METEOR: Open source taxonomy, data model and documentation. Report M3.5/P

UKSA IPP2 Grant Programme

Open File Report OR/22/026

BRITISH GEOLOGICAL SURVEY

UKSA IPP2 GRANT PROGRAMME
OPEN FILE REPORT OR/22/026

Keywords

Report; METEOR; Exposure; CAT model.

Front cover

METEOR (Modelling Exposure Through Earth Observation Routines) Project logo

Bibliographical reference

IMAGECAT 2021. METEOR: Open source taxonomy, data model and documentation. Report M3.5/P. *British Geological Survey Open File Report*, OR/22/026. 65pp.

METEOR: Open source taxonomy, data model and documentation. Report M3.5/P

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Keyworth, Nottingham British Geological Survey 2021

BRITISH GEOLOGICAL SURVEY

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Document Verification

Project	METEOR: Modelling Exposure Through Earth Observation Routines
Report Title	METEOR: Open source taxonomy, data model and documentation
Related Milestone	M3.5
Reference as	ImageCat (2021) METEOR Open source taxonomy, data model and documentation. Report M3.5/P. *British Geological Survey Open File Report*, OR/22/026. 67pp
Release Type	Public / ~~Confidential~~ / ~~Confidential with Embargo Period~~

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Date	Version	Alterations	Editor
3/19/2021	1		ImageCat
3/29/2021	1	Feedback Provided	K Smith
3/30/2021	2	Revised	ImageCat
3/31/2021	3	Reviewed; References added	K. Smith

Glossary

AIR	AIR Worldwide Corporation, formally Applied Insurance Research, is part of the Verisk Analytics family of companies
BGS	British Geological Survey: An organisation providing expert advice in all areas of geoscience to the UK government and internationally
DMD	Disaster Management Department of the Prime Minister's Office of Tanzania, focused on disaster risk
EERI	Earthquake Engineering Research Institute
EO	Earth Observation; the gathering of information about Earth's physical, chemical and biological systems via remote sensing technologies, usually involving satellites carrying imaging devices
FATHOM	Provides innovative flood modelling and analytics, based on extensive flood risk research
FEMA	Federal Emergency Management Agency
GAR	Global Assessment Report on Disaster Risk Reduction
GDP	Gross Domestic Product
GED4ALL	Open exposure database schema for multi-hazard risk analysis
GEM	Global Earthquake Model: Non-profit organisation focused on the pursuit of earthquake resilience worldwide
HAZUS	U.S. Government loss modelling
HOT	Humanitarian OpenStreetMap Team: A global non-profit organisation the uses collaborative technology to create OSM maps for areas affected by disasters
ImageCat	International risk management innovation company supporting the global risk and catastrophe management needs of the insurance industry, governments and NGOs
IPP	International Partnership Programme; the UK Space Agency's International Partnership Programme (IPP) is a £30M per year programme, which uses expertise in space-based solutions, applications and capability to provide a sustainable economic or societal benefit to emerging nations and developing economies
IPUMS	IPUMS provides census and survey data from around the world integrated across time and space
LDC	Least Developed Country on the Organisation for Economic Co-operation and Development's (OECD) Development Assistance Committee (DAC) list
M	Milestone, related to work package deliverable

METEOR	Modelling Exposure Through Earth Observation Routines; a three-year project funded by the UK Space Agency to develop innovative application of Earth Observation (EO) technologies to improve understanding of exposure and multihazards impact with a specific focus on the countries of Nepal and Tanzania
NGO	Non-Governmental Organisation; organisations which are independent of government involvement
NSET	National Society for Earthquake Technology: Non-governmental organisation working on reducing earthquake risk in Nepal and abroad
ODA	Official Development Assistance; government aid that promotes and specifically targets the economic development and welfare of developing countries
OED	Open Exposure Data: The exposure data input format supported by the Oasis Loss Modelling Framework and by all models deployed on the Oasis platform
OPM	Oxford Policy Management: Organisation focused on sustainable project design and implementation for reducing social and economic disadvantage in low-income countries
OSM	OpenStreetMap, a collaborative project to create a free and open editable map database of the world
PAGER	Prompt Assessment of Global Earthquakes for Response: An automated system developed by the United States Geological Survey to rapidly estimate earthquake shaking and the scope and impact of earthquakes around the world
PDNA	Post Disaster Needs Assessment
SDGs	Sustainable Development Goals; these goals were set up in 2015 by the United Nations General Assembly and are intended to be achieved by the year 2030
UKSA	United Kingdom Space Agency; an executive agency of the Government of the United Kingdom, responsible for the United Kingdom's civil space programme
USD	U.S. Dollars, currency
USGS	U.S. Geological Survey
WHE	World Housing Encyclopedia
WP	Work Package; discrete sets of activities within the METEOR Project, each work package is led by a different partner and has specific objectives

Foreword

This report is the published product of a study by ImageCat as part of the Modelling Exposure Through Earth Observation Routines (METEOR) project led by British Geological Survey (BGS).

METEOR is grant-funded by the UK Space Agency's International Partnership Programme (IPP), a >£150 million programme which is committed to using the UK's space sector research and innovation strengths to deliver sustainable economic, societal, and environmental benefit to those living in emerging and developing economies. IPP is funded from the Department for Business, Energy and Industrial Strategy's (BEIS) Global Challenges Research Fund (GCRF). This £1.5 billion Official Development Assistance (ODA) fund supports cutting-edge research and innovation on global issues affecting developing countries. ODA-funded activity focuses on outcomes that promote long-term sustainable development and growth in countries on the OECD Development Assistance Committee (DAC) list. IPP is ODA compliant, being delivered in alignment with UK Aid Strategy and the United Nations' (UN) Sustainable Development Goals (SDGs).

The objective of this report is to summarise the exposure detail (levels), development patterns and building attributes associated with the digital exposure dataset for use in CAT modelling.

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Summary

This report describes a specific piece of work conducted by ImageCat as part of the METEOR (Modelling Exposure Through Earth Observation Routines) project, led by British Geological Survey (BGS) with collaborative partners Oxford Policy Management Limited (OPM), SSBN Limited, The Disaster Management Department, Office of the Prime Minister – Tanzania (DMD), The Global Earthquake Model Foundation (GEM), The Humanitarian OpenStreetMap Team (HOT), ImageCat and the National Society for Earthquake Technology (NSET) – Nepal.

The 3-year project was funded by UK Space Agency through their International Partnership Programme, details of which can be located in the Foreword, and was completed in 2021.

The project aimed to provide an innovative solution to disaster risk reduction, through development of an innovative methodology of creating exposure data from Earth Observation (EO) imagery to identify development patterns throughout a country and provide detailed information when combined with population information. Level 1 exposure was developed for all 47 least developed countries on the OECD DAC list, referred to as ODA least-developed countries in the METEOR documentation, with open access to data and protocols for their development. New national detailed exposure and hazard datasets were also generated for the focus countries of Nepal and Tanzania and the impact of multiple hazards assessed for the countries. Training on product development and potential use for Disaster Risk Reduction was performed within these countries with all data made openly available on data platforms for wider use both within country and worldwide.

This report (M3.5/P) is the fifth report generated by ImageCat for the work package EO data for exposure development (WP3) led by ImageCat. The other 7 METEOR work packages included, Project Management (WP1 – led by BGS), Monitoring and Evaluation (WP2 – led by OPM), Inputs and Validation (WP4 – led by HOT), Vulnerability and Uncertainty (WP5 - led by GEM), Multiple hazard impact (WP6 – led by BGS), Knowledge sharing (WP7 – led by GEM) and Sustainability and capacity building (WP8 – led by ImageCat).

1. METEOR Project

1.1. PROJECT SUMMARY

Project Title	Modelling Exposure Through Earth Observation Routines (METEOR): EO-based Exposure, Nepal and Tanzania
Starting Date	08/02/2018
Duration	36 months
Partners	UK Partners: The British Geological Survey (BGS) (Lead), Oxford Policy Management Limited (OPM), SSBN Limited International Partners: The Disaster Management Department, Office of the Prime Minister – Tanzania, The Global Earthquake Model (GEM) Foundation, The Humanitarian OpenStreetMap Team (HOT), ImageCat, National Society for Earthquake Technology (NSET) – Nepal
Target Countries	Nepal and Tanzania for "level 2" results and all 47 Least Developed ODA countries for "level 1" data
IPP Project	IPPC2_07_BGS_METEOR

Table 1: METEOR Project Summary

1.2. PROJECT OVERVIEW

At present, there is a poor understanding of population exposure in some Official Development Assistance (ODA) countries, which causes major challenges when making Disaster Risk Management decisions. Modelling Exposure Through Earth Observation Routines (METEOR) takes a step-change in the application of Earth Observation exposure data by developing and delivering more accurate levels of population exposure to natural hazards. METEOR is delivering calibrated exposure data for Nepal and Tanzania, plus 'Level-1' exposure for the remaining Least developed Countries (LDCs) ODA countries. Moreover, we are: (i) developing and delivering national hazard footprints for Nepal and Tanzania; (ii) producing new vulnerability data for the impacts of hazards on exposure; and (iii) characterising how multi-hazards interact and impact upon exposure. The provision of METEOR's consistent data to governments, town planners and insurance providers will promote welfare and economic development and better enable them to respond to the hazards when they do occur.

METEOR is co-funded through the second iteration of the UK Space Agency's (UKSA) International Partnership Programme (IPP), which uses space expertise to develop and deliver innovative solutions to real world problems across the globe. The funding helps to build sustainable development while building effective partnerships that can lead to growth opportunities for British companies.

1.3. PROJECT OBJECTIVES

METEOR aims to formulate an innovative methodology of creating exposure data through the use of EO-based imagery to identify development patterns throughout a country. Stratified sampling technique harnessing traditional land use interpretation methods modified to characterise building patterns can be combined with EO and in-field building characteristics to capture the distribution of building types. These protocols and standards will be developed for broad application to ODA countries and will be tested and validated for both Nepal and Tanzania to assure they are fit-for-purpose.

Detailed building data collected on the ground for the cities of Kathmandu (Nepal) and Dar es Salaam (Tanzania) will be used to compare and validate the EO generated exposure datasets. Objectives of the project look to: deliver exposure data for 47 of the least developed ODA countries, including Nepal and Tanzania; create hazard footprints for the specific countries; create open protocol; to develop critical exposure information from EO data; and capacity-building of local decision makers to apply data and assess hazard exposure. The eight work packages (WP) that make up the METEOR project are outlined below in section 1.4.

1.4. WORK PACKAGES

Outlined below are the eight work packages that make up the METEOR project, which are led by various partners. Table 2 provides an overview of the work packages together with a brief description of what each of the work packages cover.

Work Package	Title	Lead	Overview
WP.1	Project Management	BGS	Project management, meetings with UKSA, quarterly reporting and the provision of feedback on project deliverables and direction across primary stakeholders.
WP.2	Monitoring and Evaluation	OPM	Monitoring and evaluation of the project and its impact, using a theory of change approach to assess whether the associated activities are leading to the desired outcome.
WP.3	EO Data for Exposure Development	ImageCat	EO-based data for exposure development, methods and protocols of segmenting/classifying building patterns for stratified sampling of building characteristics.
WP.4	Inputs and Validation	HOT	Collect exposure data in Kathmandu and Dar es Salaam to help validate and calibrate the data derived from the classification of building patterns from EO-based imagery.
WP.5	Vulnerability and Uncertainty	GEM	Investigate how assumptions, limitations, scale and accuracy of exposure data, as well as decisions in data development process lead to modelled uncertainty.
WP.6	Multiple Hazard Impact	BGS	Multiple hazard impacts on exposure and how they may be addressed in disaster risk management by a range of stakeholders.
WP.7	Knowledge Sharing	GEM	Disseminate to the wider space and development sectors through dedicated web-portals and use of the Challenge Fund open databases.
WP.8	Sustainability and Capacity-Building	ImageCat	Sustainability and capacity-building, with the launch of the databases for Nepal and Tanzania while working with in-country experts.

Table 2: Overview of METEOR Work Packages

2. Introduction

This document is an addendum to the “METEOR Exposure Data Classification, Metadata Population and Confidence Assessment Report. M3.2/P” (Huyck, et al., 2019) that provides additional information that will be useful in the context of the Level 1 building exposure database developed for 47 ODA countries (see Table 3, column 1 on page 15). A Level 1 database is large scale in effort (typically global or continental), which traditionally relies on global data sets as primary sources for exposure development. The project team used various earth observation (EO) data sets and derived EO products to classify homogenous regions with various levels of urbanity, ranging from rural to residential to urban cores to industrial zones. Each of these homogenous regions, identified as “development patterns”, are linked to a “mapping scheme”, or distribution of structural attributes and profiles of a given development pattern. These mapping schemes are created by engineers who source scholarly journals, building codes and satellite/ground imagery to identify a country’s traditional construction techniques, typical construction materials and level of engineering requirements to assist with estimations of vulnerability classes and replacement costs. Assignments of structural distributions for each development pattern within each country are then constructed with the assistance of country-wide census data and observations of satellite/ground imagery. The resultant exposure database can ultimately be used to model the losses from a number of natural physical phenomena, such as earthquake and flood.

The set of Level 1 exposure data and additional information on how the data was produced can be found on the METEOR explorer website: METEOR Explorer (maps.meteor-project.org).

More detailed descriptions of the sources and processes described prior can be found throughout the document. In Section 3, we identify the five levels of building exposure data, and categorize the variations in detail and usage for each level. Section 0 provides background on identification of the development patterns unique to each country, and describes how they are instrumental to the exposure development process. Section 5 summarizes the research procedures and sources for identifying a country’s unique structural characteristics, which are ultimately required for vulnerability modelling and loss estimations. Procedures for construction mapping schemes, or distribution of structural types, for each development pattern are also included. Section 5.3 provides an overview of estimation and development of replacement costs, unique to each individual country and development pattern.

3. Levels of Exposure Data

The “Levels” proposed below provide a general framework for communicating the approach and spatial scale of data used to create exposure data. These levels indicate only the most fundamental methods of compiling exposure data and are not designed to impart the complexity involved in a given exposure development project. Although classes are numeric, the results of a Level 5 analysis are not necessarily more accurate than from a Level 1 analysis. Comparatively, as the scale is ascended, the methods used to create the data have generally included more detail and greater effort. An exposure data set with a higher-class may produce less accurate results, however, due to how the data is processed and the accuracy of key parameters - particularly attributes that directly impact the inferred value of building stock (count of buildings, total building area, and replacement cost per square meter). These levels apply solely to the general building stock exposure development process and do not incorporate efforts to update hazard or adjust vulnerability functions. Much of the material in this section is covered in “METEOR: Exposure Data Classification, Metadata Population and Confidence Assessment Report Number: M3.2/P” (Huyck, et al., 2019), but is covered here in summation and with the insight of lessons learned throughout the METEOR project.

This documentation for M3.5 is catered towards Level 1 building exposure data; however it is important for the reader to understand the various levels and differentiations of each exposure database, therefore it has been considered in the following text.

3.1. INTRODUCTION TO THE BUILDING EXPOSURE LEVELS

The discussion below provides a brief description of the five levels of exposure data. A numeric code is used, ranging from 1 to 5, with the first three levels indicating the scale of the source data used as a global data set for Level 1, a national data set for Level 2, and a sub-national data set for Level 3. The final two classes are primary source building level data, as points or footprint polygons, where Level 4 aggregates the building data to user defined zones or grids and Level 5 retains the building-level information for each property without aggregation. Below, we discuss each level in greater detail. It is important to recognize that there is considerable leeway in these classifications, and that the purpose is to communicate the level of effort and type of products integrated into a building exposure product. The differences between some levels are subtle, and subject to user discretion.

3.1.1. Level 1: Global data

Level 1 is exposure data that does not reach the level of a national-level default. Typically available globally, available country-specific information is minimal. Global population data sets are used as a primary source, with the number of buildings or square footage inferred from a few additional attributes - the number of people per household, and very rough mapping schemes often broken down by “urban” and “rural” areas. Structural distribution by building type may be estimates gleaned from the Earthquake Engineering Research Institute (EERI) World Housing Encyclopedia (WHE) for a given country, or neighbouring countries may be used as a proxy. These may or may not include square footage information and replacement cost, as the general purpose is to evaluate the population exposure to risk. The GED4ALL (Henshaw, et al., 2018), GAR (De Bono & Chatenoux, 2015), and the exposure data behind PAGER (Jaiswal & Wald, 2008) are examples of global data sets. Even though the data is provided on a global basis, the metadata and accuracy will vary based on several aspects, including the accuracy of the census data from which population data was developed, the size of the underlying census units, the accuracy of the people per household estimate, and the accuracy of estimated structural distribution. Sample Level 1 data is illustrated for Los Angeles in Figure 1 and for Nepal in Figure 2.

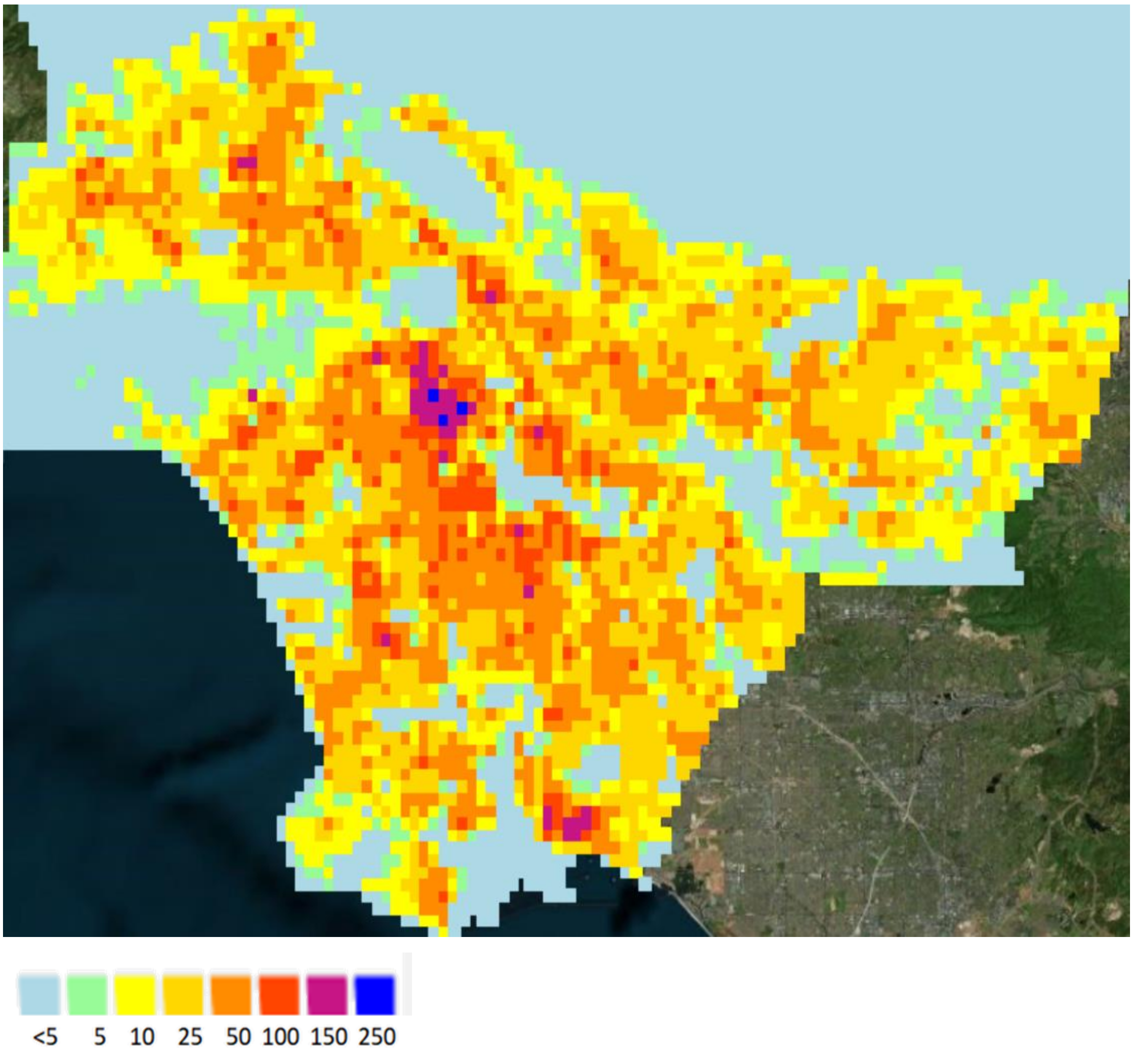

Figure 1: Level 1 data for Los Angeles County: Building Exposure in Millions of USD per 15 arc second (Source: GEM OpenQuake, viewed on ESRI Basemap World Image layer)[1]

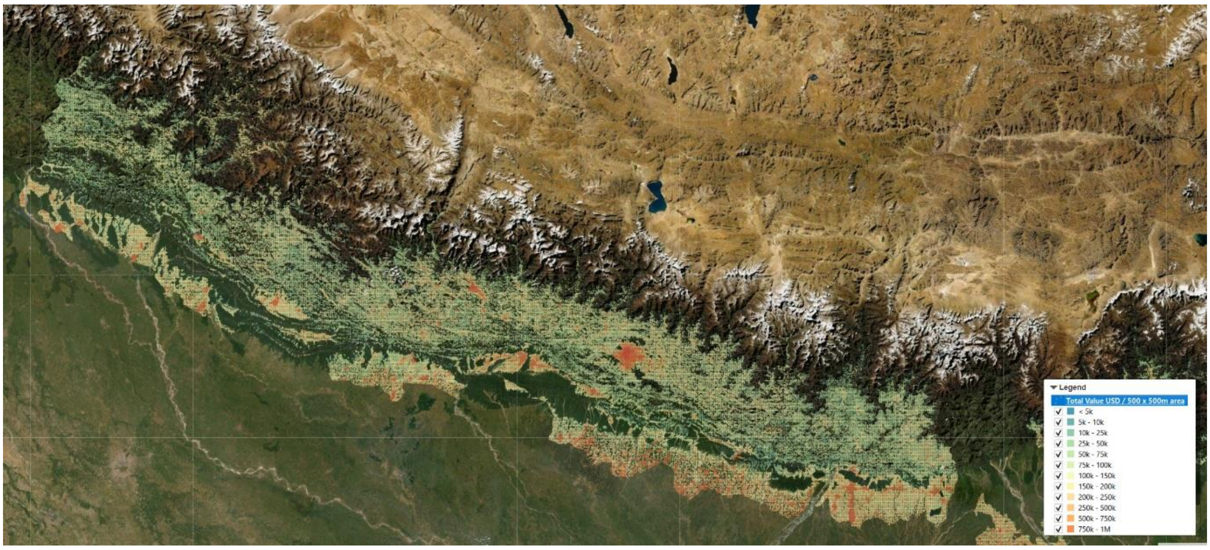

Figure 2: Level 1 data for Nepal: Building Exposure in Millions of USD per 15 arc second. (Source: METEOR project, https://maps.meteor-project.org/; data publication date: May 05, 2020; data licensed under the CC BY-NC-SA 4.0 licence)

[1] ESRI Basemap World Imagery – Source: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

3.1.2. Level 2: Country-level exposure data

For a Level 2 data set, exposure data has been collected and reviewed at the country level, with structural building type distributions and key figures such as the number of people per household and building replacement cost per square foot adjusted with country-specific data where possible. Data is reviewed and validated at the national level. An example of this type of data would include the building exposure data delivered *as a default* in the U.S. Government's loss modelling software HAZUS (FEMA, 2018). Users receive the countrywide default data and tailor the data and assumptions for their area of interest. The data may contain adjustments for local regions, but these adjustments are made at *the national scale*. For example, there may be an adjustment to estimates of persons per household, building area, or replacement cost for various regions of a country, but these improved estimates were most likely gleaned from census data or national scale reports by Non-Governmental Organisations (NGOs), the national statistical office, or other agency that might track data useful for a proxy. Sample Level 2 data is illustrated for Los Angeles in Figure 3.

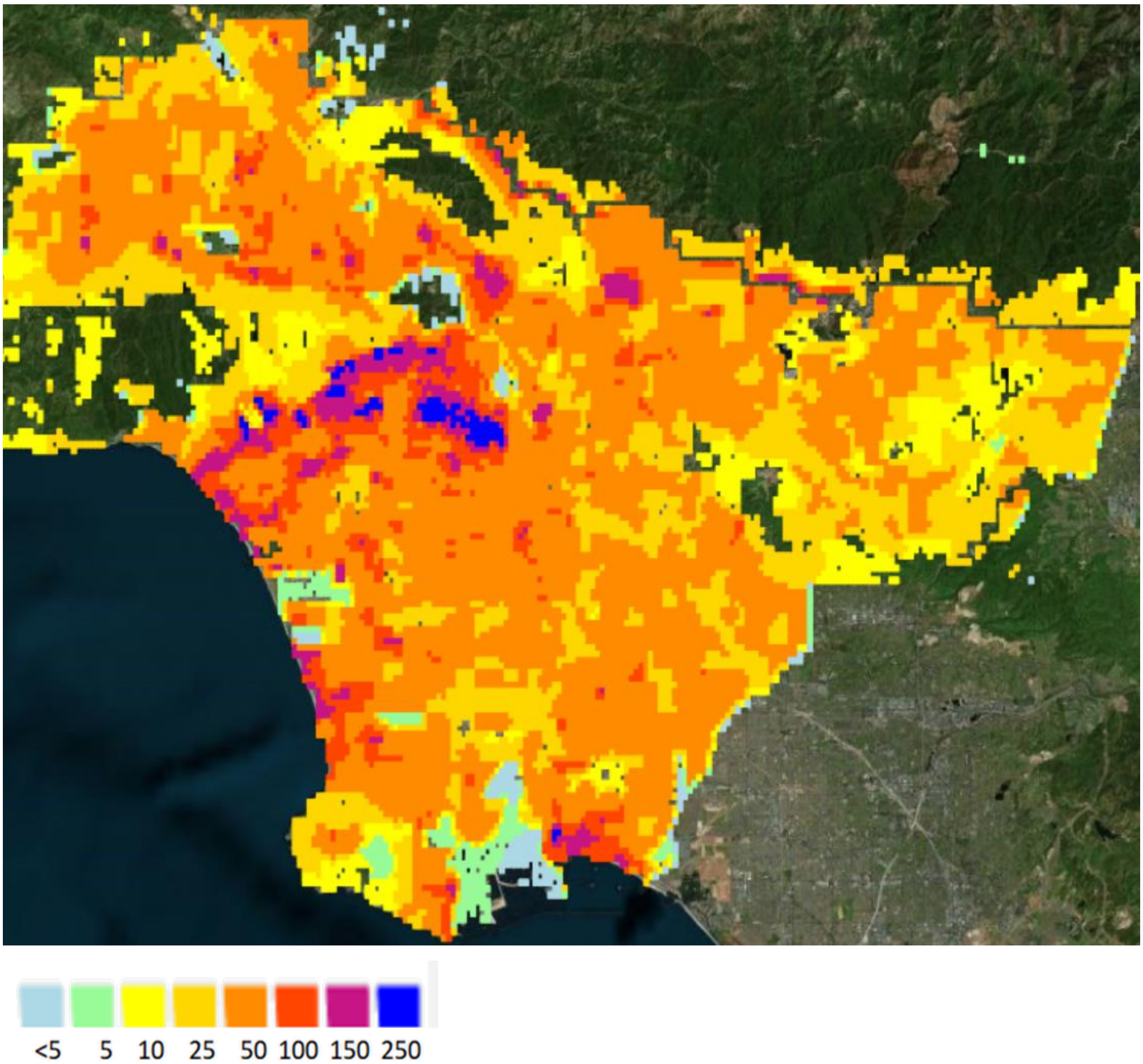

Figure 3: Level 2 data for Los Angeles County: Building Exposure in Millions of USD per 15 arc second (Source: FEMA HAZUS Program, resampled, displayed on ESRI Basemap World Image layer)[2]

[2] ESRI Basemap World Imagery – Source: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

3.1.3. Level 3: Data improvement at the sub-national scale

Level 3 goes beyond Level 2 by providing improved data on a regional scale that is either local in nature or was developed by the project team. For the general building stock, examples include 1) subdividing the country by climate or cultural regions to reflect construction patterns, 2) identifying major urban areas and enhancing building counts or structural mapping schemes in these areas, 3) reflecting development patterns throughout the country or in major urban areas with remote sensing data, 4) using dasymetric mapping (FEMA, 2015) to more accurately distribute exposure throughout large administrative regions, 5) digitizing or acquiring building footprint data to adjust building count and building size estimates, or 6) reflecting the quality of construction in building cost estimates. A specific Level 3 project may incorporate all of these methods or none of them. There are many ways of improving data at a sub-national scale, and it is particularly important to communicate to end users the process of updating the data. Level 3 data will typically be delivered along with Level 5 data beyond the general building stock, including specific locations of major essential facilities such as government buildings, schools, hospitals, or emergency operations centers. Depending on the specific purpose of collecting the data, lifelines and utilities typically have some level of representation, such as road networks, bridges, or locations of major power plants. In some cases, specific areas of the study region may be aggregated from location specific building data (either point or polygonal representations), but if building counts and areas rely entirely or almost entirely on building-specific data, the data is “Level 4”. When integrating location-specific data, it is important to acknowledge how the data is “balanced”, or how exposure in areas without site-specific data have been scaled to be consistent with point-specific data (for example, adjusting the density of buildings given population density or the average building size of residential structures by region). Level 3 data typically requires more extensive validation than other levels to assure improvements are made without introducing error. Sample Level 3 data is illustrated for Nepal in Figure 4 and for Los Angeles in Figure 5.

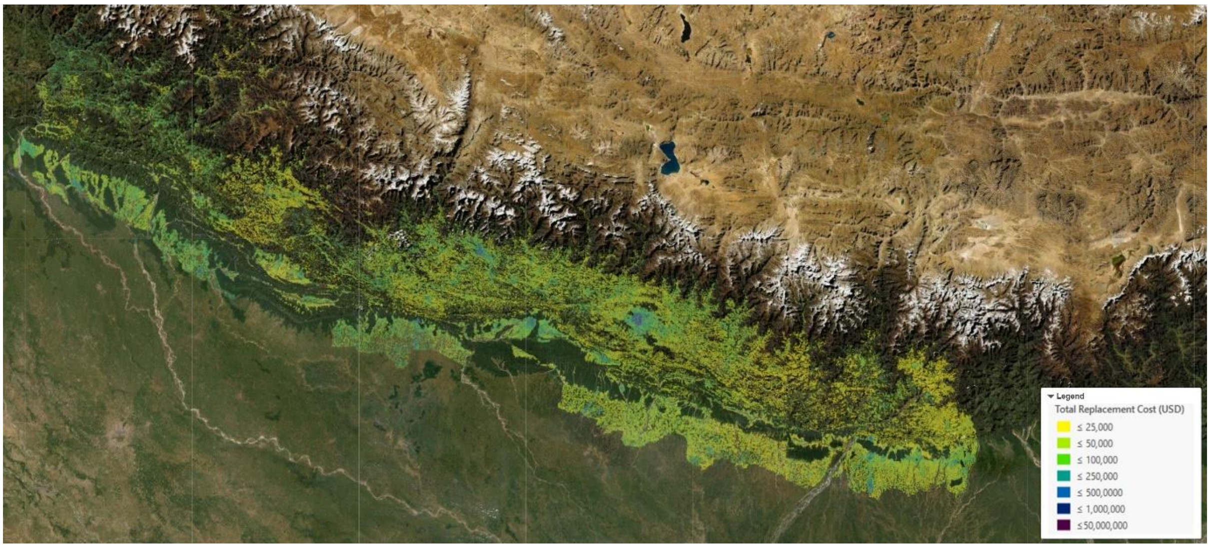

Figure 4: Level 3 data for Nepal: Building Exposure in Millions of USD per 15 arc second (Source: METEOR project, https://maps.meteor-project.org/; data publication date: Nov 02, 2020, version 2020-02-15; data licensed under the CC BY-NC-SA 4.0 licence)

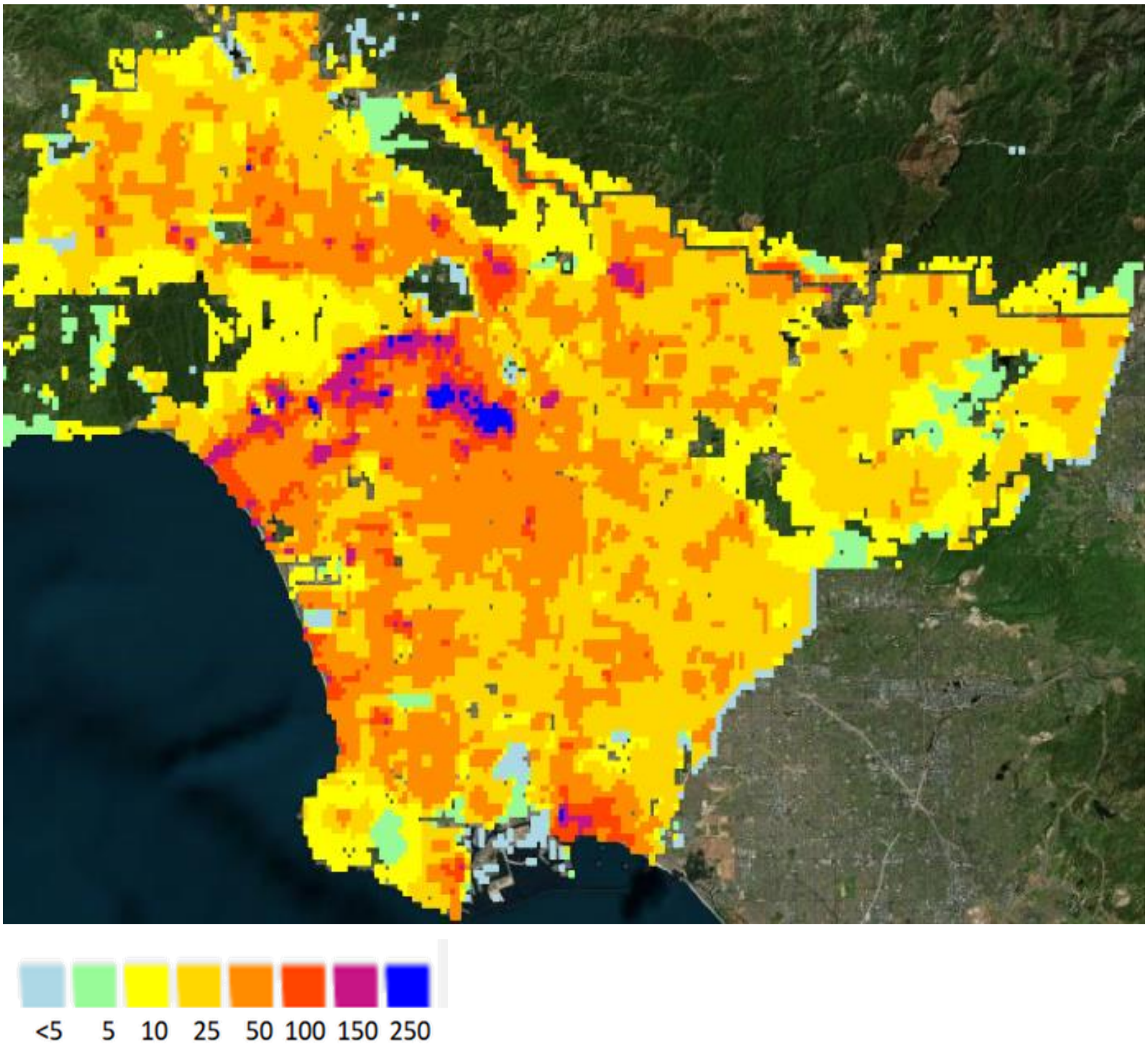

Figure 5: Level 3 data for Los Angeles County: Building Exposure in Millions of USD per 15 arc second (Source: FEMA HAZUS Program, supplemented with ImageCat valuation and inference technologies, displayed on ESRI Basemap World Image layer)[3]

3.1.4. Level 4: Aggregated building specific data

Level 4 data is based on site-specific data, such as building footprints or tax assessor data, but the data is analysed at a lower resolution in order to properly represent the diversity of assets. Building specific data is often available when a municipality has developed a detailed building footprint database, there is complete OpenStreetMap (OSM) data (OpenStreetMap, 2018), or there is a geocoded tax assessor database. But in these cases, the data was not typically collected for the purposes of risk assessment and a decision must be made as to whether to use the data at the site-specific level or to aggregate the data to a polygonal level- either a uniform grid or administrative district. The advantage to aggregating the data is that inferred data such as structural and occupancy distribution, height distribution and other fields key to assessing vulnerability can be linked to aggregated data and will not be mistaken for point-specific data. The disadvantage is that some of the spatial accuracy is lost. In some cases, point data without detailed attributes can be used by a model with the distribution of key attributes provided separately for an internal Monte Carlo simulation. Level 4 data for Los Angeles is illustrated in Figure 6.

[3] ESRI Basemap World Imagery – Source: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

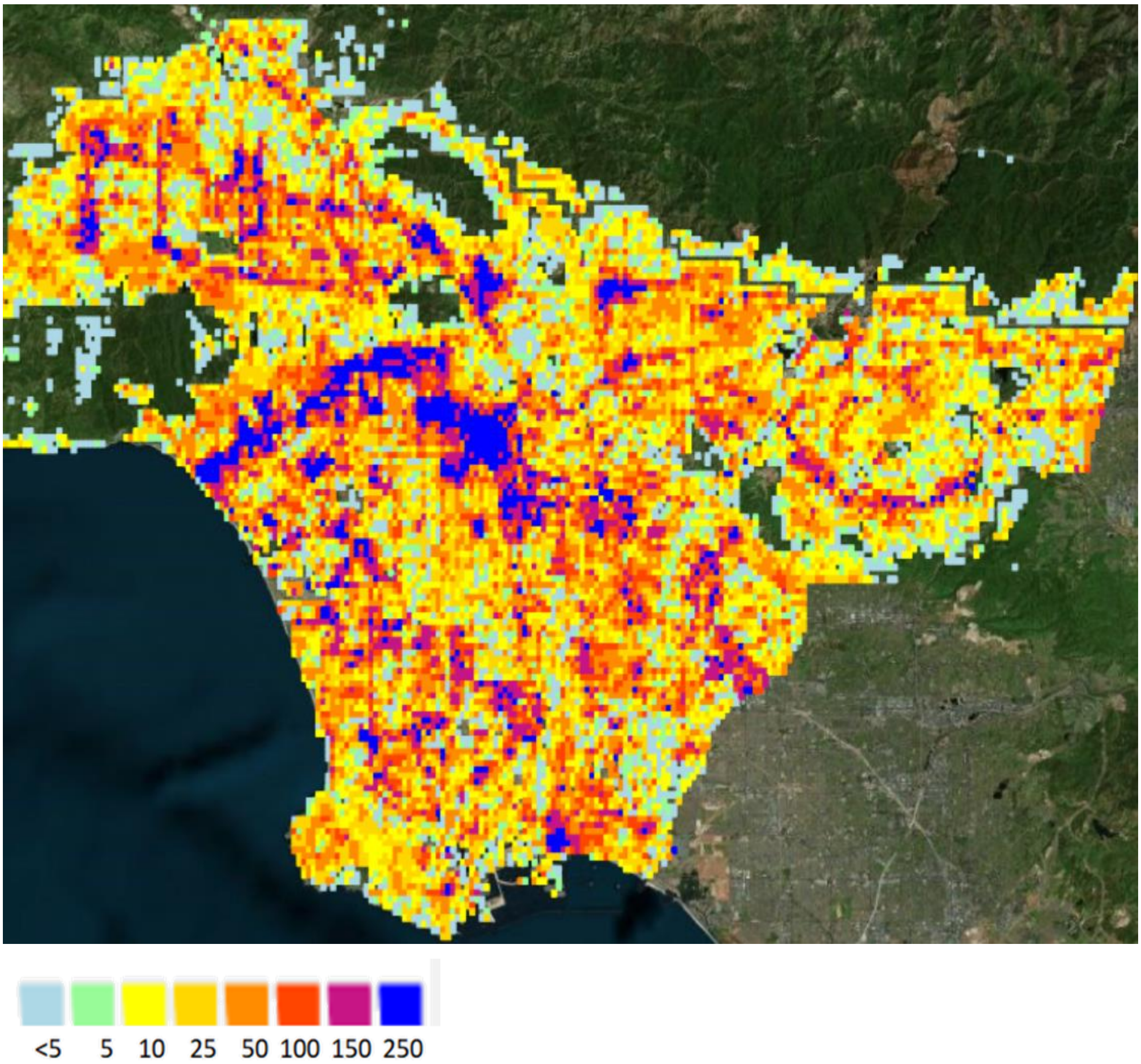

Figure 6: Level 4 data for Los Angeles County: Building Exposure in Millions of USD per 15 arc second (Source: FEMA HAZUS Program, supplemented with ImageCat valuation and inference technologies and Microsoft Bing building footprints, displayed on ESRI Basemap World Image layer)[4]

3.1.5. Level 5: Site-specific data

As noted above, jurisdictions will often have location-specific information about the locations of buildings from digitized footprints or logs of addresses. Where there is adequate building-specific data available to characterize risk for each site, it is possible to include each location as an asset as part of Level 5 data. There may also be cases in which the data has been collected or augmented after collection to characterize the site level risk (i.e., assigning material codes and date of construction to construction types based on height). In these cases, the assumptions used to produce a Level 5 need to be transparent to the end user. Note, that when the data does not cover the entire area of interest, the data should be integrated into a Level 3 exposure instead of a Level 5 exposure with special attention to incorporating point data in a manner that does not skew risk. Where little is known about point specific attributes, the data should be aggregated to the finest spatial unit for a Level 4 exposure with assumptions applied statistically to each polygon. Level 5 data for Los Angeles is illustrated in Figure 7.

[4] ESRI Basemap World Imagery – Source: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

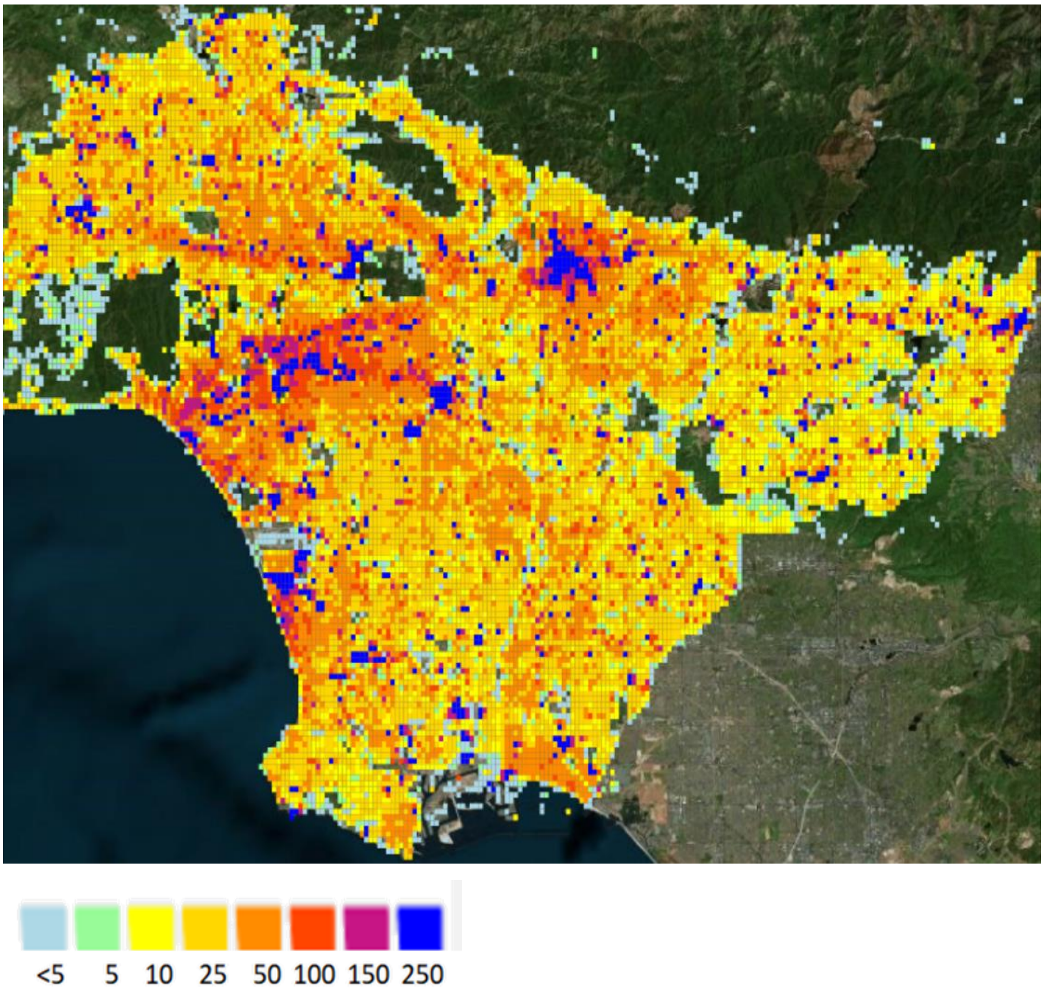

Figure 7: Level 5 data for Los Angeles County: Building Exposure in Millions of USD per 15 arc second (Source: augmented by Los Angeles County Tax Assessor data, displayed on ESRI Basemap World Image Layer)[5]

4. Development Patterns

Development patterns are used in the process of developing the Level 1 data distributed by the METEOR project. They are used to infer construction patterns and densities of buildings, and are extracted using supervised classification techniques and moderate resolution remote sensing data. Ideally, development patterns are homogenous regions within a given country that share similar built-up characteristics, such as structural types, height profiles and building densities. Each development pattern is unique and is typically indicative of the level of urbanity of a given region, ranging from rural (Development Pattern 1) to urban regions akin to a central business district (Development Pattern 6). Given the diversity of construction practices within each of the 47 ODA countries, engineers tailor these development patterns to reflect the unique built-up environment for each individual country. Figure 8 illustrates a sample map of development patterns for much of Nigeria. A visual representation of each ODA country's development pattern can be found in Appendix A. Samples are included below for Nepal (Figure 9) and Tanzania (Figure 10). Descriptions of each development pattern (identified as 1 through 7) are discussed below.

[5] ESRI Basemap World Imagery – Source: Esri, Digital Globe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

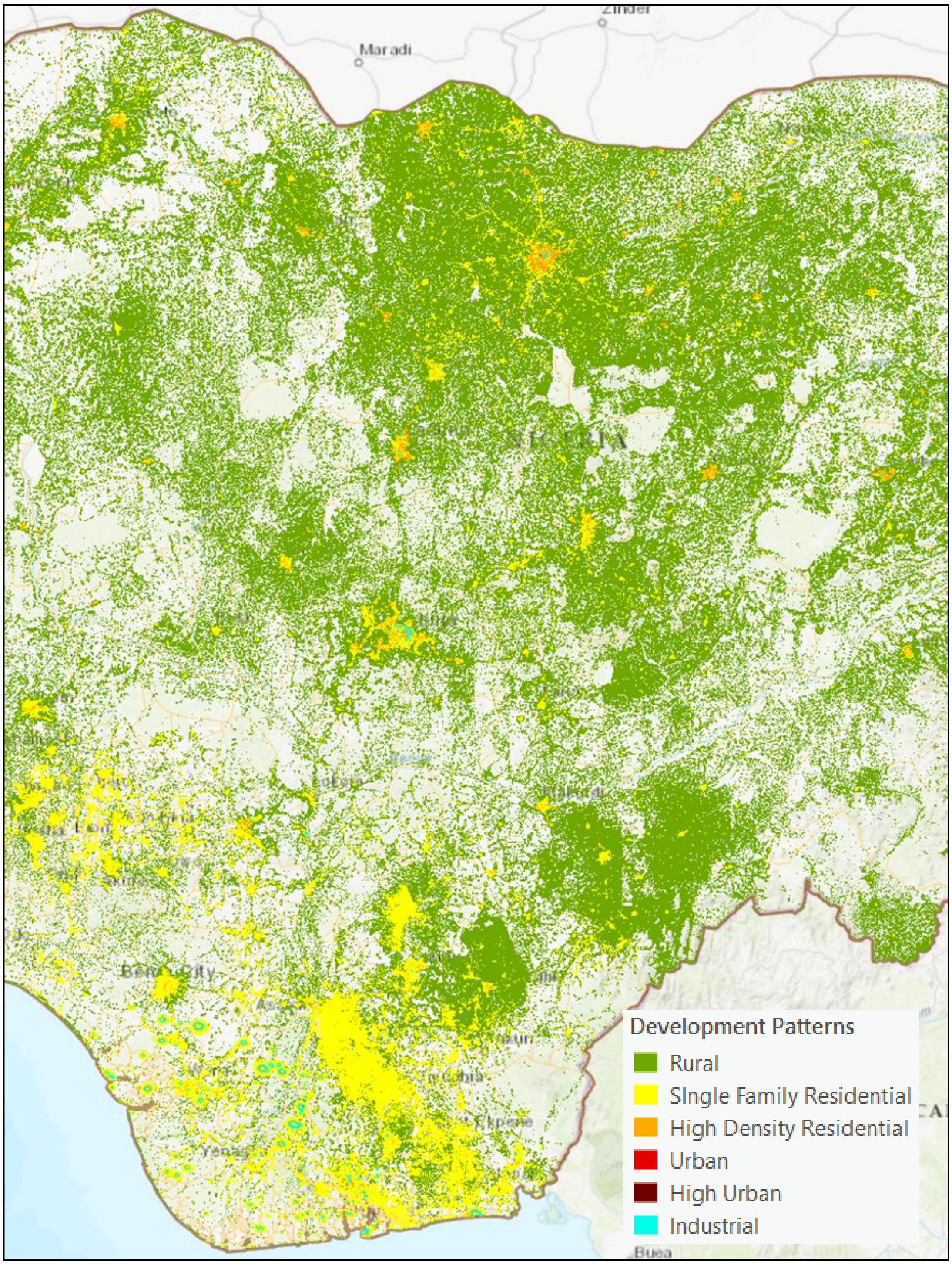

Figure 8: Example of Development Patterns for Nigeria Level 1 data (Data displayed on Esri World Topographic Basemap layer. Sources: Esri, HERE, Garmin, FAO, USGS, NGA)[6]

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[6]*Esri. Scale not Given. "World Topographic Map". 2021. Map created using ArcGIS®. Copyright © Esri. All rights reserved.*

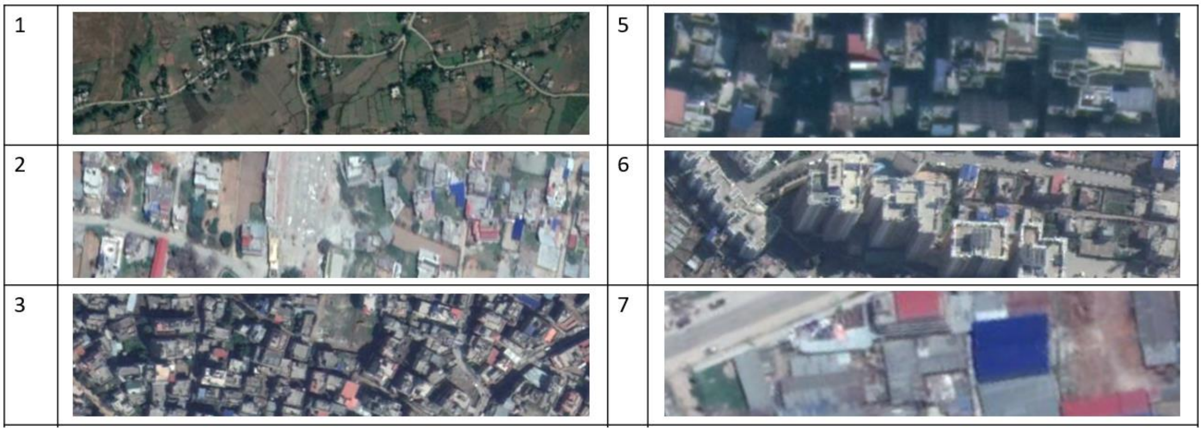


Figure 9: Samples of building patterns typical for building patterns in Nepal (GoogleEarth[7])

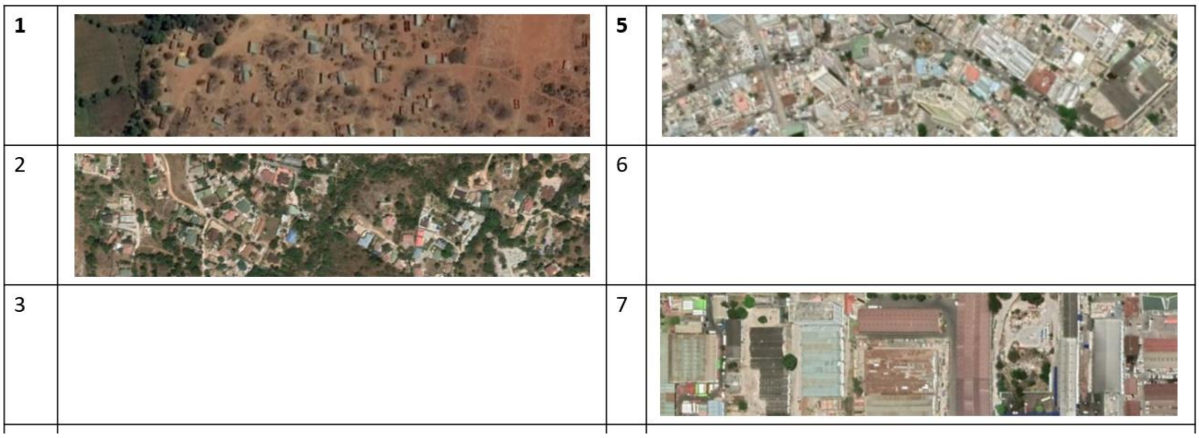


Figure 10: Samples of building patterns typical for building patterns in Tanzania (GoogleEarth[8]). Note, although development pattern 3 is found in Tanzania, it is rare and not captured in Level 1 data. Development pattern 6 is not found in Tanzania as defined below.

Development Pattern 1: This type of rural development can be found outside of city boundaries and is typically associated with agricultural development. The regions typically consist of small, remote villages with single roads in and out. Buildings are typically spaced far apart and are almost exclusively 1 to 2 stories. Local materials and construction practices are generally used and performed in these areas.

Development Pattern 2: This development pattern reflects areas typically dominated by single family residential structures. Commercial properties, such as local markets, are present, however residential structures are the primary occupancy. The built-up area is dense, however open land (yards, vacant lots, etc.) are present and can be observed via satellite imagery. All structures are low-rise, with most in the 1 to 2 story range.

Development Pattern 3: This development pattern can be characterized by structures where the majority of population lives in dense, multi-family residential housing units.

Development Pattern 4: This development pattern is typically associated with extremely dense, informal settlements. They are usually found within boundaries of large cities, and are typically comprised of very small (<100 m^2) standalone structures with little to no space between adjacent buildings. The settlement is unplanned, therefore there is no organization to the configuration of building layouts. Almost all structures are 1-story, and are typically erected using cheap and accessible local materials. Level 4 development correlates with deprived communities, but is by no means the only building pattern applicable to deprived communities. Unfortunately due to a variety

[7] Map data: Google, Maxar Technologies. Accessed in 2021
[8] Map data: Google, Maxar Technologies. Accessed in 2021

of concerns, including accuracy of classification at the national level, Level 4 is not distinguished in the Level 1 METEOR product.

Development Pattern 5: This development pattern is characterized by urban areas predominately occupied by low to mid-rise residential and commercial structures. An occasional high-rise apartment or office building may be present. These developments are typically found near or around major city centers. Buildings are tightly spaced and are fairly regular in shape.

Development Pattern 6: This development pattern is similar to the central business district of any major city. Mid to high-rise apartments and commercial offices occupy most of the area, however low-rise commercial and residential structures can be situated in between. Typical of an urban area, buildings are spaced relatively close and building layouts of both building and city blocks are structured.

Development Pattern 7: This development pattern is characterized by areas dominated by ports, mining or industrial activities. Structures are typically closely spaced and regular in shape. A majority of buildings within these regions are warehouses, rectangular shape and single story. Smaller low-rise, office and commercial structures can also be found on site.

It should be acknowledged that every development pattern may not be observed within an individual country. Development Pattern 4 (informal construction or slums) was not considered for the Level 1 analysis. This development pattern may be considered in other levels of building exposure (as described in Section 0), however the location and size of the settlements are often too small or difficult to distinguish via visual survey of satellite imagery. Other instances such as Development Pattern 6 (high urban or central business districts) may simply not exist within the country, as is the case of Tanzania.

5. Building Attributes

Given the number of buildings and the building area in square meters in a given geographic region, the structural characteristics of the buildings are required to estimate building vulnerability and value. The accuracy of the structural assessment is key to the accuracy of the final loss estimate, thus it is important to provide a description of how the distribution is developed. The taxonomy of structural classification needs to be identified, including whether it incorporates height and vulnerability (e.g., code/pre-code, L/M/H height ranges, quality of construction).

In many cases, the structural distribution is dependent on another factor- such as whether an area is “urban” or “rural”, or if an inventoried distribution of population by occupancy is available. These are generally called “mapping schemes”, which will be discussed further in Section 5.1.

In creating global data sets, the methods might be very crude- such as simply reviewing the literature available for each country. In many cases there might not be data available for a particular country so data for a neighbouring country is used in its place. The source of any published material needs to be explicit. If expert opinion is used, experts should be named, and a description of the interview process should accompany the data. For example, an author might note: 1*) a workshop was held on 9/9/18 at Jurisdiction Civic Center, with 20 local engineers from the surrounding communities. They were presented with a questionnaire included in Appendix X*, or 2) *5 local engineers were contacted through LinkedIn and paid a small stipend to estimate the percentage of structural building stock by land use class.*

Structural distributions can be garnered from surveys, or in some cases inferred from existing databases. Surveys can be quite extensive, covering nearly every building, or they can be quite sparse, representing a tiny fraction of the exposure and conducted through a review of Street View data. Users need to know approximately how many buildings were surveyed where, by whom, how, and what assumptions were made. For example, *1) 4 teams of 4 engineering students surveyed approximately 200 buildings throughout a jurisdiction over 3 days. Results of the survey were reviewed by local engineers. The resulting database was used to characterize the structural distribution pattern by land use class which was applied for the entire country*, or *2) Google Street View and Bing Streetside was available for some urban areas. This data was used to review approximately 1000 buildings. Preliminary review was conducted by staff, with triaging of unclear* *determinations to a Professional Engineer. Many buildings had stucco cladding, it was assumed that x% was wood frame and x% URM, based on a review of data available from the World Housing Encyclopaedia. This assumption was confirmed by Professor Grey at the University of Country.* In some cases, there may be regional adjustments to reflect changes- for example, Northern vs. Southern construction. These variations must be clear to the end user, and the logic for the adjustment needs to be provided.

In other cases, a third party may have collected data that can be used to infer structural type- such as a preliminary assessment through crowdsourced data collection, or a fire code collected by a tax assessor. In these cases, the developers must provide a “mapping” of the provided data to the structural class used, including any partial distributions and the logic behind them. For example, *high rise inflammable classification mapped to 75% steel frame, 25% reinforced concrete based on Senior Structural Engineer review of digital photos, construction reports, and images of buildings captured by Google Street View during construction can be confirmed by a local engineer.*

5.1. STRUCTURAL ASSUMPTIONS

Construction practices are unique for every country and are often influenced by availability of certain building materials, traditional construction techniques, enforcement (or lack) of a national building code, and many other geographic and political factors. A basic understanding of these country-specific building techniques is first required when preparing development of a Level 1 exposure database. The user must understand what is involved in the construction process, and ultimately how knowledge of these structural materials and gravity/lateral force resisting systems can appropriately be modelled to a specified taxonomy for vulnerability modelling.

To identify country-specific structural types, an engineer first conducts a web reconnaissance survey of available data. Various engineering websites and standards such as World Housing Encyclopedia [WHE] (db.world-housing.net), Prompt Assessment of Global Earthquakes for Response [PAGER], Global Earthquake Model [GEM] (Brzev, et al., 2013), country-specific building codes (if applicable), country-specific Housing and Population Census data, country-specific Post Disaster Needs Assessment (PDNA) and other scholarly journals are sourced for region specific structural data. These sources will either provide basic structural information (wall, roof and flooring material) or detailed, engineering data (structural systems, building processes, typical reinforcement, structural deficiencies, etc.). These resources will provide, at minimum, a basic understanding of region-specific structural systems that were ultimately used for mapping vulnerability to the applicable PAGER taxonomy. Where alternate building taxonomies were required, the appropriate mapping was implemented, as described in Section 0.

For the Level 1 Building Exposure database, information obtained from census data or scholarly and technical reports was available for every country. These assumptions are cross-checked with visual observations, either through Google Street View, Mapillary Street View and/or user submitted photos/videos to ensure consistency. For example, if census data identifies unreinforced masonry as a primary structural system, an analyst can determine through street view imagery whether rubble stone, fired brick, adobe, etc. can be assumed. For each of the 47 countries, we identify which common, publicly available resources were used to establish both the common construction practices and preliminary structural distributions, as shown in Table 3. Google Street View was limited in coverage, however (where available) allowed easy access to both satellite imagery and georeferenced ground imagery. Correlations between roof type, shape and material visible through satellite imagery, and structural type and/or materials could be made between the two sets of imagery. On few occasions, buildings currently under construction allowed the analyst to observe and verify the original structural assumptions regarding the country’s typical building practices, without the obstruction of an exterior façade on the finished building. Mapillary Street View offers the same type of visual information. Although more countries are covered, the extent of coverage within the country is often limited to a few cities or major roads. The resolution of the street view imagery is often inferior to that of Google, however the same correlation between roof and wall materials can often be made. PAGER, IPUMS (ipums.org) and census data offer insight to the common structural types and materials (wall, roof and flooring) prevalent within a given country. Distributions (by structural type) are available for all countries within PAGER, and are provided for four types of regions: rural residential, non-rural residential, urban residential and non-urban residential. The quality and accuracy of these mapping schemes should be checked, as a country profile is often inferred by a neighboring country and/or the original source of the data is often lacking. IPUMS and Census data, particularly housing and population data, offers the user a country-specific resource for establishing structural assignments and mapping schemes. Wall, roofing and flooring materials are often listed, and provided as a percentage breakout, typically at the “rural” and “urban” level, however on occasion finer resolutions (state, county, etc.) may be provided, such as in the case with IPUMS data.

Table 3: Structural Resources by Country used in the Development of the Level 1 data

Country	Google Streetview	Mapillary Streetview	PAGER	IPUMS	Census
Afghanistan		x	x		x
Angola		x	x		x
Bangladesh	x	x	x		x
Benin		x	x	x	x
Bhutan	x	x	x		x
Burkina Faso		x	x	x	x
Burundi		x	x		x
Cambodia	x	x	x		x
Central African Republic		x	x		x
Chad		x	x		
Comoros		x	x		x
Democratic Republic of the Congo		x	x		x
Djibouti		x	x		x
Eritrea			x		x
Ethiopia		x	x	x	x
Gambia		x	x		x
Guinea		x	x		x
Guinea-Bissau		x	x		
Haiti		x	x	x	x
Kiribati			x		x
Lao People's Democratic Republic	x	x	x	x	x
Lesotho	x	x	x	x	x
Liberia		x	x	x	x
Madagascar	x	x	x		x
Malawi		x	x	x	x
Mali		x	x	x	x
Mauritania		x	x		x
Mozambique		x	x	x	x
Myanmar		x	x		x
Nepal	x	x	x		x
Niger		x	x		x
Rwanda		x	x	x	x
Sao Tome and Principe		x	x		x
Senegal	x	x	x	x	x
Sierra Leone		x	x	x	x
the Solomon Islands		x	x		x
Somalia		x	x		x
South Sudan		x	x		x
Sudan		x	x		x

Country	Google Streetview	Mapillary Streetview	PAGER	IPUMS	Census
the United Republic of Tanzania	x	x	x		x
Timor-Leste		x	x		x
Togo		x	x	x	x
Tuvalu			x		x
Uganda	x	x	x	x	x
Vanuatu	x	x	x		x
Yemen			x		x
Zambia		x	x	x	x

5.2. MAPPING SCHEMES

To create an exposure database from development patterns, “mapping schemes,” or building height and structure type distributions are linked to each zone type on an individual country basis. These mapping schemes are created by engineers specializing in risk assessment through a visual assessment of the built-up areas using reports (WHE, EERI and scholarly journals) and census data, and validating through satellite imagery and geotagged photographs.

Mapping schemes reveal the gradual shift in construction practices from the high usage of indigenous materials in the rural regions, to the more engineered structures of the urban cores, to the large warehouses of the industrial facilities. The overall height profiles, with low-rise structures in the rural regions, to mid- to high-rise structures in central business districts are also observed.

For the creation of the Level 1 country-specific mapping schemes, census data is often established as the primary source. The reason is typically two-fold: wide-availability, and differentiation of ‘rural” and “urban” region and their respective structural materials. As mentioned in Section 5.1, census data often identifies percentage breakouts of structural wall, roof and flooring materials. Using these listed structural combinations, in conjunction with information obtained from scholarly journals, additional census data (such as PAGER) and other online resources, the analyst can infer a structural type and the appropriate taxonomy required for vulnerability modeling. A baseline mapping scheme can now be established for rural and urban development patterns, based on the findings. These assumptions are sanity-checked through a visual inspection of satellite and ground imagery. Distributions for the remaining development patterns are estimated based on a visual survey of satellite and ground imagery, and observations of height profiles, roof shape/materials visible in satellite imagery and structural systems visible in ground and online imagery.

A list of mapping schemes for the 47 ODA countries can be found in Table 4 through Table 9. Each line represents the percentage breakouts for that particular development pattern and country. For example, within Development Pattern 1 (rural) for Afghanistan, it is estimated 2% of structures are low-rise, reinforced concrete frame with unreinforced masonry infill, 71% are adobe structures, 23% are unreinforced masonry (rubble stone) and 4% are unreinforced masonry (fired brick). The sum of each row will equate to 100%, recognizing all structures within that development pattern are accounted for. The building taxonomy identified in the first row is in reference to PAGER. A full structural description, as well as mapping to other taxonomies (such as GEM), is listed in Appendix B.

Country Name	W	W1	W2	W3	W5	C	C3L	RM	M	A	RE	RS	RS1	RS2	RS3	DS	UFB	UCB	INF
Afghanistan							0.02			0.71		0.23					0.04		
Angola					0.25					0.50									0.25
Bangladesh				0.04	0.09		0.16		0.15			0.01					0.07		0.48
Benin					0.04				0.25	0.67							0.05		
Bhutan	0.11	0.02	0.15				0.15			0.02	0.06		0.36		0.07		0.03	0.03	0.00
Burkina Faso					0.05				0.72									0.13	0.10
Burundi	0.00				0.02					0.51							0.41	0.06	
Cambodia		0.01		0.56	0.11												0.13	0.19	
Central African Republic	0.01				0.05		0.05		0.05	0.75							0.04		0.05
Chad					0.04				0.25	0.67							0.05		
Comoros	0.45												0.15					0.15	0.25
the Democratic Republic of the Congo	0.05				0.22				0.07	0.17			0.00				0.27	0.09	0.12
Djibouti	0.24				0.14				0.00	0.29		0.03						0.14	0.15
Eritrea	0.07				0.13		0.01					0.42			0.09		0.01	0.12	0.16
Ethiopia	0.18				0.50				0.05	0.05		0.09					0.01		0.12
Gambia									0.70	0.13								0.13	0.05
Guinea						0.02			0.32	0.44									0.22
Guinea-Bissau						0.02			0.32	0.44									0.22
Haiti				0.01			0.12					0.02						0.75	0.10
Kiribati	0.70						0.05											0.25	
the Lao People's Democratic Republic	0.82											0.09					0.09		
Lesotho					0.05					0.03		0.01		0.33	0.11		0.05	0.43	
Liberia	0.00				0.79							0.01					0.14	0.05	0.01
Madagascar	0.10				0.15					0.10								0.55	0.10
Malawi	0.01								0.36	0.47	0.03						0.13		
Mali							0.02	0.04	0.18	0.58								0.18	
Mauritania					0.25		0.35			0.25								0.15	
Mozambique	0.07								0.37	0.40							0.13	0.03	
Myanmar	0.00				0.55				0.26								0.00		0.19
Nepal	0.05				0.17					0.01		0.49					0.20		0.07
Niger					0.27					0.30							0.05		0.38
Rwanda	0.01				0.44					0.53		0.00					0.01	0.00	0.00
Sao Tome and Principe	0.60																0.15		0.25
Senegal					0.25		0.35			0.25								0.15	
Sierra Leone	0.01				0.26					0.62		0.00					0.01	0.07	0.04
the Solomon Islands	0.96																	0.02	0.02
Somalia	0.05				0.50				0.15	0.05		0.08						0.02	0.15
South Sudan	0.07				0.86				0.06								0.01		
Sudan	0.08				0.47				0.27	0.08							0.09	0.02	
the United Republic of Tanzania	0.02				0.23					0.26		0.01					0.26	0.20	0.00
Timor-Leste	0.33				0.31					0.02		0.01					0.29		0.05
Togo					0.18					0.35		0.04					0.05	0.30	0.08
Tuvalu	0.23				0.18	0.56													0.03
Uganda					0.25					0.10		0.05					0.50	0.05	0.05
Vanuatu	0.08				0.56	0.18												0.15	0.02
Yemen					0.03				0.13	0.02		0.45				0.12		0.25	
Zambia					0.08				0.10	0.31		0.05					0.25	0.21	

Table 4: Level 1 Development Pattern 1 Mapping Schemes

Country Name	W	W1	W2	W3	W5	S3	S5	C	C3L	C3M	C3H	RM	M	A	RE	RS	DS	UFB	UFB1	UCB	INF
Afghanistan									0.10					0.80				0.10			
Angola														0.30				0.10		0.50	0.10
Bangladesh				0.01	0.05				0.53				0.05			0.02		0.05			0.30
Benin				0.03						0.05	0.01		0.10	0.14				0.25		0.42	
Bhutan	0.11	0.02	0.15						0.15					0.02	0.06			0.03		0.03	0.00
Burkina Faso					0.01				0.12				0.25							0.60	0.02
Burundi	0.00				0.02									0.51				0.41		0.06	
Cambodia		0.01		0.39	0.03				0.03									0.39			0.16
Central African Republic	0.05								0.10				0.05	0.45				0.25			0.10
Chad				0.03						0.05	0.01		0.10	0.14				0.25		0.42	
Comoros	0.10								0.15							0.15		0.50			0.10
the Democratic Republic of the Congo	0.00								0.05				0.00	0.04		0.01		0.08		0.59	0.22
Djibouti	0.24				0.14								0.00	0.29		0.03				0.14	0.15
Eritrea									0.20							0.05		0.05		0.70	
Ethiopia	0.02				0.02				0.65					0.01		0.05		0.25			
Gambia									0.10				0.15	0.35						0.35	0.05
Guinea									0.05				0.15	0.20						0.45	0.15
Guinea-Bissau									0.05				0.15	0.20						0.45	0.15
Haiti									0.25							0.05				0.55	0.15
Kiribati	0.70								0.05											0.25	
the Lao People's Democratic Republic	0.10								0.10									0.40		0.40	
Lesotho																0.05		0.10		0.85	
Liberia	0.01				0.21											0.07		0.20		0.41	0.11
Madagascar	0.10								0.10									0.75			0.05
Malawi	0.03								0.04				0.19	0.10				0.50		0.14	
Mali	0.06								0.04			0.08		0.36						0.46	
Mauritania									0.55				0.10	0.05						0.30	
Mozambique									0.35			0.17								0.42	0.06
Myanmar	0.24				0.41								0.00					0.32			0.03
Nepal					0.01	0.02	0.02		0.49	0.22				0.01					0.22		
Niger					0.05									0.50				0.30			0.15
Rwanda	0.00				0.21									0.66		0.00		0.09		0.03	0.00
Sao Tome and Principe	0.60																	0.25			0.15
Senegal									0.55				0.10	0.05						0.30	
Sierra Leone	0.01				0.03									0.36		0.00		0.00		0.48	0.11
the Solomon Islands	0.78																			0.16	0.06
Somalia					0.05									0.05		0.05				0.65	0.20
South Sudan	0.11				0.67								0.07					0.11			0.04
Sudan	0.01				0.11								0.34	0.06				0.44		0.05	
the United Republic of Tanzania	0.00																	0.16		0.83	0.00
Timor-Leste	0.14				0.03			0.00	0.00					0.00		0.00		0.75			0.08
Togo														0.15		0.01		0.15		0.64	0.05
Tuvalu	0.56				0.01			0.41													0.02
Uganda					0.05				0.43					0.11				0.35		0.06	
Vanuatu	0.14				0.03			0.48												0.31	0.05
Yemen					0.01								0.06	0.03		0.17	0.17			0.57	
Zambia														0.10		0.01		0.50		0.39	

Table 5: Development Pattern 2 Mapping Schemes

Country Name	W	W5	S3	S5	C	C3L	C3M	C3H	M	A	RS	DS	UFB	UCB	INF
Afghanistan						0.12				0.55	0.02		0.31		
Angola						0.25				0.10			0.50		0.15
Bangladesh						0.50	0.10						0.30		0.10
Benin															
Bhutan															
Burkina Faso		0.01				0.20			0.17					0.60	0.02
Burundi		0.01				0.10				0.24			0.56	0.09	
Cambodia						0.90							0.10		
Central African Republic						0.15				0.40			0.20	0.10	0.15
Chad															
Comoros															
the Democratic Republic of the Congo						0.15							0.05	0.75	0.05
Djibouti	0.05					0.15					0.05			0.70	0.05
Eritrea							0.40						0.05	0.55	
Ethiopia						0.08	0.90						0.02		
Gambia						0.45				0.05				0.45	0.05
Guinea						0.40	0.05			0.10				0.35	0.10
Guinea-Bissau						0.40	0.05			0.10				0.35	0.10
Haiti						0.25								0.65	0.10
Kiribati	0.35					0.45								0.20	
the Lao People's Democratic Republic	0.05					0.40	0.05						0.25	0.25	
Lesotho						0.10					0.05		0.10	0.75	
Liberia	0.15					0.05							0.45	0.25	0.10
Madagascar	0.10					0.10							0.75		0.05
Malawi															
Mali															
Mauritania						0.20	0.70							0.10	
Mozambique						0.20	0.53							0.27	
Myanmar	0.05					0.25	0.40						0.25		0.05
Nepal			0.01	0.00		0.37	0.35	0.01					0.26		0.00
Niger						0.90				0.05			0.05		
Rwanda						0.35	0.05						0.45	0.15	
Sao Tome and Principe	0.40					0.20							0.35		0.05
Senegal						0.20	0.70							0.10	
Sierra Leone	0.01	0.00								0.15	0.00		0.00	0.62	0.20
the Solomon Islands															
Somalia						0.15	0.10	0.02			0.13			0.40	0.20
South Sudan	0.10					0.20							0.30	0.30	0.10
Sudan	0.03					0.30	0.02			0.10			0.45	0.10	
the United Republic of Tanzania															
Timor-Leste						0.20							0.65	0.10	0.05
Togo						0.40							0.15	0.35	0.10
Tuvalu	0.56	0.01			0.41										0.02
Uganda						0.45	0.50						0.05		
Vanuatu	0.05				0.80									0.15	
Yemen						0.40	0.20				0.05	0.05		0.30	
Zambia						0.15							0.50	0.35	

Table 6: Development Pattern 3 Mapping Schemes

Country Name	W	W1	W2	W3	W5	S1L	S1M	S3	S5	C	C3L	C3M	C3H	RM	M	A	RE	RS	RS1	RS3	UFB	UCB	INF
Afghanistan											0.50	0.25	0.01			0.15					0.09		
Angola											0.25	0.50	0.15									0.10	
Bangladesh											0.05	0.60	0.05								0.30		
Benin											0.20	0.01									0.19	0.60	
Bhutan	0.05	0.04	0.06								0.40	0.13				0.02	0.02		0.07	0.07	0.07	0.06	0.00
Burkina Faso											0.37	0.01			0.10							0.50	0.02
Burundi											0.20	0.05									0.65	0.10	
Cambodia				0.10							0.70	0.05									0.10		0.05
Central African Republic											0.20	0.10				0.25					0.15	0.20	0.10
Chad											0.20	0.01									0.19	0.60	
Comoros	0.05										0.25							0.05			0.60		0.05
the Democratic Republic of the Congo											0.53	0.28	0.02									0.18	
Djibouti											0.50	0.05										0.45	
Eritrea										0.15	0.30	0.25										0.30	
Ethiopia	0.02	0.02									0.65					0.01		0.05			0.25		
Gambia											0.45					0.05						0.45	0.05
Guinea											0.50	0.15	0.05									0.25	0.05
Guinea-Bissau											0.50	0.15	0.05									0.25	0.05
Haiti											0.35	0.15										0.40	0.10
Kiribati	0.35										0.45											0.20	
the Lao People's Democratic Republic	0.03										0.50	0.35	0.02								0.05	0.05	
Lesotho											0.15	0.20	0.05								0.25	0.35	
Liberia											0.29	0.30	0.01								0.25	0.10	0.05
Madagascar											0.10	0.15									0.50	0.25	
Malawi							0.01				0.20			0.01							0.52	0.26	
Mali											0.42	0.08		0.15							0.03	0.32	
Mauritania											0.70	0.10				0.05						0.10	0.05
Mozambique						0.01	0.01				0.30	0.55		0.03							0.01	0.09	
Myanmar											0.05	0.85	0.05								0.05		
Nepal								0.00	0.00		0.14	0.56	0.03								0.26		
Niger					0.05						0.20					0.50					0.25		
Rwanda										0.05	0.50	0.10									0.20	0.15	
Sao Tome and Principe	0.40										0.20										0.35		0.05
Senegal											0.70	0.10				0.05						0.10	0.05
Sierra Leone											0.35	0.25	0.05								0.30	0.05	
the Solomon Islands																							
Somalia											0.30	0.30	0.05					0.10				0.15	0.10
South Sudan	0.10										0.40	0.10									0.20	0.20	
Sudan											0.50	0.15									0.30	0.05	
the United Republic of Tanzania								0.01		0.05	0.26	0.10	0.03									0.53	0.02
Timor-Leste											0.50	0.25									0.15	0.10	
Togo											0.50	0.15	0.01								0.10	0.24	
Tuvalu	0.56				0.01					0.41													0.02
Uganda					0.05						0.54	0.25				0.04					0.10	0.02	
Vanuatu	0.05									0.80												0.15	
Yemen											0.25	0.30	0.05									0.40	
Zambia											0.15	0.50	0.15									0.20	

Table 7: Development Pattern 5 Mapping Schemes

Country Name	W3	S5	C1H	C3L	C3M	C3H	A	UFB	UCB	INF
Afghanistan										
Angola										
Bangladesh			0.04	0.10	0.60	0.16		0.10		
Benin										
Bhutan										
Burkina Faso										
Burundi										
Cambodia	0.05			0.60	0.20	0.05		0.08		0.03
Central African Republic										
Chad										
Comoros										
the Democratic Republic of the Congo										
Djibouti										
Eritrea										
Ethiopia				0.30	0.35	0.25		0.10		
Gambia										
Guinea										
Guinea-Bissau										
Haiti										
Kiribati										
the Lao People's Democratic Republic										
Lesotho										
Liberia										
Madagascar										
Malawi										
Mali										
Mauritania										
Mozambique				0.21	0.70			0.07	0.02	
Myanmar										
Nepal		0.03		0.17	0.45	0.08		0.28		
Niger				0.25	0.65		0.05	0.05		
Rwanda										
Sao Tome and Principe										
Senegal				0.15	0.55	0.20			0.10	
Sierra Leone										
the Solomon Islands										
Somalia										
South Sudan										
Sudan										
the United Republic of Tanzania										
Timor-Leste										
Togo										
Tuvalu										
Uganda				0.35	0.60			0.05		
Vanuatu										
Yemen										
Zambia										

Table 8: Development Pattern 6 Mapping Schemes

Country Name	W	W5	S	S3	S5	C	C3L	C3M	RM	A	RS	UFB	UCB	INF
Afghanistan			0.25				0.25					0.50		
Angola							0.50					0.50		
Bangladesh			0.25				0.25					0.40		0.10
Benin							0.30					0.20	0.50	
Bhutan														
Burkina Faso							0.50						0.50	
Burundi				0.05			0.60					0.05	0.30	
Cambodia				0.25			0.50					0.20		0.05
Central African Republic							0.30					0.30	0.25	0.15
Chad							0.30					0.20	0.50	
Comoros			0.10				0.60						0.30	
the Democratic Republic of the Congo							0.25						0.75	
Djibouti			0.25				0.15					0.50		0.10
Eritrea				0.40			0.30					0.15	0.15	
Ethiopia							0.90				0.03	0.07		
Gambia														
Guinea			0.10				0.40						0.40	0.10
Guinea-Bissau			0.10				0.40						0.40	0.10
Haiti			0.65				0.15						0.20	
Kiribati														
the Lao People's Democratic Republic				0.25			0.50					0.13	0.12	
Lesotho				0.05			0.10					0.35	0.50	
Liberia							0.40					0.20	0.40	
Madagascar							0.25					0.75		
Malawi			0.20				0.32		0.11			0.30	0.07	
Mali	0.09		0.08				0.49		0.15				0.19	
Mauritania				0.55			0.35						0.10	
Mozambique			0.47				0.28		0.18				0.07	
Myanmar			0.05				0.45					0.50		
Nepal				0.09	0.03		0.28	0.23				0.35		0.02
Niger							0.70			0.20		0.10		
Rwanda							0.10					0.75	0.15	
Sao Tome and Principe														
Senegal				0.55			0.35						0.10	
Sierra Leone							0.25						0.75	
the Solomon Islands	0.20						0.15						0.40	0.25
Somalia							0.45				0.05		0.40	0.10
South Sudan							0.30					0.40	0.30	
Sudan							0.30					0.50	0.20	
the United Republic of Tanzania	0.00	0.00		0.12		0.05	0.13	0.01					0.68	0.01
Timor-Leste							0.30					0.50	0.20	
Togo							0.35					0.10	0.50	0.05
Tuvalu	0.25			0.25		0.50								
Uganda				0.05			0.79			0.04		0.02	0.10	
Vanuatu						0.80							0.20	
Yemen						0.25	0.25						0.50	
Zambia							0.15					0.10	0.75	

Table 9: Development Pattern 7 Mapping Schemes

5.3. REPLACEMENT COST

Replacement cost is typically determined by type of construction, economic factors, or country GDP (FEMA, 2012; Huizinga, et al., 2017; Huyck & Eguchi, 2017). Replacement cost data is highly vulnerable and changes drastically by country. It is also vulnerable to changes in politics, the housing market, and the exchange rate. Replacement cost is difficult to represent accurately in many developing countries, particularly where labor is donated by the community and materials are indigenous (Huyck & Eguchi, 2017). Although the amount of money that changes hands might be minimal in certain areas, the disruption experienced and the time to recover may be significant. International construction manuals overestimate building costs in these areas.

Replacement cost is often directly related to quality of construction, which can be used to adjust prices throughout the affected area. Depending on economic conditions, exchange rates or material shortages can cause replacement costs to shift by factors of 4 or more in the span of a month. It is particularly important to document the process of applying these numbers for a particular data set so that they can be updated or adjusted when needed. The unit replacement costs (USD/m^2) for the 47 ODA countries can be found in Table 10. These replacement costs are first broken out by country, and then by development pattern. Each value represents the typical cost of one square meter of built-up area within the development pattern. Variations in type and quality of construction occur within the same development pattern, however the cost is reflective of the general built-up environment. Refer to Appendix A for a visual representation of each development pattern. On a country-by-country basis, the gradual increase in cost of the indigenous materials and practices found in Development Pattern 1 (rural) to the more engineered structures found in Development Pattern 6 is evident. The intermediate levels of urbanity (Development Patterns 2-5) fall somewhere between, which can be expected. Unit costs of development Pattern 7 are representative of typical warehouse structures found in the industrial regions.

	Development Pattern					
Country	**1**	**2**	**3**	**5**	**6**	**7**
Afghanistan	72.36	144.72	289.45	339.86	849.66	254.11
Angola	149.58	299.16	598.32	666.67	1666.67	468.83
Bangladesh	114.07	228.13	456.26	518.42	1296.06	373.01
Benin	89.40	178.80	357.59	413.52	1033.80	303.71
Bhutan	146.35	292.71	585.41	653.31	1633.27	460.28
Burkina Faso	81.75	163.49	326.98	380.57	951.42	281.63
Burundi	56.34	112.67	225.34	269.41	673.54	205.73
Cambodia	109.02	218.05	436.10	497.13	1242.83	359.06
Central African Republic	69.89	139.77	279.55	329.07	822.66	246.76
Chad	82.31	164.63	329.26	383.03	957.57	283.28
Comoros	106.33	212.66	425.32	485.72	1214.30	351.56
Congo, Dem. Rep.	74.50	149.01	298.02	349.19	872.97	260.44
Djibouti	143.53	287.06	574.11	641.60	1604.00	452.77
Eritrea	63.34	126.68	253.37	300.37	750.92	227.11
Ethiopia	84.20	168.39	336.79	391.15	977.87	288.74
Gambia, The	81.79	163.58	327.16	380.76	951.90	281.76
Guinea	88.51	177.03	354.05	409.72	1024.30	301.17
Guinea-Bissau	84.86	169.73	339.46	394.03	985.06	290.67
Haiti	88.09	176.17	352.34	407.88	1019.70	299.94
Kiribati	112.15	224.30	448.61	510.35	1275.86	367.72
Lao PDR	133.27	266.53	533.07	598.93	1497.33	425.31
Lesotho	102.88	205.77	411.53	471.10	1177.74	341.92
Liberia	80.04	160.09	320.17	373.21	933.04	276.68
Madagascar	66.24	132.48	264.95	313.09	782.74	235.84
Malawi	64.66	129.32	258.64	306.16	765.41	231.09
Mali	89.32	178.64	357.29	413.19	1032.98	303.49
Mauritania	99.44	198.87	397.74	456.43	1141.08	332.23
Mozambique	71.17	142.34	284.68	334.66	836.66	250.57
Myanmar	103.70	207.40	414.81	474.57	1186.43	344.21
Nepal	94.23	188.45	376.91	434.21	1085.51	317.49
Niger	66.23	132.46	264.92	313.06	782.64	235.82
Rwanda	84.24	168.48	336.95	391.33	978.32	288.86
Sao Tome and Principe	121.51	243.03	486.05	549.76	1374.39	393.45
Senegal	109.36	218.72	437.43	498.54	1246.35	359.98
Sierra Leone	73.05	146.10	292.21	342.87	857.17	256.15
Solomon Islands	124.65	249.31	498.61	562.92	1407.31	402.01
Somalia	59.61	119.22	238.45	283.92	709.81	215.78
South Sudan	111.00	222.01	444.01	505.49	1263.74	364.54
Sudan	107.04	214.07	428.14	488.71	1221.78	353.52
Tanzania	95.17	190.34	380.67	438.22	1095.56	320.16
Timor-Leste	88.39	176.78	353.56	409.19	1022.98	300.82
Togo	80.13	160.27	320.54	373.61	934.02	276.94
Tuvalu	153.99	307.99	615.97	684.89	1712.23	480.46
Uganda	78.47	156.94	313.88	366.40	916.01	272.08
Vanuatu	144.26	288.52	577.04	644.64	1611.59	454.72
Yemen	90.98	181.96	363.92	420.30	1050.75	308.23
Zambia	109.85	219.71	439.42	500.64	1251.60	361.36

Table 10: Replacement Costs by Development Pattern, in 2020 USD.

6. PAGER Mapping for OED Building Exposure

Mapping of U.S. Geological Survey's (USGS), Prompt Assessment of Global Earthquakes for Response (PAGER) taxonomy to common taxonomies, such as AIR and OED (https://oasislmf.org/) is provided in Appendix B. Descriptions of the structural system for AIR and OED can be also found in Appendix B. GEM taxonomy strings are multi-tiered and include properties such as material types, material technologies, material properties, number of stories, etc. The structural description of GEM taxonomies is similar to those described within PAGER.

The mapping from PAGER to GEM, AIR and OED provides a bridge from one taxonomy type to another. Building materials, technologies, lateral force-resisting systems and heights are taken into account to ensure a building's vulnerability is properly reflected and consistent across all taxonomies. If a specific structural system identified in PAGER is not available for the other taxonomies, the most representative (if available) is chosen. In cases where this is not applicable, the high-level (e.g., Wood, Masonry, Steel and/or Concrete) GEM (e.g. W), AIR (e.g. 101) or OED (e.g. 5050) taxonomy is chosen.

7. Conclusion

This information provided herein offers the user a reference for the Level 1 building exposure database of the 47 ODA countries. The information herein can be used as a guide to the appropriate use of the data, how key variables are distributed by country, and as a starting point if the data is to be updated or augmented on future projects. While this work package was catered for the 47 ODA countries, the information and protocols can be used for future iterations of Level 1 building exposure development. From the document the reader should realize the different levels of building exposure (Section 0) and the how they vary in terms of spatial resolution, methodologies, primary sources, levels of effort and end products. The document discusses the importance of development patterns (Section 0), and how recognition of the differentiations in the built-up environment is vital for the creation of mapping schemes (Section 5). Mapping schemes not only estimate the distribution of a country's building stock for a given development pattern, but also relate each unique structural system to a taxonomy that can ultimately be used vulnerability model. Finally, the influence of the quality/type of construction and other economic factors in relation to a country's per unit replacement costs (Section 5.3) are discussed.

Each section provides the reader with each of the vital steps required for Level 1 building exposure databases. While the resources may vary from country to country, the overall procedure is relatively constant. With knowledge of the basics of exposure data, the reader will have a better understanding of how it interconnects with both hazard data and vulnerability modelling, which are the other key components for risk modelling of natural phenomena. The reader should visit METEOR Explorer (maps.meteor-project.org) for additional documentation.

Appendix A

All images for development patterns 1-7 are from Google Maps (Available at: http://maps.google.co.uk; Map data: Google, Maxar Technologies, accessed in 2021)

Afghanistan

1		**5**	
2		6	
3		7	
4			

Angola

1		**5**	
2		6	
3		7	
4			

Bangladesh

1		**5**	
2		6	
3		7	
4			

Benin

1		**5**	
2		6	
3		7	
4			

Bhutan

1		**5**	
2		6	
3		7	
4			

Burkina Faso

1		**5**	
2		6	
3		7	
4			

Burundi

1		**5**	
2		6	
3		7	
4			

Cambodia

1		**5**	
2		6	
3		7	
4			

Central African Republic

1		**5**	
2		6	
3		7	
4			

Chad

1		**5**	
2		6	
3		7	
4			

Comoros

1		**5**	
2		6	
3		7	
4			

Democratic Republic of the Congo

1		**5**	
2		6	
3		7	
4			

Djibouti

1		**5**	
2		6	
3		7	
4			

Eritrea

1		5	
2		6	
3		7	
4			

Ethiopia

1		5	
2		6	
3		7	
4			

Gambia

1		**5**	
2		6	
3		7	
4			

Guinea

1		**5**	
2		6	
3		7	
4			

Guinea-Bissau

1		5	
2		6	
3		7	
4			

1		5	
2		6	
3		7	
4			

Haiti

Kiribati

1		5	
2		6	
3		7	
4			

Lao People's Democratic Republic

1		5	
2		6	
3		7	
4			

Lesotho

1		5	
2		6	
3		7	
4			

Liberia

1		5	
2		6	
3		7	
4			

Madagascar

1		5	
2		6	
3		7	
4			

Malawi

1		5	
2		6	
3		7	
4			

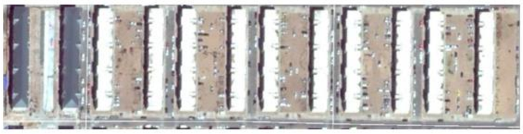
Mali

1		**5**	
2		6	
3		7	
4			

Mauritania

1		5	
2		6	
3		7	
4			

Mozambique

1		5	
2		6	
3		7	
4			

Myanmar

1		5	
2		6	
3		7	
4			

Nepal

1		5	
2		6	
3		7	
4			

Niger

1		5	
2		6	
3		7	
4			r

Rwanda

1		5	
2		6	
3		7	
4			r

Sao Tome and Principe

1		5	
2		6	
3		7	
4			

Senegal

1		5	
2		6	
3		7	
4			

Sierra Leone

1		5	
2		6	
3		7	
4			

Solomon Islands

1		5	
2		6	
3		7	
4			

Somalia

1		5	
2		6	
3		7	
4			

South Sudan

1		5	
2		6	
3		7	
4			

Sudan

1		5	
2		6	
3		7	
4			

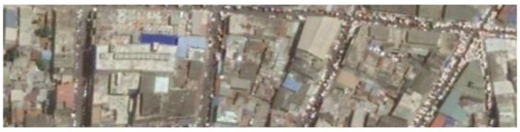
Tanzania

1		**5**	
2		6	
3		7	
4			

Timor-Leste

1		**5**	
2		6	
3		7	
4			

Togo

1		5	
2		6	
3		7	
4			

Tuvalu

1		5	
2		6	
3		7	
4			

Uganda

1		5	
2		6	
3		7	
4			

Vanuatu

1		5	
2		6	
3		7	
4			

Yemen

1		5	
2		6	
3		7	
4			

Zambia

1		5	
2		6	
3		7	
4			

Appendix B

PAGER	PAGER Description	GEM	AIR	OED
W	Wood	W	101	5050
W1	Wood stud-wall frame with plywood/gypsum board sheathing.	W+WLI/LWAL	101	5050
W2	Wood frame, heavy members (with area > 5000 sq. ft.)	W+WHE/LPB	104	5053
W3	Wood light unbraced post and beam frame.	W+WLI/LPB	102	5051
W4	Wood panel or log construction.	W+WS/LWAL	104	5053
W5	Wattle and Daub (Walls with bamboo/light timber log/reed mesh and post).	W+WWD/LWAL	102	5051
W6	Wood unbraced heavy post and beam frame with mud or other infill material.	W+WHE/LWAL	104	5053
W7	Wood braced frame with load-bearing infill wall system.	W+WLI/LWAL	101	5050
S	Steel	S	151	5200
S1	Steel moment frame	S/LFM	156	5205
S1L	Steel moment frame low-rise	S/LFM/HBET:1,3	156	5205
S1M	Steel moment frame mid-rise	S/LFM/HBET:4,7	156	5205
S1H	Steel moment frame high-rise	S/LFM/HBET:8,19	156	5205
S2	Steel braced frame	S/LFBR	153	5202
S2L	Steel braced frame low-rise	S/LFBR/HBET:1,3	153	5202
S2M	Steel braced frame mid-rise	S/LFBR/HBET:4,7	153	5202
S2H	Steel braced frame high-rise	S/LFBR/HBET:8,19	153	5202
S3	Steel light frame	S/LFM	152	5201
S4	Steel frame with cast-in-place concrete shear walls	CR+CIP/LWAL	158	5207
S4L	Steel frame with cast-in-place concrete shear walls low-rise	CR+CIP/LWAL/HBET:1,3	158	5207
S4M	Steel frame with cast-in-place concrete shear walls mid-rise	CR+CIP/LWAL/HBET:4,7	158	5207
S4H	Steel frame with cast-in-place concrete shear walls high-rise	CR+CIP/LWAL/HBET:8,19	158	5207
S5	Steel frame with unreinforced masonry infill walls	S/LFINF	157	5206
S5L	Steel frame with unreinforced masonry infill walls low-rise	S/LFINF/HBET:1,3	157	5206
S5M	Steel frame with unreinforced masonry infill walls mid-rise	S/LFINF/HBET:4,7	157	5206

S5H	Steel frame with unreinforced masonry infill walls high-rise	S/LFINF/HBET:8,19	157	5206
C	Reinforced concrete	CR	131	5150
C1	Ductile reinforced concrete moment frame with or without infill	CR+CIP/LFINF+DUC	134	5153
C1L	Ductile reinforced concrete moment frame with or without infill low-rise	CR+CIP/LFINF+DUC/HBET:1,3	134	5153
C1M	Ductile reinforced concrete moment frame with or without infill mid-rise	CR+CIP/LFINF+DUC/HBET:4,7	134	5153
C1H	Ductile reinforced concrete moment frame with or without infill high-rise	CR+CIP/LFINF+DUC/HBET:8,19	134	5153
C2	Reinforced concrete shear walls	CR+CIP/LWAL	133	5152
C2L	Reinforced concrete shear walls low-rise	CR+CIP/LWAL/HBET:1,3	133	5152
C2M	Reinforced concrete shear walls mid-rise	CR+CIP/LWAL/HBET:4,7	133	5152
C2H	Reinforced concrete shear walls high-rise	CR+CIP/LWAL/HBET:8,19	133	5152
C3	Nonductile reinforced concrete frame with masonry infill walls	CR+CIP/LFINF+DNO	140	5159
C3L	Nonductile reinforced concrete frame with masonry infill walls low-rise	CR+CIP/LFINF+DNO/HBET:1,3	140	5159
C3M	Nonductile reinforced concrete frame with masonry infill walls mid-rise	CR+CIP/LFINF+DNO/HBET:4,7	140	5159
C3H	Nonductile reinforced concrete frame with masonry infill walls high-rise	CR+CIP/LFINF+DNO/HBET:8,19	140	5159
C4	Nonductile reinforced concrete frame without masonry infill walls	CR+CIP/LFM+DNO	135	5154
C4L	Nonductile reinforced concrete frame without masonry infill walls low-rise	CR+CIP/LFM+DNO/HBET:1,3	135	5154
C4M	Nonductile reinforced concrete frame without masonry infill walls mid-rise	CR+CIP/LFM+DNO/HBET:4,7	135	5154
C4H	Nonductile reinforced concrete frame without masonry infill walls high-rise	CR+CIP/LFM+DNO/HBET:8,19	135	5154
C5	Steel reinforced concrete (Steel members encased in reinforced concrete)	SRC+CIP	159	5208
C5L	Steel reinforced concrete (Steel members encased in reinforced concrete) low-rise	SRC+CIP/HBET:1,3	159	5208
C5M	Steel reinforced concrete (Steel members encased in reinforced concrete) mid-rise	SRC+CIP/HBET:4,7	159	5208
C5H	Steel reinforced concrete (Steel members encased in reinforced concrete) high-rise	SRC+CIP/HBET:8,19	159	5208
C6	Concrete moment resisting frame with shear wall - dual system	CR+CIP/LDUAL	132	5151
C6L	Concrete moment resisting frame with shear wall - dual system low-rise	CR+CIP/LDUAL/HBET:1,3	132	5151
C6M	Concrete moment resisting frame with shear wall - dual system mid-rise	CR+CIP/LDUAL/HBET:4,7	132	5151
C6H	Concrete moment resisting frame with shear wall - dual system high-rise	CR+CIP/LDUAL/HBET:8,19	132	5151
C7	Flat slab structure	CR+CIP/LFLS	131	5150
PC1	Precast concrete tilt-up walls	CR+PC/LWAL	136	5155
PC2	Precast concrete frames with concrete shear walls	CR+PC/LDUAL	138	5157
PC2L	Precast concrete frames with concrete shear walls low-rise	CR+PC/LDUAL/HBET:1,3	138	5157

PC2M	Precast concrete frames with concrete shear walls mid-rise	CR+PC/LDUAL/HBET:4,7	138	5157
PC2H	Precast concrete frames with concrete shear walls high-rise	CR+PC/LDUAL/HBET:8,19	138	5157
PC3	Precast reinforced concrete moment resisting frame with masonry infill walls	CR+PC/LFINF	140	5159
PC3L	Precast reinforced concrete moment resisting frame with masonry infill walls low-rise	CR+PC/LFINF/HBET:1,3	140	5159
PC3M	Precast reinforced concrete moment resisting frame with masonry infill walls mid-rise	CR+PC/LFINF/HBET:4,7	140	5159
PC3H	Precast reinforced concrete moment resisting frame with masonry infill walls high-rise	CR+PC/LFINF/HBET:8,19	140	5159
PC4	Precast panels (wall made of number of horizontal precast panels, construction from former Soviet Union countries)	CR+PC/LWAL	137	5156
RM	Reinforced masonry	MR	116	5105
RM1	Reinforced masonry bearing walls with wood or metal deck diaphragms	MR/RWO	116	5105
RM1L	Reinforced masonry bearing walls with wood or metal deck diaphragms low-rise	MR/HBET:1,3/RWO	116	5105
RM1M	Reinforced masonry bearing walls with wood or metal deck diaphragms mid-rise (4+ stories)	MR/HBET:3,7/RWO	116	5105
RM2	Reinforced masonry bearing walls with concrete diaphragms	MR/RC/FC	116	5105
RM2L	Reinforced masonry bearing walls with concrete diaphragms low-rise	MR/HBET:1,3/RC/FC	116	5105
RM2M	Reinforced masonry bearing walls with concrete diaphragms mid-rise	MR/HBET:4,7/RC/FC	116	5105
RM2H	Reinforced masonry bearing walls with concrete diaphragms high-rise	MR/HBET:8,19/RC/FC	116	5105
CM	Confined masonry	MCF/LWAL	120	5109
CML	Confined masonry low-rise	MCF/LWAL/HBET:1,3	120	5109
CMM	Confined masonry mid-rise	MCF/LWAL/HBET:4,7	120	5109
CMH	Confined masonry high-rise	MCF/LWAL/HBET:8,19	120	5109
MH	Mobile homes	W+WLI/LWAL	191	5350
M	Mud walls	E99+ET99/LWAL	112	5101
M1	Mud walls without horizontal wood elements	EU+ETC/LWAL	112	5101
M2	Mud walls with horizontal wood elements	ER+ETC+RW/LWAL	112	5101
A	Adobe blocks (unbaked sundried mud block) walls	MUR+ADO	112	5101
A1	Adobe block, mud mortar, wood roof and floors	MUR+ADO+MOM/LWAL	112	5101
A2	Adobe block, mud mortar, bamboo, straw, and thatch roof	MR+ADO+RB+MOM/LWAL	112	5101
A3	Adobe block, straw, and thatch roof cement-sand mortar	MUR+ADO+MOC/LWAL	112	5101
A4	Adobe block, mud mortar, reinforced concrete bond beam, cane and mud roof	MR+ADO+RCB+MOM/LWAL	112	5101
A5	Adobe block, mud mortar, with bamboo or rope reinforcement	MR+ADO+RB+MOM/LWAL	112	5101

RE	Rammed Earth/Pneumatically impacted stabilized earth	EU+ETR/LWAL	112	5101
RS	Rubble stone (field stone) masonry	MUR+STRU B	113	5102
RS1	Local field stones dry stacked (no mortar) with timber floors, earth, or metal roof.	MUR+STRUB+MON/LWAL	113	5102
RS2	Local field stones with mud mortar.	MUR+STRUB+MOM/LWAL	113	5102
RS3	Local field stones with lime mortar.	MUR+STRUB+MOL/LWAL	113	5102
RS4	Local field stones with cement mortar, vaulted brick roof and floors	MUR+STRUB+MOC/LWAL	114	5102
RS5	Local field stones with cement mortar and reinforced concrete bond beam.	MR+STRU B+RCB+MOC/LWAL	120	5109
DS	Rectangular cut-stone masonry block	MUR+STDRE	114	5103
DS1	Rectangular cut stone masonry block with mud mortar, timber roof and floors	MUR+STDRE+MOM/LWAL	114	5103
DS2	Rectangular cut stone masonry block with lime mortar	MUR+STDRE+MOL/LWAL	114	5103
DS3	Rectangular cut stone masonry block with cement mortar	MUR+STDRE+MOC/LWAL	114	5103
DS4	Rectangular cut stone masonry block with reinforced concrete floors and roof	MUR+STDRE+MOC/LWAL	120	5109
UFB	Unreinforced fired brick masonry	MUR+CLBRS	114	5103
UFB1	Unreinforced brick masonry in mud mortar without timber posts	MUR+CLBRS+MOM/LWAL	114	5103
UFB2	Unreinforced brick masonry in mud mortar with timber posts	MUR+CLBRS+MOM/LWAL	114	5103
UFB3	Unreinforced brick masonry in lime mortar	MUR+CLBRS+MOL/LWAL	114	5103
UFB4	Unreinforced fired brick masonry, cement mortar.	MUR+CLBRS+MOC/LWAL	114	5103
UFB5	Unreinforced fired brick masonry, cement mortar, but with reinforced concrete floor and roof slabs	MUR+CLBRS+MOC/LWAL	120	5109
UCB	Concrete block unreinforced masonry with lime or cement mortar	MUR+CB99+MOC/LWAL	114	5103
MS	Massive stone masonry in lime or cement mortar	MUR+STDRE+MOL/LWAL	111	5100
INF	Informal constructions.	MATO	113	5102
NK	Not specified (unknown/default)	-	100	5000

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