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OPENVULNERABILITY: AN INTERACTIVE WEB PLATFORM TO SELECT AND SCORE PHYSICAL IMPACT MODELS

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Abstract

This work provides a preview of "OpenVulnerability", a worldwide unique web database of multi-hazard vulnerability models equipped with an interactive backend, database, and frontend software. The platform currently stores 20'000+ fragility, vulnerability, and consequence models for buildings, infrastructure, and lifelines subjected to earthquakes, floods, wind, landslide, or tsunami. Models from available collections (e.g., HAZard United States, Joint Research Centre) and individual research contributions are stored in a standardised format. The platform implements a rational methodology for scoring different physical impact models according to relevant criteria and selecting the most suitable one for any given application. OpenVulnerability is openly accessible, aiming to activate a community of practitioners, researchers, and decision-makers free to use the available models, contribute with new ones, or contribute to the development of the platform.

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1 INTRODUCTION AND MOTIVATION

Natural hazard events caused an estimated 931,000 direct fatalities and over €3.87T in economic losses in the last two decades, affecting, on average, more than 200M people annually [5]. Risk modelling allows predicting the trends of such impacts and informing evidence-based decision-making to prevent future impacts. A critical component in risk modelling is physical impact modelling, which involves quantifying how asset classes with certain exposure attributes (e.g., material, geometry, year of construction) produce different levels of impact under different values of hazard impact metrics. Physical impact modelling may require a combination of fragility models (i.e., the probability distribution of different damage states, DSs, conditioned on a hazard intensity measure, IM), vulnerability models (i.e., the probability distribution of impact metrics conditioned on a hazard IM), and/or consequence models (i.e., the probability distribution of impact metrics conditioned on a DS).

Many physical impact models are available for different combinations of asset classes and hazards (single or multiple) within various sources, including model compendia, literature review studies, and individual research papers. However, accessing and consistently adopting such models is usually challenging since 1) there is only a limited number of readily available databases resulting from model compendia (e.g., by HAZUS - HAZard United States [2], JRC - Joint Research Centre [3], Global Earthquake Model [4]); 2) such databases adopt inconsistent file formats; 3) contributions from individual research papers are often only available as tables/figures, rather than as datasets. Therefore, identifying "candidate" physical impact models potentially appropriate for the required asset/hazard/geography combinations often results in tedious manual searches involving extensive literature reviews.

The process of selecting the most suitable model among the available candidates, which may strongly influence risk estimates and decision-making, is ultimately a subjective decision of the user. Nonetheless, the selection process can be supported by a qualitative-yet-rational model scoring system based on key attributes related to the suitability of a given model. Examples of such procedures involve the work by Porter [5], Meslem et al. [6], Rossetto et al. [7], Gentile et al. [8]. However, applying such selection procedures in practice is challenging since they lack a simplified software implementation consistently linked to a database of models.

OpenVulnerability (openvulnerability.robertogentile.org) is designed to overcome the above-mentioned challenges. Section 2 of this paper describes the platform and its uses, while Section 3 provides some remarks and future developments.

2 OPENVULNERABILITY

2.1 Vision

OpenVulnerability is a worldwide unique web database of multi-hazard physical impact models equipped with an interactive model selection procedure. **OpenVulnerability is envisioned to be**:

- **A data resource for risk modelling**. The platform currently stores 20'000+ fragility, vulnerability, and consequence models in a standardised format. Models are collected from openly available compendia (e.g., HAZUS, JRC) and individual research contributions. Models are available for buildings, infrastructure, and lifelines subjected to earthquakes, floods, wind, landslides, or tsunami.
- **A tool for risk modellers.** As shown in section 2.2, the implemented database allows to interactively identify candidate models appropriate for a specific asset class/hazard/geography combination. Moreover, the platform implements the selection procedure by Gentile et al. [8], comparing and scoring each candidate model against four

suggested criteria: relevance, statistical refinement, model quality (defined differently for empirical or synthetic models), and user-defined requirements.
- **An “open” community of practice.** Researchers will be able to implement new models in the platform, thus increasing their visibility and real-life impact, as well as contributing to the growth of the platform. Risk modellers will be able to download the physical impact models suitable for their application. Software developers will be able to contribute to the platform with new functionality.

2.2 User experience and functionalities

The experience of most users of OpenVulnerability involves three web pages adopted in sequence: model database; model description; and model selection. The process is consistent with the physical impact model selection procedure by Gentile et al. [8], and the reader is referred to this document for more details. The same reference provides the details of an illustrative application of the selection procedure for a four-storey, residential building in Kathmandu. The case-study application is demonstrated on OpenVulnerability in a dedicated YouTube tutorial (youtube.com/watch?v=uJt1ZUZep5A).

On the home page, the user selects a model category to start. The currently available categories involve fragility, vulnerability and/or consequence models for buildings, infrastructure (bridges, roads, railways, pipelines, potable and wastewater networks, power grid networks, communication networks) and others (agriculture, storage tanks, energy generation facilities).

For each of those, a *model database* page is available (Figure 1a). First, it lists all the models available for the selected category. Most importantly, it allows filtering the list based on general attributes referring to hazard type and geometry (defined as continent, country, and region/city), as well as exposure attributes defined consistently with the global exposure database for all (GED4ALL [9]). Such taxonomy is selected because: 1) it considers multiple hazards including earthquakes, volcanoes, floods, tsunamis, storms, cyclones and drought; 2) it covers buildings, roads, railways, bridges, pipelines, storage tanks, power grids, energy generation facilities, crops, livestock, forestry, and socio-economic data. On this page, the user can easily identify all the models consistent with a selected combination of hazard/geometry/exposure attributes.

Such models can be explored in dedicated *model details* pages (Figure 1b), which include an interactive plot, the adopted IM, DSs and/or impact metric, a reference document for the model, a short description which may include details not commonly captured by the exposure taxonomy attributes, for example referring to the derivation methodology (e.g., synthetic, empirical). After a careful evaluation, the user can decide to include models in the selection pool. This process is named “screening” in the overarching selection procedure [8].

The *model selection* page (Figure 1c) allows scoring the models in the selection pool and selecting the most appropriate one for the risk-modelling use-case selected by the user, i.e., the “scoring” phase of the selection procedure [8]. Pop-up pages allow scoring each model according to four criteria: relevance, statistical refinement, model quality (defined differently for empirical or synthetic models), and user-defined requirements. Each criterion involves one or more attributes, which should be qualitatively scored "high", “medium”, or “low” according to a detailed scheme suggested in [8]. The “relevance” criterion involves the “geographical area” attribute, which captures the representativeness of a given model for a given area, and “asset characteristics”, which considers how the parameters of the asset’s structural details, materials, and geometry within the model reflect those required for the considered asset class, and “IM”, which is related to the sufficiency and efficiency of the adopted IM(s). The “statistical refinement” criterion involves the “uncertainties” attribute, related to the refinement of the treatment of uncertainty for a given model, and “first principles”, which accounts for any functional inconsistency in the model (e.g., the crossing of fragility functions for different DSs; unreasonably large/small maximum value of the impact metric of a vulnerability function). For empirical models, the "model quality" criterion includes the attributes "impact observations" and "IM observations" that are related to the level of error/bias involved in the fitted data, "constrained asset class" that captures how well the fitted data is suited to a single asset class, and "data quantity", which involves the number of IM vs damage/impact observations used to fit the model. For synthetic models, this criterion involves "fidelity to mechanics", which captures how well an analytical/numerical model reflects the mechanics of an asset subject to one or multiple hazards, and "aggregation level", which reflects the level of sophistication involved in the model (e.g., asset- vs component-level models). The attribute (and criterion) "user-defined requirements" reflects the level of compliance of the selected model with a set of user-defined features (e.g., time/state dependency, consistency of model assumptions across different asset classes).

Once each model is scored, the user can select weights for the selection criteria and the platform automatically calculates a model ranking based on the multi-criteria decision-making procedure TOPSIS [10], or technique for order preference by similarity to an ideal solution. Suggested default weights are 25% for "relevance", 15% for "statistical refinement", 40% for "model quality", and 20% for "user requirements".

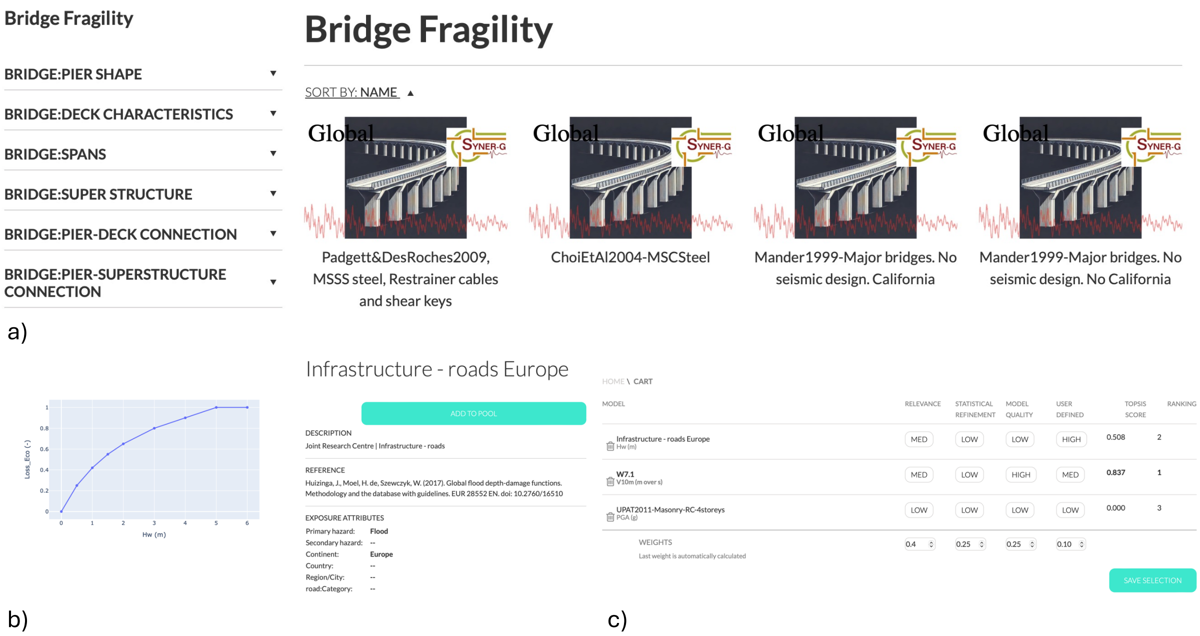

Figure 1: Page layout: a) model database; b) model description; c) model pool.

2.3 Overview of software architecture

OpenVulnerability provides an interactive, browser-based environment and it involves a client-server architecture including:

- An HTML-based *client application* that allows the user to browse the available physical impact models both via a text-based search and by filtering the database according to the required asset type (e.g., railway), model type (e.g., fragility), and relevant GED4ALL exposure attributes (e.g., material).
- A MySQL-based *database* storing the available physical impact models.
- A Python-based *server application* developed using the Flask framework. This allows retrieving and managing the required data from the database, providing plots

and text-based representations of the models, and running the model selection procedure.

3 REMARKS AND FUTURE DEVELOPMENTS

This paper presented a preview of OpenVulnerability, an interactive web platform to select and score physical impact models. Although the project is in its infancy and it is currently a beta version, it is possible to identify key remarks, as well as avenues for future development:

- OpenVulnerability is fully deployed on the web (openvulnerability.robertogentile.org).
- The platform currently includes 20’000+ fragility, vulnerability, and consequence models for buildings, infrastructure, and lifelines subjected to earthquakes, floods, wind, landslide, or tsunami. Models are collected from the following open sources: Earthquake - GEM Global vulnerability database [4], Syner G [11], RINTC [12], Physical Vulnerability Database [13]; Flood - Joint Research Centre [3], HAZUS [2], Physical Vulnerability Database [13]; Tsunami – ETRiS [14]; Wind – HAZUS [2]; Landslide – Physical Vulnerability Database [13].
- All models are stored in a standardised format able to accommodate different hazards, IMs, DSs, and impact metrics. The format can be integrated or converted to other formats for data storage (e.g., natural hazard risk markup language, NRML [15]; OASIS loss modelling framework [16]) or metadata (e.g., Risk Data Library Schema [17]).
- Individual research groups can contribute new fragility, vulnerability, and/or consequence models to the platform by compiling a submission form (https://forms.office.com/e/AENdRFUQXE).
- In the open spirit of the platform, researchers, public, and private institutions are invited to contribute to it with new models, functionalities, use cases, and file format standards, among others.

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