The situation can be summarized as follows.

- **Storm related hazards (wind, storm surges).** Wind and storm surge maps in sufficient quality are available at a regional and sub-regional scale for the Caribbean. For local assessments more detailed assessments must be conducted in order to consider local topographic effects.

- **Floods.** The situation concerning flood maps is not satisfactory and is generally suffering from the lack of the availability of detailed topographic maps and common assessment procedures.

- **Earthquakes.** Seismic hazard maps are available at the regional scale with a sufficient detail in terms of peak ground acceleration. While the situation is satisfactory at a regional to sub-regional scale, at the local scale soil maps are necessary to estimate degradation due to local soil conditions.

6.1 Storm-related hazard maps

Storm hazard maps address phenomena related to tropical cyclones, such as heavy wind, waves and storm surges. Regional storm-related wind, wave and storm surge hazard maps were created within the Caribbean Disaster Mitigation Project CDMP [23]. The resulting hazard maps have a 1 kilometre resolution, hazards are expressed as maximum wind speeds, storm surge heights and wave heights for return periods of 10, 25, 50 and 100 years. Island specific elaborations were carried out for Anguilla, Antigua and Barbuda, Barbados, Belize, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Tobago, and the Virgin Islands.

An additional source of storm related hazard maps with a world-wide coverage is NATHAN [49]. It presents a world-wide map of wind storm, expressing wind hazard in terms of probable maximum intensity of Saffir-Simpson hurricane scale with an exceedance probability of 10% in 10 years, equivalent to a 100-year storm.

Good practice. An example of good practice of wind storm mapping is given in [19], which describes the methodology for storm hazard mapping used to create wind, wave, and storm surge hazard data sets for Sain Lucia and the Ambergris Caye/San Pedro region of Belize. The methodology used is very similar to that used in the CDMP project.

6.2 Flood hazard maps

Generally, floods have a rather local geographical extent, but are the most common hazard in the Caribbean. Floods are often caused by heavy rainfall during tropical cyclones. The knowledge of local topography is crucial for the propagation of floods, so mappings should occur at a local scale of 1:25'000 or below.

According to CDERA [20], Jamaica is most flood-affected and has undertaken most flood-mapping initiatives, conducted at local scales. Flood hazard mappings of other countries were either conducted at inappropriate map scales or the methodology used to identify hazard zones was limited or not specified. Most existing flood hazard mappings show areas that have experienced floods (representing flood hazard index maps, see section 4), rather than being flood hazard maps, which should display the degree of flood hazard.

Good practice. Examples of good practice of flood hazard mapping are given in [16] and [17]. The flood hazard analysis is based on flow depth and velocity as intensity criteria combined with return period. Three hazard classes are defined according to on [11]. The analysis is conducted using a hydraulic-hydrological modelling approach.

6.3 Seismic hazard maps

In the Caribbean, most consistent information is available for earthquakes. Major initiatives in the region were conducted by the University of the West Indies ([72],[73]), during the Caribbean Disaster Mitigation Project CDMP project [23] and by the USGS [71].

During the CDMP project regional and sub-regional maps for The Bahamas, Belize, Cayman Islands, Dominican Republic, Guyana, Haiti, Jamaica, Leeward Islands and Virgin Islands (Anguilla, Antigua and Barbuda, Montserrat, Saba, St Barts, St Eustatius, St Maarten, St Kitts and Nevis, US and British Virgin Islands), Suriname, Trinidad and Tobago, Turks and Caicos Islands, and the Windward Islands (Barbados, Dominica, Grenada, Martinique, St. Lucia, St. Vincent and the Grenadines) have been elaborated for seismic hazard in terms of acceleration, intensity, and velocity [23].

Seismic hazard maps have been created for the region of the Eastern Caribbean by the Seismic Research Centre of the University of West Indies [72]. The maps show the spectral acceleration (peak ground acceleration of 0.2 and 1 sec) with a 2% probability of exceedance in 50 years, in accordance with building codes. The regional maps have a resolution of 0.25° (25 kilometres). Additionally, Puerto Rico and the US Virgin Islands, the British Virgin Islands, Haiti, and Jamaica have developed corresponding maps [21].

The French islands Martinique and Guadeloupe are entirely classified in the highest class III (strong seismicity) according to the French five-step scale [59]. Puerto Rico, the British and US Virgin Islands are covered by USGS maps with peak ground accelerations with 2% or 10% of exceedance probability in 50 years [47]. Jamaica's seismic hazard map [73] is similar to the regional maps elaborated by the Seismic Research Centre of UWI [72].

An additional source of seismic hazard maps with a world-wide coverage is the Global Seismic Hazard Assessment Program (GSHAP) [36], which offers maps of peak ground acceleration with a 10% exceedance probability in 50 years at a regional resolution.

Good practice. An example of good practice of earthquake hazard assessment is given in [72], stating the methodology applied for the mapping of the seismic risk in the Eastern Caribbean, based on probabilistic seismic hazard analysis. The results are given in maps of spectral ground accelerations of 2% exceedance probability in 50 years, chosen in accordance with building codes.

6.4 Vulnerability assessments

CDERA [20] lists more than 50 vulnerability assessments that have been conducted in the Caribbean with economic, human, structural or multiple focus. Economic assessment on coastal resources is the most common assessment.

The vulnerabilities of Caribbean tourism and natural hazards have been addressed in an economic vulnerability assessment of coastal erosion with the purpose of the assessment of beach resources [20].

Good practice. Examples of good practice are given in [18] and [22]. These assessments performed in Belize and Grenada illustrate the procedures of a semi-quantitative, point-based approach to assess the vulnerability of critical facilities.

6.5 Digital maps

Digital base maps of sufficient detail and quality are, together with statistical data, the basis for conducting risk assessments, which often take advantage of the use of geographic information systems (see section 17). CDERA [20] reviews the availability of digital maps in the Caribbean. In most countries digital maps are available for elevation, landuse, water resources, soils, geology, vegetation, buildings, utilities and roads. For several nations the maps are obsolete and outdated.

The maps are projected according to national mapping standards (datum, ellipsoid, projection/grid) that vary from one country to another, presenting a major restrain for regional compilations.

7 Similar initiatives in risk assessment

The following review briefly lists and discusses similar initiatives of risk and vulnerability assessment and hazard mapping. Similar initiatives have been conducted in the past in the Caribbean and world-wide, focusing on conceptual frameworks, partial aspects of risk analysis and assessment, or on particular hazards.

The quantitative risk assessment of the British Virgin Island [34] is one of the first quantitative risk assessment initiatives for critical infrastructures for a Caribbean government. Hazard, vulnerability and risk analysis was conducted for the hazards earthquake, wind and landslide focusing on critical infrastructures.

The quantitative risk assessment of the Portmore Municipality in Jamaica [41] addresses the risks associated with storm surge hazards at the municipality level. It includes the preparation of storm surge hazard maps for the area and the assessment of the vulnerability of the critical elements of each community to storm surge hazard; and the utilization of the storm surge hazard maps and the vulnerability assessment to determine risk associated with storm surge impact.

In an international contest, several standards address risk assessments generally or focused on technological and natural hazards ([5],[6],[15]). The importance of risk analysis as a basis for disaster risk management and the general principles of risk analysis are outlined in [37].

The "ECLAC Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters" [26] is a review of socio-economic and environmental effects of disasters and focuses rather on large scale assessments. It addresses particularly the post-disaster analysis of a wide range of consequences of disasters.

A review of the methods, availability and use of flood maps in Europe, in terms of an overview of existing flood mapping practises in 29 countries of Europe is given in [26]. Roughly half of the countries have maps covering the entire nation, one third are covered by a significant part, and five nations have only very limited or no flood maps available. Flood extent maps are the most commonly produced (23 countries), but also flood depth maps are regularly developed (seven countries). Only very few countries have flood risk maps. Flood maps are mostly developed by governmental agencies for emergency planning, land use planning, and awareness raising. In spatial planning, the flood areas depicted on flood maps usually serve as guidelines without strict binding. In a few countries (such as France and Poland) there is a legal basis to regulate flood plane developments using flood zones, nevertheless practical problems are often faced which reduce the mitigating effect of such binding legislation. Flood maps, mainly flood extent maps are also produced by the insurance industry, and by international river commissions. With respect to the EU Flood directive [31], many countries already have a good starting point to map their flood hazards. A flood risk based map that includes the consequences, however, has yet to be developed in most countries.

The NOAA Community Vulnerability, and Risk and Vulnerability Analysis tools ([50], [53]) are interactive online tools that help identify people, property, and resources at risk of injury, damage, or loss from hazardous incidents or natural hazards. This information is used to help determine and prioritize the precautionary measures to make communities more disaster-resistant. The NOOA hazard assessment tool is a GIS tool for the assessment of natural hazards [54].

HAZUS-MH [84] is a risk assessment software for analysing potential losses from floods, hurricane winds and earthquakes, implemented in a geographic information systems (ESRI ArcMap [78]) to produce estimates of hazard-related damage before, or after, a disaster occurs. It focuses on the application in the U.S., using nation-wide available geographically referenced base data.

The Australian Geotechnical Society developed a standard for the complete risk analysis of landslides, addressing direct impacts ([1], [4]). Several other authors present conceptual frameworks for risk assessment and management limited to landslides ([31], [38], [62]).

The Swiss standard for analysing risks of gravitational natural hazards ([12],[58]) addresses mainly direct impacts, delivering the conceptual and methodological framework. Hazard assessment procedures are given in [9] and [13] for geological and hydrological hazards. The methodology is generally applied at the municipality level and is summarized in [59]. The Swiss system has been applied in several countries in the world, the experiences are documented in [76], addressing policy, instruments and validation methods. Currently 60% of the country is covered by hazard maps for gravitational hazards according to this standard.

A review of approaches for measuring vulnerability to natural hazards on different scales and with different foci is presented in [7]. The various approaches are shortly summarized below.

The Disaster Risk Index is a quantitative method for assessments at the global or national scale. It assesses risks as the product of hazard occurrence probability, elements at risk and vulnerability, and uses data from the database EM-DAT [57]. The multi risk assessment of Europe's regions focuses on the assessment of the risk potential of a certain area by aggregating the spatially relevant risks, caused by natural and technological risks [35].

An assessment on the scale of single buildings focusing on a sectorial approach is presented in [74]. The financial vulnerability of developing country governments to natural hazards is addressed in [46]. A community-based risk index, which operates on the municipality level, used by the German developing aid agency GTZ, is presented in [8]. A self-assessment, bottom-up strategy, community-based disaster management is presented in [75]. It focuses, as a contrast to other, top-down strategies, on the understanding of people's vulnerability to hazards and their capacity to cope with them.

IDB conducts several initiatives on disaster risk management [42], developing several disaster and risk related indices, such as the Local Disaster Index (LDI), the Prevalent Vulnerability Index (PVI, based on an exposure analysis as part of the IDB Indicators Program), the Disaster Deficit Index (DDI, shortage/surplus of financial resources in the wake of a disaster), and the Risk Management Index (RMI).

8 Databases of natural hazard events

Data on events of natural hazards and hazard maps covering the Caribbean can be found in the online available databases of NOAA National Geophysical Data Center [52], CRED EM-DAT [30] and MunichRe NATHAN [49]. The databases have generally a world-wide or regional geographical coverage.

9 Linkage of Standard to Regional Disaster Risk Management Strategy

This Standard is accompanied by the Disaster Risk Management Strategy [64], developed under the same project "Regional Disaster Risk Management for Sustainable Tourism in the Caribbean" (ATN/OC-10085-RG). The strategic objectives of the disaster risk management strategy presented are in accordance with the phases of the disaster risk management cycle: Mitigation, preparedness, response and recovery (Figure 4).

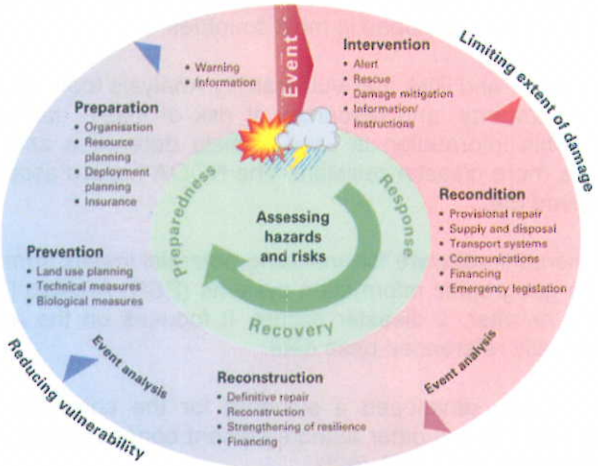


Figure 4 — Hazard assessment is a central point in the integral risk management cycle [42].

The key elements of the mitigation phase identified in the Regional Disaster Risk Management Strategy are knowledge development, risk identification, risk assessment, and risk transfer, thus addressing the essential characteristics of the Standard.

On risk assessment the Strategy states: "Effective pre-event activities for disaster risk management are not possible without a solid knowledge foundation of the potential hazards and of vulnerabilities of them. An integral and essential part of disaster risk management is the process of risk assessment, which forms the foundation of mitigation activities. The risk assessment process has as objective the identification and quantification of risks, by analysing hazards and elements at risk and determining the respective impacts."

Part B - Standard for Conducting Hazard Mapping, Vulnerability Assessment and Economic Valuation for Risk Assessment for the Tourism Sector

10 Overview of the Standard

Risk assessment, as proposed in this Standard, is an individual working step of risk management, "a systematic approach and practice of managing uncertainty to minimize potential harm and loss" [68]. The overall goal of risk management is to control and reduce risks, if necessary. The entire process requires the involvement of the affected community in order to successfully manage risks, by the identification and implementation of sustained risk management options.

Risk management follows a structured procedure. The individual working steps are (Figure 5):

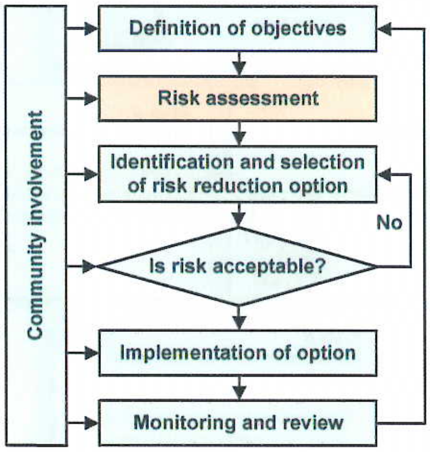


Figure 5 — Risk assessment is the central part of the risk management process.

Definition of objectives. Initially the objectives and scope of risk management must be defined, addressing intent, scale and extent of the assessment as well as the expected results.

Risk assessment. The risks must be identified and evaluated, thus the consequences that hazards may have on elements at risk are to be determined, possibly in a quantitative way. The resulting risks are compared to commonly accepted or tolerated levels of risk, which are to be identified by community involvement.

Identification and selection of risk reduction option. If the identified risks exceed the levels of tolerance and acceptance, options of risk reduction must be identified, chosen and implemented. Options are risk acceptance or avoidance, reduction of likelihood of occurrence or of consequences, and transfer of risks. Each of these options is evaluated by means of a cost-benefit analysis, where the costs of the risk reduction operations are compared to the resulting benefits in terms of risk reduction. The option with the most suitable benefit-cost ratio is identified.

Implementation of option. The risk reduction option which has been identified as suitable in the previous working step is to be implemented.

Monitoring and review. Several components in the risk management procedure may change over time, such as the hazard situation, the number and characteristics of the elements at risk, or the assessment procedures.

Monitoring of the major elements in the risk management process and the definition of review cycles are fundamental aspects of risk management.

Risk assessment. The assessment of risks is the central part of risk management (Figure 5). The main objective is the identification and quantification of risks, by analysing its main components – hazards and elements at risk – and determining the respective consequences.

ISDR defines risk assessment as [68] "a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, propert

→ The major output of this working step is a preliminary overview of the analysis to be conducted, in terms of a preliminary identification of the problem, the necessary working steps and data, and the team composition.

Step 2 – Analysis of hazards

The hazards which are important for the study area are to be identified. The Standard considers the major hazards in the Caribbean: hurricanes, storm surges, floods, and earthquakes. The hazards which are present in the study area are to be prioritized according to their importance. Based on the availability of historical hazard data or model assumptions, the hazards are analysed quantitatively, delivering the degree of hazard in terms of frequency of occurrence and physically determinable hazard characteristics, such as the flow depth of a one-hundred-year event for floods.

For risk analysis it is not necessary to have a complete coverage of the hazard situation, in terms of hazard maps. It is sufficient to identify the hazard scenario, on which the risk analysis is to be conducted. It is characterized by the expected hazard intensity and the probability of occurrence.

→ The major outputs of this working step are hazard maps and an evaluation of the key characteristics of the hazards. Essential input for the consecutive steps of risk analysis are the knowledge of the hazard scenario of given intensity (→ Step 3) and probability of occurrence (→ Step 4).

Step 3 – Analysis of vulnerabilities

Hazards are a possible threat to a number of elements at risk, such as the physical assets of tourism, individuals or communities of people connected to tourism, environmental aspects of importance to tourism, and economic activities linked to it. These elements can be directly or indirectly at risk. Firstly, the elements at risk must be identified and inventorized. Secondly the expected consequences in terms of direct damages or indirect losses must be determined.

→ The major output of this working step are maps of vulnerable elements and estimates of the expected damages and losses that may result. They are essential for conducting the next working step of calculation of risks (→ Step 4).

Step 4 – Calculation and representation of risks

The consequences that arise from the exposure of vulnerable elements to natural hazards are estimated. Risks are quantified from the superposition of hazard scenarios (→ Step 2) on vulnerable elements (→ Step 3). The results are described in a report and illustrated on risk maps (→ Step 5). In this working step the resulting risks may also be assessed, i. e. compared to risks originating form other locations and/or hazard situations.

→ The major output of this working step are quantitative risks. They identify risks in terms of financial loss or loss of lives.

Step 5 – Documentation of outcomes

The risk assessment concludes with the proper documentation of the findings in terms of maps and a conclusive report. The Standard gives guidance on how to represent hazards (→ Step 2), vulnerabilities (→ Step 3) and risks (→ Step 4) on maps, addressing map layout, scales, and colours.

→ The major output of this working step are maps of the previously elaborated hazard, vulnerability and risk analyses, and a final, conclusive report.

See Annex B for a synthesis of the risk assessment procedure and Annex C for an example application.

10.1 Quantification of risks - The risk formula

Risk is "the combination of the probability of an event and its negative consequences" [68]. In the probabilistic approach presented by the Standard, the assessment of risks depends on the knowledge of its two main components: the probability of occurrence of a hazardous event and the expected damage it may cause.

Mathematically, risk is expressed as the product of its two components, the annual probability of occurrence and the expected damage, as $R = P \cdot D$, where P is the probability of occurrence and D is the expected damage, and R is the resulting risk. The two elements are further described.

- The **occurrence of a hazard** P is expressed in terms of probability of occurrence and is related to other temporal characteristics of a hazard, such as the return period (T). In risk analysis the probability of occurrence is referred to one year, so $P = 1/T$. For example, a ten-year flood has a return period T of ten years and has a probability of occurrence P of 0.1.
- The **expected damages and losses** D are directly or indirectly linked to the hazardous event. They are expressed in terms of material damages, given by the value of exposed elements W [US$] and their relative vulnerability V [0 to 1] with respect to the hazard, and can thus be described as $D = V \cdot W$. The damage D may also be described in terms of number of people or extent of the areas affected by a hazard of a certain intensity.

Hazard scenarios. Risks are analysed in terms of hazard scenarios. A hazard scenario is a hazard event of a defined probability of occurrence and a given intensity. Since there may be a number of elements at risk due to a number of hazards, risks are assembled in a step-by-step procedure.

The risks due to all hazard scenarios acting on all vulnerable elements are analysed and summed as shown in the following formula [58]:

$$R_{i,j} = P_j \cdot D_i \quad \rightarrow \quad R_j = \textstyle\sum_i R_{i,j} \quad \rightarrow \quad R = \textstyle\sum_j R_j \tag{10.1}$$

where:

D_i = Consequence for object i. For direct damages $D_i = V_{i,j} \cdot W_i$ [US$] or affected population [number of persons] or environment [km^2].

P_j = Annual probability of occurrence of hazard scenario j [year^{-1}].

$V_{i,j}$ = Vulnerability of vulnerable object i with respect to scenario j [-].

W_i = Value of vulnerable element i [US$].

$R_{i,j}$ = Risk of vulnerable element i exposed to hazard scenario j [US$ per year].

R_j = Risk of all vulnerable elements exposed to hazard scenario j [US$ per year].

R = Collective risk as the sum over all hazard scenarios j acting on all vulnerable elements i [US$ per year].

In the procedure of risk analysis the partial aspects of risk, hazards and vulnerabilities, are determined, and risks are calculated. Risk assessment includes risk analysis and adds the successive step, in which the formerly calculated risks are evaluated for their acceptability.

10.2 Vulnerable elements, damages and losses

The choice, which vulnerable elements (or objects) are to be considered when analysing risks, depends on the focus of risk assessment. The Standard focuses on tourism and the consequences of natural hazards. So possible effects that may be analysed are primarily the direct damages to the facilities of tourism, people which are present in tourism installations, but also indirect losses, such as losses in tourism and connected economies.

The damage to a vulnerable object corresponds to its market value (direct damages to tourism facilities) or the (temporary) indirect losses caused and are expressed in terms of a monetary value [US$]. For several objects at risk it is difficult or problematic to define a monetary value. This is particularly true for social and environmental vulnerabilities. In these cases the possible damage is expressed in terms of number of people or environmental aspects affected.

The assessment of larger-scale effects (macro-economic consequences) of hazards is beyond the focus of

olded map (left), folded map (right).

ales are to be used to represent the results of risk assessment:

:1,000

0

0,000

e used to display the relative degrees of low, medium and high on hazard, ble 12). The meaning of the colour coding is to be described in the map field 3).

Table 12 — Colours to be used in maps.

p type	Degree		
	Low	Medium	High
rd map	Yellow	Orange	Red
bility map	Light green	Medium green	Dark green
k map	Light red	Medium red	Dark red

be identified on maps. No standardized symbol sets are available which cover symbols. It is thus recommended to use significant symbols to display the

16.3.2 Scales

The following indicative map sc

- Site-specific assessment: 1
- Local assessment: 1:10,00
- Regional assessment: 1:10

16.3.3 Colours

The following colours are to b vulnerability and risk maps (Ta “Explanations” (see section 16.

Map
Haza
Vulnera
Risl

16.3.4 Map symbols

The vulnerable elements are to the complete set of necessary relative vulnerable objects.

11 Risk assessment process

The risk assessment process of the Standard has the following individual working steps, which are discussed in the corresponding sections below:

1) Definition of objectives and scope → Section 12.
2) Analysis of hazards → Section 13.
3) Analysis of vulnerabilities → Section 14.
4) Calculation and representation of risks → Section 15.
5) Documentation of outcomes → Section 16.

12 Definition of objectives and scope

12.1 Summary

Initially the objectives and scope of risk assessment must be defined and the expected results determined (Figure 7). This is done by anticipating the entire process of risk assessment in a preliminary screening, according to the proposed step-by-step procedure (Table 1). The individual aspects of this initial working step are discussed below.

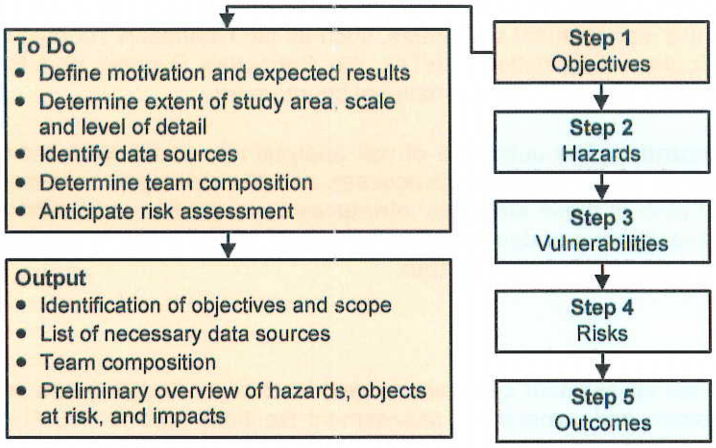


Figure 7 — Definition of objectives of risk assessment.

12.2 General information

Motivation and expected results. Define the objectives and scope of risk assessment and the expected results, identifying the motivation for the conduction of the risk assessment. Is the assessment to be conducted to determine the consequences of a specific past event, or a general assessment of the hazard situation?

Extent and scale of assessment. Define the geographic extent and scale of the assessment. Evaluate focus, scale and level of detail of assessment: individual or groups of tourism installations (site-specific, at typical scales of 1:1'000), local (community-scale, at typical scales of 1:10'000) or regional (parts or an entire nation or international, at typical scales of 1:100'000 and greater).

Team composition. The preliminary findings of the objectives and scope of the planned risk analysis identify the professional competences which are necessary for conducting the assessment. The staffing of the team to conduct the assessment must be chosen accordingly.

Table 1 — Definition of objectives and scope of risk assessment.

RISK ASSESSMENT

▶ GENERAL INFORMATION | Project-ID: ....

Target, objectives, scope	....			
Team composition	....			
Geographical extent	☐ Site specific	☐ Local	☐ Regional	☐ Attach sketch of situation
Approximate scale	1 :			
List sources for general data (general information, base maps, etc.)	....			

▶ HAZARDS TO CONSIDER

Hydrometeorological:	☐ Hurricanes	☐ Storm surges	☐ Wind storms	☐ Floods
Geological:	☐ Volcanic activity	☐ Earthquakes	☐ Mass movements	☐ Tsunamis

List data sources for hazards:

....

....

▶ VULNERABLE ELEMENTS TO CONSIDER

Tourism: ☐ Buildings ☐ Infrastructure, specify:	List data sources for vulnerable elements:
☐ People/Population, specify:	....
☐ Transport infrastructure, specify:	....
☐ Economy, specify:	....
☐ Environment, specify:	....

▶ IMPACTS TO ASSESS

Direct damages

Immovable assets ☐ Public ☐ Private

☐ Buildings and contents ☐ Vital infrastructure ☐ Traffic infrastructure

☐ Cost of repair/replacement

☐ Fatalities, injured

☐ Environmental aspects, specify: ....

....

Indirect losses

☐ Reduced number of visitors

☐ Reduced employment, unemployment

☐ Reduced incomes

Specify: ....

....

Macroeconomic effects

Impacts on:

☐ Economic activity ☐ External sector ☐ Public finances ☐ Investments ☐ Employment ☐ Impact on women

☐ Environment

Specify: ....

....

12.3 Hazards to consider

Define preliminarily the hazards to be considered in the assessment. The Standard provides assessment procedures for hydrometeorological (hurricanes, storm surges, floods), and geological hazards (earthquakes). Further hazards can be assessed, if the necessary criteria are available.

12.4 Vulnerable elements to consider

Define which vulnerable elements are to be considered in the analysis, such as buildings and infrastructures of tourism, transport infrastructure, people, economies connected to tourism, and elements of the environment, which are essential to tourism, such as beaches and reefs.

12.5 Estimation of impacts

Natural hazards have several consequences, that affect the assets of tourism (direct damages), the flow of production and services (indirect losses), and the performance of the main macro-economic aggregates of the affected area, country or region (macroeconomic effects). The various types of consequences are further described below.

12.5.1 Direct damages

Direct damages (complete or partial destruction) are related to the damages to immovable assets, such as the facilities of tourism (hotels, guest rooms), its mobile equipment (boats, machinery, vehicles) and vital infrastructure (drinking water, sewage, energy, air conditioning infrastructure), the essential transport infrastructure (roads, air and seaports), and tourism attractions (natural, sport, cultural, and historical sites). In essence direct damages are the damages occurring at the time of the occurrence of a natural hazard.

12.5.2 Indirect losses

Indirect losses are the result of the direct damages to production capacity and social and economic infrastructure. Examples of indirect losses are reduced employment or unemployment of people working directly in tourism, reduced income in the connected industries due to diminished production, higher operational costs, or additional costs due to alternative means of production.

The time frame for considering these effects is five years [26], even though most losses occur in the first two years after the occurrence of a natural hazard.

12.5.3 Macroeconomic effects

The larger the scale and extent of a natural hazard, the more important is the consideration of the way, in which a disaster modifies the performance of the main economic variables of an affected country or region. The analysis includes calculations of how the occurrence of a natural hazard affects the economic output, external accounts, and public finances, with proper attention given to the effects on public and private investments, employment and women.

A proper estimate of the macroeconomic effects of the occurrence of natural hazards requires an adequate forecast of how each of the variables would have performed without the occurrence of a natural hazard.

According to the ECLAC handbook [26], the assessment of the macroeconomic effects should include the consideration of effects on economic activity, effects on the external sector, effects on public finances, effects on investments, effects on employment, differential impact on women, and environmental impact (environmental damages usually included in tourism sector assessments and separate quantification and valuation).

12.6 Identification of data sources

Based on the above points, sources of necessary data for conducting the risk assessment must be preliminarily identified, such as base maps, data on natural hazards and elements at risk, such as formerly conducted assessment initiatives.

See section 6 for a review of the situations concerning past initiatives on hazard mapping, vulnerability assessments and digital maps in the CARICOM countries. For a more detailed review see CDERA's summary report [20] and the country reports for Anguilla, Antigua, Bahamas, Barbados, Belize, British Virgin Islands, Dominica, Grenada, Guyana, Haiti, Jamaica, Martinique, Montserrat, Nevis, Puerto Rico, St. Lucia, St. Kitts, St. Vincent, Suriname, Turks and Caicos, and Trinidad and Tobago [21].

13 Analysis of hazards

13.1 Summary

In this working step the relevant hazards, that are present in the study area, are analysed in order to determine the scenarios, based on which the risk analysis will be conducted. Of the hydrometeorological and geological hazards present in the Caribbean (see section 1), the Standard addresses hurricanes, storm surges, floods, and earthquakes. By virtue of the modular character of the Standard, more hazards can be added later on.

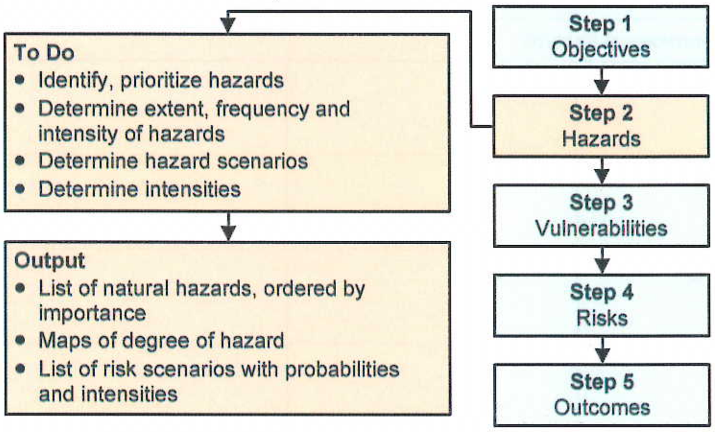


Figure 8— Analysis of natural hazards.

The following working steps are to be performed (Figure 8):

- Identification and prioritization of hazards according to their importance in the study area, in order to focus the analysis on the most important hazards.

- Identification of the degree of hazard on the complete study area, using hazard criteria of return period and intensity, for each hazard individually. The findings are displayed on hazard maps.

- Determination of the scenarios, on which the risk analysis will be conducted. Each scenario has a specific hazard intensity (I) and annual probability of occurrence (P).

13.2 Identification and prioritization of hazards

The Standard considers the following hazards: hurricanes, storm surges, floods, and earthquake. The prioritization of hazards has the scope of focusing the risk assessment procedure on important hazards, adapting the procedure to the study area.

An overview of the hazard situations at a regional and national level can be found in the international databases EM-DAT [30] or NATHAN [49] and in the regional and country reports on natural hazards by CDERA ([20], [21]). Use Table 2 to identify the priority hazards in the study area. In this qualitative procedure, for each hazard the following information is to be provided, using also local historical data sources (interviews, newspaper research).

- Type of hazard phenomenon. Of the hydrometeorological and geological hazards listed in Table 2, the Standard gives assessment procedures for hurricanes, storm surges, floods, and earthquakes.

- Years of occurrence of such hazard phenomena in the study area.
- Number of hazard events in the considered years.
- Impacts due to this hazard: injured, fatalities, direct damages (partial or complete destruction of facilities, infrastructures), and indirect losses (socio-economic and environmental consequences).
- List of available data sources which were used for compilation.

Based on the data entered in the table, a qualitative ranking can be established. According to this list of priority hazards the further risk assessment procedure is conducted, processing the list starting with the most important hazards.

Table 2 — Prioritization of hazards.

Rank	Hazard	Years	Number of events	Impacts	Available data and maps
	Hydrometeorological hazards				
	Hurricanes				
	Storm surges				
	Wind storms				
	Floods				
	Geological hazards				
	Volcanic activity				
	Earthquakes				
	Mass movements (landslides, rock fall)				
	Tsunamis				

13.3 Degree of hazard

The Standard proposes to assess and map hazards in terms of the degree of hazard (low – medium – high). The degree of a hazard is expressed in terms of the combination of two parameters: its probability of occurrence and its intensity.

- **Probability of occurrence:** The probability of occurrence describes how likely the occurrence of a hazard is and is derived from the return period or frequency of a hazard within a certain period of time. The more often a hazard occurs, the higher the degree of hazard. The probability of occurrence is divided into three classes of low, medium, and high.

- **Intensity:** The intensity of a hazard describes is described by physical parameters which are characteristic for the impacts of the hazard. Examples are the flow depth in the case of flooding or wind speed for storms. Higher intensities result in higher degrees of hazard. Also intensity is divided into three classes: low, medium and high.

- **Degree of hazard.** The resulting degree of hazard is the combination of the two parameters, probability of occurrence and intensity. Three levels of degree of hazard are defined: low, medium and high. The three degrees of hazard are displayed on maps in the colours yellow, orange, and red.

Each of these elements, probability of occurrence, intensity and degree of hazard is described in more detail below.

13.3.1 Probability of occurrence of a hazard

The probability of occurrence of a hazard is defined as:

$$P = 1 - \left(1 - \frac{1}{T}\right)^{n} \tag{13.1}$$

where P is the probability of occurrence, T is the return period and n is the time period of observation, for example the time period of usage of a building.

In risk calculations (section 15) the expected damage is referred to an annual occurrence, so $n = 1$, and the probability of occurrence simplifies to $P = 1/T$. Table 3 shows values of P for events of low, medium, and high occurrence (class boundaries of return period set to 1, 30, 100, 300 years) in a 20 year time period, a reasonable time period of usage of tourism infrastructures.

Table 3 — Probability of occurrence of hazards.

Occurrence	**Probability**	**Return period** years	**Annual occurrence** year^{-1}	**Probability of occurrence in 20 years** %
Frequent	High	1 to 30	> 0.03	100 to 49
Rare	Medium	30 to 100	0.03 – 0.01	49 to 18
Very rare	Low	100 to 300	0.01 – 0.003	18 to 6
Extremely rare	Very low	> 300	< 0.003	< 6

The concept of return periods is rather evident for some hazards, such as hurricanes, earthquakes and floods, where usually enough data is available to conduct statistical analyses. It is rather difficult to evaluate return periods for other hazards, such as mass movements, (e. g. landslides), which often are non-recurring processes. This problematic situation may be overcome, when the triggering of events is linked to other well-defined phenomena, such as the triggering of landslides by events of heavy rainfall.

In the Standard, the temporal aspect of natural hazards is chosen taking account of the characteristics and format of available data on hazards in the Caribbean, or of standards in existing building codes or insurance practice.

13.3.2 Intensity of a hazard

The intensity of a hazard is a measure for the extent of damage it may cause. The intensity is divided into three levels of low, medium and high. The individual levels have the following meaning in terms of impacts for land use, to buildings and people.

A high intensity event puts people's life at risk and buildings can be seriously damaged or destroyed, destruction may occur immediately and without warning. Medium intensity hazards put people are at risk of injury and moderate damage to buildings can occur. Low intensity hazards put people at a low risk of injury and only slight damage of buildings may occur.

The intensity of a hazard is linked to physical characteristics of a hazard event, such as flow depth for flooding, or the peak ground acceleration for earthquakes.

13.3.3 Degree of hazard

The degree of hazard is expressed in a three-step scale of low, medium, and high hazard, derived from the combination of intensity and probability of occurrence (Figure 9).

The levels indicate the degree of hazard in terms of the likelihood of injury/death of people, and damage to buildings by the impact of natural hazards, a building may encounter.

- High hazard (red): The area is prone to a high degree of hazard. As a consequence people are at a high risk, both inside and outside of buildings. Complete and immediate destruction of buildings may due to natural hazards.

- Medium hazard (orange): The area is prone to a medium degree of hazard. As a consequence people are at risk of injury outside of buildings. Considerable damage to buildings is likely due to the action of natural hazards.

- Low hazard (yellow): The area is prone to a low degree of hazard. As a consequence people are at low risk of injury inside and outside of buildings. Slight to moderate damage to buildings may occur due to the action of natural hazards.

- No hazard (no colour): The area is not prone to hazard. According to the current knowledge there is no threat due to natural hazards.

The colours of red, orange and yellow are used on hazard maps to display the degree of hazard, a certain area is subject to. Each natural hazard must be evaluated individually and an individual hazard map must be elaborated. The legend of the hazard map must clearly state for which hazard it is valid and with which assumptions it was developed.

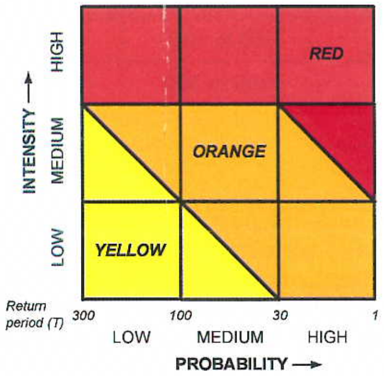


Figure 9 — Representation of the degree of hazard: low, medium and high, based on probability of occurrence and intensity [58].

A qualitative representation (Table 4) can be used in exceptional cases where it is not possible to describe a hazard quantitatively in terms of probability of occurrence and intensity. This can be due to insufficient quantity or quality of data to perform a hazard analysis, or the complexity of the hazard, or in the case of hazards which occur at very low frequencies, but in rather well defined areas. In this case the hazard analysis delivers the area which is prone to a certain hazard. Examples can be a particular area in a flood plain, which is known to be flood prone, but only insufficient data exists on occurrence and exact geographical coverage and water depths.

Table 4 — Qualitative representation of hazard.

Undifferentiated degree of hazard	Red	Area is prone to hazard

13.4 Hazard mapping

In order to facilitate standardized representations of hazards on hazard maps, the following hazard criteria are proposed.

- **Hurricane.** The degree of hazard of a hurricane is given by the wind speed of a 100-year storm, equivalent to a 10% exceedance probability in 10 years. The wind speed intensity classes are set to low medium and high.
- **Flood.** The degree of hazard corresponds to flow depths of < 0.5 m (low), 0.5-2 m (medium), and > 2 m (high) of a 100-year storm, equivalent to an exceedance probability of 10% in 10 years.
- **Storm surge.** The degree of hazard corresponds to flow depths of < 0.5 m (low), 0.5-2 m (medium), and > 2 m (high) of a storm surge caused by a 100-year storm (equivalent to an exceedance probability of 10% in 10 years).
- **Earthquakes.** The degree of hazard corresponds to the peak ground accelerations of an earthquake of a 475 year return period. This corresponds to an exceedance probability of 10% in 50 years (see equation 12.1).

Mapping criteria for further gravitational hazards, such as debris flows, rock falls, soil collapse, and landslides can be found in [9] and [13].

The areas of low, medium and high hazard are to be evidenced on topographic maps and coloured according to the proposed colour scale (yellow, orange and red).

13.5 Hazard analysis criteria

In accordance to the accompanying strategy [64] the major hazards in the Caribbean are grouped into hydrometeorological (hurricanes, storm surges, wind storms, and floods) and geological hazards (volcanic activity, earthquakes, mass movements, tsunamis). Of these hazards the Standard addresses hurricanes, storm surges, floods, and earthquakes.

Table 5 — Hazard intensity criteria.

Hazard	Hazard parameter	Intensity		
		Low	Medium	High
Hurricane	Wind speed according to SS	< SS 2 $v_w \leq$ 153 km/h (≤ 96 mph)	SS 2-SS 3 v_w: 154 km/h-209 km/h (96-130 mph)	SS 4-SS 5 v_w: ≥ 210 km/h (>131 mph)
Storm surge	Flow depth	h_f: < 0.5 m (< 1.65 ft)	h_f: 0.5 m-2 m (1.65-6.5 ft)	h_f > 2 m (> 6.5 ft)
Flood	Flow depth, or Flow depth x flow velocity	h_f: < 0.5 m (< 1.65 ft), or h_f x v_f: < 0.5 m^2/s	h_f: 0.5 m-2 m (1.65-6.5 ft), or h_f x v_f: 0.5-2 m^2/s	h_f > 2 m (> 6.5 ft), or h_f x v_f: > 2 m^2/s
Earthquake	Peak ground acceleration	PGA: < 8 %	PGA: 8-24 %	PGA: > 24 %

Abbreviations: v_w = wind speed, h_f = flow depth, v_f = flow velocity, PGA = peak ground acceleration in % of gravitational acceleration, SS = Saffir-Simpson scale.

Guidance is given on how these hazards are to be analysed and which procedures and criteria are to be used to determine the hazard intensity and degree of hazard. Table 5 summarizes the propose criteria for hazard intensity.

13.5.1 Hurricanes and storm surges

Hurricanes are intense tropical cyclones, large atmospheric systems with an extent low-pressure centre and numerous storms that produce strong winds and heavy rain. Heavy winds cause the water to pile up higher than the ordinary sea level, inducing storm surges along the coastal lines. Heavy rainfall accumulates on the land surface, provoking floods. Tropical cyclones are usually classified according to the Saffir-Simpson scale (Table 6) as tropical depressions, tropical storms, and hurricanes. The scale uses wind speed and storm surge height as classification criteria.

Table 6 — Classification of tropical cyclones [55].

Tropical cyclone	**Wind speed** km/h (mph)	**Storm surge height** m (ft)	**Damages**
Tropical depression	0-62 (0-38)	0 (0)	Only minor.
Tropical storm	63-117 (39-73)	0-0.9 (0-3)	Only minor.
Saffir-Simpson 1 (SS 1)	119-153 (74-95)	1.2-1.5 (4-5)	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also some coastal flooding and minor pier damage.
Saffir-Simpson 2 (SS 2)	154-177 (96-110)	1.8-2.4 (6-8)	Some roofing material, door, and window damage of buildings. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected anchorages break moorings.
Saffir-Simpson 3 (SS 3)	178-209 (111-130)	2.7-3.7 (9-12)	Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain may be flooded well inland.
Saffir-Simpson 4 (SS 4)	210-249 (131-155)	4.0-5.5 (13-18)	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.
Saffir-Simpson 5 (SS 5)	≥ 250 (≥ 156)	≥ 5.5 (≥ 18)	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.

The analysis of hurricanes and storm surges is usually done according to the following working steps.

1. The tracks of historical tropical cyclones are stored in regional databases (e. g. the National Hurricane Center [50]), in terms of storm centre locations and intensity (wind speed and minimal central pressure).

2. The information contained in tropical cyclone databases is used to analyse the hazard characteristics of storms, return period and intensity, using computer programs, such as TAOS/L (Table 8). Hazard maps for storm related hazards (wind speed, storm surge and wave height) are elaborated for several return periods. For the elaboration of hazard maps, additional data is needed, such as coastline geometry, land surface roughness, and ocean bathymetry. Outcomes of this analysis are wind speed, storm surge height and wave height for several return periods.

3. Depending on the level of detail of the data used in step 2, the results may need to be verified and corrected for local effects. For wind hazard, local topography, buildings and vegetation may need to be taken into account. For storm surge the resulting water heights must be transformed into flood depths, using local coastal topography.

4. Resulting wind speeds and storm surge water depths are to be classified into hazard categories (low-medium-high) according to Table 5, in order to fit the general hazard assessment scheme.

5. The resulting degrees of wind and storm surge hazard are to be represented on separate hazard maps, using the proposed colour scale: red for high degree of hazard, blue for medium degree of hazard and yellow for low degree of hazard.

Regional maps for storm related hazards have been elaborated for the Caribbean within the project CDMP [23]. The available maps have a 1 kilometre resolution and are expressed as wind speeds, storm surge heights and wave heights for return periods of 10, 25, 50 and 100 years. Island-specific elaborations have been developed for Anguilla, Antigua and Barbuda, Barbados, Belize, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines and Tobago and the Virgin Islands.

The maps were elaborated using the software TAOS/L, using the National Hurricane Center data base [50] for the data on tropical cyclones, USGS digital data for deep ocean bathymetry, data from the Digital Chart of the World for land boundaries and topography roughness [27], and satellite imagery for foreshore bathymetry and land cover. TAOS/L is integrated into a geographic information system (GIS), for pre- and post-processing, and enables the presentation of model outcomes in a format familiar to meteorological officials in the Caribbean region, and allows the results to be combined with locally available GIS and map information. The TAOS model can be used to assess any historical storm, for probable maximum events, or using real-time tropical storm forecasts from the US National Hurricane Center.

See section 6.1 for a review of the current state of storm-related hazard maps in the Caribbean and possible sources for hazard information for storm hazard assessment.

13.5.2 Floods

Floods are overflows of water that submerge land, typically a phenomenon which is caused by heavy rainfall that accompanies tropical cyclones. The conceptual framework of flood hazard analysis includes the following working steps [10],[26]:

1. Identification of flood prone areas, based on an analysis of historical data, aerial or satellite imagery, and field surveys. The resulting mappings are hazard index or danger maps (see section 4).

2. Estimation of flood discharges (hydrographs) for specific return periods of the interesting river, performing frequency analyses on historical run-off data and fitting extreme value distributions, using software such as HEC-SSP [86] or R-extRemes [94], see Table 8. If no run-off data is available, alternatively precipitation data in combination with run-off coefficients can be used to deduce discharge data, using e.g. the curve number approach [69].

3. The discharges of relative return periods are to be transformed into water levels. This can be done with rate curves, which relate discharges to water levels. More common is the usage of one- or two-dimensional hydrodynamic simulation models. See Table 8 for a review of some of the most common modelling software. Besides water depth, hydrodynamic modelling delivers additional important flood parameters, such as flow velocity, duration, and the rate of water level rise or decrease. However, additional information is required such as flood wave or rainfall characteristics (duration, peak) and a digital terrain model of the area.

4. The flooded area and water depths are determined by combining water levels with a digital terrain model, thus creating a flood map showing flood extent or depth. The outcomes of the previous working steps must be evaluated and verified with existing data from historical flood events.

5. The water depths are to be classified to intensities according to Table 5.

Table 7 — Modified Mercalli scale [1].

MMI value	Description of Shaking Severity	Summary damage description used on 1995 maps	Full description of consequences (perception by humans and damage to building types - masonry A to D and the environment)
I			Not felt. Marginal and long period effects of large earthquakes.
II			Felt by persons at rest, on upper floors, or favourably placed.
III			Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV			Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V	Light	Pictures move	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI	Moderate	Objects fall	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).
VII	Strong	Non-structural damage	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII	Very strong	Moderate damage	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX	Violent	Heavy damage	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.
X	Very Violent	Extreme damage	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI			Rails bent greatly. Underground pipelines completely out of service.
XII			Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Masonry A: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C: Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

The degree of hazard of floods is given by the flow depth (for flood events, where the velocity of the phenomenon plays a minor role), and by the product of the flow depth and flow velocity [13], see section 13.4.

See section 6.2 for a review of the current state of flood hazard maps in the Caribbean and possible sources for hazard information for flood hazard assessment.

13.5.3 Earthquakes

Earthquakes are ground vibrations, caused by immediate stress releases in the Earth's crust, that spread out through the Earth's interior and its surface. They can be generated by tectonic stresses or accompany volcanic eruptions. Earthquakes in the Caribbean are mostly of tectonic nature, as the area is located at the boundaries of the tectonic plates of North- and South-America, Cocco and Nazca. Earthquakes due to volcanic eruptions are less frequent. Earthquakes can last up to several seconds, acting in all directions, with ground amplitudes of up to several centimetres to decimetres and ground accelerations of up to several tens of % of the gravitational acceleration.

Besides the regional hazard situation due to the tectonic set-up, the local condition of the ground plays a determining role. Seismic waves are amplified in loose ground, making areas along valley bottoms, rivers, lakes, and coastal areas particularly vulnerable. Phenomena that can be triggered by earthquakes are soil settling, mass movements and soil liquefaction.

Earthquakes are classified according to two alternative schemes:

- The Richter's scale classifies earthquakes in terms of magnitudes, describing the released seismic energy. From one magnitude to the next, the energy increases by a factor of 30, and is measured in terms of ground motion (peak ground acceleration or spectral acceleration).
- Various intensity scales classify earthquakes according to their impact on the built and natural environment. In the Caribbean the 12-scale Modified Mercalli Intensity scale (MMI) is mostly used (Table 7).

The hazard analysis of earthquakes is based on physical parameters using three elements: seismotectonic zoning to describe the general hazard situation, a model to describe the decrease with distance, and consideration of local geometrical and geological effects. The necessary working steps can be summarized as follows.

1. Historical earthquakes are stored in regional databases, such as the ANSS catalogue [1]. These catalogues show the distribution of earthquakes, with their respective characteristics (magnitude, peak ground acceleration, spectral acceleration).
2. A seismo-tectonic model is needed to describe the tectonic structure of the area, determining the spatial propagation of an earthquake in the underground and on the surface.
3. Based on the above points, computer programs ([91],[93]) are used to produce macroseismic hazard maps in terms of peak ground acceleration or spectral accelerations of earthquakes of a certain return period.
4. A further refinement is attained by seismic microzonation in which an area is subdivided into zones with respect to its geological and geophysical characteristics, such as ground shaking, liquefaction susceptibility, landslide and rock fall hazard, earthquake-related flooding, so that seismic hazards at different locations within the area can correctly be identified. In most general terms, seismic microzonation is the process of estimating the response of soil layers under earthquake excitations and thus the variation of earthquake characteristics on the ground surface. Microzonation provides the basis for site-specific risk analysis, which can assist in the mitigation of earthquake damages.

For the Caribbean regional macroseismic hazard maps (above points 1 to 3) are available by the University of the West Indies ([72],[73]), the CDMP project [23] and the USGS [71]. Due to the lack of availability of local geological models, microzonations are mostly missing.

Earthquakes are classified according to their peak ground acceleration (PGA) with a 10% exceedance in 50 years (T = 475 years), divided into three classes of hazard (Table 5). See section 6.3 for a review of the current state of earthquake hazard maps in the Caribbean and possible sources for hazard information for earthquake hazard assessment.

Table 8 — Overview of computer codes for conducting hazard analyses.

Computer code	Main characteristics	Application
Extreme value analysis		
extRemes [94]	Freeware, extension of R (a free software environment for statistical computing and graphics) for the analysis of extreme values.	Determination temporal characteristics of extreme values.
Hurricanes, storm surges		
TAOS/L [96]	Freeware, stand alone software, uses data on deep ocean and foreshore bathymetry, topography, land cover, and storm data to produce storm related hazard maps, GIS interface.	Production of wind, storm surge, and wave height maps of different return periods.
Floods		
FloodArea [80]	Commercial, ArcGIS extension, two-dimensional simulation, flood input by hydrograph or rainfall, mobile barriers.	Extent of flood area, time dependent evolution of floods and flash floods, flat topographies.
Flo-2D [79]	Commercial, ArcGIS extension, two-dimensional simulation, flood input by hydrograph or rainfall.	Extent of flooded area, time dependent evolution, steep topographies, expansion pattern of debris flow.
HEC-RAS [85]	Freeware, interface with GIS, pseudo two-dimensional simulation, flood input by hydrographs.	Extent of flooded area, time dependent evolution.
HEC-SSP [86]	Freeware, stand-alone application, statistical analysis of extreme events of rainfall and floods.	Determination of intensity-duration-frequency (IDF) curves for rainfall and floods.
Earthquakes		
OpenSHA [93]	Freeware, stand-alone application, input from seismic databases.	Production of probabilistic seismic hazard maps in terms of Intensity and peak ground acceleration.
Software for US national hazard maps [91]	Freeware, stand-alone application, input from seismic databases, software used for producing the current U.S. seismic maps.	Production of probabilistic seismic hazard maps.

14 Analysis of vulnerabilities

14.1 Summary

The occurrence of natural hazards has consequences, in terms of direct damages and indirect losses. Direct damages are the immediate consequences of natural hazards, caused mainly to the physical assets of tourism (building stock and mobile equipment), infrastructures, and the environment. Not all consequences are immediately visible, but only after days and weeks after the occurrence of a hazard. Examples for these so called indirect losses are the socio-economic consequences caused by the reduced economic activity.

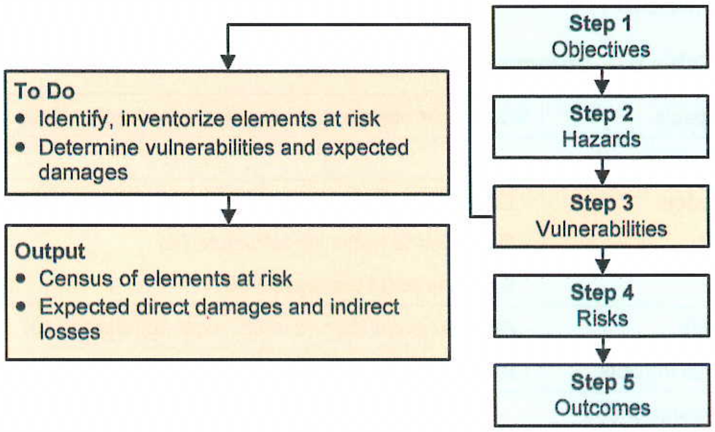


Figure 10 — Analysis of vulnerabilities.

The evaluation of the consequences of natural hazards on tourism focuses on two partial aspects: The identification and mapping of the objects at risk, and the estimation of the vulnerability of these objects with respect to a natural hazard of a certain intensity. The two major tasks to be carried out in this working step are (Figure 10):

- Identification and mapping of elements at risk on which the risk assessment is to be conducted. Elements at risk may be the facilities of tourism, the population, environmental elements, and connected economies that may suffer from a natural hazard event, directly or indirectly.

- Estimation of the expected damages and losses of the elements at risk, addressing physical, socio-economic and environmental vulnerability, and macro-economic effects caused by the occurrence of natural hazards.

14.2 Approaches and sources of information

Table 9 summarizes the vulnerable objects which are considered in the Standard and the relative approaches that are proposed.

Direct consequences. The direct impacts of hazards on vulnerable objects are visible immediately after a hazard event. The following direct consequences are considered in the Standard.

- The **physical impacts** to the building stock of tourism and its essential infrastructure, mobile assets (vehicles, boats, etc.), the traffic infrastructure, such as roads, sea and air ports, etc., and environmental damages can be assessed based on the physical vulnerability of these objects as a function of the expected hazard intensity.

- The **direct impact on the population** in terms of the number of affected people can be assessed in terms of the area affected by a hazard and the relative number of people living in this area.

Indirect consequences. The indirect impacts of hazards may be observed only days and weeks after the occurrence of a hazard. As indirect consequences the following aspects are considered in the Standard.

- **Economic impacts.** Loss of income and decrease in economic activity in tourism or in sectors directly or indirectly linked to tourism.
- **Social impacts** of hazards on the entire population or parts of particular interest (disabled, women, elderly, certain household incomes, etc.).
- **Impact on the environment** in terms of the area which is affected by a hazard phenomenon.
- **Macro-economic impacts.** This approach is proposed for studying the macro-economic effects of hazards. This analysis targets the larger scale effects of hazards on national or regional economic indicators, such as the GDP.

Table 9 — Summary of vulnerability assessment approaches.

Types of impacts	Vulnerable objects and type of assessment (A/B/C)
Direct consequences	
Physical impacts	- Damages to building stock, essential infrastructure (A) - Damages to traffic infrastructure (A) - Environmental damages (A/B)
Social impacts	- Affected population (tourists, local population) (B)
Environmental impacts	- Environmental damages (B)
Indirect consequences	
Social impacts	- Affected population (elderly, women, disabled, etc.) (B)
Economic impacts	- Loss of income (B) - Decrease in economic activity (B)
Environmental impacts	- Environmental damages (B)
Macro-economic impacts	- Impact on large-scale economic indicators (C)

Assessment approaches: A. Assessment based on physical vulnerability. B. Assessment based on area affected by hazards. C. Comparative analysis of normal and hazard situation.

The analysis and assessment of the vulnerabilities of tourism requires a thorough knowledge of the assets at risk and the extent to which these assets are risk. The necessary information is to be collected and analysed in several ways:

- On-site visits and field surveys. Particularly for site-specific assessments, on-site visits are the most important source of data.
- Analysis of statistical data and compilations, censuses, statistical year books and databases. Various sources, local, domestic and international, can be used to obtain information on the socio-economic structure of tourism and its interconnection to other sectors.

Data sources are compilations, that give information on the characteristics of tourism facilities, such as location, number and type of constructions, physical vulnerabilities. Other possible sources are censuses and surveys on tourism spending and stays edited by national statistical offices, national tourism sector authorities, hotel and tourism associations, tour operators, central banks, port and airport authorities, insurance companies.

International sources of information may need to integrated for larger scale assessments, using data sources such as the Central American Tourism Integration Secretariat, Caribbean Hotel and Tourism Association (CHTA), Caribbean Tourism Association (CTO), international reinsurance companies, and the World Tourism Organization (UNWTO).

14.3 Identification and mapping of vulnerable elements

The process of inventorizing the elements at risk is determined by the objectives of the risk assessment and should include primarily the facilities of tourism at risk due to natural hazards (such as hotels and directly connected facilities), and the people working in tourism. It should then be extended to more external infrastructures and services that are necessary for the operation of tourism, such as traffic infrastructure, and the connected industries. Also tourist attractions of environmental, historical or cultural importance may be included in the assessment.

All vulnerable elements are to be identified by their precise geographic location in order to be used in geographical information systems (GIS). The vulnerable elements are categorized according to their type of damage: direct damages and indirect losses.

14.3.1 Physical assets of tourism

These include the assets of tourism, which are directly linked to the sector, such as tourism facilities, vital infrastructures and mobile equipment, but also governmental offices, emergency infrastructure, and environmental attractions linked to tourism. In more detail they include:

- Tourism facilities, such as hospitality/accommodation facilities (hotels and guest houses, bed and breakfast, camp sites, etc.), food and beverage facilities, restaurants, fast food outlets, pubs, lounges, nightclubs, etc.
- Vital infrastructures, such as water supply, sewage, energy, air conditioning, etc.
- Mobile equipment such as boats, vehicles, sports equipment, etc.
- Key public utilities, such as transport infrastructure (airports, seaports, highways, bridges, tunnels).
- Key governmental offices (ministries of foreign affairs, national security, tourism and finance, disaster management offices, embassies/consulates, etc.)
- Emergency infrastructure, such as shelter infrastructure, ambulances, police, fire brigade, hospitals and civil protection.
- Tourism attractions: environmental (beach, reef, tropical forest, natural monument), cultural/historical (fortresses, old towns, churches, museums), and sports.

The identification and mapping of the above listed physical assets should include an estimate of the values of these elements. The characteristics may be evaluated during field surveys or can be found in compilations. Table 10 shows the example of unitary values of replacement for transport and communication assets.

14.3.2 Socio-economic aspects

In order to determine the socio-economic impacts of natural hazards on the communities and local economies which are linked to tourism, it is necessary to have base statistics on the population, and the economic activities. In order to conduct this analysis in a GIS-environment, the necessary data should be geo-referenced. The necessary data includes:

- Geographic distribution of population, population density, and distribution of particularly interesting aspects of the population, such as age structure, gender, minorities, and school formation, etc.
- Geographic distribution of economic indicators, such as income distribution, poverty, number of owners and renters, etc.
- Geographic distribution of workforce location data of the population active in tourism or in connected economies.

In order to determine and identify the economic connection between tourism and other economic sectors, it is necessary to have economic statistics of the study area, such as:

- Analysis of the economic structure with respect to interconnection with tourism.
- Employees in tourism and incomes produced.
- Employees in connected economies and incomes produced (tourist services, transport, business, food, agriculture, etc.)

14.3.3 Environmental aspects

Tourism relies on environmental aspects, such as tropical forests, reefs and beaches. If these aspects are at risk, so is tourism itself. The environmental tourism attractions must be mapped and if possible attributed with an economic value.

14.3.4 Macro-economic aspects

The assessment of the macro-economic aspects of natural hazards is beyond the focus of this Standard. The methodology discussed in [28] is based on the comparative analysis of normal and hazard affected large-scale economic indicators, comparing the previous situation with the expected evolution in 3-5 years (without a hazard event) with the effects of a hazard event.

14.4 Analysis of consequences

14.4.1 Physical damages

For the estimation of the physical damages caused by hazards, it is necessary to know the expected hazard intensity (which is an output of the hazard analysis, see section 13), the physical vulnerability, and the value of the objects that are considered. Table 10 shows estimates of values of the various elements considered as tourism facilities or other elements at risk of direct damage.

Table 10 — Approximate values of transport and communication assets [26].

Object	Approximate value [US$] of 2003
New light utility vehicle (average)	10'000
New small car (average)	10'000
New truck, rigid frame (average)	60'000
New urban bus (average)	100'000
km of dirt road: rehabilitation, flat/undulating land (reconstruction), undulating/mountainous land (reconstruction)	5'000, 10'000, 20'000
km of hardcore road: rehabilitation, flat/undulating land (reconstruction), undulating/mountainous land (reconstruction)	15'000, 50'000, 75'000
km of paved road: rehabilitation, flat/undulating land (reconstruction), undulating/mountainous land (reconstruction)	25'000, 100'000, 150'000

The formulas to calculate the expected physical damages are listed below for several types of objects.

Buildings. The direct damages to the building stock can be described as follows [58]. The expected damage to a building caused by a hazard scenario is given as:

$$D(B)_{i,j} = (1 - \varepsilon_i) \cdot V(B)_i \cdot W(B)_{i,j}$$

where $D(B)_{i,j}$ is the damage [US$] of building i due to scenario j, ε_i is the protection factor of this building (it varies from 0 to 1, value 1 means that the building is completely protected), $V(B)_{i,j}$ is the vulnerability of the building with respect to scenario j, and $W(B)_i$ is the market value of the building.

The total damage to all buildings due to hazard scenario j is given as:

$$D(B)_j = \sum_i D(B)_{i,j}$$

where $D(B)_j$ are the total damages to buildings due to hazard scenario i, and $D(B)_{i,j}$ is the damage to building i caused by hazard scenario j, as stated by equation (14.1).

Mobile assets. The damage to mobile assets, such as vehicles, boats and machinery can be taken account of as:

$$D(MA)_{i,j} = (1 - \varepsilon_i) \cdot V(B)_{i,j} \cdot W(B)_i$$

where $D(MA)_{i,j}$ is the damage to mobile asset i due to hazard scenario j, ε_i is the protection factor, $V(B)_{i,j}$ is the vulnerability of mobile asset i in hazard scenario j, and $W(B)_i$ is the value of the mobile asset.

Linear elements. The damage to linear elements, such as conducts (water, sewage, gas, etc.) can be calculated as:

$$D(L)_j = V(L)_{i,j} \cdot W(L)_j \cdot g_j$$

where $D(L)_j$ is the damage, $V(L)_{i,j}$ the vulnerability, and g_j the length of linear element j.

Areal elements. The damage to areal elements, such as parks, golf courses and forests, can be estimated as:

$$D(A)_j = V(A)_j \cdot W(A)_j \cdot A_j$$

where $D(A)_j$ is the damage to areal object j, $W(A)$ is the value per areal unit [US$/area], and A_j is the area.

The **total of direct damages** of scenario j is the sum of all the direct damages, described as:

$$D_j = D(B)_j + D(MA)_j + D(L)_j + D(A)_j$$

with the partial damages to facilities, mobile assets, linear and areal elements, $D(B)_j$, $D(MA)_j$, $D(L)_j$, and $D(A)_j$.

In the case that more scenarios are to be considered, the overall total of direct damages of all considered scenarios is calculated as the sum of all damages of all scenarios as:

$$D(dir) = \sum_j D_j$$

where D_j is the total damage of scenario j.

14.4.1.1 Estimation of physical vulnerability

Natural hazards cause direct damages to tourism facilities. The vulnerability of an object towards physical damages is given by its physical vulnerability. Physical vulnerability ranges from 0 to 1, a value of 0 means no damage and 1 means complete destruction. The analysis of hazards and vulnerabilities is a wide subject and topic of ongoing research. The text below can only address the major points which are necessary for conducting risk assessment applying the Standard. Often the reader is referred to specific literature, the usage of specific software, or the expert knowledge of the team members conducting the risk assessment.

In the following sections guidance is given on how to estimate physical vulnerability for hurricanes (wind hazard), storm surge and flooding, and earthquake.

Hurricanes. The high sustained winds that accompany hurricanes cause widespread structural damage to both man-made and natural structures. Wind induced damages on buildings are caused by wind pressure and short-termed pressure peaks. The impact increases with increasing wind speed and particularly when the characteristic frequency of the building fits the frequency characteristics of the wind.

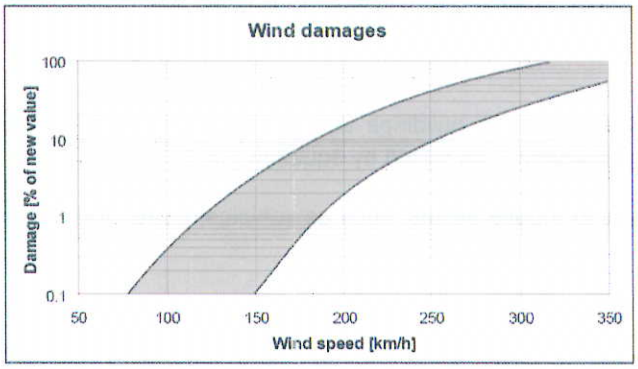


Figure 11 — Estimation of damages due to wind hazard accompanying a tropical cyclone [48].

Particularly vulnerable to heavy wind are large window fronts, doors and other apertures, and external or roof mounted equipment. The overall degree of physical damage due to wind hazard of buildings can be estimated using the Saffir-Simpson scale (Table 6) and Figure 11.

Table 11 — Physical vulnerabilities for storm surge and flood [58].

Object types	Physical vulnerability		
	Intensity		
	Low	Medium	High
Hotel	0.1	0.3	0.4
Depot	0.02	0.3	0.6
Public buildings	0.1	0.3	0.4
Camp ground	0.5	0.8	1.0
Hospital	0.1	0.3	0.4
Single-family house	0.02	0.2	0.3
Apartment house	0.006	0.15	0.25
Bridge, 8 m	0	0.01	0.1
Road, 8 m	0	0.1	0.3
Conducts, below ground	0	0.01	0.1
Electricity, above ground	0	0.3	0.8
Electricity, below ground	0.1	0.3	0.5
Drinking water, below ground	0	0.01	0.1
Drinking water, above ground	0	0.3	0.5
Golf course	0.2	0.3	0.6

Storm surges and floods. Floods and storm surges may cause damages to buildings, vital and traffic infrastructures, and attractions of tourism. Damages are mainly caused by water intrusion to physical assets. Due to the possibilities of monitoring and alert of the triggering phenomenon damages to people are secondary. Table 11 lists approximate values for physical vulnerability for a number of object types [58]. More than giving distinct values the table should be used to get indicative values. Floods and storm surges cause damages particularly to objects close to the ground surface. The damage estimation must thus focus particularly on the ground floor and the basement of buildings and the mobile assets that are contained.

Earthquakes. Earthquakes can cause damage to buildings, infrastructures, putting at risk also people inside and outside of buildings. The central point is the establishment of the physical vulnerability of buildings, which describes the extent of damage (in %) which is to be expected due to a certain earthquake. The vulnerability of a building is determined by the type of construction, the materials used and the quality of construction.

The impact of an earthquake to a building is given mostly by cyclic, horizontal movements, which are difficult to absorb by the structure, which is generally designed to sustain vertical forces. This behaviour is illustrated by the soft-storey failure: the collapse of a single storey leads to the complete destruction of the building.

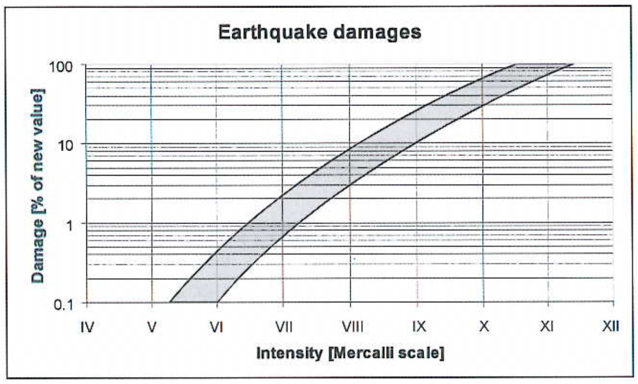


Figure 12 — Estimation of physical vulnerability for earthquakes [48].

The vulnerability of buildings can be described using vulnerability curves, which link building vulnerabilities with earthquake characteristics. These vulnerability curves are either based on intensity or other physical characteristics of earthquakes. A rough estimate of the damage to buildings by earthquakes can be conducted using Figure 12 or Table 7.

14.4.2 Losses due to interruption of services

The damage caused by the interruption of services is calculated as [58]

$$D(int)_j = C(int) \cdot d_j$$

where $D(int)_j$ is the indirect loss due to interruption of services due to hazard j, $C(int)$ is the cost of interruption per day, and d_j is the number of days of interruption. The daily cost and duration of interruption must be estimated.

14.4.3 Socio-economic and environmental impacts

The Standard proposes to express the degree of vulnerability in terms of the degree of hazard an object is exposed to. Consequently the following degrees of vulnerability are applied: Low vulnerability (population or environment is exposed to low hazard intensity), medium vulnerability (population or environment is exposed to medium hazard intensity), high vulnerability (population or environment is exposed to high hazard intensity).

See below for assessment of the socio-economic (affected population) and environmental impacts.

14.4.3.1 Affected population

The socio-economic analysis focuses on the identification of the vulnerability of a community towards the effects of natural hazards, and evidences parts of the population which may be particularly at risk with respect to natural hazards. Since the population may be directly or indirectly affected, it is necessary to distinguish and identify these two scenarios.

Several aspects of a community may be used to indicate its vulnerability towards disasters. According to [53] the analysis should focus on the following indicators.

- Minority populations. Indicates potential language or cultural considerations.
- Percent households below poverty. Indicates limited resources.
- Percent population over age 65. Indicates possible mobility or cultural considerations.

equalled or exceeded [66].

discharge. Causes inundation,

voir or a coastal region [66].

overflow of the natural channel

oss of life, injury or other health services, social and economic

earth processes, such as related geophysical processes urface collapses, and debris or nt contributors to some of these lthough they are triggered by they are essentially an oceanic hazard [68].

al or oceanographic nature that acts, property damage, loss of tion, or environmental damage.

opical cyclones (also known as ms, tornados, blizzards, heavy including flash floods, drought, nditions also can be a factor in cust plagues, epidemics, and in olcanic eruption material [68].

pact on quality of tourism, such), transportation infrastructure ays, canals).

quake at a particular place are th materials. Intensity scales in

Exceedance probability	Probability that a given magnitude of an event will be
Flash flood	Flood of short duration with a relatively high peak and because of its nature is difficult to forecast [66].
Flood	Significant rise of water level in a stream, lake, reserv
Floodplain	An area adjacent to a river, formed by the repeated bed [66].
Frequency	The inverse of → return period.
Geological hazards	Geological process or phenomenon that may cause l impacts, property damage, loss of livelihoods and disruption, or environmental damage. Comment: Geological hazards include internal earthquakes, volcanic activity and emissions, and such as mass movements, landslides, rockslides, s mud flows. Hydrometeorological factors are importar processes. Tsunamis are difficult to categorize; a undersea earthquakes and other geological events, process that is manifested as a coastal water-related
Hydrometeorological hazards	Process or phenomenon of atmospheric, hydrologica may cause loss of life, injury or other health impa livelihoods and services, social and economic disrupt Comment: Hydrometeorological hazards include tro typhoons and hurricanes), thunderstorms, hailstorr snowfall, avalanches, coastal storm surges, floods heatwaves and cold spells. Hydrometeorological co other hazards such as landslides, wildland fires, loc the transport and dispersal of toxic substances and v
Impacts	→ Consequences.
Infrastructure	Public services of a community that have a direct im as vital services (water supply, sewer treatment (airports, seaports, highways, bridges, tunnels, railwa
Intensity	A measure of the effects of a hazard.
Intensity (macroseismic)	A number by which the consequences of an earthq scaled by its effects on persons, structures, and ear

14.6 Macro-economic effects

The assessment of macro-economic effects is beyond the scope of this Standard. It addresses large scale effects of the impacts of natural hazards. Such an analysis must include calculations of how a disaster's impact on the sector would affect indicators such as economic output, external accounts, and public finances, with proper attention given to the effects on public and private investment, employment and women. According to [28] the analysis of the macro-economic effects of hazard events should focus on:

- Effects on economic activity.
- Effects on the external sector.
- Effects on public finances.
- Effects on investments.
- Effects on employment.

Generally, the analysis of macro-economic effects of natural hazards is based on the comparative analysis of the above mentioned large-scale economic indicators under normal and hazard affected conditions. The time horizon of such an analysis is of 3 to 5 years [28].

14.7 Resilience

Resilience is the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR).

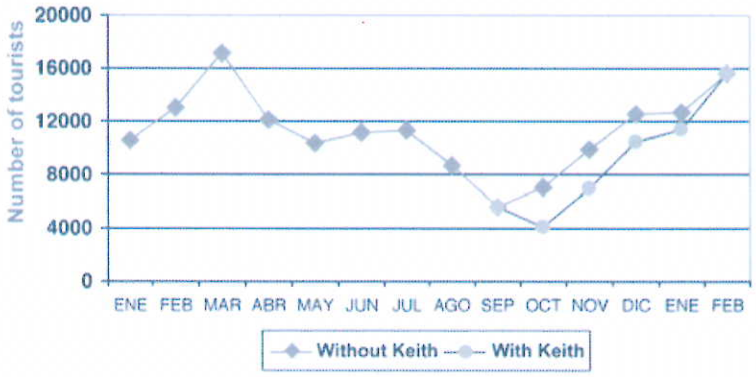


Figure 13 — Tourist arrivals in Belize before and after hurricane Keith, 2000 [28].

The resilience of tourism can be evaluated by identifying the effects of natural hazard events in economic statistical data, such as tourist arrivals, analysing how long it takes tourism to get back to normal condition. Analogously to the analysis of hazards, vulnerability and risks, it is necessary to include the aspect of the intensity of the hazard, when judging hazard resilience.

Figure 13 shows an example from Belize, where it was estimated that tourism returned to its normal condition 5 months after hurricane Keith (SS 3 to 4) in 2000. Hurricane Keith caused an estimated damage of 280 million US$.

15 Calculation and assessment of risks

15.1 Summary

In the concluding step of risk assessment the consequences that arise from the presence of vulnerable elements in an area prone to natural hazards are estimated (Figure 14). This step corresponds graphically to the superposition of the hazard maps on the maps of vulnerable elements. The results are quantitative estimates of risk.

The consequences are direct damages to the building stock and infrastructures of tourism, essential transportation facilities and infrastructure, direct losses such as cost of repairs and replacement, income loss for the operators of tourism and the connected population, casualties, and indirect losses, such as supply shortages, sales decline, and other economic losses to industries which are connected to tourism.

The resulting risks are object, or collective risks, i. e. the partial or total risks, a certain object (e. g. hotel, community, region) is subject to. It is not the scope of the Standard to determine individual risks, i. e. the risks that a single person is subject to.

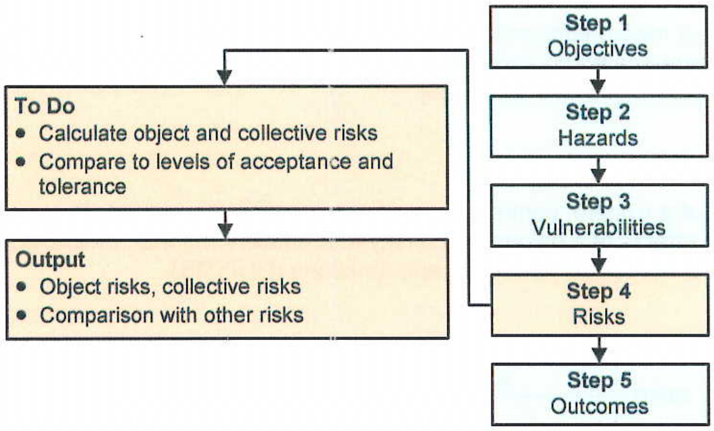


Figure 14 — Calculation and assessment of risks.

15.2 Total risks

The total risk, or sometimes also called collective risk, of a situation is obtained by summing up the risks that arise from all the considered hazards scenarios acting on all objects at risk. Mathematically, the procedure of summing up is described as:

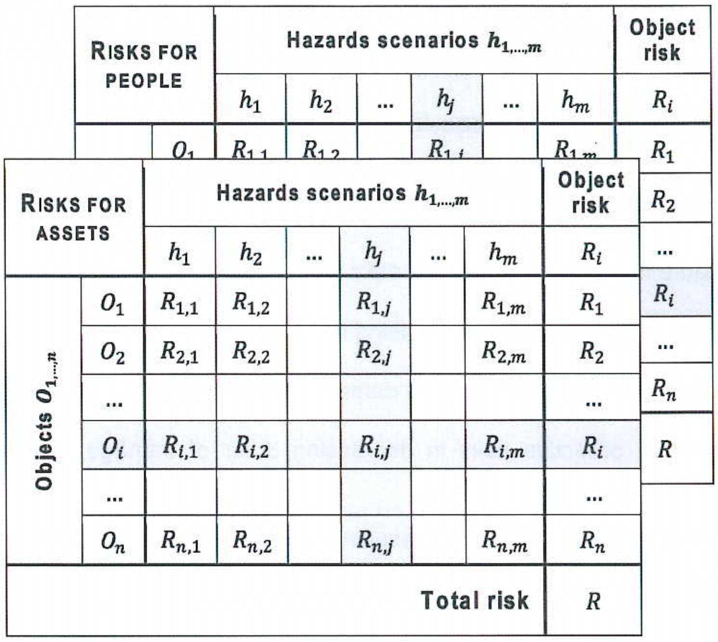
$$R_{i,j} = P_j \cdot D_i \quad \rightarrow \quad R_j = \sum_i R_{i,j} \quad \rightarrow \quad R = \sum_j R_j \tag{15.1}$$

where $R_{i,j}$ is the object risk that arises from hazard scenario j acting on object i, R_j is the risk of all objects exposed to hazard scenario i, and R is the total or collective risk.

The potential damage of an object, D_i, is given as $D_i = V_{i,j} \cdot W_i$ for direct damages (objects with a physical vulnerability $V_{i,j}$ and value W_i. For assessing indirect consequences, such as affected population or areas at risk, D_i is the number of affected people or an area (km^2).

15.3 Representation of risks – risk matrices

The risk characteristics of the studied system can be described by risk matrices (Figure 15). Risk matrices can be easily calculated using spreadsheet programs, such the programs contained in Microsoft Office [88] or OpenOffice [91].



RISKS FOR PEOPLE		Hazards scenarios $h_{1,\dots,m}$						Object risk
		h_1	h_2	...	h_j	...	h_m	R_i
	O_1	$R_{1,1}$	$R_{1,2}$		$R_{1,j}$		$R_{1,m}$	R_1
								R_2
								...
								R_i
								...
								R_n
								R

RISKS FOR ASSETS		Hazards scenarios $h_{1,\dots,m}$						Object risk
		h_1	h_2	...	h_j	...	h_m	R_i
Objects $O_{1,\dots,n}$	O_1	$R_{1,1}$	$R_{1,2}$		$R_{1,j}$		$R_{1,m}$	R_1
	O_2	$R_{2,1}$	$R_{2,2}$		$R_{2,j}$		$R_{2,m}$	R_2
	...							...
	O_i	$R_{i,1}$	$R_{i,2}$		$R_{i,j}$		$R_{i,m}$	R_i
	...							...
	O_n	$R_{n,1}$	$R_{n,2}$		$R_{n,j}$		$R_{n,m}$	R_n
							Total risk	R

Figure 15 — Calculation of object and total risks in risk matrices (modified from [12]).

Figure 9 shows an example risk matrix for calculating the risks of n objects $(O_1, \dots, O_m)$, which are subject to m hazard scenarios $(h_1, \dots, h_m)$. It is possible to calculate partial or total risks, such as:

- The risk an individual object is subject to due to a single hazard scenario $(R_{i,j})$.
- The total risk an object is subject to due to a number of hazards scenarios $(h_1, \dots, h_n)$, called object risk (R_i).
- Collective risks are the sum of the risks of all objects. Collective risks can be hazard-specific, or include all hazards (R) for all the considered objects.
- Risks are addressed separately for physical assets and for people, additional hazards or object categories can be easily added and assessed.

The procedures to calculate risks are:

1) All object risks $R_{i,j} = P_j \cdot D_i$, separated by categories (risks for material assets, people or environment affected) are summarized in a risk matrix.

2) For each object O_i all the risks caused by different hazard scenarios (h_i) are summed up to form the total object risk R_i. It represents the risk for object O_i due to all the hazards scenarios that have been considered $(h_{1,\dots,m})$. It can be written as:

$$R_i = \sum_{j=1}^{m} R_{i,j}$$

3) All the object risks R_i are summed up to give the collective risk of the system R:

$$R = \sum_{i=1}^{n} R_i$$

Risk matrices give a complete quantitative description of the risk characteristics of the system that is analysed and show the effects of the hazards on people and material assets at risk. The resulting risks can be compared to each other and assessed, see sections 15.4 and 15.5.

15.4 Visualization of risks – Occurrence-impact diagrams

The collective risks can be displayed graphically in a occurrence-impact graph, where the single risks are shown as a sum-curve (Figure 16).

The step-by-step procedure to represent collective risks in an occurrence-impact diagram is:

1) All collective risks R are ordered in decreasing order of damage D.

2) Insert the collective risk R with the largest damage and the corresponding probability of occurrence P.

3) Insert the remaining collective risks in decreasing order of damage, summing the corresponding occurrences P.

4) Connect the points to a sum-curve. The resulting risk corresponds to the area below the sum-curve.

5) Compare different sum-curves and determine the level of acceptance.

The resulting occurrence-impact curve represents the total risk of the situation that has been analysed. In a consecutive step (15.5) the tolerance or acceptability of the resulting risk shall be evaluated, comparing the risks to generally accepted or tolerated levels of risk.

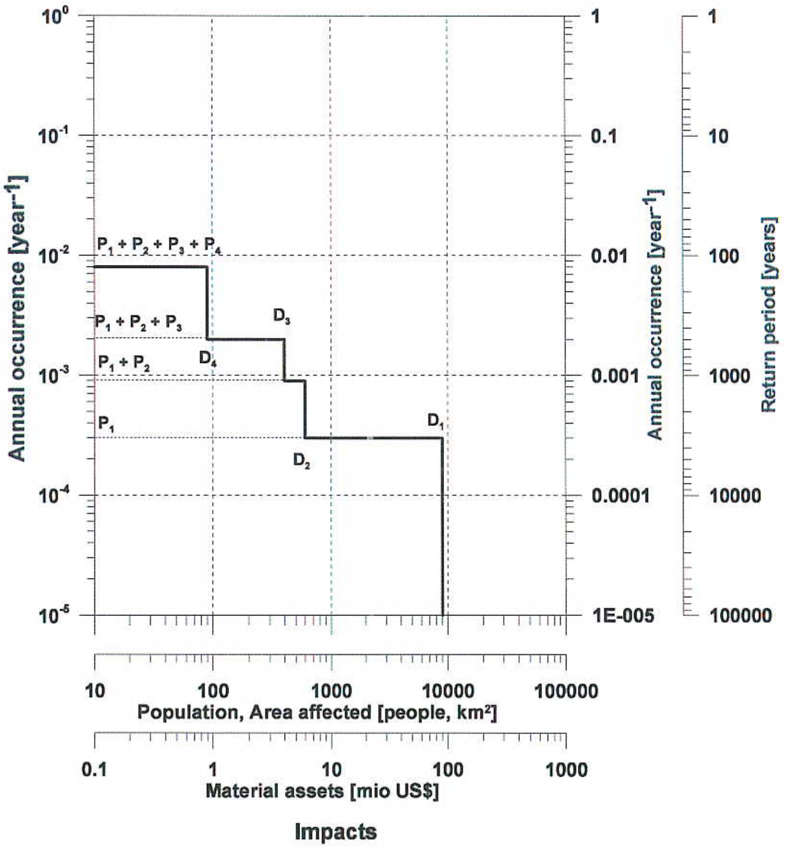


Figure 16 — Representation of collective risks in an occurrence-impact diagram (modified from [12]).

15.5 Assessment of risks

After the calculation of risks they can be assessed in order to identify if they are tolerable or acceptable or not. If risks are not acceptable, possible measures should be found to reduce the risks.

Total risks are represented in a occurrence-impact diagram (Figure 17). It is useful to compare the resulting risks among themselves locally and regionally, and with risks deriving from other hazard situations. and with existing definitions of acceptable risks of natural or technological hazards.

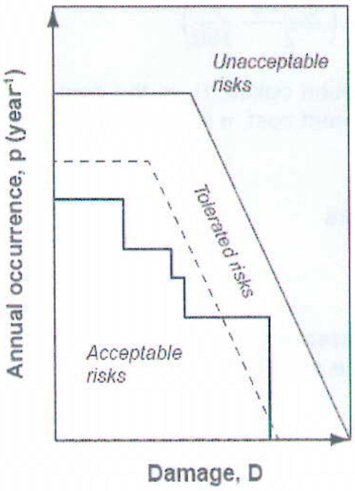


Figure 17 — Evaluation of acceptability of total risk.

In order to evaluate the acceptability of collective risks, the occurrence-impact diagram is divided into three ranges: an acceptable, an intermediate and a non-acceptable range. The acceptability of a situation is judged by the position of the sum-curve with respect to the three ranges.

The definition of the ranges of acceptability of risks involves a societal dialogue, and can only be done, when a number of risks – not only deriving from tourism and natural hazards – are known and can be compared to each other [33].

15.6 Risk reduction measures - Cost and efficiency

Risks may exceed the limits of acceptability and thus should be reduced applying appropriate measures. Possible measures are:

- **Direct protective engineering works.** Objects at risk can be protected by engineering works that act on the occurrence or propagation of a hazard, thus reducing the degree of hazard or improve the protection of an object at risk. Examples of protective measures are protective walls against flooding and reinforcement of structures against earthquakes.

- **Higher construction standards.** Land use regulations and protective works have only limited efficiency for hazards such as earthquakes and hurricanes. The implementation of higher construction standards in tourism by means of the introduction of building codes is more effective.

- **Insurance.** The damage cost can be transferred to insurance companies.

- **Risk avoidance and land use regulations.** Risks can be completely avoided or controlled by land use regulations, linking hazard mappings to land use.

Risk mitigation must be cost-effective. The efficiency can be evaluated by a cost-effectiveness analysis, which relates the risk reduction (in terms of lives saved or material damage avoided) to the cost of the risk reduction. In both cases the cost-effectiveness is expressed in as a benefit-cost ratio as

$$Benefit/Cost = \frac{Risk\ reduction}{Cost\ of\ risk\ reduction}$$

where the risk reduction is the improvement in safety, given as the difference between the risk before and after the implementation of risk reduction measures, and the cost to reduce risk. As usual in risk analysis the values are referred to one year.

The annual cost of a risk reduction option is calculated as:

$$C_{annual} = C_O + C_M + C_R + \frac{I_0 - L_n}{n} + \left(\frac{I_0 + L_n}{2} \cdot \frac{p}{100}\right)$$

The parameters refer to the risk mitigation option. C_O is the cost of operation, C_M is the cost of maintenance, C_R is the cost of repair, I_0 is the investment cost, n is the lifetime [years], L_n is the residual value after lifetime, and p is the interest rate [%].

16 Documentation of outcomes

16.1 Summary

The procedures and outcomes of risk assessment are documented in a summary report and on maps (Figure 18), according to the specifications. The specifications give guidelines on the map products, and their layout, scale, colours and symbols.

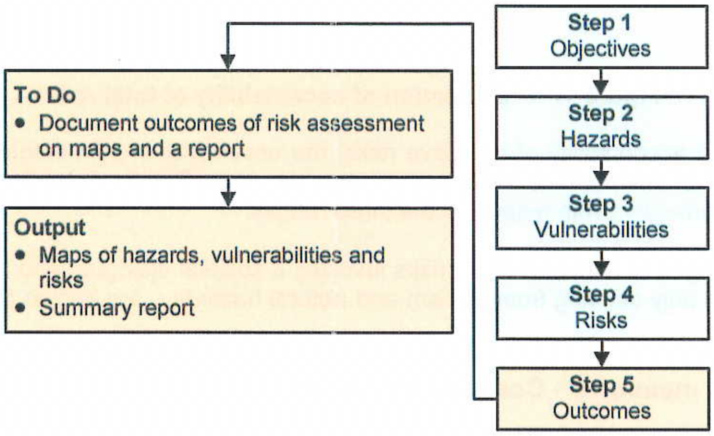


Figure 18 — Representation of results.

16.2 Maps

The map representations of the outcome of risk assessments follow a common outline and specifications, as shown in shown below. The outcomes are displayed on hazard maps, maps of vulnerable elements and risk maps (Figure 19). See Annex A for example outputs of risk assessment.

Topographic base maps. Topographic maps are to be used to display the outcomes in a comprehensive way. See section 16.3.2 for indicative map scales and section 16.3.5 for map projections and datum.

Hazard maps. Hazard maps show the degree of hazard which is present due to a natural hazard. Each hazard must be displayed individually. The map representation shows the degree of hazard, using the proposed colour scale.

Maps of vulnerable elements. Maps of elements at risk show the elements that are at risk, if possible identifying their degree of vulnerability.

Risk maps. Risk maps show the resulting risks using the proposed colour scale.

16.3 Map specifications

16.3.1 Layout

The maps follow a common layout, composed of three elements, as shown in Figure 19: The field “Map cover sheet” is of “letter” size and contains the map title and scale. The field “Map legend” lists the symbols and colours used on the map. The field “Explanations” contains additional and explanatory text and disclaimers necessary for the comprehension of the information displayed on the map. The field Map shows the map with a scale bar and a North arrow, as shown below.

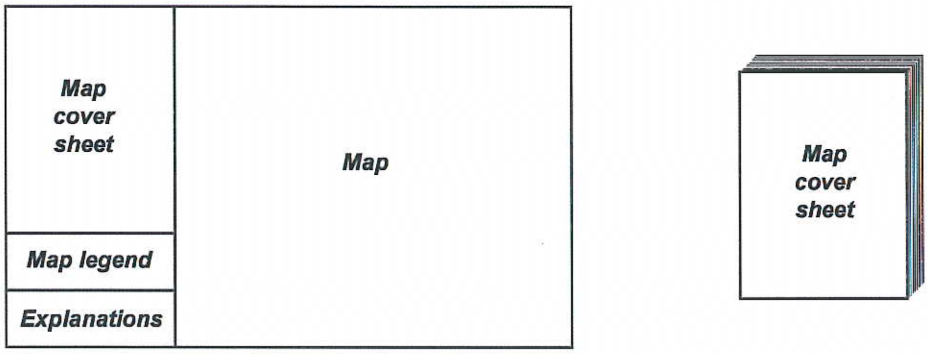


Figure 19 — General layout of maps: unfolded map (left), folded map (right)

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exposed people, property, services, livelihoods and the environment on which they depend". Risk assessments (and associated risk mappings) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.

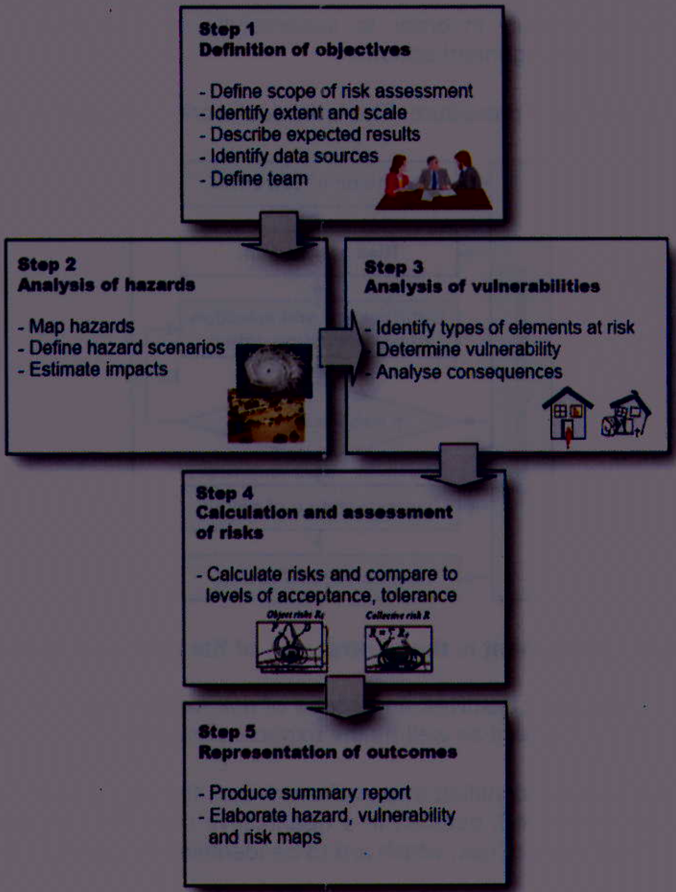


Figure 6 — The risk assessment process is composed of five working steps (Modified from [12]).

The risk assessment procedure proposed by the Standard is composed of five main working steps (Figure 6)

16.3.5 Map datum and projection

In order to facilitate the comparability and exchange of map documents, a common map datum and projection as given by the Ordnance Survey of the United Kingdom is mandatory. See the website www.ordnancesurvey.co.uk for more information.

16.4 Reports

The conduction of a risk assessment must be documented in a report, documenting and detailing the procedure that was followed. It shall contain a detailed description of:

- Objectives, extent, scale of assessment.
- Data sources and additional literature and documents that were used to perform the risk assessment.
- Documentation of the single working steps of the assessment.
- Description of the results, including disclaimers and limitations.

The report accompanies the maps that are produced. In order to facilitate the exchange of documents it is recommended to save the reports and other documents in PDF (Portable Document Format, preferably in the archiving sub-format pdf/A) by Adobe Systems Inc., a document format for archiving, exchanging and printing. The reader application Adobe Reader is freely available at the website of Adobe Systems Inc. [77].

16.5 Electronic map and data formats

The Standard defines the formats for facilitating the exchange of electronic data layers and electronic maps for printing and presentation purposes.

- In order to facilitate the exchange of data, any data layers produced in a GIS environment are to be saved in the quasi-standard for vector and raster data: ESRI shapefiles for vector data and ESRI grid files for raster data. Most GIS software contains converters to read and write ESRI shapefiles and grid files. A freely available stand-alone software for the conversion of geographic data formats is OpenEV [90].
- The electronic map layers shall contain information that identify the authorship, the date of creation and modification, and further meta-data, that facilitate the identification of information contained in the map layers.
- Finalized maps are to be saved from the GIS software in PDF (Portable Document Format, preferably in the archiving sub-format pdf/A) by Adobe Systems Inc., a document format for exchanging and printing high quality map documents. The reader application Adobe Reader is freely available at the website of Adobe Systems Inc. [77].
- Alternatively these maps can be viewed and distributed using freely available internet-based map services, such as Google Earth [81] and Google Maps [82].

17 Software tools for risk assessment

Risk assessment of natural hazards is based on the analysis of geographically referenced data. The operations of risk assessment are executed using two types of computer software:

- Geographic information systems (GIS) are used to compile the necessary input data and produce map output. Examples of common GIS software are ArcGIS [78], Idrisi [87] and the freely available GRASS [83].
- Spreadsheet calculation programs are used to perform risk calculations. Examples of such software are the spreadsheet software contained in the office suite Microsoft Office, MS Excel [88] or the freely available office software package OpenOffice.org [91].

Bibliography

[1] Advanced National Seismic System (ANSS) Composite Earthquake Catalogue. Internet resource: www.ncedc.org/anss/cnss-catalog.html.

[2] Association of Bay Area Governments (ABAG). Internet resource: www.abag.ca.gov.

[3] AGS (2000): Landslide risk management concepts and guidelines. Australian Geomechanics Society, Australian Geomechanics, Vol. 35, No. 1, March 2000. Internet resource: www.australiangeomechanics.org.

[4] AGS (2007): A national landslide risk management framework for Australia. Australian Geomechanics, Vol. 42, No. 1, March 2007. Internet resource: www.australiangeomechanics.org.

[5] ANCOLD (2003): Guidelines for risk assessment. Australian National Committee on Large Dams.

[6] AS/NZS 4360:1999: Risk Management. Australian/New Zealand Standard.

[7] Birkmann J. (2006): Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. United Nations University Press.

[8] Bollin C., Hidajat R. (2006): Community-based risk index: Pilot implementation in Indonesia. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United Nations University Press.

[9] BRP/BWW/BUWAL (1997): Consideration of mass movements in land use planning. Recommendations. 1997. In German. Internet resource: www.bafu.admin.ch.

[10] Büchele B., Kreibich H. Kron H., Thieken A., Ihringer J., Oberle P., Merz B, Nestmann F. (2006): Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks. Nat Hazards Earth Syst. Sci., 6, pp. 485-503. Internet resource: www.nat-hazards-earth-syst-sci.net.

[11] Bureau of Reclamation (1988): Downstream Hazard Classification Guidelines. Acer Technical Memorandum, No. 11. Denver (CO), USA.

[12] BUWAL (1999): Risk analysis for gravitational natural hazards. Part I: Methodology. Part II: Case studies and data. In German with English abstract. Swiss Federal Office of Environment, Forest and Landscape, Bern, Switzerland. Internet resource: www.bafu.admin.ch.

[13] BWW/BRP/BUWAL (1997): Consideration of flood hazards in land use planning. Recommendations. 1997. In German. Internet resource: www.bafu.admin.ch.

[14] CADM: Caribbean Disaster Management Project. Internet resource: www.cdera.org/projects/cadm.

[15] CAN/CSA-Q634-91: Risk Analysis Requirements and Guidelines. Canadian Standards Association, Toronto, Canada, 42 pp.

[16] CDB (2006a): Flood hazard mapping of St. Lucia. Final report. V. Cooper and J. Opadeyi. Caribbean Development Bank. February 2006.

[17] CDB (2006b): Flood hazard mapping of Grenada. Final report. V. Cooper and J. Opadeyi. Caribbean Development Bank. February 2006.

[18] CDB (2006c): Vulnerability Assessment of Critical Facilities, Grenada, West Indies. Final Report. Prepared for Caribbean Development Bank by CIPA Inc. July 2006.

[19] CDB (2008): Storm Hazard Assessment for St. Lucia and San Pedro/Ambergris Caye, Belize. Methodology for Storm Hazard Mapping. Prepared for Caribbean Development Bank. Kinetic Analysis Corporation, Savannah, Georgia, USA.

[20] CDERA (2003a): Status of hazard maps, vulnerability assessments, and digital maps in the Caribbean – Final report. Caribbean Disaster Emergency Response Agency (CDERA). Internet resource: www.cdera.org.

[21] CDERA (2003b): Status of hazard maps, vulnerability assessments, and digital maps. Country reports for Anguilla, Antigua, Bahamas, Barbados, Belize, British Virgin Islands, Dominica, Grenada, Guyana, Haiti, Jamaica, Martinique, Montserrat, Nevis, Puerto Rico, St. Lucia, St. Kitts, St. Vincent, Suriname, Turks and Caicos, and Trinidad and Tobago. Caribbean Disaster Emergency Response Agency (CDERA). Internet resource: www.cdera.org.

[22] CDERA (2006): Vulnerability Assessment of Critical Facilities, San Pedro, Ambergris Caye, Belize. Final Report. Prepared for Caribbean Disaster Emergency Response Agency by CIPA Inc. July 2006.

[23] CDMP (1999): Caribbean Disaster Mitigation Project, 1999. Organisation of American States (OAS). Internet resource: www.oas.org/en/cdmp.

[24] CHAMP: Caribbean Hazard Mitigation Capacity Building Programme. Internet resource: www.cdera.org/projects/champ.

[25] DeGraff J.V., Bryce R., Jibson R.W., Mora S., Rogers C.T. (1989): Landslides: Their extent and significance in the Caribbean. In E.E. Brabb and B.L. Harrod (eds), Landslides: Extent and Economic Significance. pp. 51-80. Rotterdam: A.A. Balkema.

[26] de Moel H., van Alphen J., Aerts J.C.J.H. (2009): Flood maps in Europe – methods, availability and use. Nat. Hazards Earth Syst. Sci., 9, pp. 289-301. Internet resource: www.nat-hazards-earth-syst-sci.net.

[27] Digital Chart of the World (DCW). Internet resource: www.maproom.psu.edu/dcw.

[28] ECLAC (2003): Handbook for Estimating the Socio-economic and Environmental Effects of Disasters. Economic Commission for Latin America and the Caribbean (ECLAC) and International Bank for Reconstruction and Development (World Bank). Internet resource: www.eclac.cl.

[29] ECLAC (2007): Statistical Yearbook for Latin America and the Caribbean. Internet resource: www.eclac.cl.

[30] EM-DAT: Emergency Events Database. Centre for Research on the Epidemiology of Disasters (CRED). Université Catholique de Louvain. Internet resource: www.emdat.be.

[31] EU Flood directive. Directive 2007/60/EC of the European parliament and of the council of 23 October 2007 on the assessment and management of flood risks. Internet resource: eur-lex.europa.eu.

[32] Fell R., Ho K.K.S., Lacasse S., Leroi E. (2005): A framework for landslide risk assessment and management. In: "Landslide Risk Management", Hungr, Fell, Couture, Eberhardt (eds.), Taylor & Francis, 2005.

[33] Fischhoff B., Lichtenstein S., Slovic P., Keeney R., Derby S. (1980): Approaches to Acceptable Risk: A Critical Guide. Oak Ridge National Laboratory.

[34] GeoSY (2006): British Virgin Islands Quantitative Risk Assessment Project, Phase II. Final Report. GeoSY Ltd, Washington D.C.

[35] Greiving S. (2006): Multi-risk assessment of Europe's regions. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United nations University Press.

[36] GSHAP: Global Seismic Hazard Assessment Program. Internet resource: www.seismo.ethz.ch/gshap.

[37] GTZ (2004): Risk Analysis – A basis for Disaster Risk Management. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Internet resource: www.proventiumconsortium.org.

[38] Gue S.-S., Karnawati D., Wong S.-Y. (2009): Policy and Institutional Framework for Landslide Mitigation and Risk Reduction. In: "Landslides: Disaster Risk Reduction", Sassa K., Canuti P. (eds.). Springer, 2009.

[39] Grünthal G. (editor): European Macroseismic Scale 1998. Luxembourg 1998.

[40] Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters (HFA). Internet: www.unisdr.org/eng/hfa/hfa.htm.

[41] IDB/CDERA (2007): Intermediate Risk Assessment Report: Portmore Municipality, Jamaica.

[42] IDB (2008): Disaster Risk Management Policy Guidelines. Internet source: idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=360026.

[43] Integral Risk Management cycle. Internet resource: www.planat.ch.

[44] IPCC (2007): IPCC Fourth Assessment Report (AR4). Intergovernmental Panel on Climate Change, Geneva.

[45] Johnson M.E. (1997): Caribbean Storm Surge Return Periods: Final Report. Organization of American States (OAS) and United States Agency for International Development (USAID). Internet resource: http://www.oas.org/CDMP/document/johnson/statpapr.htm.

[46] Mechler R., Hochrainer S., Linnerooth-Bayer J., Pflug G. (2006): Public sector financial vulnerability to disasters: The IIASA CATSIM model. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United Nations University Press.

[47] Mueller C.S., Frankel A.D., Petersen M.D., Leyendecker E.V. (2003): Seismic Hazard Maps for Puerto Rico and the U. S. Virgin Islands. United States Geological Survey. Internet resource: www.usgs.gov.

[48] Munich Re: World Map of Natural Hazards. Munich Re. Internet resource: www.munichre.com → Topics & Solutions → Geo Risks → Natural catastrophes and risks.

[49] NATHAN: NATural Hazards Assessment Network. Munich Re. Internet resource: mrnathan.munichre.com.

[50] National Hurricane Center, National Weather Service. Internet resource: www.nhc.noaa.gov.

[51] NOAA-CVAT: Community Vulnerability Assessment Tool (CVAT). NOAA Coastal Services Center. Internet resource: www.csc.noaa.gov.

[52] NOAA-NGDC: National Geophysical Data Center (NGDC). NOAA. Internet: www.ngdc.noaa.gov.

[53] NOAA-RVAT: Risk and Vulnerability Assessment Tool (RVAT). NOAA Coastal Services Center. Internet resource: www.csc.noaa.gov.

[54] NOAA-HAT. Natural hazard assessment tool (HAT). NOAA Coastal Services Center. Internet resource: www.csc.noaa.gov/hat.

[55] NWSI 10-604: Tropical cyclone definitions. National Weather Service Instruction 10-604. June 1, 2008. Internet resource: www.nws.noaa.gov/directives.

[56] Peduzzi P., Dao H., Herold C., Mouton F. (2009): Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index, Nat. Hazards Earth Syst. Sci., 9, pp. 1149-1159. Internet resource: www.nat-hazards-earth-syst-sci.net.

[57] Peduzzi P. (2006): The Disaster Risk Index: Overview of a quantitative approach. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United nations University Press.

[58] PLANAT (National Platform for Natural Hazards) 2009: Risk concept for natural hazards – guidelines. (in German). Part A: General outline of the risk concept, Part B: Application of risk concept to avalanche, flooding, debris flow, fall, spontaneous landslide, permanent landslide, earthquake, storm, hail, heat wave.

[59] PRIM-NET. Portail de la microzonation des risques majeurs. (In French). Internet resource: www.prim.net.

[60] Raetzo H., Lateltin O., Bollinger D., Tripet J.P. (2002): Hazard assessment in Switzerland – Codes of Practice for mass movements. Bulletin of Engineering Geology and the Environment. Vol. 61, No. 3, pp. 1435-9529.

[61] Risk-UE. An advanced approach to earthquake risk scenarios with applications to different European towns. Internet: www.risk-ue.net.

[62] Sassa K., Canuti P. (eds.): Landslides – Disaster Risk Reduction. Springer, 2009.

[63] SIA 261, SIA 261/1. Actions on structures/supplementary specifications. Swiss building code. www.sia.ch.

[64] stormCARIB. Caribbean Hurricane Network. www.stormcarib.com.

[65] The Disaster Risk Management Strategy for the Tourism Sector in the Caribbean. Draft of April 13th, 2009.

[66] UN/DHA/IDNDR (1992): Internationally agreed glossary of basic terms related to disaster management. United Nations Department of Humanitarian Affairs, International Decade for Natural Disaster Reduction, Geneva.

[67] UN/ISDR: Terminology: Basic Terms of Disaster Risk Reduction. International Strategy for Disaster Reduction. Internet resource: www.unisdr.org. Updated 2004.

[68] UNISDR Terminology on Disaster Risk Reduction (2009). Internet resource: www.unisdr.org.

[69] USDA-SCS. 1985. National Engineering Handbook, Section 4 - Hydrology. Washington, D.C.: USDA-SCS.

[70] Statement by the WTO Secretary-General F. Frangialli, on occasion of the UN Conference on Climate Change, Nusa Dua, Bali, Indonesia, December 2007.

[71] USGS Earthquake Hazard Program. Internet resource: earthquake.usgs.gov.

[72] UWI-SRC (2003): Seismic hazard maps for the Eastern Caribbean – Leeward Islands, Windward Islands and Barbados, Trinidad and Tobago. Seismic Research Centre of the University of the West Indies. Internet resource: www.uwiseismic.com.

[73] UWI-Earthquake Unit (2006): Spectral seismic hazard maps for Jamaica. University of West Indies – Mona, Earthquake Unit, Jamaica. Internet resource: mona.uwi.edu/cardin/virtual_library.

[74] Villagrán de León J.C. (2006): Vulnerability assessment: The sectorial approach. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United Nations University Press.

[75] Wisner B. (2006): Self-assessment of coping capacity: Participatory, proactive and qualitative engagement of communities in their own risk management. In: Measuring Vulnerability to Natural Hazards: Towards disaster resilient societies. Birkmann J. (editor), United Nations University Press.

[76] Zimmermann M., Pozzi A., Stoessel F. (2005): Vademecum – Hazard maps and related instruments. The Swiss system and its application abroad. Internet resource: www.deza.admin.ch/ressources/resource_en_25123.pdf.

Software

[77] Adobe Reader. Internet resource: www.adobe.com.

[78] ArcGIS: Geographic Information System software by Environmental Systems Research Institute (ESRI). www.esri.com.

[79] FLO-2D: Two-dimensional flood routing modelling software. www.flow-2d.com.

[80] FloodArea. Two-dimensional flood simulation software. www.savannah-simulations.ch.

[81] Google Earth. Internet-based three-dimensional mapping system. Online resource: earth.google.com.

[82] Google Maps: Internet-based two-dimensional mapping system. Online resource: maps.google.com.

[83] GRASS: Free open-source Geographic Information System software. Internet resource: grass.osgeo.org.

[84] HAZUS-MH: Nationally applicable standardized methodology and software program to estimate potential losses from earthquakes, hurricane winds, and floods. Federal Emergency Management Agency (FEMA). Internet resource: www.fema.gov/plan/prevent/hazus.

[85] HEC-RAS: Software for one-dimensional hydraulic calculations. Internet resource www.hec.usace.army.mil.

[86] HEC-SSP: Software for statistical analyses of hydrologic data. Internet resource: www.hec.usace.army.mil.

[87] Idrisi: Geographic Information System software by Clark Labs. www.clarklabs.org.

[88] Microsoft Office: Office software suite by Microsoft Corp. www.microsoft.com.

[89] Mike Flood: Software for flood modelling. www.dhigroup.com.

[90] OpenEV: A free computer program for viewing and analysing raster and vector geospatial data in 2D and 3D. Internet resource: www.openev.sourceforge.net.

[91] Open-File 96-532 "National Seismic Hazard Maps: Documentation June 1996. Internet resource: http://earthquake.usgs.gov.

[92] OpenOffice.org: Free open-source office software suite. Internet resource: www.openoffice.org.

[93] OpenSHA. Free open source software for Seismic Hazard Analysis. Internet resource: www.opensha.org.

[94] R Development Core Team (2005). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. Internet resource: www.R-project.org.

[95] RiskPlan. An online risk analysis tool. Federal office for the Environment (FOEN), Federal Office for Civil Protection (FOCP), Internet resource: www.riskplan.ch.

[96] TAOS/L: The TAOS/L Storm Hazard Model and CDMP TAOS/L Applications. Organization of American States (OAS) and United States Agency for International Development (USAID). Internet resource: www.oas.org/cdmp/hazmap/taos/ taosdoc/taosfull.htm.

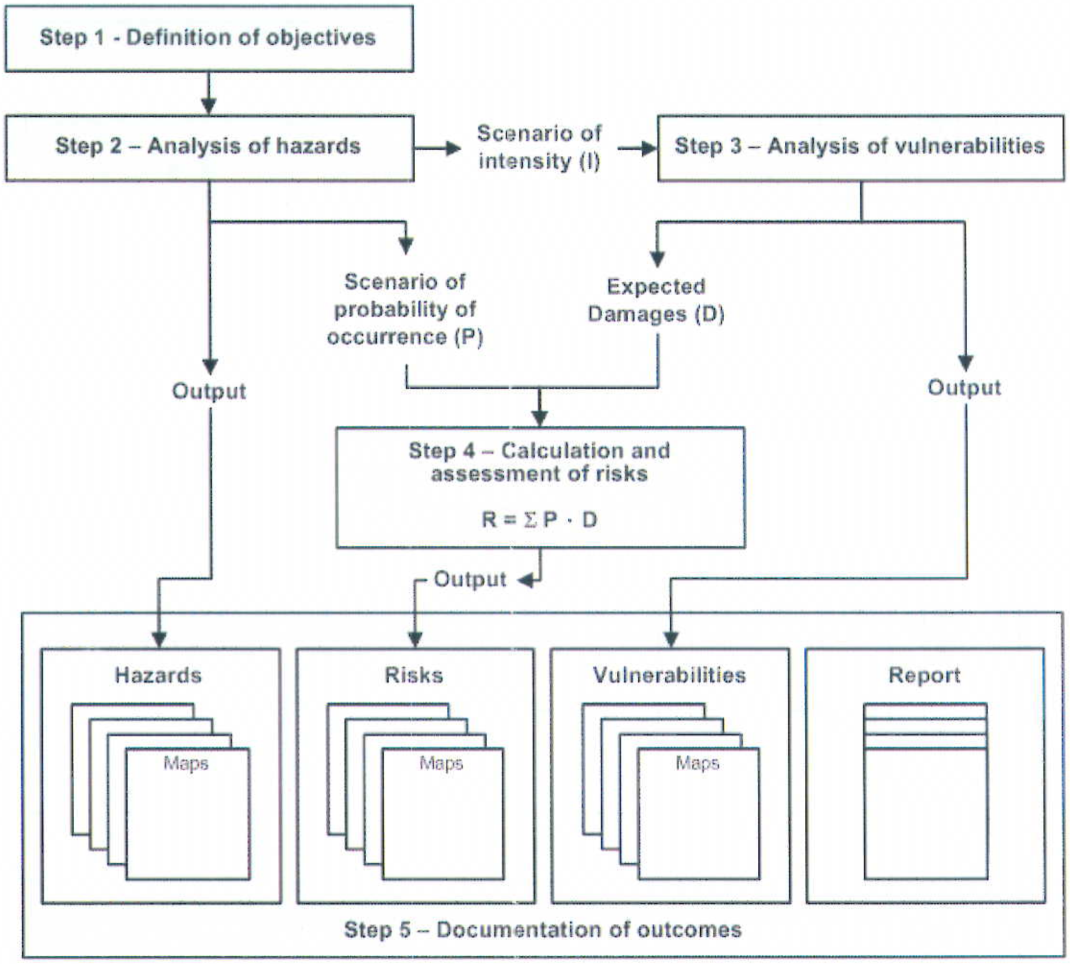
Annex A – Overview of natural hazards in the Caribbean

Percentages of national area affected by degree of exposure to natural hazards (scale from 1 - low to 5 - very high).

Hazard type →	Geological hazards															Hydrometeorological hazards																								
Hazard →	Earthquake					Volcanic activity					Tsunami					Tropical storm					Storm surge					Tornado					Flood					Drought				
Degree of exposure →	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Anguilla	-	-	-	100	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	-	100	-	-
Antigua & Barbuda	-	-	-	100	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	63	37	-	-
Bahamas	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	87	-	-	-	5	-	13	87	-	-	-	30	20	-	-	-	-	90	10	-	-
Barbados	-	100	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	100	-	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	80	20	-	-	-
Belize	-	47	37	16	-	-	-	-	-	-	-	-	-	-	-	-	25	48	27	-	-	-	-	3	-	1	99	-	-	-	24	16	12	6	3	100	-	-	-	-
British Virgin Islands	-	-	-	100	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	-	100	-	-
Cayman Islands	100	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	17	-	-	-	-	5	-	-	100	-	-	-	30	20	-	-	-	-	-	100	-	-
Cuba	4	50	26	15	5	-	-	-	-	-	-	5	-	-	-	-	-	6	62	32	-	-	-	3	-	-	100	-	-	-	24	16	12	6	3	80	17	3	-	-
Dominica	-	-	100	-	-	-	-	100	-	-	-	-	20	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	86	14	-	-	-
Dominican Republic	-	-	4	85	11	-	-	-	-	-	-	5	-	-	-	-	-	-	77	23	5	-	-	-	-	-	100	-	-	-	24	16	12	6	3	88	8	4	-	-
French Guiana	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	100	-	-	-	-	20	13	20	10	5	100	-	-	-	-
Grenada	-	100	-	-	-	-	-	100	-	-	-	-	20	-	-	-	-	-	100	-	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	92	3	-	-
Guadeloupe	-	-	-	100	-	-	-	50	-	-	-	-	10	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	95	5	-	-
Guyana	84	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	100	-	-	-	-	24	16	12	6	3	99	1	-	-	-
Haiti	-	-	32	68	-	-	-	-	-	-	-	-	5	-	-	-	-	-	62	38	-	-	-	5	-	-	100	-	-	-	26	17	8	4	2	93	7	-	-	-
Jamaica	-	-	-	100	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	100	-	-	-	10	-	-	100	-	-	-	30	20	-	-	-	49	33	18	-	-
Martinique	-	-	100	-	-	-	-	57	-	-	-	-	10	-	-	-	-	-	100	-	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	100	-	-	-	
Montserrat	-	-	-	100	-	-	-	100	-	-	-	-	20	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	100	-	-	-
Puerto Rico	-	-	-	100	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	100	-	-	-	10	-	2	98	-	-	-	30	20	-	-	-	92	2	6	-	-
St. Kitts & Nevis	-	-	-	100	-	-	-	100	-	-	-	-	20	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	-	100	-	-
St. Lucia	-	-	100	-	-	-	-	100	-	-	-	-	20	-	-	-	-	-	100	-	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	100	-	-	-	-
St. Vincent & Grenadines	-	100	-	-	-	-	-	100	-	-	-	-	20	-	-	-	-	-	100	-	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	100	-	-	-	-
Suriname	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	100	-	-	-	-	22	14	16	8	4	100	-	-	-	-
Trinidad & Tobago	-	-	-	100	-	-	-	-	-	-	-	10	-	-	-	48	48	4	-	-	-	-	5	-	-	100	-	-	-	-	30	20	-	-	-	78	19	3	-	-
Turks & Caicos Islands	100	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	51	49	-	-
Virgin Islands	-	-	-	100	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	100	-	-	-	5	-	100	-	-	-	-	30	20	-	-	-	-	-	100	-	-

Source: MunichRe Corporate Underwriting - Geospatial Solutions, Last update: February 2009.

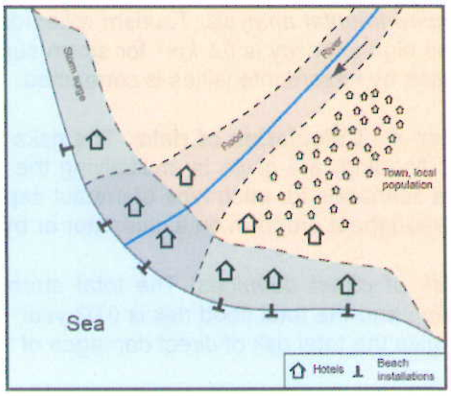
Annex B – Synthesis of risk assessment procedure



Annex C – Example of risk assessment

The following example of risk assessment illustrates briefly the working principle of the Standard. Rather than presenting the detailed procedure, it shows the main steps of the assessment and the relative outcomes.

Overview. The risk assessment is conducted for a number of hotels located along the sea side (see sketch). The hotels with direct access to the sea have beach installations with mobile equipment. Most employees in tourism are residents in the nearby town. A preliminary analysis shows that the area is prone to storm surges and river floods. Both events are caused by tropical cyclone activity. The assessment is conducted to determine the direct damages, indirect losses and estimate the social and environmental consequences of the hazards.



Sketch of situation.

Step 1 - Definition of objectives. The objective of the risk assessment is to analyse hazards, vulnerabilities and determine the resulting risks, addressing the expected direct and indirect damages and estimating the social and environmental consequences. The assessment team shall be composed of a hazard specialist (storm surge and flooding), a tourism specialist (values of facilities and mobile equipment), and an urban planner (population and land use statistics). A preliminary analysis shows that only a part of the hotels is affected and that the town (mainly local population) is only indirectly affected by the impacts of the hazards.

Step 2 - Analysis of hazards. Storm surge and flooding could be identified as the major hazards to be analysed. Even though tropical cyclone activity is the trigger for both hazards, the phenomena occur with individual return periods of 100 years for storms surge ($P = 1/100 = 0.01$) and 50 years for flooding ($P = 1/50 = 0.02$). The corresponding water depths caused by a 100-year storm surge were transformed into flood depths and mapped along the coast according to low, medium and high intensity with flow depth categories of < 0.5 m, 0.5 to 2 m and > 2 m. The flood depths of a 50-year flood could be taken from an existing flood hazard analysis. The corresponding flood depth intensity classes correspond to those of storm surge.

Six hotels with direct beach access are prone to storm surge, and two are additionally prone to flooding. One hotel is only prone to flood, and two hotels are not touched by any of the two hazards. The resulting intensities at the corresponding hotels are medium for storm surge (i.e. flow depths of 0.5 to 2 m) and low (flow depths of up to 0.5 m) for flooding.

Step 3 - Analysis of vulnerabilities. The analysis of vulnerabilities addresses direct damages to the building stock and mobile equipment, indirect losses due to interruption of service, as well as an analysis of the socio-economic and environmental impacts.

Direct damages: Putting a market value of $500{,}000\ US\$$ for a hotel, the expected damage is $D = V \cdot W$, i. e. $D = 0.1 \cdot 500'000\ US\$ = 50'000\ US\$$ for low intensity and $D = 0.3 \cdot 500{,}000\ US\$ = 150{,}000\ US\$$ for medium intensity. The beach installations of the hotels on the sea side would suffer from high intensities, the physical vulnerability of the facilities is estimated to be 0.5. Together with the mobile equipment (boats, vehicles) the total expected damage of the beach installations is estimated as $50{,}000\ US\$$ each for storm surge and $5{,}000\ US\$$ each for flooding.

The total expected direct damage is thus $1.2\ mio\ US\$$ for storm surge and $160'000\ US\$$ for flooding.

Indirect losses: The assessment addresses indirect losses due to interruption of service. It is estimated that the interruption of service is one month (30 days) for low intensity and 3 months (90 days) for medium intensity. The cost of interruption is given by the loss of income for a hotel of $10'000\ US\$$ per day. The total indirect loss is $5.4\ mio\ US\$$ for storm surge and $1.2\ mio\ US\$$ for flooding.

Socio-economic analysis: Governmental statistics report that from the local population (1,500 inhabitants) one third, 500 people, are working in tourism. Adding their families, results in a total of 1,000 people that are affected by an interruption of the activities in tourism, caused by either storm surge or flooding. No further identification of special risk groups is conducted.

Environmental analysis: Tourism relies on the local beach. The total area of beach affected by low, medium and high intensity is $0.1\ km^2$ for storm surge and $0.01\ km^2$ for flooding. No further identification of the affected areas by hazard intensities is conducted.

Step 4 - Calculation of risks. The risks for the considered scenarios ($P = 0.01$ for storm surge and $P = 0.02$ for flooding) are given by multiplying the corresponding damages and losses with the annual occurrences of the scenarios for each type of impact separately. These rather simple calculations can be carried out using a spreadsheet program on a computer or by hand, as shown below.

Risk of direct damages: The total storm surge risk is $R = P \cdot D = 0.01\ year^{-1} \cdot 1.2\ mio\ US\$ = 12{,}000\ US\$/year$, and the total flood risk is $0.02\ year^{-1} \cdot 160{,}000\ US\$ = 3{,}200\ US\$/year$. These two risks can be summed to give the total risk of direct damages of $15{,}200\ US\$/year$.

Risk of indirect losses: The risk for interruption of services is $5.4\ mio \cdot 0.01 = 54{,}000\ US\$/year$ for storm surge and $1.2\ mio \cdot 0.02 = 24{,}000\ US\$/year$ for flooding. The total risk of indirect losses is $78{,}000\ US\$/year$.

The total monetarized risk is the sum of the total risk of direct damages and of indirect losses and is $93{,}200\ US\$/year$.

Risk of affected population: The risk for the total indirectly affected population is $0.01 \cdot 1{,}000 = 10\ people/year$ for storm surge and $0.02 \cdot 1{,}000 = 20\ people/year$ for flooding. The total risk for affected population is $10 + 20 = 30\ people/year$.

Risk of environment: The risk for the tourism-relevant environment (beach) that is affected is $0.01 \cdot 0.1 = 10^{-3}\ km^2/year$ for storm surge and $0.02 \cdot 0.01 = 2 \cdot 10^{-4}\ km^2/year$. The total risk for the environment is $1.2 \cdot 10^{-3}\ km^2/year$.

Risk assessment. The resulting risks can be represented separately on graphs as shown in Figure 16. Analysing the risk of a number of situations leads to a more complete picture of risks in tourism: the risks are likely to vary considerably from one situation to another.

High and low risk situations can be identified using the representations shown in Figure 17. Based on these overviews high risk situations should be further analysed and options should be proposed to reduce risks.

Step 5 - Documentation of outcomes. Even though not displayed in this overview example, the outcomes are to be documented in detail in order to produce comprehensive and comparable findings. The following documents are to be prepared to document the risk assessment.

- Summary report. The assessment procedure and all the data that was used to perform the analysis are to be documented. The findings are presented in tabular representations.
- Hazard maps. For flooding and storm surge separate hazard maps must be prepared, which show the degree of hazard in terms of intensity and probability of occurrence.
- Vulnerability maps. The vulnerable objects, which are directly (buildings, essential infrastructure, mobile equipment, etc.) and indirectly (affected population, loss of income, etc.) at risk are shown on a map.
- Risk map. The object and total risks are displayed separated for monetary risks (US$/year) or other criterion (area/year or people affected/year).

Annex D – Documentation of hazard events

NATURAL HAZARD EVENT REPORT	
► A. HAZARDS	
A.1 Type of hazard	*Identify type of natural hazard:* Hydrometeorological: ☐ Tropical cyclone, specifically tropical: ☐ Disturbance ☐ Depression ☐ Storm ☐ Hurricane/Saffir-Simpson scale .... ☐ Storm surge ☐ Wind storm ☐ Flood Geological: ☐ Volcanic activity ☐ Earthquake ☐ Mass movement ☐ Tsunami ☐ Other: .... *Description, comments:* ....
A.2 Area and time of occurrence	*Where and when did the hazard occur?* ....
A.3 Characteristics of occurrence	*What where the characteristics of the hazard occurrence (intensity, return period)?* ....
► B. CONSEQUENCES	
B.1 Direct damages	*Identify direct damages:* ☐ Fatalities ☐ Injured ☐ Population affected Destroyed/damaged material assets: ☐ Buildings ☐ Mobile equipment ☐ Traffic infrastructure ☐ Damages to the environment *Description, comments:* ....
B.2 Indirect losses	*Identify indirect losses:* ☐ Reduced employment, unemployment ☐ Reduced economic activity *Description, comments:* ....
B.3 Macro-economic effects	*Description, comments:* ....

Annex E – Glossary

Sources: [55],[66],[67].

Term	Explanation
Acceptable risk	The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions [68].
Consequences	The damages or losses (partial or full) to individual persons or a community, property, the environment and economic activities that can be quantified in some unit of measure.
Drought	Period of deficiency of moisture in the soil such that there is inadequate water required for plants, animals and human beings [66].
Earthquake	A sudden break within the upper layers of the earth, sometimes breaking the surface, resulting in the vibration of the ground, which where strong enough will cause the collapse of buildings and destruction of life and property [66].
Element at risk	The population, buildings and civil engineering works, economic activities, public services and infrastructure, etc. exposed to hazards [66].

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this Standard. Reference is made to the ECLAC handbook [28], which proposes a comparative analysis of normal and hazard-affected statistical data of large scale indicators.

10.3 Applicability, intended audience, beneficiaries, limitations, and uncertainties

Applicability. The Standard specifies the procedures for conducting risk assessment in the tourism sector. The Standard is applicable to assess the risks of existing and of planned tourism infrastructure at different map scales. The Standard shall be used complementary to existing local, national and regional procedures, and can be adapted to fit specific needs, substituting or adding parts or procedures of the assessment.

Intended audience. The direct users of the Standard are professionals of a technical-scientific profile, such as engineers, land use planners, scientists, tourism specialists, and economists. Risk assessment follows a multi-disciplinary approach, relying on the teamwork of the involved figures.

Supervising authorities of the application of the Standard are regional governmental and non-governmental tourism and natural hazard management authorities, such as the Caribbean Tourism Organisation (CTO), the Caribbean Hotel and Tourism Association (CHTA), the Caribbean Disaster and Emergency Management Authority (CDEMA), and their national and sub-national counterparts.

Limitations and uncertainties. The outcomes of risk analysis rely on the best knowledge of the two major input components: hazards as the triggering processes and the damages or losses caused to vulnerable objects. The analysis of both of these elements introduces uncertainties which affect the resulting risk. It is part of the analysis to investigate and document the impact of uncertainties of hazards and vulnerabilities, in terms of lower and upper bounds of uncertain input.

10.4 Review cycles

Several aspects of the risk assessment cycle are subject to change, updating and improvement, particularly the methodologies of hazard and vulnerability assessment (sections 13 and 14). Also more natural hazards may be integrated into the Standard.

It is recommended that this Standard and the respective procedures are reviewed and updated regularly, at least every five years.

10.5 Terminology

The terminology used in this Standard is in agreement with UNISDR [68], UN DHA/IDNDR [62] and the Hyogo Framework for Action 2005-2015 [40]. See the glossary in Annex E for a short description of terms.

10.6 Registration of events of natural hazards

Events of natural hazards and the relative damages and losses caused by them must be stored and listed in order to be used for future analysis. See Annex D for a form to document natural hazard events. Other

	most common use are the modified Mercalli (MMI) scale [66].
Inventory	Census of the assets (population, property, and environment) considered at risk in an area.
Landslide	In general, all varieties of slope movement, under the influence of gravity. More strictly refers to down-slope movement of rock and/or earth masses along one or several slide surfaces [66].
Liquefaction	Loss of resistance to shear stress of a water-saturated sandy soil [66].
Magnitude	A measure of the strength of a hazard event.
Magnitude ("Richter scale")	Devised by C.F. Richter in 1935, an index of the seismic energy released by an earthquake (as contrasted to intensity that describes its effects at a particular place), expressed in terms of the motion that would be measured by a specific type of seismograph located 100 km from the epicentre of an earthquake. Nowadays several "magnitude scales" are in use. They are based on amplitudes of different types of seismic waves, on signal duration or on the seismic moment [66].
Microzonation (microzoning)	Subdivision of a region into areas where similar hazard-related effects can be expected. Seismic microzonation is the mapping of a local seismic hazard using a large scale (order of magnitude from 1:5'000 to 1:10'000) [66].
Natural hazard	Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Comment: Natural hazards are a sub-set of all hazards. The term is used to describe actual hazard events as well as the latent hazard conditions that may give rise to future events. Natural hazard events can be characterized by their magnitude or intensity, speed of onset, duration, and area of extent. For example, earthquakes have short durations and usually affect a relatively small region, whereas droughts are slow to develop and fade away and often affect large regions. In some cases hazards may be coupled, as in the flood caused by a hurricane or the tsunami that is created by an earthquake [68].
N-year event (see also return period)	Magnitude of an event, the mean → return period of which is N years [66].
PGA	The peak ground acceleration (PGA) is the maximum acceleration experienced by the ground during the course of the earthquake motion.
Probability of occurrence	The probability that an event of return period T occurs in n years is given as $P = 1-(1-1/T)^n$.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need [68].
Return period	The average time between occurrences of a particular hazardous event [66].
Risk	(i) The combination of the probability of an event and its negative consequences. Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks [68]. (ii) Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability [66].
Risk assessment	A methodology to determine the nature and extent of risk by analysing potential

	hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. Comment: Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process [68].
Risk management	The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Comment: Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimise risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate [68].
Risk, collective	Risk to which a reference unit (object or group of objects) is exposed.
Risk, individual	Risk to which an individual person is exposed.
Saffir-Simpson hurricane scale	A scale ranging from one to five to describe the intensity of hurricanes, according to the sustained one-minute averaged wind speed at ten meter elevation.
Spectral acceleration	The spectral acceleration is approximately what is experienced during an earthquake by a building, as modelled by a particle on a massless vertical rod having the same natural frequency of vibration as a building.
Storm surge	A sudden rise of sea as a result of high winds and low atmospheric pressure; sometimes called a storm tide, storm wave, or tidal wave. Generally affects only coastal areas but may intrude some distance inland [66].
Tropical cyclone	Generic term for a non-frontal synoptic scale cyclone originating over tropical or sub-tropical waters with organized convection and definite cyclonic surface wind circulation [66]. Further divided with increasing intensity into tropical disturbance, tropical depression, tropical storm, and hurricane.
Vulnerability	(i) The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. Comment: There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time. This definition identifies vulnerability as a characteristic of the element of interest (community, system or asset) which is independent of its exposure. However, in common use the word is often used more broadly to include the element's exposure. (ii) Degree of loss (from 0% to 100%) resulting from a potentially damaging phenomenon [66].
Vulnerability assessment	Procedure to determine the degree of → vulnerability.