



MOVER – Level 3 Data schema for Physical and Social Vulnerability Indicators, Indices, and Functions

A report submitted by 

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Executive Summary

This report is the fourth (and last) of a series of reports produced for the fulfilment of the deliverables of the MOVER (Multi-Hazard Open Vulnerability Platform for Evaluating Risk) project. It follows the “MOVER Inception Report”, the “GFDRR-DFID Challenge Fund Expert Workshop -Feedback Report” and “MOVER – Level 2 Data schemas for Physical and Social Vulnerability Indicators, Indices, and Functions Report”.

The inception report outlined a reverse pyramid approach for the development of the MOVER vulnerability data schema. This involved developing a series of data schema versions, starting from a wide data schema (Level 1) that does not take into account issues of data availability, a more refined version (Level 2) of the data schema that is applicable to developed country contexts, and finally a reduced data schema (Level 3) that is more applicable to the case of developing countries. The main aim of this report is to provide a detailed description of the final Level 2 and Level 3 data schemas.

To aid the reader in the comprehension of this report, a brief introduction on the scope of the overall Challenge 3 MOVER project is provided. This is followed by a description of the revision of the Level 2 data schema and development of the Level 3 data schema. The structure of both Level 2 and Level 3 data schemas is modular and comprises four main modules for the multi-hazard and multi-asset assessment of physical and social vulnerability: the physical vulnerability indicators module, the social vulnerability indicators module, the vulnerability, fragility and damage to loss functions module and the physical, social and hybrid vulnerability indices module. These modules call upon several shared supporting tables that list the hazards, assets, intensity measures, loss parameters, damage scales, engineering demand parameters, references and data sources. The presented Level 3 data schema has been coded in PostgreSQL and has been provided with a fully-fledged administration interface. The user is guided in the compilation of the data schema by the advanced customisation of each of the data fields which, with aliases and pre-populated drop-down menus, ensures a seamless data entry experience. Explanations of the terms adopted in the pre-populated menus are provided in the Level 3 data schema description as well as in Annexes III – VI of the report. The data schema is compatible with data types from Challenges 1 and 2 and can accommodate data at different geographical scales. The modular structure of the data schema facilitates its future extension.

The data schema is populated with vulnerability data and models for Tanzania and 5 other countries. The developed fragility and vulnerability function scoring system is used to assess the suitability of existing functions for adoption in case study scenarios in these countries. An example of how to enter data into the coded data schema is provided in Annex VII.

Finally, a revised summary of the project deliverables and a work schedule are presented.



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Acronyms

BGS	British Geological Survey
BRU	Building Research Unit, Ministry of Lands, Housing and Urban Development, Dar es Salaam.
DfID	UK Department for International Development
DOI	Digital Object Identifier
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
DS	Damage State
DtL	Damage-to-Loss
EDP	Engineering Demand Parameter
EP	Exceedance Probability
EPICentre	UCL Earthquake and People Interaction Centre
ER	Entity-Relationship
FF	Fragility Function
GDP	Gross Domestic Product
GAM	Generalized Additive Model
GEM	Global Earthquake Model
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographical Information Systems
GLM	Generalised Linear Model
IM	Intensity Measure
IML	Intensity Measure Level
IMPE	Intensity Measure Prediction Equations
ISSN	International Standard Serial Number
LR	Lethality Ratio
MIDR	Maximum Inter-storey Drift Ratio
MOVER	Multi-Hazard Open Vulnerability Platform for Evaluating Risk
ODI	Overseas Development Institute
PDF	Probability Density Function
RR	Repair Rate
UCL	University College London
V_Cat	Vulnerability Category
V_Ch	Vulnerability Characteristic
VF	Vulnerability Function



VI Vulnerability Indicator

Vix Vulnerability Index

WP Work Package



1 Introduction

This work is carried out as part of the Global Facility for Disaster Reduction and Recovery (GFDRR) and the UK Department for International Development (DfID) competitive Challenge Fund, which aims at creating more robust, open, accessible, high-resolution and trusted risk data analyses, thus promoting the reduction of the uncertainties that characterise the evaluation of DRM and DRR strategies. Challenge 3 is led by UCL EPICentre and looks to develop an open multi-hazard vulnerability database (i.e. MOVER – Multi-Hazard Open Vulnerability platform for Evaluating Risk) that considers different assets (people, buildings and select critical infrastructure) and loss measures, which is appropriate for use in developing country contexts.

The Inception Report for Challenge 3 was submitted and accepted by GFDRR in June 2017. It detailed the approach to be taken to develop a first prototype vulnerability data schema, (termed Level 1 data schema), which through expert review and consultation with team members and stakeholders in developing countries would be refined into Level 2 and Level 3 data schemas, appropriate for use in developed and developing countries, respectively. A workshop for the Challenge fund data schemas was organised by the Challenge 3 Team and was held in London in July 2017. This resulted in the “GFDRR-DFID Challenge Fund Expert Workshop - London, 27th July 2017 -Feedback Report”, which was submitted and approved by GFDRR in October 2017. The MOVER Level 2 data schema was presented in the report “MOVER – Level 2 Data schemas for Physical and Social Vulnerability Indicators, Indices, and Functions” delivered by UCL in November 2017 and accepted in March 2018 following the incorporation of feedback received. The latter report also modified the original work packages and deliverables drafted at inception.

The current report details work carried out as part of the revised Work Packages 4 and 5, “Review of Level 2 vulnerability data schema and its application to Tanzania” and “Application of Level 2 vulnerability data schema to 5 other countries and final data schema development”, respectively. This report should be considered as Output 3 of the revised work plan.

1.1 Aims, Objectives and Scope of the report

The overarching goal of Challenge 3 is to develop a multi-hazard open vulnerability database schema that is appropriate for use in developing country contexts. The data schema is designed to consider different assets and loss measures. The assets include people, crops, residential buildings, industrial warehouses, commercial properties, schools and hospitals as well as key components of selected lifelines (water, electricity, gas, telecommunications, and transports). This project will not look at assets pertaining to nuclear power plants, chemical and petrochemical plants and their distribution systems, nor any offshore infrastructure. The scope covers the main hazards of strong winds (including hurricanes, typhoons, tropical and extra-tropical cyclones), earthquakes, riverine floods, storm surge, landslides and tsunamis. The hazards of volcanic ash and drought will also be looked at, but it is noted that limited vulnerability studies exist for these hazards globally. The final Vulnerability Data Schema is presented in this report and is able to explicitly address the typical lack of data on vulnerability that exists in developing countries. It also accommodates vulnerability representations at different geographical scales (Level 0 National, Level 1 Sub-country, Level 2 Local level, Level 3 single asset). The database schema also supports a gridded system compatible with the Challenge 2 implementation.

The main aim of this report is to present the detailed revised MOVER Level 2 and new MOVER Level 3 Vulnerability Data Schemas and associated Scoring Systems.

The final Level 2 MOVER data schema for Developed Countries: The revised (final) Level 2 data schema presented in this report has been developed following an extensive literature review, feedback from experts in risk participating at the London Workshop (detailed in the London Workshop Report), consultation amongst the Challenge 3 Team members and from



international expert review. The final Level 2 MOVER data schema is presented as appropriate for use in developed country contexts and contains fields of data that look forwards towards expected development of future technologies and the potential for bespoke vulnerability data collection programmes. It includes fields that cannot currently be populated for many developing countries.

The final Level 3 MOVER data schema for Developing Countries: The Level 3 (final) MOVER vulnerability data schema consists of a reduced version of the Level 2 MOVER vulnerability data schema, wherein fewer data fields are included and a substantial number of “nullable” entries are included. This is in recognition of the paucity of information common in developing countries. As such, the presented Level 2 data schema presents the expanded version of the newly proposed Level 3 database. The subset of vulnerability data fields is chosen through a combination of consultation with Challenge 3 Team members in Tanzania, Challenge 1 and 2 teams, the expert opinion of the multi-disciplinary Challenge 3 Research and Review Team (see Inception Report Annex) and from learning through the process of populating the data schema with data from Tanzania and nearby countries, Kenya, Malawi, Uganda, Ethiopia and Mozambique. Through this application, the Level 3 data schema is proven to be adequate for use in developing countries. Furthermore, one of the findings of this application is that due to the paucity of vulnerability models found, the proposed scoring system takes on particular importance in helping decide which of the models that are developed for other countries are applicable to the assessment of vulnerability in the assessed areas.

It is highlighted that an additional *manual* has been produced for the data schema, and provides more details on the type of data that can be entered in the data schema, and how to enter the data

1.2 Definitions

For ease of reference, key definitions are presented here. These are adopted in all reports pertaining the Challenge 3 MOVER project. The report acknowledges that the evaluation of the vulnerability of an urban community exposed to natural hazards requires a comprehensive and holistic approach that considers both physical and social characteristics which can make communities more susceptible to harm and more likely to sustain greater human and economic losses. Hereafter, the term physical vulnerability is used to refer to the susceptibility of assets (people, infrastructure, etc.) exposed to hazardous events to incur losses (e.g. deaths and economic loss). Social vulnerability refers more specifically to the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed. These impacts are due in part to characteristics inherent in social interactions, institutions, and systems of cultural values.

Other commonly adopted terms are also defined here to aid the understanding of the report. These follow the definitions adopted in the Global Earthquake Model (GEM) series of reports on vulnerability (e.g. Rossetto et al. 2014, D’Ayala and Meslem, 2012, D’Ayala et al. 2016), and are consistent with the terminology used at the London Workshop to discuss the Data Schemas with the risk experts.

Within the risk literature the severity of a natural hazard effect at a particular site is described in terms of an Intensity Measure (IM) and an Intensity Measure Level (IML) is a particular value of the relevant IM.

Vulnerability characteristics (V_Ch) are descriptors of the main factors contributing to the (social or physical) vulnerability of the asset to a hazard. An example of a V_Ch is level of literacy, which contributes to the social vulnerability of populations.

Vulnerability categories (V_Cat) are a grouping of vulnerability characteristics that fall under the same theme. For example, the V_Ch of ‘Access to Education’ and ‘Education Attainment’ are grouped within a V_Cat of “Knowledge and Education”.



A Vulnerability Indicator (VI) is a direct measure or proxy for measuring a vulnerability characteristic (V_Ch). It is a quantitative measure of a single phenomenon. An example VI is the percentage of the population with a primary school level education, when this is used as a proxy for literacy (V_Ch) as part of an evaluation of the V_Cat of “Education”. VIs are most commonly used to indicate factors of social vulnerability, but in physical vulnerability are the equivalent of direct quantitative measures or proxies for vulnerability characteristics of the exposure.

A Vulnerability Index (VIx) is a quantitative representation of multiple phenomena, i.e., of multiple V_Cat. It is a vulnerability model and is formed through a mathematical combination of several Vulnerability Indicators. An example VIx from the social vulnerability literature is the Human Development Index. In the physical vulnerability sphere VIx usually result from rapid visual surveys of buildings. Examples include the Building Vulnerability Index for tsunami by Papatoma and Dominey-Howes (2003).

It is highlighted that neither VI nor VIx vary with hazard intensity.

A Vulnerability Function (VF) is defined as a relationship between a parameter of loss (e.g. fatalities) and an intensity measure (IM). Such functions can be represented in the form of continuous or discrete relationships. VFs can be derived “directly” from regression on historical loss data (empirical), and through the elicitation of expert opinion (heuristic). VFs can also be derived “indirectly” from the combination of a Fragility Function and a Damage-to-Loss model.

A Fragility Function (FF) describes the propensity of physical assets (e.g. buildings) to sustain damage under hazardous events. Formally, they express the probability of a damage state (DS) being reached or exceeded given a range of hazard intensity measure levels. FFs can be developed empirically, heuristically, but also analytically (i.e. where a numerical/computational model simulates the response of a structure under increasing hazard intensities).

A Damage-to-Loss model (DtL) relates values of loss to the damage states expressed in a Fragility Function. For buildings and most infrastructure DtL models commonly take the form of repair to replacement cost ratios for the examined building class. In the case of pipelines and cables Repair Rates (RR), which describe the average number of repairs per unit length, are more common. In the case of casualties, Damage-to-Loss relationships often take the form of Lethality Ratios (LR), defined by Coburn and Spence (2002) as the ratio of the number of people killed to the number of occupants present in a collapsed building.

1.3 Structure of the Report

Within Section 2.0, an overview of the approach taken for the development of the revised Level 2 vulnerability data schema and of the process followed for the selection of the data fields to retain in the Level 3 data schema is presented. A detailed description of both data schemas is provided in Section 3.0 as the data schema architecture as well as most of the data fields are common to both data schemas. Details on the data field entries for the data schema supporting tables are provided in Annex III to VI. Section 4.0 describes the data sources and data issues found when populating the Level 3 data schema with vulnerability information for Tanzania and five other countries. Section 5.0 shows how the data schemas meet the original objectives for data schema characteristics set out in the Inception report. Finally, Sections 6.0 and 7.0 outline the remaining work and deliverables.



2 Revisions of the Level 2 data schema and development of Level 3 data schema

2.1 International expert review

The Level 2 Data Schema was sent for review to, our team of advisors, collaborators and reviewers., namely:

- Dr. Cassidy Johnson (UCL) - urban development/social vulnerability;
- Dr. John Twigg (ODI) – social vulnerability;
- Prof. Dina D’Ayala (UCL) - physical vulnerability/ non-engineered building vulnerability;
- Prof. Ulugbek Begaliev (IntUIT) - Bishkek, Kyrgyzstan - physical vulnerability and developing country context;
- Prof. Kanatbek Abdrakhmatov (IS NAS KR) - Bishkek, Kyrgyzstan - hazard information and risk - developing country context;
- Prof. Wilbard Kombe (Ardhi University) - Tanzania - Disaster Risk management expert and developing country context;
- Dr Guido UHINGA (Ardhi University) - Tanzania - Disaster Risk management and developing country context.

Through these reviewers we covered all disciplinary areas of the vulnerability data schema. The reviewers were asked to comment on:

1. the appropriateness of the data fields included in the data schema;
2. the structure and architecture of the data schema;
3. any limitations/difficulties/issues they would foresee in populating the schema with data from developing countries.

The received reviews were of varying detail and focus. All the comments received have been considered carefully in the revision of the Level 2 data schema and development of the Level 3 data schema. Some of the main points made are reproduced here, together with the actions taken (in brackets and italic):

1. Detailed comments on Physical and Social Vulnerability Indicators, their appropriateness, ambiguities in their definition. Some examples are provided:
 - Building ductility is redundant as a field if you know design code level (*The ductility field has been retained in the Level 2 data schema to ensure the user records appropriately the level of ductility of the structure, given the possible ambiguity in the understanding of different levels of hazard-based design. This is also to distinguish between the design level and implementation effectiveness*).
 - Type of retrofit is more important than when it was carried out. More detail on retrofit type should be included instead of a yes/no answer to whether the asset has been retrofitted (*There are too many types of retrofit when all the assets are considered for there to be a field on this. Hence, no additional field has been added at this stage, the inclusion of another field to specify the type of retrofitting will be however considered carefully if the data schema is developed further. It remains assured that, as data about retrofitting are difficult to obtain both in developed and developing countries, should a new field be created that would be associated to a “nullable” condition*).
 - Buildings: no need to classify into height ranges if the number of storeys is known. If height grouping is to be carried out, then assumptions are to be stated (*This point has been considered carefully and, for the following stage of the development of the data schema, a review of the classification of height grouping will be carried out to verify if a standard can be derived. Even though, it is important to state that height ranges can be considered*



redundant only if the number of storeys is known. Such data are not always available and when estimated by remote sensing data it may be approximate. In these cases, having a range rather than a null field can be useful, provided a standard for the definition of the height grouping is set.)

- A reference field has to be associated also with the damage scale, not just the fragility or vulnerability functions *(This has been added)*
- Building irregularity fields: These 4 fields seem redundant and require pre-knowledge which will not be available on site for instance, or structural skills which are also not available. On site you will only know that there are geometric irregularities either in plan or elevation. Enumerate them and then find out afterwards if they result in mass or stiffness irregularity. *(These fields have been retained in light of the Level 2 data schema being for developed countries, for which this type of data can be available. It is noted that two of the fields on irregularity have been removed from the Level 3 data schema)*
- In the report text on physical vulnerability of infrastructure the electricity network seems to only be considered as underground cables whilst electricity networks can comprise over-head cables instead, which do not experience the same threats. For mobile networks, transmitters can be mounted on buildings or on higher ground. *(The reviewer is correct. However, in the current version of the data schema only electricity sub-stations and telecommunication central offices are considered due to the lack of fragility and vulnerability functions for other components. In the future, the data schema should be expanded further to consider other infrastructure components for these systems)*
- Crop vulnerability indicators: two seasons, spring and winter, are used which may not apply to local contexts of crop growth. *(This has been modified in the Level 2 and 3 data schemas.)*
- Are economic categories relating to social classes ignored? For instance, access to education or work is not just a matter of gender. The social vulnerability indicators used seem to ignore the location of the population, urban versus rural, for instance, which also affects their opportunity and hence vulnerability. *(In both Level 2 and Level 3, the economic categories relating to social classes have been assessed in the Financial and Material welfare category which spans across several sub-categories including Employment and Employment security which are two key determinants of social class. The access to “opportunity” has been evaluated in the Access and Provision of services category, which is seen as a proxy for evaluation the urban/ rural divide given that rural areas are generally less served than urban ones, and this is particularly true for developing countries).*

2. Data schema structure and architecture:

- No issues were raised as to the architecture of the data schema *(Noted)*

3. Comments on applicability in developing countries:

- Many of the social vulnerability indicators will be difficult to populate in developing countries, in particular those relating to food security, preparedness and risk awareness. *(The reviewer is correct in stating that some of the social indicators will be difficult to measure with the available data. It is also clear that this difficulty will be more evident in developing countries which may lack the infrastructure to store valuable social data in a systematic and standardised way. The structure of the social indicators data schema is surely very ambitious when applied to the context of a developing country. Nevertheless, the structure and the indicators used are not dissimilar from the ones used and validated by international development donors. It has been deemed appropriate therefore to keep the structure as it is, allowing for*



“nullable” field to be present rather than discarding them completely, in the hope that the schema can grow with time and improve in the quantity and quality of data that are collected and stored.)

- Religious buildings could be added as specific assets of interest in future development of the data schema. *(The observation has been noted)*
 - For buildings and developing countries it is hard to classify buildings into high medium and low code due to either the lack of code implementation in practice or the fact that most codes of practice are of similar (non-hazard design) level. This field might only be relevant to modern steel or concrete construction. *(The Challenge 3 team agrees with this point. However, the field of design code has been retained in both Level 2 and 3 as it is regarded as important by the literature and is commonly adopted also in the development of fragility and vulnerability functions)*
 - There are institutional challenges to finding the appropriate data with which to populate the data schema – competing agencies involved in spatial planning and many agencies which are under different obligations have information about hazards. For instance, in the Kyrgyz Republic, the Institute of Seismology National Academy of Science have information on seismicity and seismic hazard; the Institute of Rock Mechanics National Academy of Science have an information on landslides and some data on radionuclide waste; the Ministry of Emergency situations have information on floods, landslides etc. and so do many other Agencies. *(The observation has been noted and the question will be explored at the Tanzania workshop. At the time of writing of the report, this comment has been only partially addressed. Even though it is impossible to model how institutional challenges affect the availability of shared and inter-operable data, in the data schema a supporting table has been designated ad hoc to keep track of data coming from different data sources, different users, and acquired at different times. The data table is, in its design, an essential repository of useful metadata to check the integrity and comparability of the data).*
 - There are challenges posed in the regulatory framework. There can be a lack of integrated planning practice. Hence, who has the responsibility to fill in the data schema? *(The observation has been noted and the question has been explored at the Tanzania workshop. However, the vision of building an expandable and open repository of social and physical vulnerability data does call for a large uptake of the schema to ensure that data are available for several of countries and at different scales. The comment of the reviewer is very relevant and the question in very good, even though it cannot be answered at this stage.)*
4. Suggestions for future work:
- In future, roads could be included as part of the transport infrastructure. There is extensive evidence and literature about failure of road tracts on slopes or embankments. These are also the major reason of road interruptions, as they are affected by slope failure or landslide (either below or above road level). Also, this is much more common in medium level hazards for both rain related and storm surge related events. Most common reason for road interruption in developing countries where bridges are rarer. *(This point has been noted, and in the future could enter the physical indicator data schema. As far as the FF and VF, the Challenge Team have not seen such functions in the literature for road tracts yet. These may become available in the future.)*
 - Inclusion in the future of fire as a hazard. *(This hazard will be considered in the future development of the data schema, beyond the current Challenge 3 project).*



2.2 Revised Level 2 Data Schema

Small changes to the contents of the Level 2 data schema were implemented following the international review. However, a significant change was made to the data schema architecture during the process of its implementation and interface customisation.

The revised Level 2 data schema is implemented with a modular design. The modular design presents several advantages. It reduces repetition of data entries, helps maintain consistency in naming and references across the data schema (e.g. through unique supporting), aids to define and modify relationships between different components of the data schema and facilitates data schema expansion or reduction.

The most notable difference between the Level 2 and Level 3 schema is that, in the latter, the Vulnerability, Fragility, Damage to Loss Function module comprises three base tables as opposed to the single base table architecture of Level 2. This design revision was done in the interest of clarity. Fragility, Vulnerability and DtL functions are described by a number of different parameters and have therefore shared fields. However, there are some specific components (e.g., information on the damage scale used, Engineering Demand Parameter (EDP)), which only some functions draw upon. If the single table design had been used, the data entry of a damage to loss function would have forced the user to skip through numerous fields which are not applicable to functions of this type; producing in the end a data schema that appears, at a first glance, largely unpopulated. The new design ensures a faster data entry and improves the data exploration experience.

Furthermore, to facilitate data entry and reduce ambiguity and errors in data entry by different users, the data schema has been provided with an online interface accessible after a credentials check done by the main administrator. The schema is hosted on Heroku – a Platform as a service (PaaS) that allows developers to build, run, and operate applications in the cloud. The customisation uses the Heroku add-on called Adminium. The combination of these software solutions has allowed the developer to have control on the final look and user-friendliness of the data schema and to test multiple solutions, whilst performing rounds of data entry, testing, and standards control.

The overarching objective of the customisation has been to simplify the data entry for the final user whilst preserving data integrity, and therefore also limiting data cleansing after data input. The data entry process has been facilitated by providing for many fields drop down menus with pre-populated options (i.e., enumerated fields). These pre-defined data types can be accessed and modified (e.g., adding and removing possible alternatives) only by the administrator of the source code and cannot be altered at the level for the interface.

It is noted that only the scoring system for vulnerability and fragility functions presented in the MOVER Level 2 data schema report (and reproduced in Annex II for ease of reference) is included in the final Level 2 data schema. This is due to practical considerations, as it is not deemed feasible to score every single data entry to the physical and social indicators data schemas. The scoring tables associated to the Physical Vulnerability, Social Vulnerability, and Physical, Social and Hybrid Indices modules are presented only for illustrating the relationships that each scoring table has with the base tables of the respective modules.

The coded final Level 2 data schema is presented in Section 3.0 of this report.

2.3 From Level 2 to Level 3

The Level 3 data schema is a reduced version of the Level 2 data schema and is designed to be applicable to developing country contexts. By “reduced” here we mean that, as compared to the Level 2 data schema, the Level 3 data schema has:

- a smaller number of data entry fields
- a greater number of data fields that are “nullable”, i.e. for which it is allowed to enter no data



To decide on which data fields to retain in the Level 3 data schema and which data fields needed to be “nullable”, the following approaches were taken:

1. **Expert judgement and review:** All components of the data schema were reviewed by members of the Challenge 3 team, with the purpose of identifying redundant data fields and data fields considered critical to vulnerability evaluation as opposed to desirable.
2. **Literature search of FF and VF for Tanzania and neighbouring countries:** A literature review was undertaken of the vulnerability and fragility functions available for Tanzania and neighbouring countries for the different assets and hazards in the MOVER data schema.
3. **Check with data availability in Challenge 2 Exposure:** A consultation was undertaken with GEM to identify the format and availability for developing countries of data for physical and social vulnerability indicators derived from exposure information.
4. **Data field relevance evaluation for Tanzania:** An evaluation of the relevance of all data fields to the local context in Tanzania was carried out by the Ardhi University Challenge 3 team members.
5. **Vulnerability data availability survey for Tanzania:** A survey of availability of data for the physical vulnerability indicators was undertaken by the Ardhi University team members of Challenge 3.

The results of 4 and 5 are presented in Annex 1, where a table presents information on data availability for populating the physical vulnerability indicators, the data sources from which data may be obtained and the geographical scale at which the data is available.

The criteria used to eliminate data fields from the Level 3 data schema were:

- The data field was evaluated as redundant by experts;
- The data field was evaluated as desirable by experts, and the data to populate the data field was determined as unavailable in approaches 3, 4 and 5;
- The data field was evaluated as desirable but rated as not relevant in approach 4;
- The data field was evaluated as desirable but systematically did not appear in the reviewed FF and VF literature of approach 2.

It is noted that if a data field was considered critical by experts and the literature (1 and 2), but data was not available for its evaluation (from 2 and 4) or it was not identified as relevant (from 3), this data field was NOT eliminated from the Level 3 data schema.

All data fields determined as critical and with available data for their population are deemed not “nullable” in the data schema. All those data fields evaluated retained in the Level 3 data schema but evaluated as unlikely to have data available for their population have been made “nullable”.

3 The Final Level 2 and Level 3 Data Schemas

The final MOVER data schema consists of 4 separated modules; the Vulnerability, Fragility and damage to Loss Functions module, The Physical Indicators module, the Social Indicators module, and the Physical, Social and Hybrid Indices module. These modules work and are presented independently.

Each of the module comprises one or more base tables (e.g., the Vulnerability, Fragility and damage to Loss Functions module has in fact three base tables: one for the Fragility functions, one for the Vulnerability functions, and one for the Damage to Loss functions) on which the main information of functions, indicator, and indices are presented. The base tables are linked and point to specific fields of the supporting tables, which work as dictionaries from which supplementary information can be retrieved.



Overall, the data schema operates on an intricate system of entities and relationships. Links to the Entity-Relationship (ER) diagrams for each of the modules of the data schema are provided below:

All modules schema: <https://drive.google.com/open?id=1RTHteLvcBIT-OYpfZWdDukgCpmFQ435X>

Vulnerability, Fragility and Damage to Loss Function Module: <https://drive.google.com/open?id=1YNPb65JBmCgmeXcmRwYWe1IF0krqy-dj>

Vulnerability Functions base table and supporting tables: https://drive.google.com/open?id=1BxZFAV6_wJtM-Yt3kJzDoeFweFGmNp6S

Fragility Functions base table and supporting supporting tables: https://drive.google.com/open?id=1iz2hD64UrR1pG72ZSR1zT_TXa5oiCgTA

Damage to Loss Functions base table and supporting supporting tables: https://drive.google.com/open?id=1hnhj96XV2pf1IditUXQfxsom_1cZq3fu

Physical Indicators Module: https://drive.google.com/open?id=1cs2e-xdA3_W0MmdiBrUFKir1fulZ-lzQ

Social Indicators Module: <https://drive.google.com/open?id=1ZBYapDI1qgVPjTQ7jHuvktDrP460cF1M>

Physical, Social and Hybrid Indices Module: https://drive.google.com/open?id=1-bBMJyfPEW8JaqQ0RLn5JP1Z_rPx8SMC

3.1 Description of components

3.2.1 MODULE 1: Vulnerability, Fragility and Damage to Loss functions

The Vulnerability, Fragility and Damage to Loss Functions module consists of three base tables (i.e., ff_table, vf_table, and dtl_table) and of six supporting tables which are not shared with the other three modules (i.e., edp, loss_parameter, damage_scale, ff_scoring_table, vf_scoring_table, im_table). The module is also linked to the Hazard, Asset, Reference, and Data tables, which contain supporting data shared across all the four modules.

The following subsections unpack the fields of each of the base tables of the Vulnerability, Fragility and Damage to Loss Function module, provides a short description on the type of data stored in each field and, most importantly, highlights the evolution of the schema of each base table from the Level 2 to Level 3.

Vulnerability functions table

Figure 3.1 lists all the fields of the Vulnerability Functions base table (vf_table) which are characterised by the associated data type and constraints. In the pictures, key symbols are associated to fields which are either a primary or foreign key; namely a field which connects the base table to the supporting tables that allows associate data discovery in the linked tables.



Column name	Type	Null
 id	 integer	 NOT NULL
 hazard	 hazard_enum	 NOT NULL
 asset	 asset_enum	 NOT NULL
sub_asset	 character varying(100)	
taxonomy	 character varying(250)	
country_iso	 character varying(250)	 NOT NULL
approach	 approach_enum	 NOT NULL
 reference	 character varying(100)	 NOT NULL
vf_relationship	 f_relationship_enum	
vf_math	 f_math_enum	
par_names	 character varying(100)	
ub_par_value	 character varying(100)	
med_par_value	 character varying(100)	
lb_par_value	 character varying(100)	
im_range	 character varying(25)	
im_method	 im_method_enum	 NOT NULL
im_sim_type	 sim_method_enum	
 impe_reference	 character varying(100)	

Figure 3.1 – Schema of the Vulnerability Function base table.



	scale_applicability	scale_app_enum	
Q	im_name_f	im_all_enum	
	sample_f	sample_enum_f	
	vf_math_model	f_mathtype_enum	
Q	bespoke_model_ref	character varying(200)	
	ub_par_perc	character varying(250)	
	lb_par_perc	character varying(250)	
Q	lp_name	lp_all_enum	
	an_model_type	an_model_type_enum	
	vf_disc_im	character varying(50)	
	vf_disc_ep	character varying(50)	
	data_countries	character varying(100)	
Q	im_data_source	character varying(100)	
	n_events	integer	
	n_assets	integer	
	nonsampling_err	nonsampling_err_enum	
	type_nonsampling_err	type_nonsampling_err_enum	
	is_fix_nonsamp_err	boolean	
	is_data_aggregated	boolean	
	n_data_points_aggr	integer	
	is_data_disaggr	boolean	
	n_data_points_disaggr	integer	
	an_analysis_type	an_analysis_type_enum	
	em_analysis_type	em_analysis_type_enum	
	jd_analysis_type	jd_analysis_type_enum	
	is_fit_good	boolean	NOT NULL
	fit_ref	fit_ref_enum	
	is_validation	boolean	NOT NULL
	val_data_source	character varying(50)	
	is_existing_val_study	boolean	
Q	val_study_reference	character varying(50)	
	scale_applicability	scale_app_enum	NOT NULL
Q	im_name_f	im_all_enum	NOT NULL
	sample_f	sample_enum_f	
	vf_math_model	f_mathtype_enum	
Q	bespoke_model_ref	character varying(200)	
	ub_par_perc	character varying(250)	
	lb_par_perc	character varying(250)	
Q	lp_name	lp_all_enum	NOT NULL
	an_model_type	an_model_type_enum	
	vf_disc_im	character varying(50)	
	vf_disc_ep	character varying(50)	

Figure 3.1 (continued) – Schema of the Vulnerability Function base table.



Table 3. 1 provides a more detailed description of the fields of the vulnerability function table. The fields are listed in the same order in which they appear to the user performing the data entry using the Adminium interface. It is noted, that certain fields in the schema are flexible in the number of values entered. These are used to accommodate where multiple descriptors of the same type are required to capture the features of the functions. For example, in the vulnerability function description the names of the parameters used in the function can be listed in the par_names field. Multiple names can be listed, separated by semi-colons. The fields then containing values for these parameters, e.g. ub_par_values), should contain the same number of entries, and the entries should be listed in the order of entry of the parameter names.

The last column of the table put emphasis on the changes made from the Level 2 to the Level 3 data schema. At the first glance, it can be noticed that the schemas of the Vulnerability, Fragility and Damage to Loss Functions tables have only changed slightly from the Level 2 schema. However, the design of the Level 3 assumes that in its application to data-poor countries, many fields of the schema may remain unpopulated. The design of the Level 3 has taken into consideration this possibility by limiting the number of fields which have to abide to the 'NOT NULL' constraint. This design solution allows to fulfil the objective for a fully expandable data schema, by retaining fields that may remain empty, whilst also allowing applicability to both developed and developing countries. The existence of non-nullable fields also provides some guidance regarding the information that are essential and must be collected for the record to be usable and representative.



Table 3. 1 – Schema of the Vulnerability Functions table, described field by field.

id	ID (Hidden field)	Unique identifier of the Vulnerability function and Primary Key	
hazard	Hazard type	Enumerated field. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought.	From varchar to enum
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop.	From varchar to enum
sub_asset	Sub-asset	Description of sub-asset. Example: Unreinforced Masonry	
taxonomy	Taxonomy	GEM taxonomy	<u>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</u>
country_iso	Country/ies (ISO1; ISO 2; ...)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.	Adjustment to ISO country codes
approach	Approach	Enumerated type which lists the possible types of vulnerability functions. These include: Empirical, Analytical, Judgement, Hybrid - Analytical/Empirical, Hybrid - Analytical/Judgement, Hybrid - Empirical/Judgement, and Hybrid - Analytical High Fidelity/Low Fidelity.	Inclusion of more categories in the enumerative options.
reference	Reference	Reference study of the vulnerability function. Details on each of the reference studies are provided in the Reference table.	Definition of a separate Reference table.



Table 3. 1 (continued) – Schema of the Vulnerability Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
vf_relationship	Mathematical/ Discrete	Enumerated field to distinguish between Mathematical and Discrete functions.	
vf_math	Parametric/Bespoke	Enumerated field to distinguish between Parametric or Bespoke discrete functions.	
par_names	Parameters names (Par1; Par2;...)	Parameters values names Example: MIDR , Ash depth	
ub_par_values	Upper bound parameters value (Value1; Value2;...)	Example: 0.9; 350	These values correspond to the parameters listed in the filed indicated as Parameters names. Depending on the type of function, the parameters used to characterise the function may be different. Structured in this way the data schema allows for a standardised representation of all function, allowing the user to specify, the names of the parameters used to characterise a function and their corresponding upper bound, median, and lower bound values.
med_par_value	Median parameter values (Med1; Med2;...)	Example: 0.2; 0.75	
lb_par_values	Lower bound parameters value (Value1; Value2;...)	Example: 0.01; 3	
im_range	IM range	Range of intensity measures. Example: 0;500	
im_method	IM method	Enumerated field. Possible entries include: Recorded, Surveyed, Simulated, Unknown	
im_sim_type	IM Simulation type (for simulated method only)	Enumerated field: Physics-based; IMPE	



impe_reference	IMPE reference (for IMPE simulation only)	Reference study of the IMPE simulation.	
data_countries	Data countries (ISO1; ISO2)	Adjustment to Country ISO codes	
im_data_source	IM data source/s	Reference studies for the IM data sources	
n_events	N events	Numeric entry which specifies the number of events the function has been built on	



Table 3. 1 (continued) – Schema of the Vulnerability Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
n_assets	N assets	Numeric entry which specifies the number of assets the function has been built on.	
nonsampling_error	Is there a non-sampling error?	Enumerative field. Possible entries are: Yes, No, Unknown	
type_nonsampling_error	Type of non-sampling error	Enumerative field. Possible entries include: Under coverage, Incomplete data, Measurement error, Unknown.	
is_fix_nonsamp_err	Has non-sampling error being fixed?	Boolean TRUE/FALSE	
is_data_aggr	Is data aggregated?	Boolean TRUE/FALSE	
n_data_points_aggr	N of data points aggregated	Number of aggregated data points used for the evaluation of data quality.	
is_data_disaggr	Is data disaggregated?	Boolean TRUE/FALSE	
n_data_points_disaggr	N of data points disaggregated	Number of disaggregated data points used for the evaluation of data quality.	
an_analysis_type	Type of analysis for Analytical functions	Enumerated field. Possible entries include: Simplified, Advanced	
em_analysis_type	Type of analysis for Empirical functions	Enumerated field which lists possible types of regression and include: Least squares, GLM, GAM	
jd_analysis_type	Type of analysis for Judgement functions	Enumerated field which lists possible elicitation methods and include: Delphi, Cookes.	
is_fit_good	Is the fit good?	Boolean TRUE/FALSE	This field is <u>NULLABLE</u> in the <u>Level 3 data schema</u> but marked as a <u>compulsory field</u> in the <u>Level 2</u> .



Table 3. 1 (continued) – Schema of the Vulnerability Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
fit_ref	Reference model for fitting	Enumerated field. Possible entries include: AIC, BIC, Kolmogorov-Smirnov.	
is_validation	Has the function been validated?	Boolean TRUE/FALSE	<u>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</u>
val_data_source	Data source of independent data	If a validation has been conducted, this field indicates the source of the independent data.	
is_existing_val_study	Is the validation study existing?	Boolean TRUE/FALSE	
val_study_reference	Validation study reference (if existing)	Reference of the Validation study	
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability of the damage to loss function Country (Level 0), Sub-country (Level 1), Local (Level 2), Asset (Level 3).	The scale of applicability has been matched to the GEM taxonomy.
im_name_f	IM name	Enumerated field which list all the	
sample_f	Sample	This enumerated field indicates the type of sampling used and include as possible entries: Single-asset class, Multi-assets classes, Single-asset.	<u>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</u>
vf_math_model	Mathematical Model	Enumerate field. Possible entries include: Cumulative lognormal Cumulative normal Exponential Bespoke - see reference	Inclusion of more categories in the enumerative options.
bespoke_model_reference	Bespoke model reference	Reference study of the bespoke model	Added field from Level 2



Table 3. 1 (continued) – Schema of the Vulnerability Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
ub_par_perc	Upper bound parameters percentiles (Perc1; Perc2;..)	Percentiles associated to the upper bound parameters for parametric functions	
lb_par_perc	Lower bound parameters percentiles (Perc 1;Perc 2;...)	Percentiles associated to the lower bound parameters for parametric functions	
lp_name	Loss Parameter name	Enumerated field which lists all the identified loss parameters.	Definition of a separate Loss parameter table.
an_model_type	Analytical model type	Enumerated field. Possible entries include: Simplified, Advanced	
vf_disc_im	IM values (for discrete functions)	This field lists the IM values for the characterization of discrete functions	
vf_disc_ep	EP values (for discrete functions)	This field lists the associated exceeded probability values to the IM values of the previous field.	
Formula	The field 'Formula' in the Level 2 Schema has been dropped.		

Fragility functions table

Figure 3.2 lists all the fields of the Fragility Functions base table (ff_table). Like the Vulnerability Function table was the only one connecting to the Loss Parameters supporting table, the Fragility Function table is the only table connecting with the EDP table. It is noted that fragility functions are entered for specific damage states. If a study contains a set of fragility functions for 5 damage states, the fragility function is entered 5 times for each damage state due to differences that can exist in how each damage state curve is derived (especially in empirical studies).



It is noted, that certain fields in the schema are flexible in the number of values entered. These are used to accommodate where multiple descriptors of the same type are required to capture the features of the functions. For example, in the fragility function description the names of the parameters used in the function can be listed in the par_names field. Multiple names can be listed, separated by semi-colons. The fields then containing values for these parameters (e.g. ub-par-values) should contain the same number of entries, and the entries should be listed in the order of entry of the parameter names.

Column name	Type	Null
id	integer	NOT NULL
hazard	hazard_enum	NOT NULL
asset	asset_enum	NOT NULL
sub_asset	character varying(100)	
taxonomy	character varying(250)	
country_iso	character varying(250)	NOT NULL
approach	approach_enum	NOT NULL
reference	character varying(100)	NOT NULL
dm_scale_type	dm_scale_ty_enum	
dm_scale_reference	character varying(100)	
n_dm_states	character(1)	
dm_states_name	character varying(100)	
edp_dmstate_thre	character varying(100)	
ff_relationship	f_relationship_enum	
ff_math	f_math_enum	
par_names	character varying(100)	
ub_par_value	character varying(100)	
med_par_value	character varying(100)	
lb_par_value	character varying(100)	

Figure 3.2 – Schema of the Fragility Function base table.



	ff_disc_im	character varying(100)	
	ff_disc_ep	character varying(100)	
	im_range	character varying(25)	
	im_method	im_method_enum	NOT NULL
	im_sim_type	sim_method_enum	
⌘	impe_reference	character varying(100)	
	data_countries	character varying(100)	
⌘	im_data_source	character varying(100)	
	n_events	integer	
	n_assets	integer	
	nonsampling_err	nonsampling_err_enum	NOT NULL
	type_nonsampling_err	type_nonsampling_err_enum	
	is_fix_nonsamp_err	boolean	
	is_data_aggregated	boolean	
	n_data_points_aggr	integer	
	is_data_disaggr	boolean	
	n_data_points_disaggr	integer	
	an_analysis_type	an_analysis_type_enum	
	em_analysis_type	em_analysis_type_enum	
	jd_analysis_type	jd_analysis_type_enum	
	is_fit_good	boolean	
	fit_ref	fit_ref_enum	
	is_validation	boolean	
	val_data_source	character varying(50)	
	is_existing_val_study	boolean	
⌘	val_study_reference	character varying(50)	
	scale_applicability	scale_app_enum	NOT NULL
	sample_f	sample_enum_f	
⌘	bespoke_model_ref	character varying(200)	
	ff_math_model_f	f_mathtype_enum	
	dm_state_f_name	damage_states_all_enum	
⌘	damage_scale_name	damage_scales_all_enum	NOT NULL
⌘	im_name_f	im_all_enum	NOT NULL
⌘	edp_name_all	edp_name_enum	
	ub_par_perc	character varying(100)	
	lb_par_perc	character varying(100)	
	an_model_type	an_model_type_enum	

Figure 3.2 (continued) – Schema of the Fragility Function base table.



Table 3. 2 – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
id	ID (Hidden field)	Unique identifier of the Vulnerability function and Primary Key	
hazard	Hazard type	Enumerated field. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought.	From varchar to enum
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop.	From varchar to enum
sub_asset	Sub-asset	Description of sub-asset. Example: Unreinforced Masonry	
taxonomy	Taxonomy	GEM taxonomy	<u>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</u>
country_iso	Country/ies (ISO1; ISO 2 ;...)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.	Adjustment to ISO country codes



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
approach	Approach	Enumerated type which lists the possible types of vulnerability functions. These include: Empirical, Analytical, Judgement, Hybrid - Analytical/Empirical, Hybrid - Analytical/Judgement, Hybrid - Empirical/Judgement, and Hybrid - Analytical High Fidelity/Low Fidelity.	Inclusion of more categories in the enumerative options.
reference	Reference	Reference study of the vulnerability function. Details on each of the reference studies are provided in the Reference table.	Definition of a separate Reference table.
dm_scale_type	Damage scale type	Enumerated field which specifies if the damage scale used by the function is 'Existing' or 'Bespoke'.	



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
dm_scale_reference	Damage scale reference	Reference study of the damage scale. Each damage scale study is recorded in the Reference table.	Definition of a separate References table.
n_dm_states	N of damage states	Number of damage states studied in the reference study of the function.	
dm_states_name	Damage states names in the original reference	Names of the damage states studied in the reference study of the function, listed using the exact names used in the reference damage scale. The names are separated by a semicolon.	
edp_dmstate_thre	EDP threshold	It indicates the specific damage state EDP threshold.	
ff_relationship	Mathematical/ Discrete	Enumerated field to distinguish between Mathematical and Discrete functions.	
ff_math	Parametric/Bespoke	Enumerated field to distinguish between Parametric or Bespoke discrete functions.	
par_names	Parameters names (Par1; Par2; ...)	Parameters values names Example: Mean; logSD	
ub_par_values	Upper bound parameters value (Value1; Value2; ...)	Example: 0.9; 350	



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
med_par_value	Median parameter values (Med1; Med2; ...)	Example:0.2; 0.75	
lb_par_values	Lower bound parameters value (Value1; Value2; ...)	Example: 0.01; 3	
ff_disc_im	IM values (for discrete functions)	This field lists the IM values for the characterization of discrete functions	
ff_disc_ep	EP values (for discrete functions)	This field lists the associated exceeded probability values to the IM values of the previous field.	
im_range	IM range	Range of intensity measures. Example: 0; 500	
im_method	IM method	Enumerated field. Possible entries include: Recorded, Surveyed, Simulated, Unknown	
im_sim_type	IM Simulation type (for simulated method only)	Enumerated field which indicates the type of simulation used to assess the IM. Possible entries are: Physics-based, IMPE	
impe_reference	IMPE reference (for IMPE simulation only)	Reference study of the IMPE simulation method.	



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
data_countries	Data countries (ISO1; ISO2; ...)	Adjustment to Country ISO codes	
im_data_source	IM data source/s	Reference studies for the IM data sources	
n_events	N events	Numeric entry which specifies the number of events the function has been built on	
n_assets	N assets	Numeric entry which specifies the number of assets the function has been built on.	
nonsampling_error	Is there a non-sampling error?	Enumerative field. Possible entries are: Yes, No, Unknown	
type_nonsampling_error	Type of non-sampling error	Enumerative field. Possible entries include: Under coverage, Incomplete data, Measurement error, Unknown.	
is_fix_nonsamp_err	Has non-sampling error being fixed?	Boolean TRUE/FALSE	
is_data_aggr	Is data aggregated?	Boolean TRUE/FALSE	
n_data_points_aggr	N of data points aggregated	Number of aggregated data points used for the evaluation of data quality.	



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
is_data_disaggr	Is data disaggregated?	Boolean TRUE/FALSE	
n_data_points_disaggr	N of data points disaggregated	Number of disaggregated data points used for the evaluation of data quality.	
an_analysis_type	Type of analysis for Analytical functions	Enumerated field. Possible entries include: Simplified, Advanced	
em_analysis_type	Type of analysis for Empirical functions	Enumerated field which lists possible types of regression and include: Least squares, GLM, GAM	
jd_analysis_type	Type of analysis for Judgement functions	Enumerated field which lists possible elicitation methods and include: Delphi, Cookes.	
is_fit_good	Is fit good?	Boolean TRUE/FALSE	This field is <u>NULLABLE</u> in the <u>Level 3 data schema</u> but <u>marked as a compulsory field in the Level 2.</u>
fit_ref	Reference model for fitting	Enumerated field. Possible entries include: AIC, BIC, Kolmogorov-Smirnov.	
is_validation	Has the function been validated?	Boolean TRUE/FALSE	This field is <u>NULLABLE</u> in the <u>Level 3 data schema</u> but <u>marked as a compulsory field in the Level 2.</u>



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
val_data_source	Data source of independent data for validation	If a validation has been conducted, this field indicates the source of the independent data.	
is_existing_val_study	Is the validation study existing?	Boolean TRUE/FALSE	
val_study_reference	Validation study reference (if existing)	Reference of the Validation study	
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability of the damage to loss function Country (Level 0), Sub-country (Level 1), Local (Level 2), Asset (Level 3).	The scale of applicability has been matched to the GEM taxonomy.
sample_f	Sample	This enumerated field indicates the type of sampling used and include as possible entries: Single-asset class, Multi-assets classes, Single-asset.	<u>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</u>
bespoke_model_reference	Bespoke model reference	Reference study of the bespoke model	Added field from Level 2



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
ff_math_modelf	Mathematical Model	Enumerate field. Possible entries include: Cumulative lognormal Cumulative normal Exponential Bespoke - see reference	Inclusion of more categories in the enumerative options.
dm_state_f_name	Damage state of the function	Name of the specific damage state studied by the function. The name follows specific nomenclature of the damage scale used.	
damage_scale_name	Damage scale name	Enumerated field that allows the user to choose the name of the damage scale from those listed in the damage scale table. Entries like 'Bespoke - see reference', and 'Unknown' allow the user to specify if the damage scale is bespoke or if the damage scale is not known.	Definition of a separate damage scale table.



Table 3.2 (continued) – Schema of the Fragility Functions table, described field by field.

Column name	Alias shown in interface	Description	Level 2 to Level 3 - Notes of changes
im_name_f	IM name	Enumerated field which list the name of the IM. A drop- down list of IM names is provided that links to the IM table.	New separate IM table
edp_name_all	EDP name	It indicates the specific engineering demand parameter (EDP) used to the DS thresholds.	Definition of a separate EDP table.
ub_par_perc	Upper bound parameters percentiles (Perc1; Perc2)	Percentiles associated to the upper bound parameters for parametric functions	
lb_par_perc	Lower bound parameters percentiles (Perc1; Perc2; ...)	Percentiles associated to the lower bound parameters for parametric functions	
an_model_type	Analytical model type	Enumerated field. Possible entries include: Simplified, Advanced	
Formula	The field 'Formula' in the Level 2 Schema has been dropped.		



Damage to Loss functions table

Figure 3.3 lists the fields of the Damage to Loss Functions base table (dtl_table). The Damage Scale table is the supporting table which data are linked to both the Fragility Function and Damage to Loss tables, by means of the 'Damage scale name' field which is an enumerative field in both tables and is a unique identifier for the entries of the damage scale table. Differently from the vulnerability and fragility functions base tables, the DtL table is the only base table of the model that does not have an associated scoring table. The assumption here is that, as DtL function are used as “conversion” functions from the damage assessment of the fragility function to a loss assessment for an indirect vulnerability function. Hence, it is assumed that the scoring given to the Fragility Function to which the DtL function will also apply to the resulting indirect vulnerability function.

It is noted, that certain fields in the schema are flexible in the number of values entered. These are used to accommodate where multiple descriptors of the same type are required to capture the features of the functions. For example, in the damage to loss function description the names of the parameters used in the function can be listed in the dtl_parameter field. Multiple names can be listed, separated by semi-colons. The fields then containing values for these parameters, (e.g. dtl_parameters_values), should contain the same number of entries, and the entries should be listed in the order of entry of the parameter names.

The Level 3 schema of the Damage to Loss table has no variation from the schema presented in Level 2. Hence, the fourth column is not present in Table 3.3.

	Column name	Type	Null
PK	id	integer	NOT NULL
FK	hazard	hazard_enum	
FK	asset	asset_enum	
	sub_asset	character varying(100)	
	taxonomy	character varying(250)	
	country_iso	character varying(250)	
FK	reference	character varying(100)	
	dtl_pdf_type	dtl_pdf_type_enum	
	dtl_parameters	character varying(100)	
	dtl_parameters_values	character varying(100)	
	dm_scale_type	dm_scale_ty_enum	
	dm_scale_reference	character varying(100)	
	n_dm_states	character(1)	
	dm_states_name	character varying(100)	
FK	damage_scale_name	damage_scales_all_enum	
	dm_state_f_name	damage_states_all_enum	
	scale_applicability	scale_app_enum	

Figure 3.3 – Schema of the Damage to Loss base table.



Table 3. 3 – Schema of the Damage to Loss table, described field by field.

Column name	Alias shown in interface	Description
id	ID (Hidden field)	Unique identifier of the Dtl function and Primary Key
hazard	Hazard type	Enumerated field. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought.
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop.
sub_asset	Sub-asset	Description of sub-asset. Example: Unreinforced Masonry
taxonomy	Taxonomy	GEM taxonomy
country_iso	Countries (ISO1; ISO 2)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.
reference	Reference	Reference study of the damage to loss function
dtl_pdf_type	Dtl PDF type	Enumerated field indicating the type of probability distribution used in the function. Possible entries include: Beta, Normal, Lognormal, Uniform, Single-value.
dtl_parameter	Parameters names (Par1; Par2; ...)	Names of parameters that are used in the probability distribution function, separated by a semi-colon. Example: Mean; SD
dtl_parameters_values	Parameters values (Value1; Value2; ...)	Names of parameters that are used in the probability distribution function, separated by a semi-colon. Example: 1.000; 0.000



Table 3.3 (continued) – Schema of the Damage to Loss table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
dm_scale_type	Damage scale type	Enumerated field which specifies if the damage scale used by the function is 'Existing' or 'Bespoke'.
dm_scale_reference	Damage scale reference	Reference study of the damage scale. Each damage scale study is recorded in the Reference table.
n_dm_states	N of damage states	Number of damage states used in the reference study of the function.
dm_states_name	Damage states names in the original reference	Names of the damage states studied in the reference study of the function, listed using the exact names used in the reference damage scale. The names are separated by a semicolon.
damage_scale_name	Damage scale name	Enumerated field that allows the user to choose the name of the damage scale from the existing known damage scales listed in the damage scale table. Entries like 'Bespoke - see reference', and 'Unknown' allow the user to specify if the damage scale is bespoke or if the damage scale is not known.
dm_state_f_name	Damage state of the function	Name of the specific damage state studied by the function. The name follows specific nomenclature of the damage scale used.
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability of the damage to loss function Country (Level 0), Sub-country (Level 1), Local (Level 2), Asset (Level 3).



3.2.2 MODULE 2: Physical indicators

The physical indicator module comprises a base table, supporting scoring table, and also two additional tables: the physical vulnerability categories and characteristics tables. These are used as dictionaries and provide descriptions for the Physical Categories and Characteristics identified in the Level 2 data schema. Appendix I provides a list of the indicators that have been kept in Level 3 after the validation of the local consultants in Tanzania. The module also links to the Hazard, Asset, Data and Reference tables.

Column name	Type	Null
id	integer	NOT NULL
hazard	hazard_enum	NOT NULL
asset	asset_enum	NOT NULL
sub_asset	character varying(100)	
country_iso	character varying(250)	
scale_applicability	scale_app_enum	NOT NULL
adm_0	character varying(50)	
adm_1	character varying(50)	
adm_2	character varying(50)	
adm_3	character varying(50)	
phy_v_cat_name	phy_vul_cat_enum	NOT NULL
phy_v_cat_symbol	phy_vul_sym_enum	NOT NULL
phy_v_char_name	phy_vul_char_enum	NOT NULL
phy_v_char_symbol	phy_vul_csym_enum	NOT NULL
indicator_type	phy_indicator_type_enum	NOT NULL
indicator_name	phy_indicator_name_enum	NOT NULL
indicator_value	real	
grid	integer	

Figure 3.4 – Schema of the Physical Vulnerability Indicators table.



Table 3.4 – Schema of the Physical Vulnerability Indicators table, described field by field.

Column name	Alias shown in interface	Description
id	ID (Hidden field)	Unique identifier of the physical vulnerability indicator and Primary Key
hazard_type	Hazard type	Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, Drought, and Multi-hazard
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop. In the integration with the data schemas of the Challenge Exposure, this table will be replaced with the Asset table of their schema and it will provide a link to all tables of that schema.
subasset	Sub-asset	The field lists and describes all the sub-assets to which the indicator is applied. Example: RC, Masonry, Timber
country_iso	Country/ies (ISO1; ISO 2)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability:Country (Level 0), Sub-country (Level 1), Local(Level 2), Asset (Level 3).
adm_0	Adm_0 (Country ISO)	Name of the Country (ISO country code) for which data are available for the analysed physical indicator
adm_1	Name of Adm_1	Example: name of region
adm_2	Name of Adm_2	Example: Name of city



Table 3.4 (Continued)– Schema of the Physical Vulnerability Indicators table, described field by field.

Column name	Alias shown in interface	Description
adm_3	Name of Adm_3	Example: Address of asset
phy_v_cat_name	Physical Vulnerability Category	Enumerative field: which lists all the Physical Vulnerability Categories identified in Level 2
phy_v_cat_symbol	Physical Vulnerability Category (Symbol)	Defined abbreviations for the Physical Vulnerability Categories
phy_v_char_name	Physical Vulnerability Characteristic	Enumerative field: which lists all the Physical Vulnerability Characteristics identified in Level 2
phy_v_char_symbol	Physical Vulnerability Characteristics (Symbol)	Defined abbreviations for the Physical Vulnerability Characteristics
indicator_type	Indicator Type (Ratio, Percentage)	Enumerative field listing the types of available indicators. Example: Percentage
indicator_name	Indicator Name	Example: % of irregular residential buildings
Indicator_value	Indicator value	Real number
grid	Grid	Example: Grid#

3.2.3 MODULE 3: Social indicators

Like the physical indicators module, the social indicators module comprises a base table, supporting scoring table, and also two additional tables: the social vulnerability categories and characteristics tables. The module also links to the Hazard, Asset, Data and Reference tables. Schema and Description table are therefore the same as the Physical Vulnerability Indicators Module.



	Column name	Type	Null
🔍	id	integer	NOT NULL
🔍	hazard	hazard_enum	NOT NULL
🔍	asset	asset_enum	NOT NULL
	sub_asset	character varying(100)	
	country_iso	character varying(250)	
	scale_applicability	scale_app_enum	NOT NULL
	adm_0	character varying(50)	
	adm_1	character varying(50)	
	adm_2	character varying(50)	
	adm_3	character varying(50)	
🔍	soc_v_cat_name	soc_vul_cat_enum	NOT NULL
	soc_v_cat_symbol	soc_vul_sym_enum	NOT NULL
🔍	soc_v_char_name	soc_vul_char_enum	NOT NULL
	soc_v_char_symbol	soc_vul_csym_enum	NOT NULL
	indicator_type	indicator_type_enum	NOT NULL
	indicator_name	soc_indicator_name_enum	NOT NULL
	indicator_value	real	
	grid	integer	

Figure 3.5 – Schema of the social Vulnerability Indicators table.



Table 3.5 – Schema of the social Vulnerability Indicators table, described field by field.

Column name	Alias shown in interface	Description
id	ID (Hidden field)	Unique identifier of the social vulnerability indicator and Primary Key
hazard_type	Hazard type	Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, Drought, and Multi-hazard
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop. In the integration with the data schemas of the Challenge Exposure, this table will be replaced with the Asset table of their schema and it will provide a link to all tables of that schema.
subasset	Sub-asset	The field lists and describes all the sub-assets to which the indicator is applied. Example: RC, Masonry, Timber
country_iso	Country/ies (ISO1; ISO 2)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability: Country (Level 0), Sub-country (Level 1), Local (Level 2), Asset (Level 3).
adm_0	Adm_0 (Country ISO)	Name of the Country (ISO country code) for which data are available for the analysed physical indicator
adm_1	Name of Adm_1	Example: name of region
adm_2	Name of Adm_2	Example: Name of city



Table 3.5 (Continued) – Schema of the social Vulnerability Indicators table, described field by field.

Column name	Alias shown in interface	Description
adm_3	Name of Adm_3	Example: Address of asset
soc_v_cat_name	Social Vulnerability Category	Enumerative filed: which lists all the Social Vulnerability Categories identified in Level 2
soc_v_cat_symbol	Social Vulnerability Category (Symbol)	Defined abbreviations for the Social Vulnerability Categories
soc_v_char_name	Social Vulnerability Characteristic	Enumerative filed: which lists all the Social Vulnerability Characteristics identified in Level 2
soc_v_char_symbol	Social Vulnerability Characteristics (Symbol)	Defined abbreviations for the Social Vulnerability Characteristics
indicator_type	Indicator Type (Ratio, Percentage)	Enumerative field listing the types of available indicators. Example: Percentage
indicator_name	Indicator Name	Example: % of irregular residential buildings
Indicator_value	Indicator value	Real number
grid	Grid	Example: Grid#

3.2.4 MODULE 4: Physical, Social and Hybrid Indices

The Physical, Social and Hybrid Indices module comprises and base table and the associated scoring table. It is linked to the Reference table which stores the attributes of the reference study which first introduced the index. At this stage of development of the schema the names and values of the indicators that contribute to the index are input manually. At this stage of the development, it is not envisaged that the Indices Module can be used for modelling. Like for the function module, the Indices Module is a collection of indices, and of their attributes, categorised based on their specific applicability to pre-selected hazard and assets. All the attributes listed (e.g., values, weights) refer to the known applications of the index in the literature and cannot be assumed valid for all the case studies.



Column name	Type	Null
id	integer	NOT NULL
hazard	hazard_enum	NOT NULL
asset	asset_enum	NOT NULL
sub_asset	character varying(100)	
scale_applicability	scale_app_enum	NOT NULL
adm_0	character varying(100)	
adm_1	character varying(100)	
adm_2	character varying(100)	
adm_3	character varying(100)	
index_name	index_name_enum	NOT NULL
index_description	character varying(250)	NOT NULL
index_reference	character varying(100)	
index_ind	character varying(250)	NOT NULL
index_ind_values	character varying(250)	NOT NULL
index_ind_weights	character varying(250)	
grid	integer	
country_iso	character varying(250)	

Figure 3.6 – Schema of the Indices table.

Table 3.6 – Schema of the Indices table, described field by field.

Column name	Alias shown in interface	Description
id	ID (Hidden field)	Unique identifier of the index and Primary Key
hazard_type	Hazard type	Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, Drought, and Multi-hazard
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop. In the integration with the data schemas of the Challenge Exposure, this table will be replaced with the Asset table of their schema and it will provide a link to all tables of that schema.
subasset	Sub-asset	The field lists and describes all the sub-assets to which the indicator is applied. Example: RC, Masonry, Timber



Table 3.6 (Continued) – Schema of the Indices table, described field by field.

Column name	Alias shown in interface	Description
scale_applicability	Scale applicability	Enumerated field listing as possible entries the four scales of applicability: Country (Level 0), Sub-country (Level 1), Local (Level 2), Asset (Level 3).
adm_0	Adm_0 (Country ISO)	Name of the Country (ISO country code) for which data are available for the analysed physical indicator
adm_1	Name of Adm_1	Example: name of region
adm_2	Name of Adm_2	Example: Name of city
adm_3	Name of Adm_3	Example: Address of asset
index_name	Index name	Enumerative field: which lists all the Social Vulnerability Categories identified in Level 2
index_description	Description	Description of the index
index_reference	Reference study	Reference study which first used the Index.
index_ind	Indicators names (Ind1; Ind2)	Separated by a semi-colon
index_ind_values	Indicators Value (Value1, Value2)	Separated by a semi-colon
index_ind_weights	Indicators names (Weight1, Weight 2)	Separated by a semi-colon
grid	Grid	Example: Grid#
country_iso	Country/ies (ISO1; ISO 2)	List of countries which the function can be applied to, unequivocally identified by their ISO codes, separated by a semi-colon.



3.2.5 Supporting tables: Hazards, Asset, Intensity measures, Damage Scales, Loss Parameters, EDPs, Reference, Data, and Scoring tables, Categories and Characteristics.

This Section describes the supporting tables of the MOVER data schema with emphasis given to the fields of the schema.

As mentioned in Section 2, the supporting tables store supplementary information which the user may wish to access when selecting entries of the main base tables. For example, a user may want to verify the range of the Intensity Measure used in a Fragility Function. As the Fragility Function base table is linked to the IM table, this operation is made possible in the interface by means of associated data discovery, which traduces in hyperlinks all the fields in a base table for which a relationship to the any supporting tables exists. The associative discovery links act in all effects as digital dictionaries providing information on attributes that are not fundamental to the characterization of functions, indicators, or indices but that may aid its comprehension and usage.

It is also important to note that the fields for which a relationship between base and supporting table has been implemented are often enumerated fields. The entries of the supporting tables have been established by means of a careful review of the literature and validated during the process of population of the data schema, which has helped establish which IMs, damage scales, EDPs and loss parameters are more commonly used. Detailed information on the definitions and formulas of IM, damage scales, EDPs, and loss parameters are provided in the Annex III-VI.

Whilst the Hazards, Asset, Intensity measures, Damage Scales, Loss Parameters, EDPs table operate as digital dictionaries, the Reference and Data tables act as repositories of metadata. Lastly, the scoring tables are used to associate scores to the vulnerability and fragility functions.

Hazard table

The Hazard table contains a very limited number of fields (Figure 3.7). This is done on purpose in anticipation of the integration of the data MOVER data schema with the schema of Challenge 1 (Hazard). The Hazard table is used here to illustrate which fields are required in the Hazard table so that a join query can be performed on the base tables of the MOVER data schema. It is envisaged that the 'Hazard type' entry will be one of the main parameters which will be used by users looking for specific functions, indicators, or indices. Hence, this supporting table is linked to all the base tables of the 4 modules of the MOVER data schema and it also linked to the damage scale table.

Column name	Type	Null
hazard_id	integer	NOT NULL
hazard_type	hazard_enum	NOT NULL
description	character varying(250)	NOT NULL

Figure 3.7 – Schema of the Hazard table.



Table 3.7 – Schema of the Hazard table, described field by field.

Column name	Alias shown in interface	Description
hazard_id	ID (Hidden field)	Unique identifier of the hazard type and Primary Key
hazard_type	Hazard type	Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought. The Hazard field is also indexed to link to the FF, VF, DtL functions tables and Intensity Measure and Damage Scale tables.
description	Description	The field describes the hazard type and specifies which hazard subcategories are excluded. Example: Flood excludes flash floods.

Asset table

Similar to the Hazard table, the Asset table simulates the integration of the data MOVER data schema with the schema of Challenge 2 (Exposure). This supporting table is linked to all the base tables of the 4 modules of the MOVER data schema and it also linked to the damage scale table. Data types, constraints and description of the fields are provided in Figure 3.8 and Table 3.8

Column name	Type	Null
asset_id	integer	NOT NULL
asset	asset_enum	NOT NULL
sub_asset	character varying(100)	
taxonomy	character varying(250)	

Figure 3.8 - Schema of the Asset table.



Table 3.8 – Schema of the Asset table, described field by field.

Column name	Alias shown in interface	Description
asset_id	ID (Hidden field)	Unique identifier of the hazard type and Primary Key
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crop. In the integration with the data schemas of the Challenge Exposure, this table will be replaced with the Asset table of their schema and it will provide a link to all tables of that schema.
sub-asset	Sub-asset	Description of sub-asset. Example: Unreinforced Masonry
taxonomy	Taxonomy	GEM taxonomy

Intensity Measures (IM) table

The Intensity Measure (IM) table lists all intensity measures adopted in the description of the most commonly found fragility and vulnerability function literature for the hazards investigated. The definitions of the intensity measures used to prepopulate the table are provided in Appendix III. The IMs described by Challenge 1 in their submitted report are included as a subset of the IMs in this table, for interoperability between the data schemas of Challenge 1 and 3. The IM Table is called upon by the Fragility Function and Vulnerability Function modules.

Column name	Type	Null
im_id	integer	NOT NULL
hazard_type	hazard_enum	NOT NULL
im_symbol	character varying(10)	NOT NULL
definition	character varying(500)	NOT NULL
units	character varying(10)	
range	character varying(10)	
im_name_f	im_all_enum	NOT NULL

Figure 3.9 - Schema of the IM table.



Table 3.9 – Schema of the IM table, described field by field.

Column name	Alias shown in interface	Description
im_id	ID (Hidden field)	Unique identifier of the intensity measure and Primary Key.
hazard_type	Hazard type	<p>Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought.</p> <p>In the integration with the data schemas of the Challenge Hazard, this table will be replaced with the Hazard table of their schema and it will provide a link to all tables of that schema.</p>
im_symbol	IM Symbol	The symbol of the intensity measure.
definition	Definition	The field describes the intensity measure as a dictionary entry would do. As it is envisaged that, the IM table will operate as a dictionary, this entry cannot be null.
units	Units	Units of reference of the intensity measure. This field can be null if the information is not available.



Table 3.9 (continued) – Schema of the IM table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
range	Range (lower bound; upper bound)	Range of the intensity measure, defined by its lower bound and upper bound values. When both values are present, these are separated by a semicolon. If only one value is present, this is set to correspond to the lower bound value. This field can be null if the information is not available.
im_name_f	IM name (indexed field) - For details	The field specifies the name of the intensity measure. The field is enumerated and indexed so that the entries are predefined and allow for the associative discovery of the VF and FF function using a specific intensity measure. The field is also constrained to allow only for unique entries, so as to avoid that multiple user can input the same intensity measure, associating for instance two different definitions to the same intensity measure.

Damage Scales table

The Damage Scales table lists the most commonly found damage scales in the fragility function literature for the hazards investigated. The Damage Scales that currently are listed in the data schema are briefly presented in Annex IV. The Damage Scale Table is called upon by the Fragility Function module.



Column name	Type	Null
dm_scale_id	integer	NOT NULL
dm_scale_reference	character varying(100)	
asset	asset_enum	NOT NULL
sub_asset	character varying(100)	
n_dm_states	character(1)	NOT NULL
dm_states_id	character varying(50)	NOT NULL
dm_states_name	character varying(100)	NOT NULL
is_edp_thre	boolean	NOT NULL
is_dm_factor	boolean	NOT NULL
is_casualties	boolean	NOT NULL
is_downtime	boolean	NOT NULL
damage_scale_name	damage_scales_all_enum	NOT NULL
hazard_type	hazard_enum	NOT NULL

Figure 3.10 - Schema of the Damage Scale table.

Table 3.10 – Schema of the Damage Scale table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
dm_scale_id	ID (Hidden field)	Unique identifier of the intensity measure and Primary Key
dm_scale_reference	Reference (Author_Year_a,b,c)	This field specified the reference study of the damage scale and points to the Title and other attributes of the study in the Reference table. A standard is set for the data entry: Author_Years_a,b,c to make sure that each reference can be used to uniquely identify the associated reference study. For existing damage scales which do not have a well-known acronym the damage scale name and the reference can be the same. Example: Crowley et al_2004.
asset	Asset type	Enumerated type. Possible entries include: Buildings, Lifelines, People, Crops.



Table 3.10 (continued) – Schema of the Damage Scale table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
subasset	Sub-asset	The field lists and describes all the sub-assets to which the damage scale can be applied. Example: RC, Masonry, Timber
n_dm_states	N of damage states	This field specifies the total number of damage states that the damage scale studies. This information is important because not all the damage scale have the same numbers of damage states. Example: 4
dm_states_id	Damage states identifiers in the original reference	This field lists all the damage states (separated by a semicolon) as they are identified in the specific damage scale. Example: 1;2;3;4
dm_states_name	Damage states name in the original reference	This field lists all the damage states names (separated by a semicolon) as they are identified in the specific damage scale. It is important to note that, as it happens for the damage states too, different damage scales will have different names associated to a damage state. Example: 1;2;3;4
is_edp_thre	Associated with EDP threshold?	This a boolean TRUE/FALSE field which explains is the damage scale is associated to an EDP threshold.
is_dm_factor	Associated with Damage Factor?	This a boolean TRUE/FALSE field which explains is the damage scale is associated to a damage factor.



Table 3.10 (continued) – Schema of the Damage Scale table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
is_casualties	Associated with Casualties?	This a boolean TRUE/FALSE field which explains is the damage scale can be associated to a casualties estimation study.
is_downtime	Associated with Downtime?	This a boolean TRUE/FALSE field which explains is the damage scale can be associated to a downtime estimation study. Example: a damage scale which distinguishes damage states between Operational/ Non-operational can be used to estimate downtime.
damage_scale_name	Damage scale name (indexed field)	The entry to this fields are enumerated to include all known and frequently used damage scales. An option is included to point to Bespoke damage scales which refer to a specific reference study. The damage scale name field also creates a relationship between the damage scale table and the FF and DTL tables. Example: Crowley et al_2004.
hazard_type	Hazard type	Enumerated type. Possible entries include: Earthquake, Tsunami, Flood, Wind, Landslide, Storm surge, Volcanic ash, and Drought.

Loss parameters table

The Loss parameter table lists the most commonly found loss parameters in the vulnerability function literature. The Loss parameters that currently are listed in the data schema are briefly presented in Annex VI. The Loss parameter table is called upon by the Vulnerability Function module.



Column name	Type	Null
lp_id	integer	NOT NULL
description	character varying(500)	NOT NULL
units	character varying(10)	
lp_name	lp_all_enum	NOT NULL
lp_symbol	character varying(10)	NOT NULL

Figure 3.11 - Schema of the Loss Parameter table.

Table 3.11 – Schema of the Loss Parameter table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
lp_id	ID (Hidden field)	Unique identifier of the loss parameter and Primary Key
description	Description	This field describes the loss parameter.
Units	units	Standard units used to measure the loss parameter
lp_name	Loss Parameter name (indexed field)	Enumerated type. Possible entries include: Relative loss, Fatality Rate, Total fatalities, Economic loss total, Annual average loss, Downtime, Mean damage ratio, Economic loss ratio, Damage Index. This field is indexed and points to the lp_name field in the VF table.
lp_symbol	Loss Parameter symbol	This field specifies the acronym/ symbol usually associated to the loss parameter name.

Engineering Demand Parameter (EDP) table

The Engineering Demand Parameter (EDP) table lists the most commonly found EDPs in the analytical fragility function literature for the hazards investigated. The EDPs that currently are listed in the data schema are briefly presented in Annex I. The EDP table is called upon by the Fragility Function module.



Column name	Type	Null
edp_id	integer	NOT NULL
edp_symbol	character varying(10)	NOT NULL
description	character varying(500)	NOT NULL
units	character varying(50)	
edp_name_f	edp_name_enum	NOT NULL

Figure 3.12 - Schema of the Loss Parameter table.

Table 3.12 – Schema of the Loss Parameter table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
edp_id	ID (Hidden field)	Unique identifier of the EDP and Primary Key
edp_symbol	EDP symbol	This field specifies the acronym/symbol usually associated to the EDP name.
description	Description	This field describes the loss parameter.
units	Units	Standard units used to measure the loss parameter
edp_name	EDP name (indexed field)	Enumerated type. Possible entries include: Park-Ang damage index, Peak floor acceleration, Roof drift ratio, Maximum inter-storey drift ratio, Inter-storey drift ratio for storey i, Demand to capacity ratio. This field is indexed and points to the edp_name field in the FF table.

Reference table

The Reference table stores all the information necessary to the identification of reference studies which are associated to the study and validation of functions, damage scales, and intensity measures. It is designed to provide the user with a complete bibliography of the reference studies consulted during the data entry process.

As many of these parameters (e.g., IM, damage scale) may exist in the same record of a single function, the Vulnerability, Fragility and Damage to Loss base tables are linked to the



reference table by multiple relationships and by several fields (e.g. im_name, damage_scale_name).

Column name	Type	Null
id	integer	NOT NULL
author_year	character varying(100)	NOT NULL
title	character varying(500)	NOT NULL
issn	character varying(100)	
doi	character varying(100)	

Figure 3.13 - Schema of the Reference table.

Table 3.13 – Schema of the Reference table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
id	ID (Hidden field)	Unique identifier of the Reference study and Primary Key
author_name	Reference (Author_Year_a,b,c) (indexed field)	This field identifies the reference studies based on the author/s name/s, year of publication and number of subsequent publications in the same year. This field is indexed and points to the VF, FF, DTL, Damage scale tables.
title	Title	Title of the reference study.
issn	ISSN	When available the International Standard Serial Number is specified. This field can be null.
doi	DOI	When available the Digital Object Identifier is specified. This field can be null.

Data table

Like the Reference table, the Data table also serves as a repository. It has a dual purpose. The first is to identify data sources based on which functions, indicators, and indices have been scored against. The second is to retain the possibility to check on the resources that are available for populating the database, not only to avoid duplication but also to acquire metadata on the user/ institution that has made such data available. It is highlighted that the date of acquisition of the data is an important parameter to consider in the assessment of indicators and indices.



Column name	Type	Null
id	integer	NOT NULL
data_source	character varying(100)	NOT NULL
description	character varying(100)	NOT NULL
data_collector	character varying(100)	NOT NULL
date_collection	timestamp with time zone	NOT NULL

Figure 3.14 - Schema of the Data table.

Table 3.14 – Schema of the Data table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
id	ID (Hidden field)	Unique identifier of the Data source table and Primary Key
data_source	Data source	Source or storage location of the data set
description	Description	Description of the data set
data_collector	Data collector	Unique identifier of the data collector
date_collection	Date/Time of collection	Timestamp with time zone field

Scoring tables

The scoring tables have the same schema, which is shown in Figure 3.15.

Even though the scoring is an attribute of the functions, indicators and indices, the design of the schema handles these tables as separate entities. Hence, there is a scoring table for each base table of the 4 modules. This has been done because, for instance, a same function can be applied to more than a country also to the same country by using different set of data. Having the scoring as attributes of the base tables would have implied the need for a data source field in all those tables to score for data quality and would have forced the user to have as many duplicate entries for all possible combination of countries and data sets available. This design solution resolves the issue of duplication.



Column name	Type	Null
 id	 integer	 NOT NULL
geo_applicability	 character(3)	 NOT NULL
 function_id	 integer	 NOT NULL
 data_source	 character varying(100)	 NOT NULL
rationality_score_lev0	 rationality_score_enum	
rationality_score_lev1	 rationality_score_enum	
rationality_score_lev2	 rationality_score_enum	
rationality_score_lev3	 rationality_score_enum	
data_quality_score	 data_quality_score_enum	
combf_score_lev0	 combf_score_enum	
combf_score_lev1	 combf_score_enum	
combf_score_lev2	 combf_score_enum	
combf_score_lev3	 combf_score_enum	
combf_score_simple_lev0	 combf_score_simple_enum	
combf_score_simple_lev1	 combf_score_simple_enum	
combf_score_simple_lev2	 combf_score_simple_enum	
combf_score_simple_lev3	 combf_score_simple_enum	

Figure 3.15 - Schema of scoring tables.



Table 3.15 – Schema of the scoring tables, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
id	ID (Hidden field)	Unique identifier of the score given to a function given its geographic applicability and data, and Primary Key
geo_applicability	Geo-applicability	Country ISO code. Example: TZA
function_id/ indicator_id/index_id	ID of the function/indicator/ index	
data_source	Data source	This field specifies the source of the data available.
rationality_score_lev0	Rationality score - Level 0,1,2,3	Enumerative field. Possible entries include: Excellent, Good, Needs Improvement, Unusable. <i>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</i>
rationality_score_lev1		
rationality_score_lev2		
rationality_score_lev3		
data_quality_score	Data quality score	Enumerative field, which assesses the quality of the data available to building the function. Possible entries include: Excellent, Good, Needs Improvement, Unusable. <i>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</i>



Table 3.15 (continued) – Schema of the Data table, described field by field.

Column name (ordered as in the interface)	Alias shown	Description
combf_score_lev0	Combined function score - Level 0,1,2,3	Enumerative field. Possible entries include: Excellent, Good, Needs Improvement, Unusable. The values of this field are established by taking into consideration both the Rationality score, for each the 4 scales of applicability, and the Data quality score. <i>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</i>
combf_score_lev1		
combf_score_lev2		
combf_score_lev3		
combf_score_simple_lev0	Combined function score (Simplified) - Level 0,1,2,3	Enumerative field. Possible entries include: Representative, Unrepresentative. Simplified representation of the combined scoring to the function. <i>This field is NULLABLE in the Level 3 data schema but marked as a compulsory field in the Level 2.</i>
combf_score_simple_lev1		
combf_score_simple_lev2		
combf_score_simple_lev3		

Categories and Characteristics tables

These tables are, in essence, dictionaries that aid the user in understanding the meaning of the physical and social vulnerability categories and characteristic and the areas of knowledge that they cover. These tables are essential for the social indicators where definitions of the indicators are not as self-explanatory as physical indicators. The Category and Characteristics tables are based on the same schema which is shown in Figure 3.16.

Column name	Type	Null
id	integer	NOT NULL
soc_v_cat_name	soc_vul_cat_enum	NOT NULL
soc_v_cat_abb	soc_vul_sym_enum	NOT NULL
description	character varying(250)	

Figure 3.16 - Schema of the Categories and Characteristics tables.



4 Trial population of data schema and data gaps

To test the adequacy of the Level 3 data schema for use in developing countries, an attempt is made to populate the data schema with vulnerability data and models for use in the vulnerability assessment of Tanzania and 5 other countries. This section briefly describes the approach taken to obtain the vulnerability data and models and provides an overview of the challenges and data gaps identified through this process.

4.1 For Tanzania

The level 3 data schema is populated with vulnerability data relevant to the different assets and hazards included in the data schema. The aim of this exercise is to prove the adequacy of the data schema and test its ability to accommodate data of different resolution and type. Different approaches were taken to the population of different components of the data schema:

Physical vulnerability indicators module:

Only Tanzania-specific exposure data has been sought to populate this module. For indicators associated with buildings, the vulnerability indicators have been evaluated from the data collected by Challenge 2 for Tanzania. Indicators associated with crops have been derived from the 2014/2015 Annual Agricultural Sample Survey Report of Tanzania (2016). For infrastructure components Ardhi University team members have researched data sources, successfully finding data for bridges, which have been included in the data schema. Data on other infrastructure systems has not been readily found and requires discussion with individual infrastructure owners/operators.

This module contains data at local level (level 2) only for buildings and crops due to available data limitations, and at asset level (level 3) for bridges.

Social vulnerability indicators module:

Only Tanzania-specific social vulnerability data has been sought to populate this module. The social vulnerability indicators have been evaluated from data collected by the Challenge 2 for Tanzania.

This module contains data at resolution level 2 only due to available data limitations.

Hybrid vulnerability indices module:

Hybrid vulnerability models have been gathered from the international literature. Example key studies have been included. These include for instance the Social Vulnerability Index and the Earthquake Disaster Risk Index. These indices were not developed for Tanzania but can be used in Tanzania, provided that the necessary data are available. The literature reviews of the existing hybrid vulnerability indices has not found indices developed specifically for Tanzania.

Vulnerability Function, Fragility function and Damage to Loss Model Module:

In all cases of vulnerability functions, fragility functions and damage to loss models, for all assets and hazards, the approach taken has been to search the literature first for Tanzania specific models. These were found to be very few and to only cover a small number of assets and hazards. Hence, studies relating to similar assets to those in Tanzania but deriving from



neighbouring countries were researched next. Finally, the international literature was looked at to find sample vulnerability models for application to Tanzanian assets.

The fragility and vulnerability functions found mainly relate to single assets (level 3) in the case of physical infrastructure, while the functions for buildings range from single asset level (level 3) to national level (level 0). Overall 15 vulnerability functions and 63 fragility functions are included in the data schema. 5 of these are specific to Tanzania (2 vulnerability and 3 fragility functions), 7 derive from other countries in Africa (4 vulnerability and 3 fragility functions), whereas 66 are from international studies (9 vulnerability and 57 fragility functions).

For each fragility function and vulnerability function entered in the data schema the scoring system was applied to assess the quality of the functions and their relevance to the vulnerability assessment of Tanzania at the single asset level (Level 3), local level (Level 2) sub-country level (Level 1) and national level (level 0).

An example of the data entry for a fragility model and its scoring, is provided in Annex VII.

4.2 For other countries

The level 3 data schema is populated with readily available vulnerability data relevant to the different assets and hazards included in the data schema, for the countries of Kenya, Malawi, Uganda, Ethiopia and Mozambique. The aim of this exercise is to prove the adequacy of the data schema for varying developing country contexts. Different approaches were taken to the population of different components of the data schema:

Physical vulnerability indicators module:

Only country-specific data has been sought to populate this module. For indicators associated with buildings, the vulnerability indicators have been evaluated from exposure data collected by Challenge 2.

This module contains data at resolution level 2 only due to available data limitations.

Social vulnerability indicators module:

Only country-specific data has been sought to populate this module. The social vulnerability indicators have been evaluated from data collected by the Challenge 2.

This module contains data at resolution level 2 only due to available data limitations. Entry of this data is still being finalised at the time of submission of this report.

Hybrid vulnerability index module:

Hybrid vulnerability models have been gathered from the international literature. Example key studies have been included in the data schema. Data are being sought to apply these indices to other countries.

Vulnerability Function, Fragility function and Damage to Loss Model Module:

In all cases of vulnerability functions, fragility functions and damage to loss models, for all assets and hazards, the approach taken has been to first search the literature first for country specific models. These were found to be very few and to only cover a small number of assets and hazards. Hence, studies relating to similar assets to those in the assessed country but deriving from neighbouring countries were researched next. Finally, the international literature was looked at to find sample vulnerability models for application to Kenya, Malawi, Uganda, Ethiopia and Mozambique.



Due to the scarcity of country-specific fragility and vulnerability models, this literature search resulted in the same database of fragility functions, vulnerability functions and damage-to-loss models as was developed for Tanzania. Essentially all functions found to be relevant to Tanzania, are also relevant to the other countries assessed.

Here the scoring system is seen to play a key role in helping determine which functions are most relevant to each country application. Similarly to the case of Tanzania, for each fragility function and vulnerability function entered in the data schema the scoring system was applied to assess the quality of the functions and their relevance to the vulnerability assessment of each country (Kenya, Malawi, Uganda, Ethiopia and Mozambique) at the single asset level (Level 3), local level (Level 2) sub-country level (Level 1) and national level (level 0).

4.3 Observations on data gaps

This section presents the main observations on data gaps found through the process of populating the data schema with vulnerability and fragility functions for Tanzania, (it is highlighted that the same set of functions also applies to Kenya, Malawi, Uganda, Ethiopia and Mozambique).

Overall, more than 100 research studies and reports were reviewed, most of which included multiple fragility and/or vulnerability functions. However, data gaps were still observed to occur for several different asset-hazard combinations. Figures 4.1 and 4.2 visually illustrate the availability of usable existing fragility and vulnerability functions for different combinations of hazards and assets. By usable, we mean functions for which enough information is provided to mathematically reproduce the function (i.e. studies that only provide images of vulnerability or fragility functions, without reporting the associated mathematical function equation, are deemed unusable). In these tables, green boxes indicate the availability of a significant number of usable functions (4 or more) for the asset-hazard pair. Orange-coloured boxes indicates a small number of usable functions (1 to 3 functions) are available for the asset-hazard pair. Red coloured boxes indicate that either there are no functions available for the asset-hazard pair or that those that exist are unusable.

Hazard type	Fragility functions		
	Asset type		
	Buildings	Lifelines	Crops
Earthquake	Green	Green	Red
Tsunami	Green	Red	Red
Flood	Orange	Red	Red
Wind	Red	Red	Red
Landslide	Green	Red	Red
Storm surge	Red	Red	Red
Volcanic Ash	Red	Red	Red
Drought	Red	Red	Red

Figure 4.1 – Schematic representation of number of fragility functions in the Level 3 data schema for Tanzania, per asset and hazard. Green boxes indicate the availability of 4 or more functions, orange boxes indicate the availability of 1 to 3 functions, and red boxes indicate that either there are no functions available.



Hazard type	Vulnerability functions			
	Asset type			
	Buildings	Lifelines	People	Crops
Earthquake	Orange	Red	Orange	Red
Tsunami	Red	Red	Red	Red
Flood	Orange	Red	Red	Red
Wind	Red	Red	Red	Red
Landslide	Red	Red	Red	Red
Storm surge	Red	Red	Red	Red
Volcanic Ash	Orange	Red	Red	Green
Drought	Red	Red	Red	Red

Figure 4.2 – Schematic representation of number of vulnerability functions in the Level 3 data schema for Tanzania, per asset and hazard. Green boxes indicate the availability of 4 or more functions, orange boxes indicate the availability of 1 to 3 functions, and red boxes indicate that either there are no functions available.

Inspection of Figure 4.1 reveals that a significant number of fragility functions for building assets exist for earthquake, tsunami and landslide hazards. A small number of fragility functions for floods and buildings are also available. Lifeline fragility functions are only found for earthquakes. No fragility functions were found for wind, storm surge, volcanic ash and drought hazards, nor for crops.

Figure 4.2 presents the usable vulnerability functions employed in the data schema. Like in the case of the fragility functions, most vulnerability functions are available for the building asset type. However, the number of such functions is smaller in the case of vulnerability than in the case of fragility functions. In particular, a small number of functions for buildings is found for earthquake, flood, and also volcanic ash hazards. Instead a significant number of volcanic ash vulnerability functions are found for crops. Additionally, a small number of vulnerability functions predicting human losses (people) are available for the earthquake hazard.

From consideration of both fragility and vulnerability functions (see Figures 4.3), it can be observed that no functions are found for the hazards of wind, storm surge and drought, for any asset type. With regard to building assets, there are also significant gaps in the function availability for volcanic ash and floods. Very few studies exist for lifelines, crops and for casualty estimation. Furthermore, only a small number of these are specific to any of the investigated African countries. This means that there is a global lack of knowledge (functions) for these asset-hazard pairs.

A significant research effort that goes beyond the remit of this report, is required to further engage in-country and produce location-specific vulnerability and fragility functions.



	Combined functions			
	Asset type			
Hazard type	Buildings	Lifelines	People	Crops
Earthquake	Green	Green	Yellow	Red
Tsunami	Green	Red	Red	Red
Flood	Yellow	Red	Red	Red
Wind	Red	Red	Red	Red
Landslide	Green	Red	Red	Red
Storm surge	Red	Red	Red	Red
Volcanic Ash	Yellow	Red	Red	Green
Drought	Red	Red	Red	Red

Figure 4.3 – Schematic representation of number of fragility and vulnerability functions in the Level 3 data schema for Tanzania, per asset and hazard. Green boxes indicate the availability of 4 or more functions, orange boxes indicate the availability of 1 to 3 functions, and red boxes indicate that either there are no functions available.



5 Meeting the Data Schema Objectives

At inception several desired characteristics were set as objectives for the Level 3 data schema. In this section an overview is provided as to how the MOVER Level 3 vulnerability data schema meets these objectives.

Multi-Hazard: The level 3 data schema currently includes intensity measures for the hazards of strong winds, earthquakes, riverine floods, storm surge, landslides, tsunami, volcanic ash and drought. Both the physical and social vulnerability indicators are developed considering these hazards and capture the characteristics relevant to determining vulnerability to these hazards. The data schema has been populated with several fragility and vulnerability functions relevant to the stated hazards.

Multi-asset: The level 3 data schema currently includes several assets: people, crops, residential buildings, industrial warehouses, commercial properties, schools and hospitals as well as key components of selected lifelines (water, electricity, gas, telecommunications, and transports).

Open: The data schema uses the power of the cloud (Heroku) and the customisation of Adminium for ease of use and population.

Expandability: The Level 3 data schema is associated with a modular structure that aids its expansion by separating out the different data schema components. A number of supporting tables are provided wherein the options for populating those data fields that are common across the different modules are defined. This facilitates the inclusion of new assets, hazards and model components (e.g. intensity measures and damage scales) into the data schema. Moreover, the Level 2 data schema presented is seen to provide a possible expanded version of the Level 3 data schema.

Interoperability: The data schema has been developed in close communication with the Challenge 1 (Hazard) and Challenge 2 (Exposure) teams. The hazard intensity measures included in the data schema include those adopted by the Challenge 1 team, and the vulnerability indicator modules of the data schema are being tested and populated with data from Challenge 3. The Challenge 3 team has corresponded with GeoSolutions to ensure data is transferrable to the system they will develop.

Applicable to Developing Countries: The Level 3 data schema has been proven to be applicable to the developing country context, through the applications described in Section 4.0. In particular the data schema has number of data fields that are allowed to be “nullable” to account for the lack of vulnerability data that is typical of developing country contexts. It is also associated with a scoring system for the rating of the vulnerability data or model quality and relevance to the location of application. The latter is particularly important in the case of vulnerability and fragility functions, as shown in Section 4.0, due to the paucity of country-specific such functions.

6 Remaining project components

The inception report defined the mover projects as consisting of 6 main work packages (WPs), which content and outputs were revised in the MOVER Level 2 Data schema Report. To date, WP1-5 have been completed. WPs1-3 related to the project inception, the development of the Level 1 data schema, obtaining feedback through an expert workshop (the London workshop) and the development of the Level 2 Vulnerability data schema and scoring system.



WP4 and 5 are described in this report and relate to the applicative phase of the project, towards the development of a revised level 2 and final level 3 data schema. WP6 consists of the project dissemination in Tanzania through a final workshop and development of a manual for the data schema. The work schedule is presented in Section 6.0.

6.1 WP6: Dissemination

In-country dissemination of the project outcomes will be carried out at the final joint workshop to be held in Tanzania on the 20-22 March 2018. The workshop has been organised by World Bank and from a Challenge 3 perspective, the final workshop will explain the vulnerability data schema and show how the database has been populated for Tanzania. Stakeholders will be asked to comment on the database and on use cases for the data schema.

In addition to this, GEM and UCL-EPICentre will publicize the MOVER project and its activities to their wider networks and collaborators throughout and after the project duration, and a web-page will be set up on the UCL EPICentre web-site containing a project description, in order to provide a reference point for people seeking to find out more.

Finally, a manual will be developed for the Level 3 data schema, which provides information and examples on how to navigate the data schema and enter data into it.

Outcomes	Objectives
O4: Joint final workshop in Tanzania.	The final workshop will: <ul style="list-style-type: none"> - present the Level 3 data-schema to local stakeholders. - present the vulnerability data findings for Tanzania and the other 5 countries - provide information on vulnerability data, limitations of existing data and how future vulnerability data can be included in the data-schema;
O5: Manual for MOVER data-schema	The manual will: <ul style="list-style-type: none"> - describe the Level 3 data schema, the data entry interface and provide examples.



7 Summary of deliverables and work schedule

The revised schedule of outputs of the MOVER project are listed here under the different stages of the work, together with their status, in brackets:

Proposal stage

Output 0 (O0) - Technical Proposal **(delivered and approved)**

Inception phase

Output 1 (O1) - Inception report **(delivered and approved)**

Explorative stage

Output 2a (O2a) – GFDRR-DFID Challenge Fund Expert Workshop - London, 27th July 2017 -Feedback Report (delivered, approved and disseminated)

Output 2b (O2b) - Report detailing the Level 1 data-schema presented at the London workshop, the workshop findings and the revised Level 2 vulnerability data-schema with the scoring system **(delivered and approved)**

Applicative stage

Output 3 (O3) – Report on the finalised Level 2 vulnerability data schema and scoring system, and the final Level 3 vulnerability data-schema and scoring system populated for Tanzania and 5 other countries. **(current report)**.

Dissemination stage,

Output 4 (O4) - Joint final workshop in Tanzania **20th- 22nd March 2018**.

Output 5 (O5) - Manual on Level 3 MOVER data-schema **(31st March 2018)**

These deliverables are developed through a staged work programme with regular discussion with other challenge team leads. The detailed work schedule is presented in Table 6.1.



Table 6.1: Revised work schedule for the MOVER project

TOR Sub-Task	Activity	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18
WP 1: Inception													
1.1	Inception workshop												
1.2.	Drafting of inception report												
1.3	Submission of inception report												
1.4	Feedback from other Challenges and integration												
O 1	Final revised report being approved.												
WP 2: Draft database structure – Level 1													
2.1	Review and compiling of characteristics of vulnerability for physical and social system by hazard and by asset												
2.2	Definition of a preliminary system of rating												
2.2	Definition of architecture of data schema (Level 1)												
2.3	Preparation of London workshop												
WP 3: Expert Review and vulnerability database schema prototype (London Workshop)													
3.1	Expert informant review summary												
3.2	Revision of Level 1 vulnerability database schema (Level 2)												
O2a	GFDRR-DFID Challenge Fund Expert Workshop-Feedback Report												
O2b	Report detailing the Level 1 data-schema presented at the London workshop, the workshop findings and the revised Level 2 vulnerability data-schema with the scoring system												
WP4: Application of vulnerability database to Tanzania													
4.1	Tanzania field trip/data collection												
4.2	Review of Level 2												
4.2	Compiling vulnerability data for Tanzania												



TOR Sub-Task	Activity	Apr 17	May 17	Jun 17	Jul 17	Aug 17	Sep 17	Oct 17	Nov 17	Dec 17	Jan 18	Feb 18	Mar 18
WP 5: Application of vulnerability database to 5 other countries with open data													
5.1	Compiling vulnerability data for 5 additional countries												
O3	Report on the finalised Level 2 vulnerability data schema and scoring system, and the final Level 3 vulnerability data-schema populated for Tanzania and 5 other countries												
WP 6: Final workshop													
6.1	Joint preparation of workshop and final Workshop												
O4	Joint final workshop in Tanzania												
O5	Manual on Level 3 MOVER data schema												
Workshops & meetings													
Kick-off workshop													
Bi-weekly Challenge leaders meeting (coordination fieldwork meetings, as necessary)		0	2	2	2	2	2	2	2	2	2	2	
London workshop													
Final workshop													

Key

- Critical path
- Preparatory/supporting activities
- Deliverable
- Field work activity



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ANNEXES



Annex I – Evaluation of Physical Indicator Applicability and Data Availability for Tanzania by Tanzanian Team Members

The following tables present a detailed evaluation of the Level 2 Physical Vulnerability Indicators in terms of their relevance to the vulnerability evaluation of Tanzania, provided by the Tanzanian team members of MOVER. The table presents information on data availability for populating the indicators, data source and geographical scale at which it is available. The fields that have been evaluated as relevant and where data is said to be available, have been retained in the Level 3 data schema. Those physical vulnerability indicators that are shown with grey fill are those that have been eliminated in moving from the Level 2 to Level 3 data schema due to either being irrelevant, the lack of data or a judgement made by experts in the Team as to their importance relative to other measures. Some indicators, despite being evaluated by the Tanzanian team as not being relevant to the Tanzanian context, have been kept in the Level 3 data schema due to their acknowledged importance in the literature for vulnerability evaluation. These indicators are denoted by an asterisk and we have ensured they can take a null value in the data schema, to be able to deal with the current lack of data for their evaluation.

Table I.1 - Physical Vulnerability Indicators data schema: asset features, buildings

Field name	Relevance for Tanzania	Data Availability for Tanzania	Data Collected by which Organization	Scale of Analysis of Data Available
LRS_material	Relevant	Information not available	Not applicable	Not applicable
material_type	Relevant	This information is available	The National Housing and Building Research Agency (NHBRA) and Tanzania Bureau of Standards (TBS)	National level
material_tech	Relevant	information is available	The National Housing and the Building Research Agency (NHBRA) and Tanzania Bureau of Standards (TBS)	National level



LLRS	Not Relevant	Not Relevant	Not Relevant	Not Relevant
storeys_n_ag	Relevant	This information is relevant for Tanzania	Such information is collected by Local Government Authorities (LGAs)	Municipal and District level
storeys_n_bg	Relevant	This information is relevant for Tanzania	Such information is collected by Local Government Authorities	Municipal and District level
height_gf_ag	Not Relevant	Not Relevant	Not Relevant	Not Relevant
is_regular*	Not Relevant	Not Relevant	Not Relevant	Not Relevant
irregular_dir	Relevant	This information is relevant for Tanzania and	Such information is collected by Local Government Authorities	Regions, Districts, Cities and Municipal levels
irregular_type	Not Relevant	Not Relevant	Not Relevant	Not Relevant
Irregular_type_v	Not Relevant	Not Relevant	Not Relevant	Not Relevant
modifiers_sec	Not Relevant	Not Relevant	Not Relevant	Not Relevant
roof_shape	Relevant	This information is not documented	Not Relevant	Not Relevant
roof_sy_mat	Relevant	This information is available	The National Housing and the Building Research Agency (NHBRA) and Tanzania Bureau of Standards (TBS)	National Level
roof_sy_type	Relevant	This information is not documented	Not Relevant	Not Relevant



roof_co_mat	Relevant	This information is available	The National Housing and the Building Research Agency (NHBRA) and Tanzania Bureau of Standards (TBS)	National Level
roof_conn	Relevant	This information is not documented	Not Relevant	Not Relevant
floor_sy_mat	Relevant	This information is available	The National Housing and the Building Research Agency (NHBRA) and Tanzania Bureau of Standards (TBS)	National Level
floor_sy_type	Relevant	This information is not documented	Not relevant	Not relevant
floor_conn	Relevant	This information is not documented though it is important	Not relevant	Not relevant
foundation_sy	Relevant	This information is relevant	Such information is collected by Local Government Authorities	Municipal, district level
is_design	Relevant	This information is available	This information is available at local authorities and Engineers Registration Board (ERB)	National and municipal and district level



design_code	Relevant	This information is not documented	Not relevant	Not relevant
is_design_duct	Relevant	This information is not documented	Not relevant	Not relevant
is_design_retrofit	Relevant	This information is not documented	Not relevant	Not relevant
bld_age_retrofit	Relevant	This information is not documented	Not relevant	Not relevant
bld_age	Relevant	Not available	Not document	Not document
Occupancy_type	Relevant	Not available	Not document	Not document
occupancy_cl	Relevant	Not available	Not document	Not document

Table I.2 - Physical Vulnerability Indicators data schema: asset features, lifelines

Field name	Relevance for Tanzania	Data Availability for Tanzania	Data Collected by which Organization	Scale of Analysis of Data Available
bridge_type	Relevant	This information is available	This information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
spans_n	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
abutment_type	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level



deck_height	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
is_bridge_design	Relevant	Is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
bridge_mat	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS) and Tanzania Bureau of Standards (TBS)	National Level
pier_type	Relevant	This information is available	This information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
deck_type	Relevant	This information is available	This information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
is_span_cont	Relevant	This information is available	This information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
bearing_type	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level



bridge_usage	Relevant	This information is available	The information is collected and available at the Tanzania Roads Agency (TANROADS)	National Level
tel_co_type	Relevant	This information is available	This information is collected and available at the Tanzania Communication Regulatory Authority (TCRA)	National Level
is_co_anchorage	Relevant	This information is available	This information is collected and available at the Tanzania Communication Regulatory Authority (TCRA)	National Level
tel_co_usage	Relevant	This information is available	This information is collected and available at the Tanzania Communication Regulatory Authority (TCRA)	National Level
w_burpipe_age	Relevant	Available	Tanzania Bureau of standards (TBS) and the Urban Water supply and Sanitation Authorities (UWSA)	National (0) and Sub-municipal level (2)
w_burpipe_dia	Relevant	Available	Tanzania Bureau of standards (TBS) and the Urban Water supply and Sanitation Authorities	National (0) and Sub-municipal level (2)



			(UWSA)	
w_burpipe_joint	Relevant	Available	Tanzania Bureau of standards (TBS) and the Urban Water supply and Sanitation Authorities (UWSA)	Sub-municipal level (2)
w_burpipe_mat	Relevant	Available	Tanzania Bureau of standards (TBS) and the Urban Water supply and Sanitation Authorities (UWSA)	National (0) Sub-municipal level (2)
w_burpipe_usage	Relevant	Available	Tanzania Bureau of standards (TBS) and the Urban Water supply and Sanitation Authorities (UWSA)	National (0) Sub-municipal level (2)
is_w_pump_indgen	Relevant	Available	Independent custodian (Individual clients)	Per asset level (3)
is_w_pump_retrofit	Relevant	Not available	Not applicable	Not applicable
is_w_pump_design	Relevant	Available	Occupation Health and Safety Authority (OSHA)	Level (0) Country to District level
is_ps_anchorage	Relevant	Not available	Not applicable	Not applicable
w_ps_anchorage_type	Relevant	Not available	Not applicable	Not applicable
w_pump_usage	Relevant	Not available	Not Applicable	Not Applicable



w_storage_size	Relevant	Available	Individual clients	Per asset (3)
w_storage_roof_mat	Relevant	Not available	Not available	Not available
w_storage_body_mat	Relevant	Available	Individual clients	Per asset (3)
is_w_storage_anchorage	Relevant	Available	Individual clients	Per asset (3)
w_storage_anchorage_type	Not very relevant	Not available	Such designs are more relevant to Earth quake prone areas	Not available
is_w_storage_design	Relevant	Available	OSHA and the National Environmental Management Council (NEMC)	Level (0) Country to district level
w_storage_usage	Relevant	Available	Individual clients	Per asset (3)
is_el_sub_insulated	Relevant	Available	The Tanzania Electric Supply Company LTD (TANESCO)	National Level
el_sub_usage	Relevant	Available	The Tanzania Electric Supply Company LTD (TANESCO)	National Level
is_ww_lift_design	Relevant	Available	City/Town/ Municipal Water Supply Authorities	Municipal/ City level
is_ww_lift_retrofit	Relevant	Available	City/Town/ Municipal Water Supply Authorities	Municipal/ City level
is_ww_lift_indgen	Relevant	Not Available/Not document	Not applicable	Not applicable
ww_lift_usage	Relevant	Not Available/Not document	Not applicable	Not applicable
is_ww_lift_anchorage	Relevant	Not	Not applicable	Not



		Available/Not document		applicable
ww_lift_anchorage_type	Relevant	Not Available/Not document	Not applicable	Not applicable

Table I.3 - Physical Vulnerability Indicators data schema: asset features, crops

Field name	Relevance for Tanzania	Data Availability for Tanzania	Data Collected by which Organization	Scale of Analysis of Data Available
crop_growcycle	Relevant	Available	Such information is collected by the Ministry of Agriculture, (Food Security Division) and is available at district level	District level
crop_sp	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level
crop_var	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level
crop_season	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level
crop_land_type	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level



crop_product_type	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level
crop_process_type	Relevant	Available	Collected by the Ministry of Agriculture	District level
crop_cultivation_method	Relevant	Available	Collected by the Ministry of Agriculture (National Food Security Division)	District level



Annex II – MOVER Scoring system for Vulnerability and Fragility Functions

The MOVER scoring system for the Level 3 data schema Vulnerability Functions (VF) and Fragility Functions (FF) is reproduced here for ease of reference.

Table II.1. Scoring criteria of the Rationality of a given VF or FF

Rationality Score (RS)	Description
Excellent (Ex)	<p>VF or FF is constructed for the same asset class and for the same geographical area to the asset class of the application.</p> <p>AND</p> <p>The damage or loss definition in the VF or FF matches the damage or loss definition of interest.</p> <p>AND</p> <p>VF or FF uses an Intensity Measure (IM) that is accepted in the international literature as being highly representative of the damage/loss potential of the assessed hazard on the assessed asset class.</p> <p>AND</p> <p>First principles are met.</p> <p>AND</p> <p>Uncertainty around the VF or FF is presented.</p> <p>AND</p> <p>The damage or loss observations used to construct the VF or FF cover the range of IMLs of interest in the assessment.</p>



<p>Good (G)</p>	<p>VF or FF is constructed for a similar (or same) asset class and from the same geographical area as the asset class of the application.</p> <p>AND</p> <p>VF or FF uses an Intensity Measure (IM) that is accepted in the international literature as being somewhat representative of the damage/loss potential of the assessed hazard on the assessed asset class.</p> <p>AND</p> <p>First principles are met.</p> <p>AND</p> <p>Uncertainty around the VF or FF is presented.</p> <p>AND</p> <p>The damage or loss observations used to construct the VF or FF cover the range of IMLs of interest in the assessment.</p>
<p>Needs Improvement (NI)</p>	<p>VF or FF is constructed for a similar (or same) asset class to the class of interest and for a similar (or same) geographical area to that of the application.</p> <p>AND</p> <p>VF or FF uses an Intensity Measure (IM) that is accepted in the international literature as being somewhat representative of the damage/loss potential of the assessed hazard on the assessed asset class.</p> <p>AND EITHER</p> <p>First principles are not met.</p> <p>OR</p> <p>Uncertainty around the VF or FF is not presented.</p> <p>OR</p> <p>The damage or loss observations used to construct the VF or FF do not cover the range of IMLs of interest in the assessment.</p>



<p>Unusable (Un)</p>	<p>VF or FF is not constructed for a similar asset class to the class of interest OR for a similar geographical area to that of the application.</p> <p>OR</p> <p>VF or FF uses an Intensity Measure (IM) that is accepted in the international literature as not being representative of the damage/loss potential of the assessed hazard on the assessed asset class.</p>
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Table II.2. Scoring criteria of the Function Quality of a given VF or FF.

Function Quality Score (FQS)	VF or FF Type	Description
Excellent (Ex)	Empirical	<p>VF or FF based on samples representative of the impact of the event to the area that are either unbiased or have been corrected for identified biases.</p> <p>AND</p> <p>At least 200 damage or loss observations used to construct the VF or FF. For aggregated damage data, a minimum of 20 observations per bin of IM is used for a minimum of 10 bins.</p>
	Analytical	<p>VF or FF uses high-level asset modelling and engineering assessment carried out according to the accepted state-of-the-art for the hazard.</p> <p>AND</p> <p>VF or FF includes variability in asset performance at any given Intensity Measure Level (IML) due to the variability in the hazard loading AND in the asset characteristics across an asset class.</p> <p>AND</p> <p>At least 200 realisations are used to construct the VF or FF.</p>



	Heuristic	VF or FF obtained from an application of the Cooke's method or similar.
Good (G)	Empirical	<p>VF or FF based on samples representative of the impact of the event to the area that are either unbiased or have been corrected for identified biases.</p> <p>AND</p> <p>Between 50 and 199 damage or loss observations used to construct the VF or FF. For aggregated damage data, a minimum of 5 observations per bin of IM is used for a minimum of 10 bins.</p>
	Analytical	<p>VF or FF adopt EITHER a simplified asset modelling OR simplified engineering assessment carried out according to the accepted state-of-the-art for the hazard (NOT BOTH).</p> <p>AND</p> <p>At least 50 realisations are used to construct the VF or FF.</p> <p>OR</p> <p>VF or FF uses high-level asset modelling and engineering assessment carried out according to the accepted state-of-the-art for the hazard.</p> <p>AND</p> <p>VF or FF includes variability in asset performance at any given Intensity Measure Level (IML) due only to the variability in the hazard loading OR only due to the variability in the asset characteristics across an asset class.</p> <p>AND</p> <p>At least 50 realisations are used to construct the VF or FF.</p>
	Heuristic	VF or FF obtained from an application of the Delphi Method or similar.



Needs Improvement (NI)	Empirical	<p>VF or FF based on samples representative of the impact of the event to the area that are either unbiased or have been corrected for identified biases.</p> <p>AND</p> <p>Between 20 and 50 damage or loss observations used to construct the VF or FF</p>
	Analytical	<p>VF or FF adopt simplified asset modelling</p> <p>AND</p> <p>A simplified engineering assessment, carried out according to the accepted state-of-the-art for the hazard.</p> <p>AND</p> <p>At least 20 realisations are used to construct the VF or FF.</p> <p>AND/OR</p> <p>The damage or loss observations used to construct the VF or FF do not cover the range of IMLs of interest in the assessment</p> <p>AND/OR</p> <p>VF or FF includes variability in asset performance at any given Intensity Measure Level (IML) due to the variability in the hazard loading OR in the asset characteristics across an asset class.</p>
	Heuristic	<p>Consensus-based assessment reached by eliciting without a formal procedure using at least 5 experts.</p>
Unusable (Un)	All	VF or FF does not meet the criteria of NI



Table II.3. Combined Rationality and Data Quality Scoring system for VF and FF

Detailed VI Score	Combinations of RS and FQS		Simple VI Score
	RS	FQS	
Excellent	Ex	Ex	Representative
Good	Ex	G	
	G	G	
Needs Improvement	G	NI	
	NI	NI	
Unusable	NI	Un	
	Un	Un	



Annex III – Intensity Measures (IM) used in MOVER Data Schema

This Annex presents the typical and most common intensity measures used in risk modelling for each of the 8 hazard types, which are used in this data schema.

Earthquake IMs

The seismic loading to structural systems (i.e. acceleration time history $a(t)$ applied at the foundation of the system) is commonly approximated by a ground motion parameter, which is chosen based on its ability to best represent the actual ground motion record. The selection of the most suitable hazard descriptor may vary depending on the type of structural system as shown in Table III.1 and its sensitivity to the main features of a temporal signal, i.e. amplitude; frequency content; duration and number of effective cycles; and its sensitivity to the different components of motion, i.e. displacement, velocity and acceleration, in given directions.

Table III.1 - Earthquake IMs.

IM Symbol	IM Name
PGA	Peak ground acceleration
PGV	Peak ground velocity
PGD	Peak ground displacement
$PGDf$	Permanent ground deformation
$Sa(T_1)$	Spectral acceleration
$Sv(T_1)$	Spectral velocity
$Sd(T_1)$	Spectral displacement
CAV	Cumulative absolute velocity
I_a	Arias Intensity



N_{eq}	Effective number of cycles
DB	Bracketed duration
Da_{5-95}	Significant duration a5-95
Da_{5-75}	Significant duration a5-75
MMI	Modified Mercalli Intensity
EMS	European macroseismic scale
I_{Np}	IM by Bojórquez and Iervolino
$AvgSa$	Average spectral acceleration

- Peak ground acceleration (PGA): The PGA is equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake. Expressed in g or m/s^2 .
- Peak ground velocity (PGV): The PGV is equal to the maximum ground velocity that occurred during earthquake shaking at a location. Expressed in m/s.
- Peak ground displacement (PGD): The PGD is equal to the maximum ground displacement that occurred during earthquake shaking at a location. Expressed in m.
- Permanent ground deformation ($PGDf$): The permanent ground deformation refers to the unrecoverable soil displacement due to faulting, landslide, settlement or liquefaction induced lateral spreading. In some cases, $PGDfV$ is used for vertical ground deformation and $PGDfH$ for horizontal ground deformation. Expressed in m.
- Spectral acceleration ($Sa(T_1)$): The $Sa(T_1)$ is the maximum acceleration experienced by a structure, as modelled by a mass on a vertical spring having the same natural period of vibration, T , as the building. Expressed in g or m/s^2 .
- Spectral velocity ($Sv(T_1)$): The $Sv(T_1)$ is the maximum velocity experienced by a structure, as modelled by a mass on a vertical spring having the same natural period of vibration, T , as the building. Expressed in m/s.
- Spectral displacement ($Sd(T_1)$): The $Sd(T_1)$ is the maximum displacement experienced by a structure, as modelled by a mass on a vertical spring having the same natural period of vibration, T , as the building. Expressed in m.
- Cumulative Absolute Velocity (CAV): The CAV is defined as:

$$CAV = \int_0^{t_{max}} |a(\tau)| d\tau$$

where $|a(\tau)|$ is the absolute value of acceleration at time t and t_{max} is the total duration of the ground motion record. Expressed in m/s.



- Arias Intensity (I_a): The Arias Intensity is defined as:

$$I_a = \frac{\pi}{2g} \cdot \int_0^{t_{\max}} a(\tau)^2 d\tau$$

I_a is measured in units of length per time. Expressed in m/s.

- Effective number of cycles (N_{eq}): The N_{eq} is defined as:

$$N_{eq} = \frac{1}{2} \cdot \sum_{i=1}^{2n} \left(\frac{u_i}{u_{\max}} \right)^c$$

where n is the total number of cycles, u_i is the amplitude of the i th half cycle, u_{\max} is the amplitude of the largest half cycle, and c is an application-dependent damage coefficient ($c = 2$ in Hancock and Bommer, 2005). No units.

- Bracketed duration (D_B): D_B is defined as the time elapsed between the first and last excursions beyond a specified threshold acceleration (typically 0.05 g or 0.1 g). Bracketed duration parameters can be sensitive to the threshold accelerations and to small subevents occurring towards the end of a recording. For these and other reasons, other definitions of duration are often preferred. Expressed in s.
- Significant duration (D_{a5-95}): D_{a5-95} is defined as the time interval over which the integral of the square of the ground acceleration is within a range between 5 and 95%. Expressed in s.
- Significant duration (D_{a5-75}): D_{a5-75} is defined as the time interval over which the integral of the square of the ground acceleration is within a range between 5 and 75%. Expressed in s.

*It is noted that significant duration can be also represented as function of the velocity and displacement record, denoted as D_{v5-95} and D_{d5-95} respectively.

- Modified Mercalli Intensity (MMI): This scale is an arbitrary ranking based on observed effects, and does not have a mathematical basis. MMI is composed of increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. Expressed in own units.
- IM proposed by Bojórquez and Iervolino (I_{Np}): I_{Np} , proposed by Bojórquez and Iervolino (2011), is a spectral-shape proxy based on $S_a(T_1)$ and the parameter N_p , defined as:

$$I_{N_p} = S_a(T_1) N_p^\alpha$$

where α parameter is assumed to be $\alpha = 0.4$, and N_p is defined as:

$$N_p = \frac{S_{a,avg}(T_1, \dots, T_N)}{S_a(T_1)} = \frac{\left[\prod_i^N S_a(T_i) \right]^{1/N}}{S_a(T_1)}$$

T_N corresponds to the maximum period of interest and lays within a range of 2 and 2.5 T_1 . Expressed in m/s².

- Average spectral acceleration ($AvgSa$): $AvgSa$ is defined as the mean of the spectral accelerations at a set of periods that are crucial for risk assessment and loss estimation of a structure of interest. These periods, for example, could be equally spaced in the 0.2 T_1 to 1.5 T_1 range.

$$AvgSa = \left[\prod_{i=1}^n S_a(T_i) \right]^{1/n}$$



- The quantity n refers here to the number of SA(T)s being averaged. Expressed in m/s^2 .

Tsunami IMs

Table III.2 - Tsunami IMs.

IM Symbol	IM Name
h_{ts}	Tsunami inundation depth
v_{ts}	Tsunami velocity
Fr	Froude number
F_{drag}	Drag force
MF	Momentum flux
MMF	Modified momentum flux
F_{QS}	Quasi-steady force

- Tsunami inundation depth (h_{ts}): Peak observed or simulated tsunami inundation depth (h_{peak}) at each building location. Expressed in m.
- Tsunami velocity (v_{ts}): Peak tsunami velocity generally calculated from numerical simulation as the vector sum of the velocity components in the directions of the two orthogonal axes of the 2D flow calculation. Expressed in m/s.
- Froude number (Fr): A measure of flow velocity non-dimensionalized by the gravity-wave velocity:

$$Fr = \left(\frac{v}{\sqrt{gh}} \right)_{peak}$$

Unitless IM. .

- Drag force (F): The force exerted on an object (per unit width perpendicular to the direction of flow) due to the movement of a surrounding fluid of density ρ :

$$F_{drag} = \frac{1}{2} \rho C_d (h v^2)_{peak}$$

where the drag coefficient (C_d) is a function of the object shape and orientation. Expressed in kN.



- Momentum flux (MF): A vector in the direction of flow, of magnitude equal to the mass-flow per unit area:

$$MF = (\dot{m}v^2)_{peak}$$

Expressed in m^3/s^2 .

- Moment of momentum flux (MMF): The product of momentum flux and inundation depth, considered a proxy for the overturning moment induced by the flow:

$$MMF = (h\dot{m}v^2)_{peak}$$

Expressed in m^4/s^2 .

- Quasi-steady Force (F_{QS}): Alternative steady-state force estimation considering choked and sub-critical flow for a body of width b in a channel of width w :

$$F_{QS} = \begin{cases} \frac{1}{2} \left[C_{D0} \left(1 + \frac{C_{D0}}{2} \left\{ \frac{b}{w} \right\} \right) \right] \rho v^2 h, & Fr < Fr_c \\ \lambda \rho g^{1/3} v^{4/3} h^{4/3}, & Fr \geq Fr_c \end{cases}$$

where:

- λ is a function of hydrostatic and form drag coefficients, and up-and down-stream Froude Numbers.
- Fr_c is a function of drag coefficient and blockage ratio (b/w).

See Foster et al. (2017) for calculation procedure. Expressed in Kn.

It is noted that Tsunami flow depth is also one of the most common parameter used when examining tsunami-building interaction and has been extensively used as the hazard variable, or demand parameter, in the construction of existing tsunami fragility curves. This is due to the relative ease with which it can be measured in the field after a tsunami event (e.g. from mud-lines in buildings), and due to the relative reliability of depth outputs from numerical inundation simulations. Furthermore, in recent building design codes the loads associated with tsunami have been considered similar to the loads associated with floods with increased velocities (FEMA, 2008). As the main parameter in flood studies is inundation depth, this has been adopted also in the case of tsunami.

However, caution must be applied when comparing flow depth measurements from different studies. During post-tsunami surveys, flow depth is commonly defined as being the height of water measured above ground level (Synolakis & Okal 2005; Rossetto et al. 2007; Reese et al. 2007). However, various definitions and names for flow depth can be found in the literature: water level (Reese et al., 2007), inundation depth (Inoue et al., 2007), tsunami depth or water depth (Nandasena et al. 2008). Flow depth should not be confused with tsunami height, or inundation height, which usually represents the maximum water level measured with reference to mean sea level (Inoue et al., 2007; Liu et al. 2005; Nandasena et al., 2008; Tsuji et al. 2006). If parameters are not carefully defined this can lead to inconsistent results.

Flow velocity influences the hydrodynamic force, surge force, debris impact and damming forces applied by tsunami when they impact buildings. Flow velocities have only rarely been used in the derivation of fragility functions for tsunami (Gokon et al. 2010; Suppasri et al. 2011; Suppasri et al. 2009). This is because they are hard to determine from observations



(Reese et al., 2007). Numerical models can simulate offshore wave characteristics of tsunami wave forms. However, the physics of the wave form, as it enters the shallow water and encroaches onshore, becomes more complex and requires a much higher bathymetric and topographic resolutions for the numerical model to provide a realistic simulation of the flow.

Flood IMs

Table III.3 - Flood IMs

IM Symbol	IM Name
h_{η}	Flood water depth
v_{η}	Flood velocity of flow

- Flood water depth/Over-floor depth (h_{η}): Used almost universally because of relative ease to measure in the field, and the relative reliability of depth outputs from numerical inundation simulations. Highly correlated to structural damage of residential buildings. Expressed in m.
- Flood velocity of flow (v_{η}): Water velocity describes the rate at which flood waters move. Highly correlated to structural damage to infrastructures. Expressed in m/s.

Windstorm IMs

Table III.4 - Windstorm IMs

IM Symbol	IM Name
WV	1-minute sustained wind speed at 10 meters above the ground
$PGWS$	Peak Gust Wind Speed

- 1-minute sustained winds at 10 meters above the ground (WV): Used almost universally and highly correlated to structural/non-structural damage of residential buildings/infrastructures. Expressed in m/s.
- Peak Gust Wind Speed ($PGWS$): Defined as the peak gust wind speed in the open terrain. Expressed in m/s.

Landslide IMs

Table III.5 - Landslide IMs



IM Symbol	IM Name
d_{lan}	Landslide flow depth
v_{lan}	Landslide flow velocity
IDF	Debris-flow intensity index
SD_{lan}	Slide displacement
MFD	Maximum foundation displacement

- Landslide flow depth (d_{lan}): Represents the depth of the landslide flow. Expressed in m.
- Landslide flow velocity (v_{lan}): Represents the impact velocity of the landslide. Expressed in m/s.
- Debris-flow intensity index (IDF): IDF is a landslide intensity index proposed by Jakob et al. (2012), and is computed as:

$$I_{DF} = d_{lan} v_{lan}^2$$

Expressed in m^3/s^2 .

- Slide displacement (SD_{lan}): Is the displacement associated with the slow-moving landslides. Expressed in m.
- Maximum foundation displacement (MFD): Is the maximum (absolute) foundation displacement due to landslide. Expressed in m.

Storm Surge

Table III.6 - Stormsurge IMs

IM Symbol	IM Name
d_{ss}	Storm surge inundation depth
$v_{ss, max}$	Storm surge maximum water velocity

- Storm surge inundation depth (d_{ss}): d_{ss} describes the height of water above ground level. Expressed in m.
- Storm surge maximum water velocity ($v_{ss, max}$): $v_{ss, max}$ describes the maximum water velocity. Expressed in m/s.



Volcanic ash

Table III.7 – Volcanic Ash IMs

IM Symbol	IM Name
h_{AF}	Ash fall thickness
L_{AF}	Ash loading

- Ash fall thickness (h_{AF}): describes the thickness of the ash, starting from 0.001m and can exceed 0.1m. Expressed in m.
- Ash loading (L_{AF}): refers to the loading exerted by an ash fall, and depends on its density ρ (in kg/m³) and the thickness h_{AF} (in m):

$$L_{AF} = \rho g h_{AF}$$

Expressed in kPa.

Drought

Table III.8 - Drought IMs

IM Symbol	IM Name
SPI	Standard Precipitation Index
$SPEI$	Standard Precipitation Evapotranspiration Index
$PDSI$	Palmer Drought Severity Index
CMI	Crop Moisture Index

- Standard Precipitation Index (SPI): It shows the actual precipitation compared to the probability of precipitation for various time frames. The SPI is an index based on precipitation only. It can be used on a variety of time scales, which allows it to be useful for both short-term agricultural and long-term hydrological applications. Expressed in own units – SPI values, as shown in the table below.

Table III.9 – SPI Values



SPI values	Description
2.0 or more	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry

- Palmer Drought Severity Index (*PDSI*): The *PDSI* is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil. Palmer values may lag emerging droughts by several months; are less well suited for mountainous land or areas of frequent climatic extremes; and are complex—has an unspecified, built-in time scale that can be misleading. Expressed in own units – *PDSI* classification as shown in the table below.

Table III.10 – PSDI Classification

PSDI Classifications	Description
4.0 or more	extremely wet
3.0 to 3.99	very wet
2.0 to 2.99	moderately wet
1.0 to 1.99	slightly wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal



-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

- Crop Moisture Index (*CMI*): The *CMI* is a derivative of the *PDSI*, which looks at moisture supply in the short term for crop producing regions. It monitors week-to-week crop conditions. Whereas the *PDSI* monitors long-term meteorological wet and dry spells, the *CMI* was designed to evaluate short-term moisture conditions across major crop-producing regions.



Annex IV – Damage Scales used in MOVER Data Schema

Damage scales represent a set of discrete damage-states, ideally defined by using both text and figures to assess building performance (structural and non-structural) with damage levels classified from no damage to collapse. In this data schema we have included a selection of damage scales that have been widely used seismic risk assessments and post-earthquake damage surveys. The damage scales used in the MOVER data schema are summarized in the table below.

Table IV.1 – Damage Scales

Damage scale reference	Hazard	Asset/s of reference	No. of Damage States
EMS-98 (Grünthal, 1998)	Earthquake	RC; Masonry	5
HAZUS-MH MR4 (FEMA, 2003)	Earthquake	US building types	5
Vision 2000 (SEAOC, 1995)	Earthquake	RC; Masonry	5
FEMA 356 (FEMA, 2000)	Earthquake	RC; Masonry	4
Milutinovic and Trendafiloski (2003)	Earthquake	RC; Masonry	6
Blong (2003)	Earthquake	RC; Masonry	6
HRC (Rossetto and Elnashai, 2003)	Earthquake	RC	7
Crowley et al (2004)	Earthquake/ Landslide	RC	4
Lang and Bachmann (2004)	Earthquake	Masonry	6
GNDT 2010	Earthquake	Italian building types	4
Japan Cabinet Office (2013)	Tsunami	RC, Masonry, Timber	6



EEFIT (2006)	Tsunami	RC	5
Fraser et al. (2013)	Tsunami	RC, Masonry, Timber	5



Annex V – Engineering Demand Parameters (EDP) used in MOVER Data Schema

In analytical approaches, Engineering Demand Parameters (EDP) are typically used as a proxy of damage level, with EDPs chosen such that they are indicative of the damage state of the entire asset. For instance, in earthquake engineering ranges of values of roof drift or inter-storey drift are commonly adopted to represent specific damage states.

Table V.1 – EDPs

EDP Symbol	EDP Name
<i>PFA</i>	Peak floor acceleration
<i>RDR</i>	Roof drift ratio
<i>IDR_i</i>	Inter-storey drift ratio for storey <i>i</i>
<i>MIDR</i>	Maximum inter-storey drift ratio
<i>D/C</i>	Demand to capacity ratio
<i>DI</i>	Park-Ang damage index

- Peak floor acceleration (*PFA*): The *PFA* represents the peak (over time) acceleration at each floor. Expressed in m/s².
- Roof drift ratio (*RDR*): The *RDR* is the ratio of the peak lateral roof displacement to the building height. Unitless IM.
- Inter-storey drift ratio for storey (*IDR_i*): The *IDR_i* represents the peak (over time) inter-storey drift ratio and is calculated as the largest difference between the lateral displacements of two adjacent floors, divided by the height of the storey. Unitless IM.
- Maximum inter-storey drift ratio (*MIDR*): The *MIDR* is the maximum (over all stories) *IDR_i*. Unitless IM.
- Demand to capacity ratio (*D/C*): The *D/C* simply refers to the ratio between the external actions applied to the structure (demand) over the ability of the structure to carry the imposed actions (capacity). In its simplest form, a *D/C*>1 implies failure. However, it is acceptable that the ratio exceeds unity where ductile response is assured. Unitless IM.
- Park-Ang damage index (*DI*): The *DI* (Park et al., 1987) is a damage index that takes into account the effect of maximum deformation and cyclic loads, and is calculated as shown in the formula:

$$DI = \frac{\delta_m}{\delta_u} + \frac{\delta}{Q_y \delta_u} \int dE$$



where δ_m is the maximum experienced deformation of the element (nonlinear dynamic analysis), δ_u is the ultimate deformation (push-over analysis), Q_y is the yielding strength of element, dE is the hysteretic energy absorbed by the element during the analysis of the time of reply and β is the model's constant parameter. Unitless IM.



Annex VI – Loss Measures used in MOVER Data Schema

Table VI.1 – Loss measures

LP Symbol	LP Name
<i>ELR</i>	Economic loss ratio
<i>MDR</i>	Mean damage ratio
<i>DT</i>	Downtime
<i>AAL</i>	Annual average loss
<i>ELT</i>	Economic loss total
<i>FT</i>	Fatality total
<i>FR</i>	Fatality rate
<i>Rloss</i>	Relative loss
<i>DI</i>	Damage Index

• Economic loss ratio (*ELR*): The economic loss ratio is defined as the economic loss normalized by the economic exposure.

- Mean damage ratio (*MDR*): The *MDR* is the ratio of the repair cost of the structure to its replacement value.
- Downtime (*DT*): Downtime includes the time necessary to plan, finance, and complete repairs on facilities damaged by other various disasters.
- Annual average loss (*AAL*): *AAL* is the value expected to be saved every year in order to cope with all the future losses, and it can be derived from the loss exceedance curve as the of the exceedance rate of loss:

$$AAL = \int_0^{\infty} v(p) dp$$

Where $v(p)$ is the exceedance rate of loss, p .

- Economic loss total (*ELT*): *ELT* represent the total level of economic loss expressed



in USD.

- Fatality total (FT): Total number of fatalities related to a hazard.
- Fatality rate (FR): Fatality rate is defined as the ratio of the total number of disaster-related fatalities (FT) to the total population exposed.
- Relative loss ($Rloss$): The loss is shown as a fraction of the percentage of the estimated total replacement value of property or area and its contents. $Rloss$ is mainly used for flood loss estimation.
- Damage index (DI): Damage Index judges the proportion of the replacement cost of the structure.



Annex VII – MOVER Data Schema - Data Entry Example

In this section the procedure for entering data in the schema is presented through a simple example. To this aim, the first study presented in the *Fragility function table* (Ff_table, ID:1), i.e. Jalayer et al. (2013), is used here as a worked example. Each entry in the *Fragility function table* or *Vulnerability function table* (Ff_table, Vf_table) corresponds to one fragility or vulnerability curve. For example, if a study presents two set of fragility functions consisting of five curves each, a total of 10 entries are expected in the *Fragility function table* for the given study.

The chosen study provides fragility functions for both Floods and Earthquakes, but only the Flood hazard function is considered in this example. Note that some studies may present more

Hazard: Select the hazard associated with the inputted function from the drop-down menu.

Hazard	Flood
Asset	Earthquake Tsunami
Sub-asset	Flood
Taxonomy	Landslide Wind Storm surge Volcanic ash Drought

Asset: Choose the asset type for which the inputted function is developed.

Asset	Buildings
Sub-asset	Buildings
Taxonomy	Lifelines People Crops

Sub-asset: Type a more detailed description of the specific asset within the asset group.

Sub-asset	1-storey cement stabilized sand brick structures
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Taxonomy: Type the GEM taxonomy code associated with the sub-asset field. GEM taxonomy codes only apply for building Assets and can be generated using the GEM taxonomy tool found in the following link: <https://platform.openquake.org/taxtweb/>

Taxonomy	EU/HEX:1
----------	----------

Country/ies (ISO1; ISO 2): Type the 3 letter ISO code associated with the country/ies of interest. A semicolon is used to separate the ISO codes if more than one country.

Country/ies (ISO1; ISO 2)	TZA
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Scale applicability: Choose the scale applicability between Level 0 to Level3.



Scale applicability

Local - Level 2

Country - Level 0

Sub-country - Level 1

Local - Level 2

Asset - Level 3

Approach: Scroll down to find the type of approach used or simply type the first few letters to narrow down the available options.

Approach

Analytical

Analytical

Hybrid - Analytical/Empirical

Hybrid - Analytical/Judgement

Hybrid - Analytical HF/LF

Reference (Author_Year_a,b,c): In this field type the author(s) name(s) followed by an underscore and the year of publication. Before filling out this field, the reference study must be first entered in the *Reference table* (reference_table). In case more two or more reference entries have same name and year of publication, simply add an underscore and a letter a,b,c to distinguish the different entries, e.g. Smith et al_2018_a, Smith et al_2018_b etc.

Reference (Author_Year_a,b,c)

Jalayer et al_2013 |

Damage scale type: Choose the type of damage scale from the drop-down menu.

Damage scale type

Bespoke

Existing

Bespoke

Unknown

Damage Scale name: Scroll down the list to find the name of the damage scale used in the study, or choose the *Bespoke – see reference* choice, in case the damage scale study is not listed in the menu.



Damage Scale name (TO KEEP) Bespoke - see reference

Milutinovic and Trendafilovski_2003

FEMA_356

Vision_2000

HAZUS_MH_MR4

EMS_98

Bespoke - see reference

Damage Scale Reference: Type the reference study describing the damage scale type.

Damage Scale Reference (Only for Bespoke) Jalayer et al. 2013

N of damage states of the study: Specify the number of damage states presented in the current study. Note that this is not the total number damage states included in the damage scale. For instance, in the example study shown here only 1 damage state is presented (out of a number of damage states included in the damage scale). In this case, the user should enter 1 in this field.

N of damage states of the study 1

Corresponding damage states names: Type the corresponding names of the N number of damage states entered above. Use semicolon to separate names in cases where more than one states exist.

Corresponding damage states names Collapse

Damage state of the function: Select from the drop-down the name of the damage state of the function or simply type the first few letters to narrow down the available options. Note that unlike the *Corresponding damage states names* option (where all the corresponding names of the N number of damage states are entered), here you only need to specify one damage state.

Damage state of the function Collapse

coll

Collapse

Collapsed

Partial collapse

Collapse prevention

Near Collapse

EDP name (for Analytical and Hybrid functions only): Choose from the drop-down the name of the EDP used or simply type the first few letters to narrow down the available options.

EDP name (for Analytical and Hybrid functions only) Demand to capacity ratio

dc

Park-Ang damage index

Inter-storey drift ratio for storey i

Demand to capacity ratio



EDP damage state threshold (for Analytical and Hybrid functions only): Define the threshold of EDP associated with the damage state. This entry does not apply for empirical or judgemental functions.

EDP damage state threshold (for Analytical and Hybrid functions only)

1

Parameters names (Par1; Par2): Enter the names of the mathematical parameter(s) separated by a semicolon. Based on these parameter will

Parameters names (Par1; Par2)

Mean; SD]

Upper bound parameters values (Value 1; Value 2): Not applicable for this study. There is no information is not provided for upper/lower bound parameters.

Upper bound parameters percentile for parametric functions (Perc1, Perc2): Not applicable for this study. There is no information is not provided for upper/lower bound percentiles.

Median parameter: Specify the values of the median parameters corresponding to the parameter names, separated by a semicolon.

Median parameter

1.0; 0.6]

Lower bound parameters values (Value 1; Value 2): Not applicable for this study. There is no information is not provided for upper/lower bound parameters.

Lower bound parameters percentile for parametric functions (Perc1, Perc2): Not applicable for this study. There is no information is not provided for upper/lower bound percentiles.

IM (only for discrete fragility functions): Not applicable for this study.

EP (only for discrete fragility functions): Not applicable for this study.

IM name: Select from the drop-down the name of the IM used or simply type the first few letters to narrow down the available options.

IM name

Flood water depth

depth

Storm surge inundation depth

Landslide flow depth

Flood water depth

Tsunami inundation depth

IM range: Define the minimum and maximum IM range of the function, separated by a semicolon.

IM range

0; 4

IM method: Choose from the drop-down menu the type of IM method.



IM method

Simulated

Recorded

Simulated

Surveyed

Unknown

IM simulation type (for Simulated type only): When a simulated IM method is chosen, select the type of IM simulation.

IM simulation type (for Simulated type only)

Physics-based

Physics-based

IMPE

IMPE reference: Provide the IMPE reference. This entry is not applicable in this example because a physics-based IM simulation type is used here.

Data countries (ISO1; ISO2; ...): Not applicable for this study.

IM data source/s: Not applicable for this study.

N events: This information is not provided in this study.

N assets: Type the number of assets used for the derivation of this function.

N assets 50

Is there a sampling error? - This information is not provided in this study, therefore, the unknown option is chosen.

Is there a sampling error?

Unknown

No

Yes

Unknown

Type of non-sampling error: This information is not provided in this study.

Has sampling error been fixed? - This information is not provided in this study.

Has the data been aggregated? - Not applicable.

N of data points aggregated: Not applicable.

Has the data been disaggregated? - Not applicable.

N of disaggregated data points: Not applicable.

Type of analysis for Analytical functions: Choose analysis type of the analytical function.



Type of analysis for Analytical functions

Advanced

Advanced

Simplified

Type of analysis for Empirical functions: Not applicable.

Type of analysis for Judgement functions: Not applicable.

Sample: Select from the drop-down menu the type of asset sample.

Sample

Single-asset class

Single-asset class

Multi-asset classes

Single-asset

Is the fit good? - No goodness of fit test is provided for this study.

Reference study of fitting: Not applicable.

Has the function been validated? - Specify if the function has been validated.

Has the function been validated? No

Data sources of validation study: Not applicable.

Id: Type the unique ID number of the function.

Type of relationship: Select from the drop-down menu the type of relationship.

Type of relationship

Mathematical

Mathematical

Discrete

Parametric/Bespoke: Select if the study is parametric or bespoke.

Parametric/Bespoke

Parametric

Parametric

Bespoke

Mathematical Model: Choose the mathematical model utilized for the derivation of the function.



Mathematical Model

Cumulative lognormal

Cumulative lognormal

Cumulative normal

Exponential

Bespoke - see reference

Bespoke model reference: Not applicable.

Is the validation study existing? - Not applicable.

Validation study reference (if existing): Not applicable.