Southwest Indian Ocean Risk Assessment Financing Initiative (SWIO-RAFI):

Component 2 - Exposure

Final Report Submitted to the World Bank

March 18th, 2016

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Contact Information

If you have any questions regarding this document, contact:

AIR Worldwide Corporation
388 Market Street, Suite 750
San Francisco, CA 94111
USA
Tel: (415) 912-3111
Fax: (415) 912-3112

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Executive Summary

The South West Indian Ocean Risk Assessment and Financing Initiative (SWIO RAFI) was established at the request of the Indian Ocean Commission (IOC) on behalf of Comoros, Madagascar, Mauritius, Seychelles, and Zanzibar. The goal of SWIO RAFI is to improve the resiliency and capacity of the island states through the creation of disaster risk financing strategies. A key component of this effort involves the quantification of site-specific risk of floods, earthquakes, and tropical cyclones as well as their secondary hazards of storm surge and tsunamis.

The present report details project Component 2, which comprises the development of regional exposure databases for residential, commercial, industrial, and government assets. These datasets represent the built environment of each island nation and provide nationally appropriate replacement values, construction characteristics, and occupancy classes. Replacement value refers to the estimated cost to rebuild a structure as new, and does not include secondary financial metrics, such as depreciation. The exposure database for each island nation is constructed by combining information from various data sources, such as government censuses, local agencies, satellite imagery, publically available spatial statistics, and previous regional investigations.

For all countries, the residential, commercial, and general industrial asset exposure databases are developed on a 30 arc-second (approximately 1km) grid. In countries where high-resolution government and infrastructure data is available, these assets are captured at their individual exposure locations. For countries where location level information is not available, government and infrastructure assets are also distributed to the 1km grid. GIS compatible layers (i.e., shapefiles) and accompanying metadata for the exposure datasets in each island nation are provided as electronic addendums to this report.

The total replacement value of structures in $M USD (2015) for each island nation is provided in Table 1. Replacement values are also converted to the local currency of each country using exchange rates valid in year 2015 (see Table 9). The exposure database does not include the value of building contents, appurtenant structures or out-buildings, vehicles (e.g., automobiles, aircraft, marine craft, etc…), agriculture, or business interruption.

Table 1: Total replacement value of residential and non-residential assets for each island nation

Island Nation	*Residential ($M USD)*	*Non-Residential ($M USD)*	**Total ($M USD)**
Comoros	1,711	869	2,580
Madagascar	19,576	15,220	34,796
Mauritius	13,574	19,886	33,460
Seychelles	3,368	3,557	6,925
Zanzibar	3,170	1,128	4,298
SWIO Region	**41,398**	**40,661**	**82,059**

1 Introduction

In support of each model, AIR compiles an exposure database of at-risk assets for modeled country. The resulting databases are essential for estimating the spatial distribution of asset value at risk and for cataloging construction and occupancy attributes necessary for assessing the vulnerability of classes of assets to various natural hazards. For each island nation in the SWIO region, AIR has developed an exposure database using information provided in the datasets outlined in the Terms of Reference (ToR) and ancillary data from other private and public sources. As per the ToR provided by the World Bank, Component 2 comprises the following four main objectives:

- The creation of a dataset of nationally appropriate replacement values and construction costs within the different islands for residential, commercial and public properties as well as major public infrastructure, such as roads, bridges, power generation facilities, etc.
- The development of occupancy and construction characteristics for structures based on census data and ancillary information.
- The enhancement of existing exposure data to improve coverage over all major islands for Comoros, Madagascar, Mauritius, Seychelles, and Zanzibar
- Creation of a GIS-compatible exposure database for use on a GeoNode.

The general approach adopted for achieving these objectives consists of (1) the collection of island-specific information on valuation and construction costs for a suite of residential, commercial, and public properties, as well as public infrastructure, with varying construction and occupancy classes and (2) digitizing and geo-referencing occupancy and construction classes using census data and other ancillary information.

Occupancy and construction classes are site-specific for public infrastructure and assets with high valuation in countries with good data quality. For countries with low population, low exposure values, or poor data quality, occupancy and construction classes and valuation are distributed to a 30 arc-second (approximately 1km) grid. All residential, commercial, and general industrial assets are similarly distributed to the 1km grid.

The sections presented herein describe the general exposure database development framework applied for the SWIO region. Detailed descriptions of the individual considerations and methodologies applied for each of the SWIO island nations are provided in Appendix A. The final outputs of Component 2 are, for each country, geospatial databases of residential, commercial, industrial, public, and infrastructure assets. The exposure databases and associated metadata are provided as a digital addendum to this report.

Limitations

The exposure database summarized in this report is intended for use by the governments of the SWIO island nations and the World Bank to assist them with the process of understanding the risk from natural catastrophes. Proper application of this information requires recognition and understanding of the limitations of both the scope and methodology of the entire study.

The scope of services performed during this assessment may not adequately address the needs of other users, and any re-use of (or failure to use) this report or the findings, conclusions, or recommendations presented herein are at the sole risk of the user. Our conclusions and recommendations are based on our professional opinion, engineering experience and judgment, analyses conducted during the course of the study, information and data available in the literature and those provided by the World Bank and various local agencies, and are derived in accordance with current standards of professional practice.

2 Exposure Database Development

Exposure Database Development Framework

An integral part of a country-wide risk assessment is the exposure database, which is a country-specific database containing risk counts and their respective replacement values, along with information about physical and non-physical characteristics of the modeled assets at risk, such as construction type, occupancy type, and height classification. These databases provide a foundation for modeled loss estimates, whether for simulated events from a stochastic catalog, the reanalysis of historical events, or for actual events unfolding in real time. The considered exposure at risk consists of residential and non-residential buildings (i.e., primary structures). This database is intended be used as an input to catastrophe risk models that estimate the economic losses sustained due to physical damage to buildings from natural hazards. In addition, this database can be used as a proxy to estimate the potential impacts on other sectors, such as affected population, and for calculating post-disaster emergency losses. This section provides details about the methodology used to develop the SWIO exposure database of buildings, as well as its composition.

Population Database

An accurate and up-to-date population database is essential for spatially identifying populations at risk and serves as a primary input to the exposure database of buildings. The population database for the SWIO region, which is produced in both tabular and GIS format, is developed from available official government census data for each island nation. While the vintage of the most recent census varies for each country, each nation's population is projected to the year 2015 using historical population growth rates (Table 2).

Table 2: Census vintage for each investigated country and population projections to 2015

Island Nation	*Census Year*	*Growth Rate (%)*	*Census Population*	*2015 Population*
Comoros	2003	2.1	575,660	738,712
Madagascar	2013[1]	2.7	21,842,166	23,037,566
Mauritius	2011	0.8	1,236,817	1,276,873
Seychelles	2010	1.0	90,187	94,787
Zanzibar	2014	3.1	1,193,383	1,230,378
SWIO Region	**-**	**-**	**-**	**26,378,316**

The resolution of the census population databases varies depending on the nation under consideration. In order to maintain consistency across the region, the various Administration Regions are harmonized into the classes presented in Table 3. Administrative Region 0 represents the coarsest level of resolution (e.g., the island nation) and Administrative Region 4 represents the finest level of resolution (e.g., enumeration area). The

[1] Data provided by INSTAT, derived from official 1993 census

number of available Administrative Regions and naming conventions depend on the country under consideration. For example, while the majority of the countries in the SWIO region have published borders at Administrative Region 4, only Administrative Region 3 boundaries are available for Comoros and Zanzibar. In some cases, population statistics are available at finer resolutions than Admin. Region 4; however, this level of detail exceeds the necessary resolution for the model and is incompatible with other fundamental input datasets (discussed further herein).

Table 3: Administrative Region classifications and counts, from coarsest (0) to finest (4)

Country	*Admin. Region 0*	*Admin. Region 1*	*Admin. Region 2*	*Admin. Region 3*	*Admin. Region 4*
Comoros	Island Nation	Island	Prefecture	Commune	-
	1	3	17	55	-
Madagascar	Island Nation	Province	Region	District	Commune
	1	6	22	110	1,433
Mauritius	Island Nation	Island	Region	Municipal/Village Council Area	Enumeration Area
	1	4	12	150	3,921
Seychelles	Island Nation	Region	Region	District	Enumeration Area
	1	3	6	26	536
Zanzibar	Island Nation	Region	District	Ward	-
	1	5	10	331	-

In order to estimate the population distribution at a more granular level, a gridded population dataset is also developed for the SWIO region. The gridded population dataset is calculated by distributing the population available at Administrative Regions 3 (Comoros, Mauritius, Zanzibar) or 4 (Madagascar, Seychelles) according to weighting factors derived from the LandScan (Oakridge National Lab, 2012) and World Night Lights (NASA, 2012) datasets. The LandScan and Night Lights spatial datasets consist of population distribution and nighttime satellite imagery, which collectively provide a globally consistent proxy for habitation intensity on a 30 arc-second (approx. 1km) grid. AIR statisticians then harmonize these intensities into scaling factors, which are subsequently used to distribute the population within each Administrative Region to a uniform grid. The final regional gridded population for the SWIO region is presented in Figure 1 and provided as high-resolution images in the digital addendum.

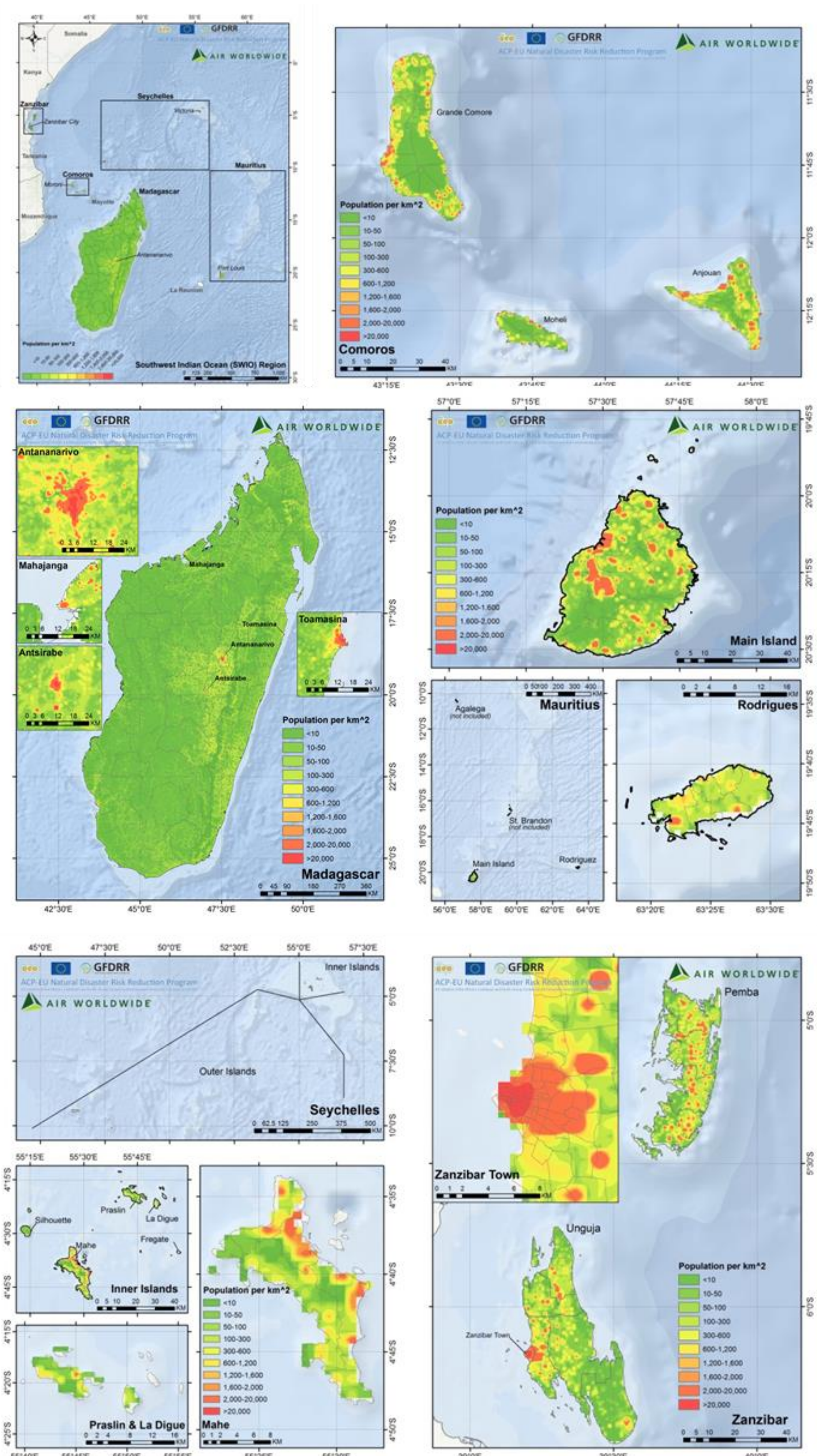

Figure 1: Gridded population distribution in the SWIO region

Developing the Exposure Database of Buildings

Following the construction of the gridded population database, the exposure database of buildings is developed from the bottom-up following the general methodology outlined in Figure 2. AIR leverages information and data from sources such as official censuses, local agencies, publically available reports, and academic papers to derive risk counts (e.g., number of dwellings) and associated statistics (e.g., percentage of dwellings by occupancy and construction type). With the exception of certain public and infrastructure assets, the SWIO exposure database is developed at the same 30 arc-second (approx. 1 km) grid as the population database in order to maintain consistency in the regional modeling approach. Where detailed auxiliary public and infrastructure exposure information are publically available or provided by local agencies, these exposures are individually considered at the site of each asset. After risk counts are derived, a rebuild cost approach is used to calculate the replacement values for all buildings. Additional information obtained from census and other ancillary datasets pertaining to the physical characteristics of the risks, such as floor area, occupancy, construction type, and height, is used in conjunction with construction cost estimates to derive the replacement values.

Due to the disparity in available data between each considered island nation, country specific modifications are applied to the general approach presented in Figure 2. The details of these approaches are discussed further in Appendix A.

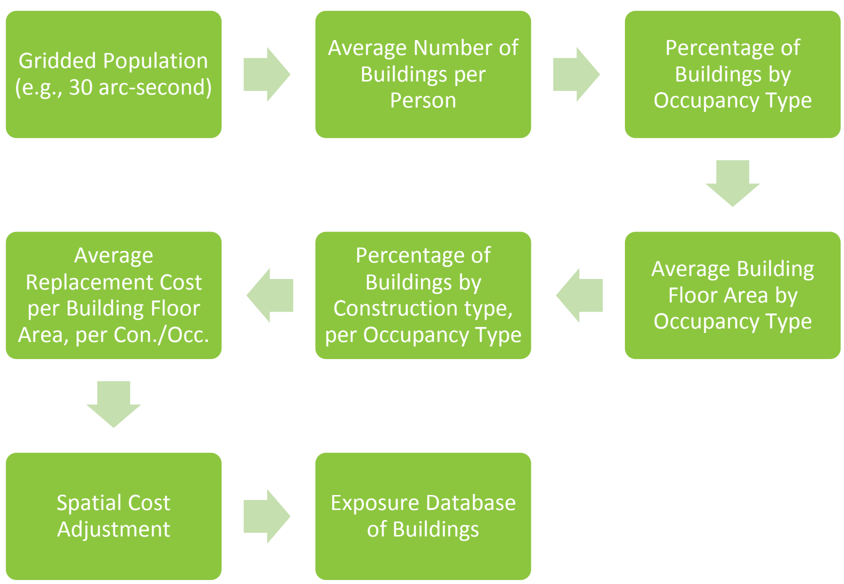

Figure 2: General approach for developing the SWIO exposure database of buildings

Data Sources

A variety of data sources are used to develop the SWIO database of exposed assets. Data on risk-counts, building characteristics, and construction costs are obtained from available census, local agency, and publically available data sources as well as risk assessment reports, such as a recent UNISDR/UNDP investigation. When regional data is not available, data and statistics from regions with similar economic development (i.e., GDP) are leveraged and applied. Due to the wide range of economic development in the SWIO region, the quality and consistency of available exposure data is highly dependent on the country of interest. While certain agencies in Mauritius and Seychelles maintain detailed regional construction and building-use statistics, in general, the availability of high-quality exposure data throughout the SWIO region is quite limited. Thus, a number of modeling assumptions are employed when developing the exposure database, which are discussed further in the "Exposure Database Limitations" section and Appendix A. Selected references used in the development of the exposure database are provided in Table 4. Table 4 also provides the data source classification ID, which relates each element in the exposure database to its respective data source.

Table 4: Data sources listed by region, which consist of Global, Africa, SWIO, Comoros (COM), Madagascar (MDG), Mauritius (MUS), Seychelles (SYC), and Zanzibar (ZAN), and type, which consist of ancillary, publically available, government census, and local agency.

ID	*Data Source Type*	*Sources*
0	Ancillary Data	• IMF - International Monetary Fund; • World Bank - Data and Statistics; • UNFPA - United Nations Population Fund; • Wikipedia
1	Publically available data (Global)	• CARMA - Carbon Monitoring for Action; • OpenStreetMap; • NASA - Night Lights & GRUMP; • ORNL – Landscan; • ACW - Aircraft Charter World; • University of Southampton - WorldPop
2	Publically available data (Africa)	• African Development Bank Group; • KPMG Africa Limited; • Centre for Affordable Housing Finance in Africa; • Infrastructure Africa
3	Publically available data (SWIO Region)	• UNISDR - United Nations International Strategy for Disaster Reduction; • IOC - Indian Ocean Commission
11	Government Census data (COM)	• Direction de la Statistique
12	Local agency data (COM)	• Union of Comoros, Ministry of Finance, Economy, Budget, Investment and External Trade and in charge of Privatization; • DGSC - General Directorate of Civil Protection; • Ministry of Environment; • EDA - Electricité d'Anjouan; • MAMWE - Gestion de l'Eau et de l'Electricité aux Comores; • Commisariat General au Plan

14	Publically available data (COM)	• CNDRS - Centre National de Documentation et de Recherche Scientifique
21	Government Census data (MDG)	• INSTAT - Institut National de la statistique de Madagascar
22	Local agency data (MDG)	• FTM - Foiben-Taosarintanin' i Madagasikara; • Ministere du Tourisme, des Transports et de la Meteorologie; • MEN - Ministère de l'Education Nationale; • CPGU - Cellule de Prevention et Gestion des Urgences a la Primature
23	Publically available data (MDG)	• JIRAMA
31	Government Census data (MUS)	• Statistics Mauritius
32	Local agency data (MUS)	• Ministry of Public Infrastructure and Land Transport; • RDA - Road Development Authority; • MHL - Ministry of Housing and Lands; • CWA - Central Water Authority; • Ministry of Finance and Economic Development
33	Publically available data (MUS)	• CEB - Central Electricity Board; • CWA - Central Water Authority;
41	Government Census data (SYC)	• National Bureau of Statistics
42	Local agency data (SYC)	• MLUH - Ministry of Land Use and Housing; • SLTA - Seychelles Land Transport Agency; • PUC - Public Utilities Corporation
43	Publically available data (SYC)	N/A
51	Government Census data (ZAN)	• NBS - National Bureau of Statistics; • OCGS - Office of Chief Government Statistician
52	Local agency data (ZAN)	• Revolutionary Government of Zanzibar; • ZIFA - Zanzibar Institute of Financial Administration; • Ministry of Lands, Housing and Human Settlements Developments
53	Publically available data (ZAN)	N/A

Occupancy Types

Occupancy, in the context of the exposure database and subsequent risk profiles, refers to the primary use of a building or asset. Occupancy is an essential component to consider for assessing the replacement value of an asset and its vulnerability to natural catastrophes (e.g., wind, ground shaking). The occupancy classes considered in the SWIO exposure database include residential, commercial, general industrial, public, and infrastructure assets. Although the considered occupancy classes are consistent between each SWIO island nation, the modeling resolution for each asset type varies between countries depending on the availability of data. Primary occupancy classes are provided in Table 5 along with their respective modeling resolution. The residential occupancies consist of single-family and multi-family dwellings. The residential occupancy class also includes traditional or rural housing. The commercial and industrial occupancies consist of non-infrastructure commercial and general industrial assets (e.g., hotels, office buildings, manufacturing buildings, warehouses). The public occupancy class consists of education facilities, public services, healthcare facilities, government buildings, and religious institutions. Lastly, the infrastructure occupancy class consists of roads, bridges, transportation facilities (e.g., airports, ports), water utilities, and energy utilities.

All residential, commercial, and general industrial assets are derived statistically and subsequently distributed to the 1km grid. Certain public and infrastructure assets, such as power plants, airports, marine ports, and roads, are modeled at their individual locations for all countries. Other public and infrastructure assets, such as schools, universities, hospitals, emergency facilities, water utilities, and electrical utilities, are modeled at their individual locations when sufficient information is either publically available or provided by local agencies. In the exposure database, a spatial resolution flag ("SpatRes") is provided to distinguish between assets modeled on the 1km grid versus those captured at their individual locations. In most cases, the assets considered at the location level are not considered in the census statistics used to develop the gridded exposure database (e.g., roads, ports), preventing overlap or double-counting between the two resolution classes. For other assets, overlap is minimized by removing the contribution of site-specific assets from the general exposure statistics. For example, building footprints associated with hospitals and universities are separated and removed before generating statistics for general healthcare or education assets.

Table 5: Occupancy classes and spatial resolution for the SWIO exposure database

ID	Occupancy Class	Description	Database Resolution
300	Unknown	"Unknown use"; "bridges"	1km × 1km
302	Residential – Single-family	"House"	1km × 1km
303	Residential – Multi-family	"Apartment"	1km × 1km
304	Commercial - Accommodation	"Accommodation", "hotel"	1km × 1km
311	Commercial - General commercial	"Commercial"	1km × 1km
316	Public - Healthcare services	"Clinic"; "hospital"; "other health"	Location [1,2,3]
321	Industrial - General industrial	"Industrial/manufacturing"; "warehouse"	1km × 1km
341	Public - Religion	"Religion"	1km × 1km
343	Public - General public facility	"Community facility"; "Government Office"; "NGO"	1km × 1km
344	Public - Emergency services	"Fire station"; "police station"	Location[1,2,3]
345	Public - Education, University	"University"; "college"; "technical school"	Location[1]
346	Public - Education, Primary	"Preschool"; "primary school"; "secondary school";	Location[1,2,3]
351	Infrastructure - Roads/Highway	"Highway", "primary road", "secondary road", "tertiary road", "onramp"	Location
352	Infrastructure - Bus/Rail	"Bus station"; "rail station"; "railway"	Location
353	Infrastructure - Airport	"Airport"; "runway"	Location
354	Infrastructure - Maritime Port	"Maritime port"	Location
361	Infrastructure - Electrical Utilities	"Power plant"; sub-station"	Location
362	Infrastructure - Water Utilities	"Dam"; "pump station"; "water treatment"; "desalination"	Location

[1]1km × 1km for Comoros
[2]1km × 1km for Madagascar
[3]1km × 1km for Zanzibar

Construction Types

Similar to occupancy, risk attributes, such as construction type and height, are key components for assessing the value and vulnerability of assets in the exposure database. The classification of risks by structural type plays an important role in catastrophe modeling because differences in building materials, quality, and design all have significant impacts on building vulnerability and, ultimately, modeled loss estimates. Developing the construction distribution first requires the collection of information about the characteristics of each nation's building-stock from census statistics and local agencies. In classifying the building stock, buildings are grouped according to their main structural characteristics, namely construction material, load resisting mechanism, and height. Engineering expertise is then used in conjunction with these statistics to classify each asset by its primary construction type.

The construction classes considered in the SWIO exposure database of buildings are provided in Table 6. These construction classes were established following the extensive review of available regional data and literature regarding local construction materials and building practices. Additional qualitative information about typical building types and practices was obtained through interviews with local agencies and regional consultants. The predominant construction classes in the SWIO region are low-rise masonry and concrete. Traditional structures made from wood, bamboo, straw, brick, or other earthen materials, are also prevalent throughout the region, particularly in Madagascar and Zanzibar. With the exception of Mauritius, high-rise construction in the SWIO region is rare, thus buildings are classified as either low-rise (1-2 stories) or multi-story (>2 stories). Steel construction is also sporadic in the SWIO region, with the notable exceptions of certain high value infrastructure assets, such as airports and industrial facilities. Infrastructure construction classes are reserved for non-building type assets, such as bridges, roads, railways, and dams. In the absence of detailed construction information, infrastructure buildings are considered to be either masonry/concrete or unknown.

Table 6. Construction Classes Considered in the SWIO Exposure Database of Buildings

ID	Construction Class	Description	Height Class
100	Unknown	"Unknown"	Low-Rise; Multi-Story
101	Wood Frame	"Timber frame"	Low-Rise; Multi-Story
102	Traditional Wood	"Traditional wood"; "bamboo"; "straw"	Low-Rise
111	Masonry/Concrete	"Load bearing wall", "Concrete wall”; “Concrete column", "tilt-up slab"	Low-Rise; Multi-Story
112	Traditional Earthen	"Traditional earthen"; "mud brick";"cob"	Low-Rise
151	Steel Frame	"Steel column"; "steel frame"	Low-Rise; Multi-Story
201	Multiple Span Bridges	"Multi-span bridge"	N/A
202	Continuous Bridges	"Continuous bridge"	N/A
203	Other Bridges	"Other bridge"; "Single span bridge"	N/A
204	Railroads	"Railway"; "railroad"	N/A
205	Roads/Highways	"Highway", "primary road", "secondary road", "tertiary road", "onramp"	N/A
206	Runways	"Paved"; "unpaved"; "helipad"	N/A
211	Dams	"Concrete dam"; "earthen dam"	N/A

Replacement Values

Following the derivation of risk locations and their respective attributes, a replacement or rebuild cost approach is used to generate building replacement values by occupancy and construction type. The rebuild cost approach calculates replacement values by multiplying estimates of building floor area by average construction costs, which are typically expressed in terms of a unit area (e.g., cost per square meter). These are estimates of the cost to rebuild a structure and do not include appurtenant structures, contents, or, in the case of commercial establishments, business interruption.

Several local and regional data sources were leveraged to obtain estimates of rebuild cost per unit area for buildings of various occupancies, heights, and construction types (see Table 4). In general, construction cost data and statistics are limited in the SWIO region and cost estimates are derived from external agencies (e.g., NGOs), previous studies, and engineering judgement. These rebuild costs vary between islands, sometimes considerably, thus rebuild costs for construction-occupancy pairs are developed separately for each island nation.

Construction cost data for each island nation is presented in the rebuild cost matrix in Appendix B. The rebuild cost matrix, which is organized in terms of occupancy-construction pairs (e.g., residential masonry/concrete or commercial wood-frame), contains estimates of rebuild cost per unit area (e.g., square meter of building), unit length (e.g., meter of road), or individual unit (e.g., port, airport).

Urban and rural designations that incorporate the regional building size and cost of construction are used to further differentiate regional construction costs within each island nation. The modeled urbanization category is based on population density following the scale presented in Table 7. Occupancy, construction, and cost statistics are typically dependent on the urbanization category. For example, traditional bamboo, wood, stone, and cob type dwellings exist primarily in rural areas, and have a considerably lower rebuild costs than standard concrete, masonry, and wood dwellings found in primarily urban areas. Multi-story dwellings (e.g., apartments, commercial buildings) similarly exist in primarily urban areas and typically have a higher rebuild cost due to higher quality construction and additional cost associated with non-livable floor area (e.g., stairwells, halls).

The relationship between cost and urbanization category is considered in exposure database (1) by using a higher unit replacement costs for occupancy classes that are more likely to exist in urban areas and (2) by employing a GDP based spatial cost adjustment factor that accounts for regional variation in urbanization.

Table 7: Population urbanization categories and percentages for each island nation[2]

Population Density (per km^2)	Urbanization Category	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar
>20,000	Metro	6.6%	7.6%	1.8%	0.0%	6.6%
>2,000	Urban	51.0%	14.4%	68.5%	39.9%	51.0%
>1,600	Sub-Urban	13.8%	1.7%	3.0%	13.1%	13.8%
<1,600	Rural	28.7%	76.3%	26.7%	46.9%	28.7%

Validating the Industry Exposure Database

In the SWIO region, few independent reports containing building inventory data are available, which complicates any direct comparisons with the exposure database of buildings. Recent collaborations between UNISDR and Indian Ocean Commission (IOC) as part of the ISLANDS initiative have yielded the most comprehensive risk profiles in region to date. These multi-hazard studies consider earthquake and tropical cyclone risk in each of the SWIO island nations, and leverage a database of regional urban capital stock

[2] Totals may not sum to 100% due to rounding

developed for the United Nations Global Assessment Report (GAR, 2015). In the SWIO region, the GAR urban capital stock values are calculated using a 5km grid and represent the total value of buildings and infrastructure, which provides a spatially distributed direct comparison to the modeled exposure values for various occupancy classes (e.g., residential, commercial, and industrial). For validation, the AIR SWIO exposure database was resampled to the 5km grid and compared to the UNIDSR/GAR urban capital stock. A visual comparison between the UNISDR/GAR and AIR exposure values for Madagascar is presented in Figure 3, which suggests that the results are both visually and qualitatively similar. A quantitative comparison at each grid point is presented in Figure 4, and demonstrates statistically significant correlation and generally good agreement between the datasets for each modeled country and the SWIO region in its entirety.

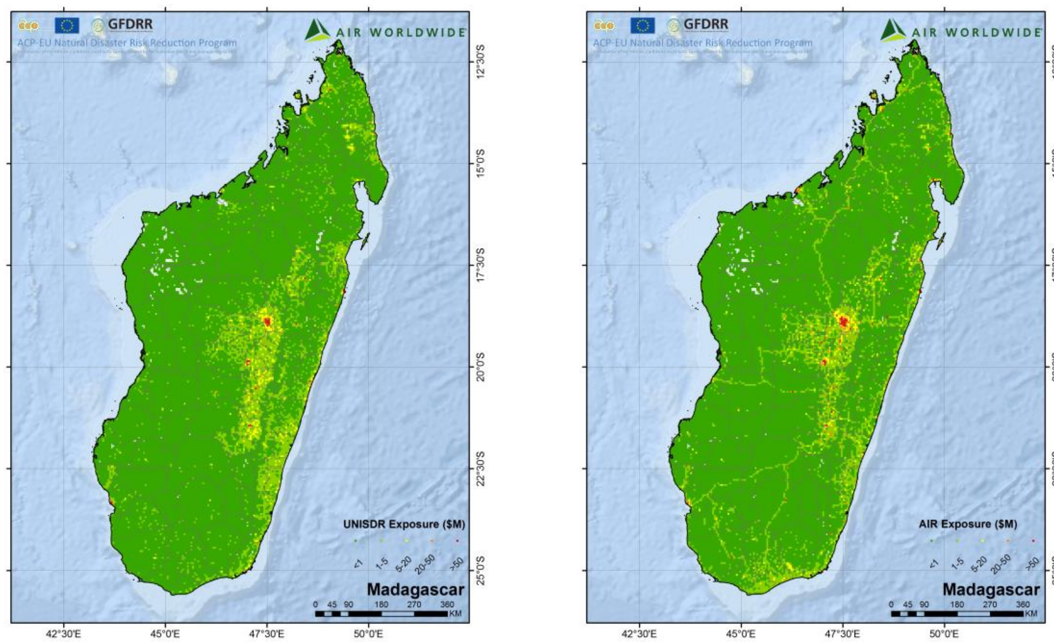

Figure 3: Comparison of UNISDR/GAR total urban capital stock (left) and AIR exposure value (right) aggregated to a 5km grid for Madagascar

In addition to validating the spatial distribution exposure value, national exposure values are benchmarked against various independent indicators, such as GDP. Table 8 presents the 2013 GDP (World Bank, 2015), both total and in terms of purchasing power parity (PPP), for each island nation normalized by the total GDP of the region. Total and PPP GDP have been proposed as suitable proxies for estimating building value, as these indicators correlate well with regional exposure values (Jaiswal and Wald, 2011). The resulting ratios are compared with the total AIR modeled exposure value for each island nation normalized by the total exposure value of the SWIO region. As expected, the distribution of exposure assets generally agrees with the distribution of regional GDP.

Table 8: Comparison of normalized regional GDP, GDP PPP, and AIR exposure values. The blue bars correspond to each percentage and illustrate the distribution of each indicator in the SWIO region[3].

Island Nation	*Normalized GDP (2013)*	*Normalized GDP PPP (2013)*	*Normalized Exposure Value*
Comoros	2%	2%	3%
Madagascar	41%	53%	42%
Mauritius	46%	36%	41%
Seychelles	6%	4%	8%
Zanzibar	5%	5%	6%
SWIO Region	***100%***	***100%***	***100%***

[3] Totals may not sum to 100% due to rounding

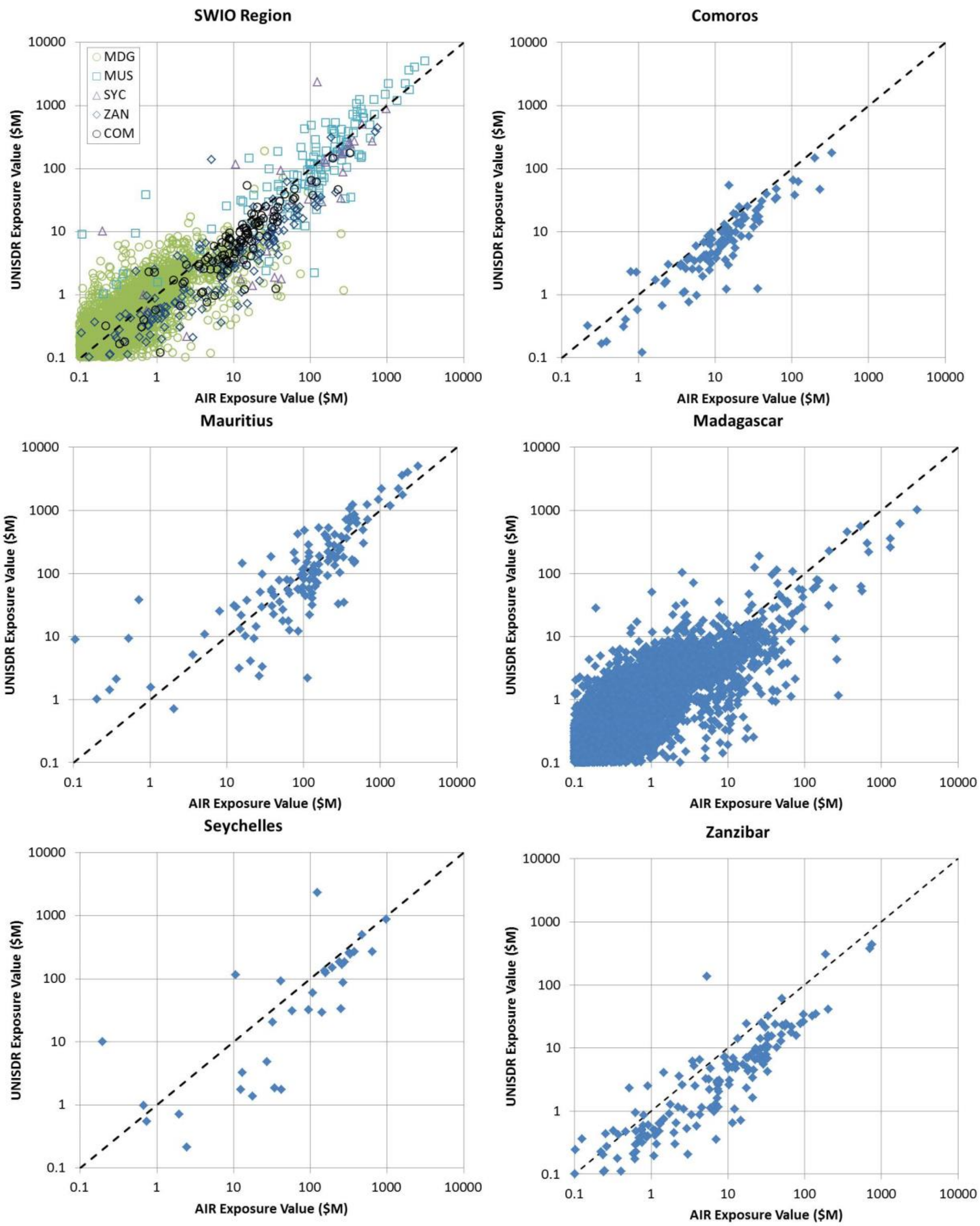

Figure 4: Comparison of spatial distribution of exposure between the UNISDR/GAR investigation (*y-axis*) and the AIR SWIO exposure database (*x-axis*)

Exposure Database Limitations

The SWIO exposure database of buildings has been developed for the purposes of a portfolio-based country-wide risk assessment to natural hazards, with the specific intent to estimate economic losses from damage resulting from disaster events. The exposure database does not necessarily represent truth or fact of the actual building stock, but is rather an interpretation based on available data, statistical techniques, state-of-the-art catastrophe modeling methodologies, and engineering judgment. Since the database has been designed to be used for a portfolio-based risk assessment, certain simplifications, aggregations, and averaging methods have been used to develop the exposure database. As such, the resolution, scope, and precision of the exposure database are deemed valid on an average basis. Additionally, individual asset locations, when provided, are derived from existing geospatial datasets provided by local agencies or estimated from satellite imagery. Thus, no warranty is provided with respect to the exact location of individual assets.

Data limitations, in terms of its existence, accessibility, accuracy, and precision, significantly complicated the development of the SWIO exposure database. Several "data gaps" were identified during the construction of the SWIO exposure database and additional data in these categories is expected to be the most useful for improving the development of any future exposure databases. The "data gaps" include:

- Rebuild cost data: Incomplete unit rebuild cost estimates were available for only three countries (Seychelles, Comoros, and Mauritius) and, where available, were limited to a handful of occupancy and construction classes. Detailed unit cost data could be used to improve the estimated rebuild values in the exposure database, and thereby the exposure value distribution in each country;
- Construction data: Few construction classes were documented in census or local agency data, and, when available, typically only applied for residential occupancies. Furthermore, the construction attributes collected typically documented "wall" or "roof" type, which do not aid in the determination of the primary structural system of each building. Additionally, information about building codes and local construction practices would be beneficial for estimating likely construction types and their respective vulnerabilities;
- Geospatial attributes: Several countries provided geospatial databases, but few of these databases contained any information beyond building footprints. While useful for mapping, the utility of footprint data is quite limited without expository building attributes, such as of construction, occupancy, height, number of inhabitants, cost, etc… Additionally, provided geospatial databases were often in conflict with statistical census data for building counts, occupancies, or construction types. For example, in Mauritius, the 2011 census lists a total of approximately 300,000 buildings on the main island, while the provided building footprint layer consists of over 440,000 buildings;
- Infrastructure data: Cost and construction information for high value infrastructure and critical assets (e.g., airports, hospitals, dams, power plants) was not provided for any country, but it is likely that the Ministries of Finance of each country maintain this information. These high value assets have a significant impact on the total exposure value for a country and the spatial distribution of these assets. The same is true for lower value, ubiquitous infrastructure assets, such as roads and bridges.

- Employment statistics: Detailed spatial statistics for commercial, industrial, and public employees were only available to a limited extent in certain countries. Detailed employment statistics could help improve the distribution and valuation of commercial, industrial, and public assets in the exposure database.

Summary of the Exposure Database

This summary section provides statistics and maps that demonstrate the spatial distribution of exposure values in the SWIO exposure database of buildings. The exposure database, associated geospatial files, and high resolution maps are provided as a digital addendum to this report. The replacement values presented in Table 9 include structure value (i.e., Coverage A) only. The total replacement value of modeled buildings in the SWIO region is approximately $82 billion USD. The distribution of total exposure value between all considered occupancy and construction classes is presented in Table 10 and Table 11, respectively. The spatial distribution of total exposure value in the SWIO region is illustrated in Figure 5.

Table 9. SWIO Exposure Summary Statistics

Island Nation	*Comoros*	*Madagascar*	*Mauritius*	*Seychelles*	*Zanzibar*
Capital	Moroni	Antananarivo	Port Louis	Victoria	Zanzibar City
Local Currency	KMF (Comorian Franc)	MGA (Malagasy Ariary)	MUR (Mauritian Rupee)	SCR (Seychelles Rupee)	(TZS) Tanzanian Shilling
Exchange Rate to USD*	442	3030	33.7	12.6	1970
GDP (2013, $B)	0.62	10.61	11.94	1.45	1.16
GDP per Capita ($)	846	463	9,593	15,565	848
GDP (PPP, I$B)	1.1	32.41	22.3	2.3	117.66
Total Population	738,712	23,037,566	1,276,873	94,787	1,230,378
Urban Population	58%	22%	70%	40%	70%
Exposure Database Scope	Cov.A - Structure	Cov.A - Structure	Cov.A - Structure	Cov.A - Structure	Cov.A - Structure
Exposure Vintage	2015	2015	2015	2015	2015
Exposure Native Resolution	0.0083333°	0.008333°	0.008333°	0.008333°	0.008333°
Replacement Value (2015, $M)					
Residential	1,710.8	19,575.7	13,573.6	3,368.0	3,169.6
Commercial	138.3	3,865.5	6,649.2	2,112.0	484.6
Industrial	22.2	2,491.2	3,208.0	270.0	54.7
Public	271.0	3,564.7	1,441.7	298.0	88.6
Infrastructure	437.7	5,298.5	8,587.4	877.3	500.2
Total	2,580.0	34,795.7	33,460.0	6,925.3	4,297.8

*Average for the year 2015

Table 10: Distribution of exposure value by occupancy class. The blue bars correspond to the listed percentage for each occupancy type and serve to illustrate the distribution in each island nation[4].

ID	Occupancy Type	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar	SWIO Region
300	Unknown	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
302	Residential - Single family	58.7%	45.7%	27.3%	38.1%	66.1%	39.0%
303	Residential - Multi-family	7.6%	10.6%	13.2%	10.5%	7.7%	11.4%
304	Commercial - Accommodation	0.2%	0.6%	2.8%	21.9%	1.4%	3.3%
311	Commercial - General commercial	5.2%	10.5%	17.1%	8.5%	9.9%	12.8%
316	Public - Health care services	0.1%	0.9%	0.6%	0.3%	0.1%	0.6%
321	Industrial - General industrial	0.9%	7.2%	9.6%	3.9%	1.3%	7.4%
341	Public - Religion	0.7%	0.0%	0.0%	1.1%	0.4%	0.2%
343	Public - General public facility	6.3%	3.8%	0.4%	1.4%	0.4%	2.1%
344	Public - Emergency services	1.2%	0.4%	0.6%	0.1%	0.3%	0.5%
345	Public - Education, University	0.4%	0.3%	0.3%	0.3%	0.5%	0.3%
346	Public - Education, Primary	1.8%	4.9%	2.4%	1.2%	0.4%	3.2%
351	Infrastructure - Roads/Highway	12.9%	11.9%	18.0%	5.6%	8.6%	13.7%
352	Infrastructure - Bus/Rail	0.5%	0.7%	0.0%	0.1%	0.0%	0.3%
353	Infrastructure - Airport	1.0%	0.5%	1.0%	0.4%	2.5%	0.8%
354	Infrastructure - Maritime Port	2.0%	1.1%	0.4%	0.2%	0.6%	0.7%
361	Infrastructure - Electrical Utilities	0.5%	1.1%	4.4%	2.4%	0.0%	2.5%
362	Infrastructure - Water Utilities	0.0%	0.0%	1.9%	3.8%	0.0%	1.1%

Table 11: Distribution of exposure value by construction class. The blue bars correspond to the listed percentage for each construction type and serve to illustrate the distribution in each island nation[3].

ID	Construction Type	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar	SWIO Region
100	Unknown	3.2%	2.6%	0.8%	2.6%	0.0%	1.7%
101	Wood Frame	0.0%	4.3%	0.1%	8.6%	0.0%	2.6%
102	Traditional Wood	0.8%	6.9%	0.4%	0.0%	13.9%	3.9%
111	Masonry/Concrete Wall	82.6%	61.8%	77.7%	79.0%	74.3%	71.0%
112	Traditional Earthen	0.0%	11.5%	0.0%	0.0%	0.9%	4.9%
151	Steel Frame	0.0%	0.1%	1.1%	0.5%	1.2%	0.6%
201	Multiple Span Bridges	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%
202	Continuous Bridges	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%
203	Other Bridges	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
204	Railroads	0.0%	0.7%	0.0%	0.0%	0.0%	0.3%
205	Roads/Highways	12.9%	11.6%	18.0%	5.6%	8.6%	13.6%
206	Runways	0.5%	0.1%	0.0%	0.1%	1.1%	0.2%
211	Dams	0.0%	0.0%	1.8%	3.3%	0.0%	1.0%

[4] Totals may not sum to 100% due to rounding

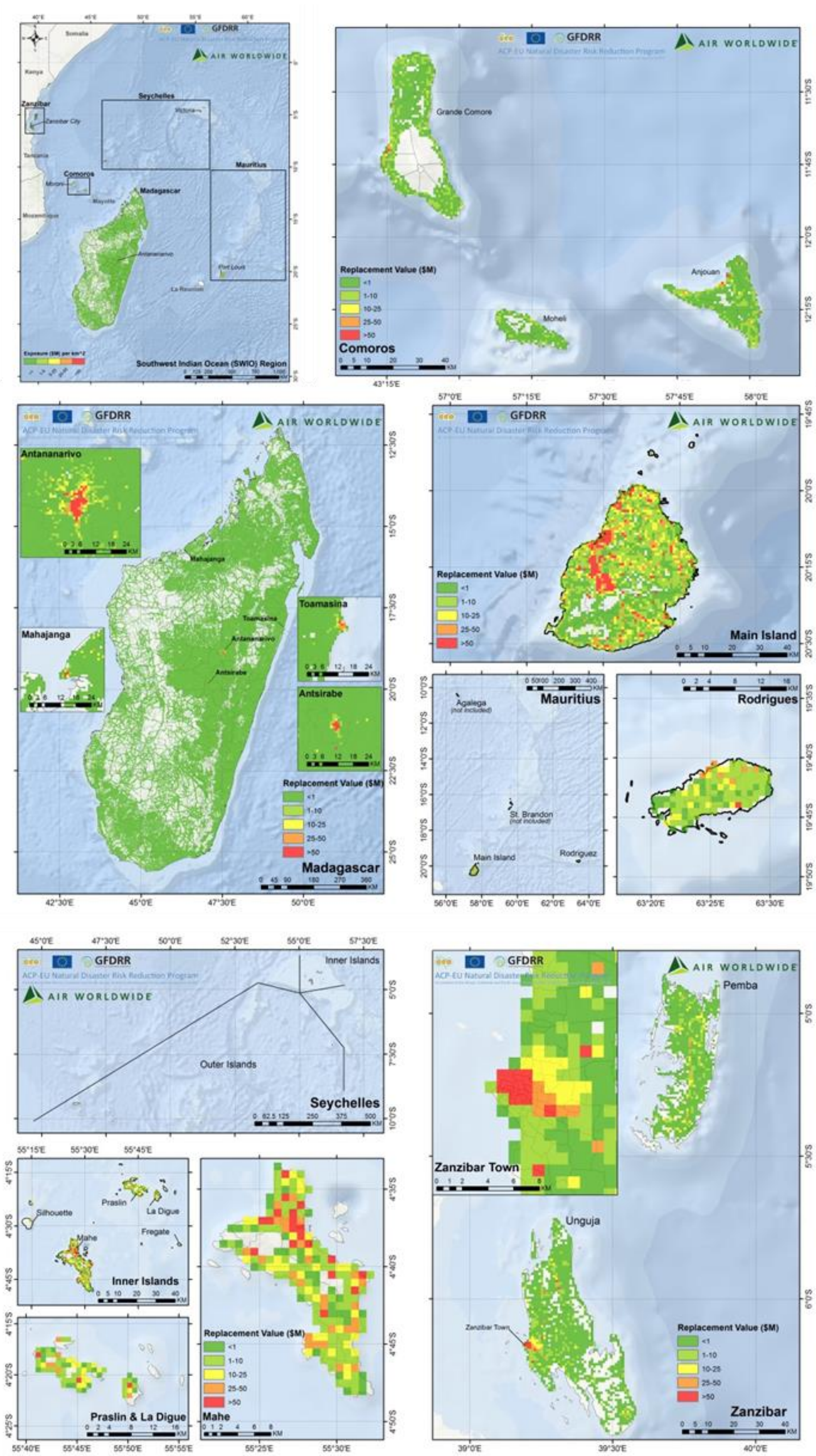

Figure 5: Spatial distribution of total exposure value of the SWIO region

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5 Appendix A: Country Exposure Development Methodology

The general methodology shown in Figure A.1 is applied during the development of the exposure database for each island nation in the SWIO region. However, due to the disparity in available data between island nations, the exact exposure database development approach was country specific. The details of the approach applied in each country are discussed herein. A qualitative data quality score (*Excellent, Good, Satisfactory, Poor*) is also assigned to each country based on the accessibility and utility of available exposure information, as interpreted by AIR exposure analysts.

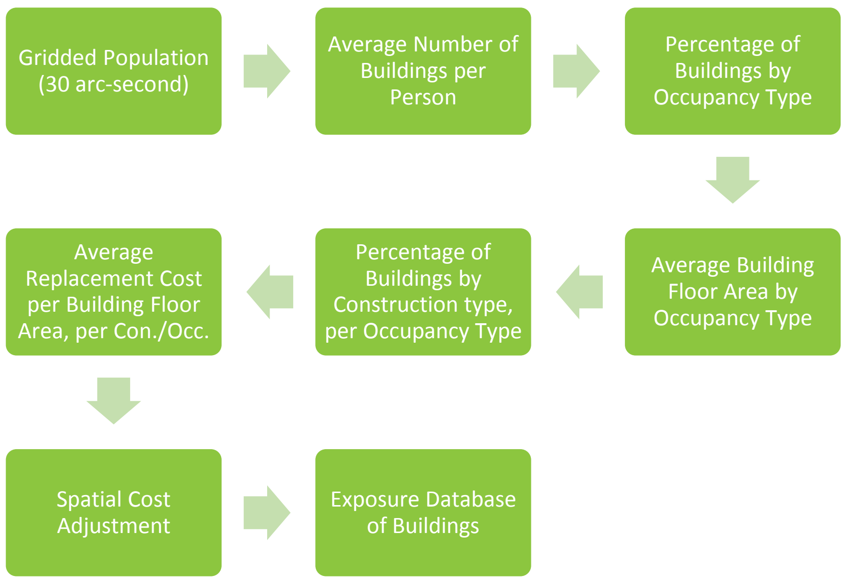

Figure A.1: General approach for developing the SWIO exposure database of buildings

Comoros

Data quality score: *Poor*

Geospatial databases developed as part of the 2014 UNDP risk assessment in Comoros served as the primary exposure data source. These databases provided building footprint data for the capital city of Moroni, which was used to derive the building attributes, such as construction types, size, and value, for the building stock of Comoros. The database also provided some site-specific details for roads, airports, and ports. The gridded exposure database for Comoros includes residential, commercial, general-industrial, and public assets. The Comoros exposure development differs from the standard methodology due to the availability of select building footprint and attribute data.

The available building footprints provided only a partial representation of the city of Moroni, as many of these footprints lacked attributes. Approximately 1,770 of the 10,118 building footprints contained building attributes, such as roof material, estimated value, number of floors, and occupancy (e.g., residential, commercial, hotel). Occupancy and construction percentages were derived from the 1,770 building footprints with attribute data, which were used to calculate the gridded proportion of construction types and occupancies. Wall construction, which was not provided, was assumed as masonry for the majority of roof types based research of typical construction practices in Comoros. Other buildings types that indicated light wood (e.g., poles, native plants) or straw were cataloged as traditional residential structures.

Based on the designation of areas as metro, urban, suburban, or rural, the available building footprint data was found to be primarily representative of urban areas in Comoros. To account for the lower number of non-residential establishments (e.g., hotels, commercial buildings, hospitals) in rural areas, the proportion of non-residential buildings in rural regions was reduced by a factor of 3-6, depending on occupancy. As limited information is available about public buildings in Comoros, an estimate of 10 civil employees per building was derived from a report issued by the World Bank ("*WB 2015 - Civil Service Recruitment in Comoros*") and used with employment statistics to estimate the number of general public buildings. For each grid point, all calculated number of buildings less than 1 (i.e., the residual) were aggregated and added to single family residential with construction type as the one with the largest percent by region (typically low-rise, masonry/concrete) as indicated by the census.

Infrastructure locations, construction types, and costs for airports, power plants, and ports were obtained from publically available literature and the web. No infrastructure cost data was provided. Details for selected infrastructure assets are provided as follows:

- Road data was obtained from UNDP geospatial database. Roads were segmented into lengths of 2 kilometers (or less) and assigned a value based on per capita GDP-scaled client data from Seychelles and Mauritius and from researched literature.
- Power plants locations and capacities were sourced from CARMA and the locations derived from satellite imagery. The unit values were then estimated from the capacity of each plant from an EPRI case study ("*Costs of Utility Distributed Generators, 1-10 MW*") for diesel generators.
- Port dock area was calculated using satellite imagery. The replacement value per unit area was derived from per capita GDP-scaled cost data for the port of Mauritius.
- Airports locations and area were estimated using satellite imagery. Runway lengths and widths were derived from satellite imagery and publically available data.

Madagascar

Data quality score: *Poor*

The Institute of Statistics Madagascar (INSTAT) and the recent UNISDR study served as the primary sources for the Madagascar exposure database. The census information was typically available at district level and the UNISDR data was available at either the country or commune level. The census data provided average household size for each district, which was used to estimate the number of dwellings based on the gridded population. INSTAT also provided commune level counts of schools, hospitals, and clinics. The UNISDR study, in combination with the Madagascar business census, provided statistics regarding employee counts in various occupancy classes. The gridded exposure database for Madagascar includes residential, commercial, general-industrial, and public assets. Location specific infrastructure assets in Madagascar include roads, bridges, airports, ports, power plants, rail roads, rail stations, and universities. The Madagascar exposure development approach closely followed the standard methodology.

The census contained regional information about the percentages of the population employed in different occupancies, which were mapped to standard AIR occupancy classes. Additionally, census construction information (e.g., wall materials) was also mapped to standard AIR construction classes. Using these statistics, per-person occupancy and construction distributions were applied to the gridded population to calculate the expected number of buildings in each construction-occupancy pair. For each grid point, any calculated number of buildings less than 1 (i.e., the residual) were aggregated and added to low-rise single family residential masonry/concrete.

Unit cost data for each occupancy class in Madagascar was estimated by scaling cost data from the Seychelles, Comoros, and that reported by KPMG Africa Limited (KPMG, 2014; KMPG, 2015). The scaling factors were calculated as functions of per capita GDP ratios (in terms of Purchasing Power Parity, PPP), which were further calibrated for each occupancy class using per capita GDP cost ratios calculated for countries with known cost information. For example, if the ratio of per capita GDP PPP between Madagascar and Seychelles is 0.06, and the exposure under consideration has a per capita GDP occupancy cost adjustment of 2 (derived by comparing per capita GDP and known unit cost values in Seychelles and Comoros), then the unit replacement value in Madagascar is calculated as the product of the Seychelles commercial occupancy unit value, the per capita GDP ratio (0.06), and the occupancy cost adjustment (2).

Infrastructure locations for roads and railroads were derived from OpenStreetMap (OSM) data, which covered most regions in Madagascar. OSM was only used for roads and railways in Madagascar due to a geographic bias of the data in other categories, such as commercial, residential, and public building footprints. Locations and costs for airports, ports, electric utilities, and universities were derived from publically available sources, such as published agency reports, NGO datasets, and news articles. No infrastructure cost data was provided. Details for selected infrastructure assets are provided as follows:

- Roads and bridges were segmented into lengths of 2 kilometers (or less) and assigned a value based on per capita GDP-scaled client data from Seychelles and Mauritius and from researched literature.
- Airport and runway locations and footprints were estimated using publically available databases and satellite imagery.
- Port locations were derived from the World Port Index (WPI). The replacement value was derived from publically available sources on a port-by-port basis. A minimum value of $500,000 was assumed.
- Universities and the number of associated students were individually located using publically available information. Floor area was estimated as a function of the number of students based on information provided in the UNISDR dataset.
- Energy utility assets were derived from the local power utility, JIRAMA, and CARMA. Valuation of power plants was derived as a price-per-MW, based on publically reported documents.

Mauritius

<u>Data quality score</u>: *Satisfactory*

Geospatial databases for Mauritius were provided by various local agencies, including the Ministry of Housing and Land (MHL), Ministry of Public Infrastructure and Land Transport, Road Development Authority (RDA), Ministry of Environment and Sustainable Development, and Statistic Mauritius. In addition to spatial construction and occupancy statistics, these datasets included building footprint data for the Main Island. The limitation of this data was the absence of building attributes (e.g., construction, occupancy, height) for each footprint. Occupancy, construction, and height distributions were derived from the census, which contained information available at the Administrative Region 3. Location information for infrastructure assets was also provided in the geospatial database, however structural attributes were similarly absent from these datasets. Limited estimates of unit rebuild costs were available from the recent National Risk Profile provided by the Ministry of Environment and Sustainable development. Other unit cost data for Mauritius was derived from the recent UNISDR study, the Seychelles, and publically available sources. Gridded exposure for Mauritius includes residential, commercial, general-industrial, and some public assets. The Mauritius exposure development differs from the standard methodology due to the availability of select building footprint, public asset, and infrastructure data.

Floor area totals for Mauritius were extracted directly from building footprint datasets, while occupancy, construction, and height distributions were derived from the housing census. While construction information by occupancy was not available in the census, a review of publically available information suggested construction type distributions for commercial and industrial assets that differed slightly from those provided in the census for residential occupancies (i.e., masonry, concrete, and steel vs. masonry, wood, and traditional). The census did however provide detailed building height distributions by Administrative Region 3, which were used to spatially augment floor area estimates. For each grid point, any calculated number of buildings less than 1 (i.e., the residual) were aggregated and added to low-rise single family residential masonry/concrete.

Certain public assets (e.g., schools, hospitals) and primary infrastructure assets (e.g., airports, roads, bridges, dams, power plants), were represented in the geospatial databases. Infrastructure cost data was only provided for roads. Details for selected infrastructure assets are provided as follows:

- Roads were segmented into lengths of 2 kilometers (or less). Bridge locations, types, and lengths were extracted from the geospatial database. Value for roads and bridges are assigned using cost per meter data provided by the RDA.
- Airport and runway locations were provided. Their respective areas and lengths were either derived from the geospatial database or estimated using satellite imagery. The valuation of airports was derived from publically available reports.
- Port locations and areas were provided. The valuation of ports on Mauritius and Rodrigues was derived from the most recent Mauritius Port Authority annual report.
- School, university, clinic, and hospital locations were provided. Floor area estimates were obtained by spatially joining these locations with the building footprint layer.
- Water utility assets were derived from the geospatial database. Their valuations were estimated based on floor area (e.g., treatment facilities) or publically available government documents and news articles (e.g., dams).
- Energy utility assets were derived from the geospatial database and supplemented with information available from CARMA and the Central Electricity Board (CEB). Valuation of power plants was derived from the most recent CEB annual report.

Seychelles

<u>Data quality score</u>: *Satisfactory*

Geospatial databases for Seychelles were provided by various local agencies, including the Ministry of Land Use and Housing (MLUH), Seychelles Land Transport Agency (SLTA), and the National Bureau of Statistics (NBS). These datasets included building footprint data for the Inner Islands and detailed land-use data for Mahe, Praslin, and La Digue. The primary limitation of this data was the absence of building attributes (e.g., construction, occupancy, height) for each footprint. While the occupancy of buildings in Mahe could be inferred from land-use maps, general statistics about occupancy had to be derived from the census for the other islands. Additionally, construction details were not included in any datasets and were only available in the census, per enumeration area under broad construction classes. Building height distribution statistics were not available. Location information for infrastructure assets was also provided in the geospatial database, however structural attributes were similarly absent from these datasets. Seychelles MLUH provided estimates of unit rebuild costs for a variety of occupancies and construction types. The gridded exposure database for Seychelles includes residential, commercial, general-industrial, and some public assets. The Seychelles exposure development differs from the standard methodology due to the availability of select building footprint, public asset, infrastructure, and rebuild cost data.

Occupancy distributions and floor area totals for Seychelles were extracted directly from geospatial datasets, while construction and height distributions were derived from the housing census. Construction information by occupancy was not available; therefore the census construction distributions by enumeration area were uniformly applied across all occupancies (excepting traditional structures, which were only assigned to residential occupancies). For each grid point, any calculated number of buildings less than 1 (i.e., the residual) were aggregated and added to low-rise single family residential masonry/concrete.

Certain public assets (e.g., schools, hospitals) and primary infrastructure assets (e.g., airports, roads, bridges, dams, power plants), were represented in the provided geospatial databases. Infrastructure cost data was only provided for roads. Details for selected infrastructure assets are provided as follows:

- Roads were segmented into lengths of 2 kilometers (or less). Bridge locations, types, and lengths were extracted from the geospatial database. Value for roads and bridges were assigned using cost per meter data provided by the SLTA.
- Airport and runway locations were provided. Their respective areas and lengths were either derived from the geospatial database or estimated using satellite imagery. The valuation of airports was estimated based on square footage and the cost per square meter provided for industrial assets.
- Port locations and area footprints were provided. The valuation of ports was estimated based on square footage and the cost per square meter provided for industrial assets.
- School, university, clinic, and hospital locations and rebuild costs were provided. Floor area estimates were obtained by spatially joining these locations with the building footprint layer.
- Energy and water utility assets were derived from the geospatial database. Their values were estimated based on square footage and the cost per square meter provided for industrial assets.

Zanzibar

Data quality score: *Poor*

The Tanzania National Bureau of Statistics, Census 2012, served as the primary source for the Zanzibar exposure database. The census information was available at the region level for Zanzibar (Kaskazini-Unguja, Zanzibar South and Central, Zanzibar West, Kaskazini-Pemba, and Kusini-Pemba). The census provided average household size for each region, which was used to estimate the number of dwellings based on the gridded population. The gridded exposure database for Zanzibar includes residential, commercial, general-industrial, and public assets. Location specific infrastructure assets in Zanzibar include roads, airports, ports, and universities. The Zanzibar exposure development closely follows the standard methodology.

The census contained regional information about the percentages of the population employed in different occupancies, which were mapped to standard AIR occupancy classes. Additionally, census construction information (e.g., wall materials) was also mapped to standard AIR construction classes. When additional occupancy or construction information was available, the distribution statistics were modified to reflect this auxiliary information. For example, excerpts from the "*Zanzibar Strategy for Growth and Reduction of Poverty*" and "*Zanzibar Human Development Report 2009: Towards Pro Poor Growth*", provided total country estimates for number of hotels and business, which were trended to the current year to estimate proportions of these establishments. Using these statistics, per-person occupancy and construction distributions were applied to the gridded population to calculate the expected number of buildings in each construction-occupancy pair. For each grid point, all calculated number of buildings less than 1 (i.e., the residual) were aggregated and added to single family residential with construction type as the one with the largest percent by region (typically low-rise, masonry/concrete for Unguja Island, and low-rise traditional wood for Pemba Island) as indicated by the census.

Unit cost data for each occupancy class in Zanzibar was estimated by scaling data reported by KPMG Africa Limited (KPMG, 2014; KMPG, 2015) for Dar Es Salaam, Tanzania. Rebuild costs were derived primarily by comparing publically available sale and rental prices for occupancies in Zanzibar to those reported by KPMG for Dar Es Salaam. The average ratio between the two locations was then used to uniformly scale the remaining KMPG data. For occupancy classes not considered by the KPMG data, the per capita GDP scaling approach described above for Madagascar was employed.

Infrastructure locations, construction types, and costs for roads, airports, ports, and major universities were derived from State University of Zanzibar and OpenStreetMap data. State University of Zanzibar (in collaboration with STATOIL) data covered the area of Zanzibar Town and OpenStreetMap covered the whole of Zanzibar. No infrastructure cost data was provided. Details for selected infrastructure assets are provided as follows:

- Roads were segmented into lengths of 2 kilometers (or less) and assigned a value based on GDP-scaled client data from Seychelles and Mauritius and from researched literature.
- Airports locations and area were estimated using satellite imagery. Runway lengths and widths were derived from satellite imagery and publically available data.
- Port dock area was calculated using satellite imagery. The replacement value per unit area was derived from GDP-scaled cost data for the port of Mauritius.
- Major universities were individually located using publically available information.
- No electric power plants are listed for Zanzibar. The island has large submarine cables from Tanzania which import the electricity to substations. Although public articles confirm this, no specific information for the substations locations or values was found.

6 Appendix B: Rebuild Cost Matrix

Construction-occupancy pair unit replacement values assumed in the development of the exposure database are provided in Table B.1 below. For each country, blank entries in Table B.1 indicate that the corresponding construction-occupancy pair was either not present in that country's exposure database or insufficient data was available to derive a rebuild cost. The nominal replacement values are derived from data provided by local agencies, scaled from similar regions using per capita GDP ratios, or estimated from publically available data. No warranty, express or implied, is provided with respect to the exact replacement costs listed herein.

Table B.1: Nominal unit replacement cost values assumed for the SWIO exposure database

Index	ConCode	OccCode	ConCode Type	OccCode Type	Cost Unit	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar
1	101	302	Wood Frame	Residential - Single family	m^2	-	76	384	507	-
2	111	302	Masonry/Concrete Wall	Residential - Single family	m^2	120	102	288	675	149
3	151	302	Steel Frame	Residential - Single family	m^2	-	109	720	722	-
4	102	302	Traditional Wood	Residential - Single family	m^2	94	38	96	254	74
5	112	302	Traditional Earthen	Residential - Single family	m^2	-	38	96	-	74
6	100	302	Unknown	Residential - Single family	m^2	94	89	336	591	-
7	101	303	Wood Frame	Residential - Multi-family	m^2	-	76	432	628	-
8	111	303	Masonry/Concrete Wall	Residential - Multi-family	m^2	204	102	576	836	251
9	151	303	Steel Frame	Residential - Multi-family	m^2	-	88	720	722	-
10	102	303	Traditional Wood	Residential - Multi-family	m^2	94	38	144	-	125
11	112	303	Traditional Earthen	Residential - Multi-family	m^2	-	38	144	-	125
12	100	303	Unknown	Residential - Multi-family	m^2	94	89	576	732	-
13	101	304	Wood Frame	Commercial - Accommodation	m^2	-	99	1,250	1,318	-
14	111	304	Masonry/Concrete Wall	Commercial - Accommodation	m^2	145	132	1,667	1,754	373
15	151	304	Steel Frame	Commercial - Accommodation	m^2	-	132	1,667	1,754	-
16	102	304	Traditional Wood	Commercial - Accommodation	m^2	-	-	-	-	186

Index	ConCode	OccCode	ConCode Type	OccCode Type	Cost Unit	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar
17	112	304	Traditional Earthen	Commercial - Accommodation	m^2	-	-	-	-	186
18	100	304	Unknown	Commercial - Accommodation	m^2	-	116	1,528	1,536	-
19	101	311	Wood Frame	Commercial - General commercial	m^2	-	64	360	612	-
20	111	311	Masonry/Concrete Wall	Commercial - General commercial	m^2	92	85	480	815	234
21	151	311	Steel Frame	Commercial - General commercial	m^2	-	75	720	722	-
22	102	311	Traditional Wood	Commercial - General commercial	m^2	-	-	-	-	117
23	112	311	Traditional Earthen	Commercial - General commercial	m^2	-	-	-	-	117
24	100	311	Unknown	Commercial - General commercial	m^2	-	75	520	714	-
25	101	316	Wood Frame	Public - Health care services	m^2	-	229	540	506	-
26	111	316	Masonry/Concrete Wall	Public - Health care services	m^2	324	305	720	674	234
27	151	316	Steel Frame	Public - Health care services	m^2	-	305	720	-	-
28	102	316	Traditional Wood	Public - Health care services	m^2	-	-	-	-	117
29	112	316	Traditional Earthen	Public - Health care services	m^2	-	-	-	-	117
30	100	316	Unknown	Public - Health care services	m^2	-	-	660	-	-
31	101	321	Wood Frame	Industrial - General industrial	m^2	-	94	540	543	-
32	111	321	Masonry/Concrete Wall	Industrial - General industrial	m^2	132	126	720	722	230
33	151	321	Steel Frame	Industrial - General industrial	m^2	-	126	720	722	-
34	102	321	Traditional Wood	Industrial - General industrial	m^2	-	-	-	-	115
35	112	321	Traditional Earthen	Industrial - General industrial	m^2	-	-	-	-	115
36	100	321	Unknown	Industrial - General industrial	m^2	-	110	660	632	-
37	101	341	Wood Frame	Public - Religion	m^2	-	82	336	612	-
38	111	341	Masonry/Concrete Wall	Public - Religion	m^2	114	109	384	815	251
39	151	341	Steel Frame	Public - Religion	m^2	-	-	-	-	-
40	102	341	Traditional Wood	Public - Religion	m^2	-	-	144	-	125
41	112	341	Traditional Earthen	Public - Religion	m^2	-	-	144	-	125
42	100	341	Unknown	Public - Religion	m^2	-	95	252	714	-
43	101	343	Wood Frame	Public - General public facility	m^2	-	197	288	491	-
44	111	343	Masonry/Concrete Wall	Public - General public facility	m^2	279	262	384	654	320

Index	ConCode	OccCode	ConCode Type	OccCode Type	Cost Unit	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar
45	151	343	Steel Frame	Public - General public facility	m^2	-	289	720	722	-
46	102	343	Traditional Wood	Public - General public facility	m^2	-	-	-	-	160
47	112	343	Traditional Earthen	Public - General public facility	m^2	-	-	-	-	160
48	100	343	Unknown	Public - General public facility	m^2	-	229	464	573	-
49	101	344	Wood Frame	Public - Emergency services	m^2	-	197	288	491	-
50	111	344	Masonry/Concrete Wall	Public - Emergency services	m^2	324	262	384	654	320
51	151	344	Steel Frame	Public - Emergency services	m^2	-	289	720	722	-
52	102	344	Traditional Wood	Public - Emergency services	m^2	-	-	-	-	160
53	112	344	Traditional Earthen	Public - Emergency services	m^2	-	-	-	-	160
54	100	344	Unknown	Public - Emergency services	m^2	-	229	464	573	-
55	101	345	Wood Frame	Public - Education, University	m^2	-	-	216	497	-
56	111	345	Masonry/Concrete Wall	Public - Education, University	m^2	279	115	288	662	480
57	151	345	Steel Frame	Public - Education, University	m^2	-	-	-	-	-
58	102	345	Traditional Wood	Public - Education, University	m^2	-	-	-	-	-
59	112	345	Traditional Earthen	Public - Education, University	m^2	-	-	-	-	-
60	100	345	Unknown	Public - Education, University	m^2	-	-	-	580	-
61	101	346	Wood Frame	Public - Education, Primary	m^2	-	87	216	497	-
62	111	346	Masonry/Concrete Wall	Public - Education, Primary	m^2	122	115	288	662	202
63	151	346	Steel Frame	Public - Education, Primary	m^2	-	-	-	-	-
64	102	346	Traditional Wood	Public - Education, Primary	m^2	-	-	-	-	101
65	112	346	Traditional Earthen	Public - Education, Primary	m^2	-	-	-	-	101
66	100	346	Unknown	Public - Education, Primary	m^2	-	-	-	-	-
67	100	361	Unknown - Power Plant	Infrastructure - Electrical Utilities	MW or m^2	0.47M	1.0M	1.81M	45.9K[1]	-
68	100	361	Unknown - Sub-Station	Infrastructure - Electrical Utilities	m^2	-	-	360	722	-
69	205	351	Roads/Highways - Freeway	Infrastructure - Roads/Highway	m	775	202	4,750	1,163	775

Index	ConCode	OccCode	ConCode Type	OccCode Type	Cost Unit	Comoros	Madagascar	Mauritius	Seychelles	Zanzibar
70	205	351	Roads/Highways - Primary	Infrastructure - Roads/Highway	m	775	202	1,667	1,163	775
71	205	351	Roads/Highways - Secondary	Infrastructure - Roads/Highway	m	472	133	1,433	763	472
72	205	351	Roads/Highways - Tertiary	Infrastructure - Roads/Highway	m	17	54	200	757	17
73	205	351	Roads/Highways - Onramp	Infrastructure - Roads/Highway	m	-	-	200	460	-
74	201	300	Conventional - Multiple Span Bridges	Unknown	m	-	1,551	5,333	11,632	-
75	202	300	Conventional - Continuous Bridges	Unknown	m	-	1,009	4,167	7,567	-
76	203	300	Other Bridges	Unknown	m	-	614	2,667	4,603	-
77	100	353	Unknown	Infrastructure - Airport	m^2	722	370-740	5,368	722	722
78	206	353	Runways - Paved	Infrastructure - Airport	m	6,056	1,400	1,667	1,163	6,056
79	206	353	Runways - Unpaved	Infrastructure - Airport	m	3,634	700	5,368	763	3,634
80	206	353	Runways - Helipad	Infrastructure - Airport	m^2	-	-	-	166	-
81	100	354	Unknown	Infrastructure - Maritime Port	m^2 or unit	-	0.5-200M	4-121M	722 [1]	6.5-20M
82	100	352	Unknown - Stations	Infrastructure - Bus/Rail	m^2 or unit	-	262 [1]	-	722 [1]	-
83	204	352	Railroads	Infrastructure - Bus/Rail	m	-	250	-	-	-
84	100	362	Unknown - Untreated Pump Sta.	Infrastructure - Water Utilities	m^2 or unit	-	-	321 [1]	722 [1]	-
85	100	362	Unknown - Treated Pump Sta.	Infrastructure - Water Utilities	m^2 or unit	-	-	362 [1]	722 [1]	-
86	100	362	Unknown - Desalination	Infrastructure - Water Utilities	m^2 or unit	-	-	-	722 [1]	-
87	211	362	Dams	Infrastructure - Water Utilities	unit	-	-	55.5M	77.0M	-

[1]per m^2

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