An Introduction to the Global Earthquake Consequences Database (GEMECD)

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SUMMARY
In past decades a large number of reconnaissance surveys have been carried out, recording the direct impacts of earthquake ground motion as well as those due to secondary hazards. However there has been little effort in collating and compiling such surveys into a single standardised domain.

Under the auspices of the Global Earthquake Model (GEM), an international consortium of 10 partners is working to create a structure to enable the assembly and storage of earthquake consequence data in a single database called the Global Earthquake Consequences database (GEMECD). The repository will include consequences of more than 60 global events with records of building damage due to ground shaking, damage to lifelines and other infrastructure, effects of secondary and induced hazards (ground failure, tsunami, fire following), human casualties, social disruption, and economic loss. The project started in November 2010 and in this paper, the major advances since its inception are presented.

Keywords: earthquake, database, global, consequences, damage

1. INTRODUCTION

To improve the performance of buildings and other structures in earthquakes, it is essential, in addition to analytical and experimental studies, to observe and quantify the performance of structures after damaging earthquakes. Only by such observations can we gain confidence that structural design is achieving its aim of providing safety and by field observations, the causes of the failure of aspects of design can be identified, and steps to rectify them can be found. Earthquake damage observations and surveys are also of crucial importance for assessing the vulnerability of existing buildings, in applications such as rapid impact assessments, mitigation planning and risk modelling. For best use to be made of these data, it is essential to bring the data together and make it accessible to the research community, to enable cross-event analysis to take place, and to determine to what extent lessons learnt in one country or region can be applied elsewhere.

Despite a plethora of losses in past earthquakes, as a generalisation, the quality and uniformity of the loss data collected for some of these events can be described as poor, due to inconsistencies in methods and reporting. Though limited, these data provide important constraints for loss model development, validation and calibration. The utility of existing global data can also be substantially improved with dedicated focus on proper data taxonomy and uniformity, and aggregation of widely dispersed and variable format data sets into a formal database. Given the state of past data, then, it is equally important to develop a proper framework for collecting perishable loss data for earthquakes in the future. For this project, we envision a database that will inform data collection and integration and enable a clearer understanding of the true consequences of earthquakes around the world thus contributing to the eventual risk mitigation actions that bring those at risk closer to a desirable level of earthquake protection.

The aim of the Global Earthquake Consequence Database (GEMECD) project under the auspices of GEM, the Global Earthquake Model is to make possible, for the first time, the easy and open access to data that have been painstakingly collected by various authorities and researchers after important recent and historical earthquake disasters around the globe. By seeking out relationships linking past events and the environments they affect, it is hoped that our understanding of the potential regional consequences from earthquakes will improve, especially in parts of the world where there have been fewer documented events in the recent past. This will be accomplished by a thorough investigation of the key consequences of past earthquakes around the world, compiled into a database of the best available data. The data will be collated, learning from local knowledge and existing regional initiatives, drawing on new regional capabilities and international reconnaissance missions and linked to a GIS mapping of ground shaking and other induced secondary hazards. What will set this database apart from previous efforts is a strict adherence to the developing inventory and structure taxonomies being developed in parallel to this effort, ensuring that our consequences database can be directly utilised for vulnerability development and loss model validation.

The nature of this project is collaborative. The consortium of regional experts will assemble a structured and web-accessible geospatial database of consequence data including building damage, human casualties, social disruption, and other secondary impacts from events around the world in the past four decades. At the same time, the database will be designed for users to contribute their own data from past events and document future consequences. It will contain features to enable post-processing across events, structure types and ground motion severities for specific consequences globally or within geographic regions. Our vision is to ensure that the best possible, user-driven and interactive consequences database is delivered to GEM, and made accessible to all GEM users. The three year project started in November 2010.

2. THE GEMECD CONSORTIUM

The GEMECD consortium has been formed to ensure the best available knowledge is employed to fulfil each of these tasks while including partners with expertise in all the important earthquake-prone regions of the world. The existing working relationships and geographical awareness of this international group of partners is what is crucial in a global initiative such as this. The project team and our responsibilities are shown in Figure 2.1.

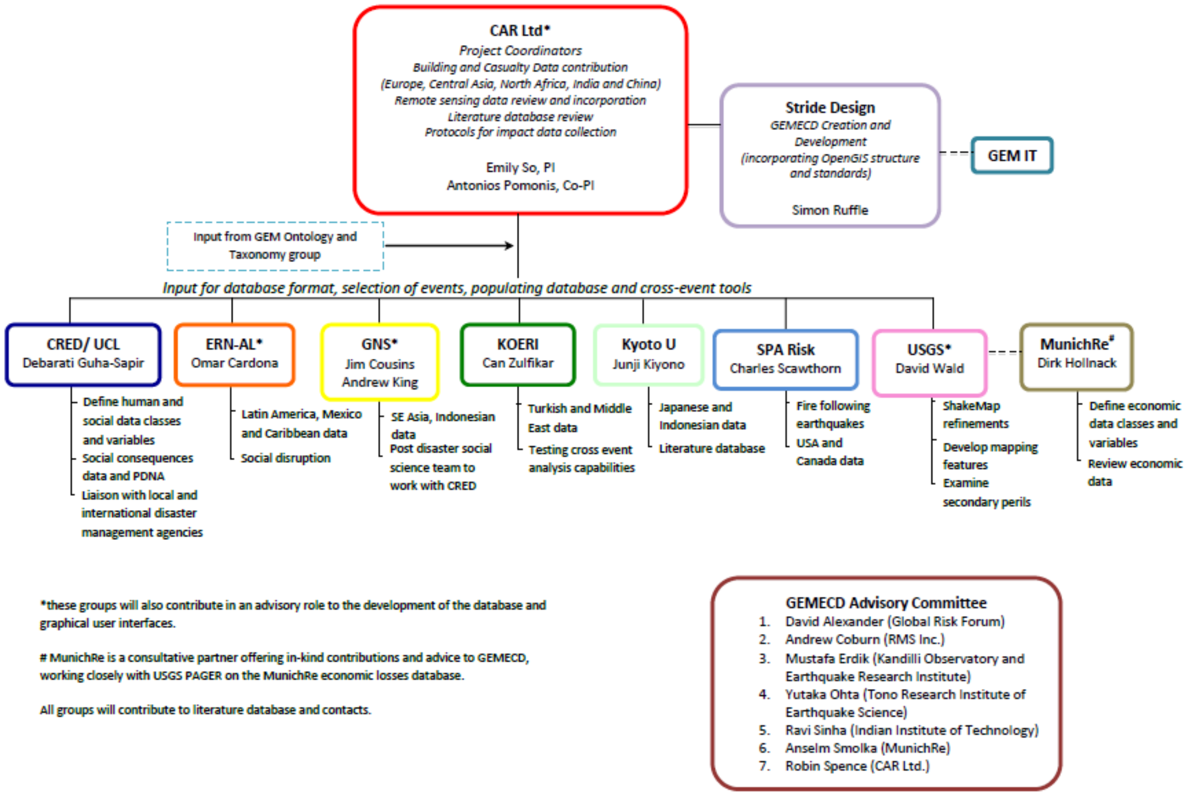


Figure 2.1. Organogram of the consortium

This consortium is in the best position to provide the widest possible geographic coverage, the most valuable and validated data for past events and for laying the foundation for efficiently and thoroughly capturing consequence data from future events. In addition to those identified, the team expects to leverage contributions from other experts within the GEM and the field at large.

Within the overall GEM development agenda it has been envisaged that the GEMECD project will provide data that are useful for seismic risk modelling purposes and particularly to furnish other GEM Risk projects with the necessary information to carry-out inventory assessments, vulnerability assessments, model calibrations and model validations. Initially GEM's development agenda is to address modelling of risk to standard buildings due to ground shaking, as this interaction of hazard and exposure is the greatest contributor to earthquake risk worldwide. GEMECD will give emphasis to building damage due to ground shaking studies, although the database will also cover other aspects of earthquake consequences.

The GEMECD project shall be collecting consequence data of five different categories as follows:

a) Ground shaking damage to standard buildings.
b) Human casualty studies and statistics.
c) Ground shaking consequences on non-standard buildings, critical facilities, important infrastructure and lifelines.
d) Consequences due to secondary, induced hazards (landslides, liquefaction, tsunami and fire following) to all types of inventory classes, i.e. standard and non-standard buildings, lifelines and critical facilities.
e) Socio-economic consequence and recovery data.

Thus GEMECD is designed to capture the full spectrum of earthquake consequences and can be visualised as a matrix of the interaction between the various inventory assets and the earthquake-related damage agents, as shown in Figure 2.2.

Figure 2.2. Matrix of consequences to be considered in GEMECD

3. THE DATABASE STRUCTURE AND LIST OF EVENTS

The final list of events and types of consequence studies to be included in GEMECD can be downloaded from GEM/NEXUS (http://www.nexus.globalquakemodel.org/gemecd/files). The 68 events for which consequence data will be collected, and their responsible partners are shown geographically in Figure 3.1. As new events will occur over the duration of the project and because it may prove difficult in some parts of the world to find useful consequence data for some of the older events listed, the final list of events may be subject to changes.

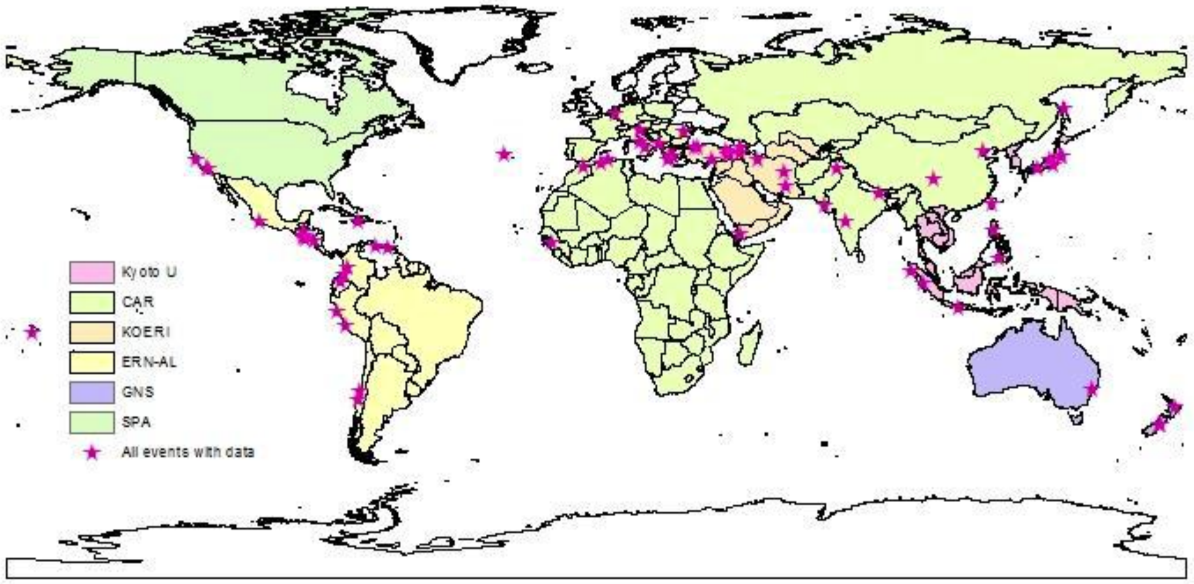


Figure 3.1. Map showing the geographical locations of the 68 events in GEMECD and their responsible partners

The consequence database will contain data in four consecutive tiers (Tier 0 to Tier 3). The Tier structure is explained in Figure 3.2.

3.1. Tier 0: Global Map of Events

At the top tier (Tier 0), a homepage will show a global map indicating epicentres of all earthquakes for which data are available, and list the earthquakes by countries and dates. The website will use digital maps, which can be viewed at any scale is desired, and viewed in standard modes – road map, terrain map, or satellite image.

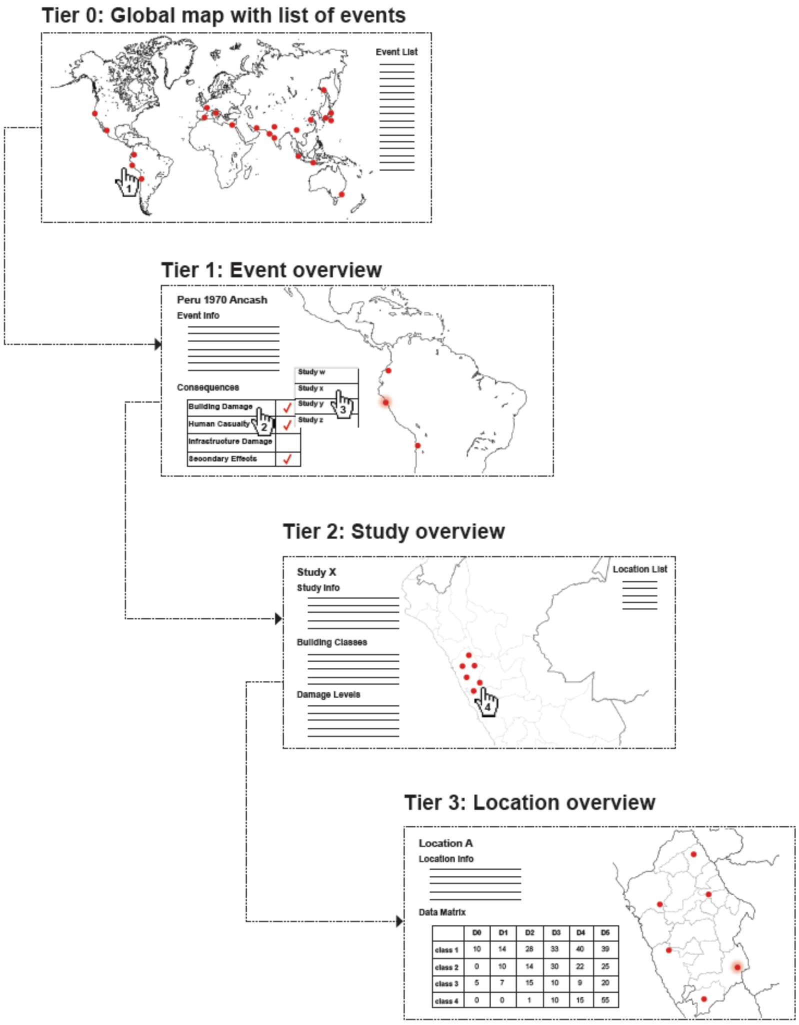


Figure 3.2. Schematic of the GEMECD tier structure

3.2. Tier 1: Event Overview

Upon selecting one of the events in the list or its epicentre on the map, Tier 1 will appear. The basic event information will be seen containing primary data shown in Table 3.1. A link will also be provided to the USGS ShakeMap Atlas for each event.

Central to the GEMECD is the use of USGS ShakeMaps as a common seismic hazard denominator that will serve to inform users on consequences from past events based on the estimated ground shaking. All consequences recorded in the GEMECD can then be related spatially to a ground motion intensity level and used for subsequent analyses.

Table 3.1 presents the primary data of the May 31st, 1970 Peru (Ancash/Chimbote) earthquake. For events affecting more than one country (e.g. the 2005 Kashmir earthquake etc.), it is anticipated that the summary table at Tier 1 will contain the summary of the casualties, damage and losses for all the affected countries. The table structure allows for references and comments to be added so that the data source is transparent and any issues related to the accuracy and completeness of the data are flagged.

Table 3.1. Basic seismological and consequence data for the Peru earthquake of May 31, 1970

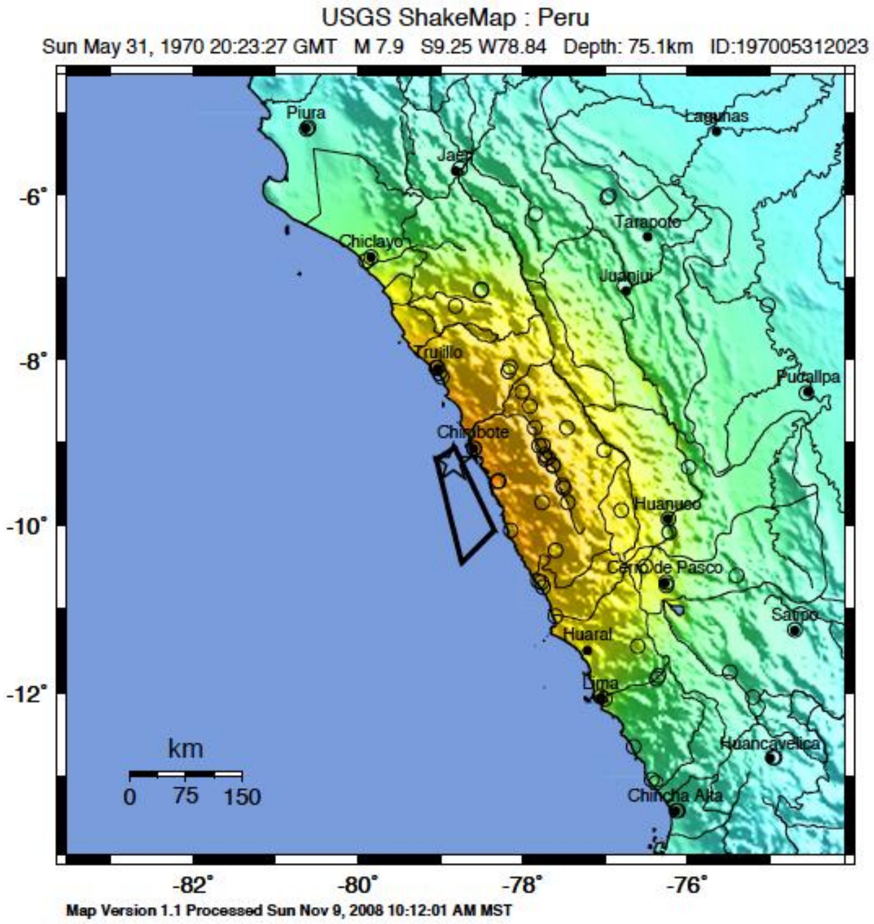
Data Fields	Data Format	Source	General Comments
Event ID (date & GMT occur. time)	197005312023	text	text
Event Name	Ancash (Chimbote)	text	text
Date of occurrence (UTC)	31/05/1970	text	text
Date of occurrence (Local)	31/05/1970	text	text
Day of the Week (Local)	Sunday	text	text
Time of occurrence (UTC)	20:23	text	text
Time of occurrence (Local)	15:23	text	text
Magnitude	7.9	text	text
Magnitude type	M_w	text	text
Focal Depth (in km)	75.1	text	text
Epicentral Coordinates (Long)*	-9.248	text	text
Epicentral Coordinates (Lat)*	-78.842	text	text
Total number of people killed	~32,000	text	text
Total number of people missing	~35,000	text	text
People killed due to ground shaking	~49,000	text	text
People killed due to slope failures	~2,000	text	text
People missing due to slope failures	~16,000	text	text
People killed due to tsunami	0	text	text
People missing due to tsunami	0	text	text
People killed due to fire following	0	text	text
People missing due to fire following	0	text	text
People dying post-disaster but earthquake-related	n/a	text	text
Total number of people injured	~143,500	text	text
People seriously injured and/or hospitalized	n/a	text	text
Total number of buildings collapsed or damaged beyond repair due to ground shaking	n/a	text	text
Total number of buildings damaged due to ground shaking	n/a	text	text
Total number of dwelling units collapsed or damaged beyond repair due to ground shaking	186,000	text	text
Total number of dwelling units damaged due to ground shaking	n/a	text	text
Total number of buildings in the affected country at the time	n/a	text	text
People Homeless	~ 1,700,000	text	text
Total Estimated Direct Economic Loss (contemporaneous, in million US$)	507 ml US$	text	text
Total Estimated Indirect Economic Loss (contemporaneous, in million US$)	n/a	text	text

*For the epicentral coordinates a negative value is used for the western longitudes and southern latitudes.

The basic seismological data are already included in USGS' EXPO-CAT (Allen *et al.*, 2009b) database, while summary damage information, casualties by cause and homelessness are included in USGS' PAGER-CAT (Allen *et al.* 2009a). Except in cases where it is not available the moment magnitude will be used for all the events in the GEMECD, as defined by the USGS in the ShakeMap

Atlas and the citations/references therein. This is to ensure uniformity and comparativeness is maintained. However, for other consequence fields in Table 3.1 (casualties, damage, homelessness and loss) should there be local data that are deemed more accurate than what is in the above two databases, these will be proposed with the appropriate references noted in the source field.

At Tier 1 the user will be able to select and view the macroseismic intensity ShakeMap of the event and the surface fault rupture (if it occurred) or the fault plane of the event (particularly in the case of large subduction events). Such maps are already available for all the events selected for the GEMECD, although improvements are currently being implemented by the USGS. Figure 3.3 shows the macroseismic intensity ShakeMap for the 1970 Peru (Ancash/Chimbote) event.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 3.3. USGS ShakeMap for the May 31, 1970 Peru (Ancash/Chimbote) earthquake

For the events that contain consequence studies due to secondary and induced hazards: landslide outline maps, liquefaction outline maps, tsunami inundation maps (including tsunami flow height when possible) and fire affected area maps, these may in some cases be included depending on availability.

For recent events, value added maps derived using remotely sensed data (particularly for tsunami inundation extents and landslide occurrence, but also for ground shaking damage to buildings, infrastructure) will also be considered. Such maps are made available through websites such as

Reliefweb, GDACS and Disaster Charter, as well as other research groups and national laboratories. A link to these maps may be provided in the GEMECD and sorted by theme. In terms of the raw satellite/aerial photographs, there have been cases where access to raw data was granted free of charge (e.g. 2010 Haiti earthquake), links to these datasets may also be provided in GEMECD where appropriate.

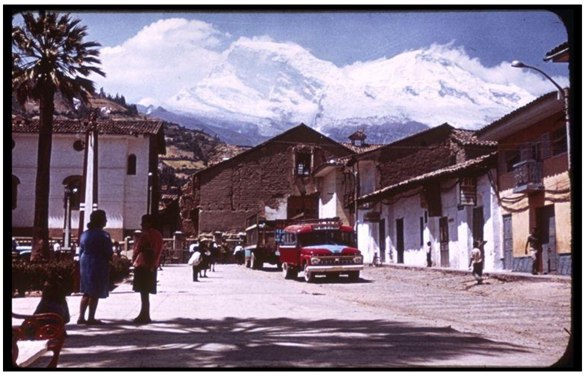
For simplicity, events in the secondary hazard consequence studies will address the impacts of a single dominant secondary hazard (e.g. landslides for the 2008 Wenchuan, China earthquake; tsunami inundation for the 2011 Tohoku, Japan earthquake; liquefaction for the 2011 Christchurch and the 2010 Darfield earthquakes in New Zealand; fire following for the 1923 Great Kanto, Japan earthquake etc.). Whilst in Tier 1, the user will be able to see at this interface whether there are consequences data for this event in each of the five consequence data categories described above (a to e). Upon pointing the mouse to any of the five consequence data categories, a new pop-up menu will appear showing the list of studies available in this category (see Figure 3.1). These studies will be clearly named (by type of data and regional name). In addition there will be links to a literature database for each event and the ability to show graphical overviews, e.g. bar charts of damage. These charts will be attached as JPEG images as the web interface will not be generating charts from the data. In addition there will be the ability to assign confidence-reliability levels to the surveys/data (e.g. depending on sample size, the format of data etc.).

In the event information section of the screen, additional information may also include images of typical construction types, typical damage and population exposure at the time of the event, likely references being, the World Housing Encyclopaedia (WHE), the EXPO-CAT database and other online or partner's own resources. For example, Table 3.2 below shows the estimated population exposed to ground shaking of Modified Mercalli Intensity (MMI) VI and above (at half intensity intervals) for the illustrated 1970 Ancash/Chimbote, Peru earthquake (separately for urban and rural areas). Photos 1 to 3 show typical damage in the town of Huaraz and a pair of pictures of the town of Yungay destroyed by an avalanche (before and after the avalanche). A photo archive of JPEGS or links to external sites will be included for different events and consequences.

Table 3.2. EXPO-CAT population hindcast by intensity zone for urban and rural areas (MMI≥VI) for the May 31, 1970 Peru (Ancash/Chimbote) earthquake

MMI	Estimated Population	Zone
U060	877,627	Urban
U065	601,223	Urban
U070	92,953	Urban
U075	13,696	Urban
U080	223,398	Urban
U085	0	Urban
U090	0	Urban
U095	0	Urban
U100	0	Urban
R060	428,048	Rural
R065	457,396	Rural
R070	361,988	Rural
R075	84,788	Rural

Photo 1 Destruction of adobe houses in Huaraz with a 3-storey reinforced masonry building surviving the shaking (Source: NISEE – The Earthquake Engineering On-Line Archive)



Photos 2 and 3 Yungay central square before the avalanche (left); Yungay central square after the avalanche (note the still standing palm trees) (Source: NISEE – The Earthquake Engineering On-Line Archive)

In addition, a general summary of each earthquake may also be provided at this tier giving the user an overview of the consequences of the event. This will help users gain a better understanding of the various earthquakes included in the dataset. For example, for the 2001 Gujarat (Bhuj) earthquake, India, the following description could be included:

"*The M_w 7.6 Gujarat (Bhuj) earthquake occurred in the state of Gujarat, India, at 03:16 UTC (8:16 a.m., local time) on 26 January 2001. The event struck within the Kachchh peninsula near India's western coast and was felt over much of the Indian subcontinent. In addition to strong ground shaking, the earthquake resulted in liquefaction spread over more than 1000 km^2. The earthquake exposed the high seismic risk in urban areas in India; dozens of buildings collapsed in Ahmedabad, which was located over 200 km from the epicentre, killing hundreds. Official government data placed the death toll at over 13,000 and the number of injured at 166,000. Government estimates place direct economic losses due to the earthquake at 1.3 billion US dollars, although more recent estimates indicate losses as high as 5 billion US dollars*."

In this general summary the number of buildings (and/or number of dwelling units) damaged by cause (e.g. ground shaking, landslides, tsunami, liquefaction, fire following) will be provided when possible.

3.3. Tier 2: Study Overview

At Tier 1, upon choosing one particular consequence study in the pop-up menu the user will enter Tier 2, the Study Overview. This tier is specific to a particular consequence study. For each study, a geo-referenced map would show all the locations of individual surveys, the dates when these surveys were carried-out and the data collected in that study. At the *Study Information* section of the screen further details of the studies will be provided.

If the study is about damage to buildings due to ground shaking, there will be a building classes section giving information about the structural types included, their GEM Taxonomy code, the number of buildings surveyed, and a link to the glossary of images described by this structural typology, with possibly a bar chart summarising the damage observed. A link to the literature database will be available directing the user to the documentation and reference material used for the study.

An important requirement of GEMECD is that all study locations are geo-coded (whether a town district or neighbourhood, a village or an intensity zone) as accurately as possible. The user can then link the reported consequences to the estimated instrumental ground motion intensity, peak ground acceleration (or velocity) and spectral acceleration (for given periods) and the soil category, based on the Vs30 versus slope categorisation (Wald and Allen, 2007) from the relevant ShakeMap.

In addition, where good quality maps of the survey areas are available (e.g. isoseismal maps, damage survey maps, tsunami inundation maps, landslide outline maps, burned area maps, liquefaction area maps etc.) these will be provided. In recent events, with the advent of GIS tools, damage surveys are increasingly becoming available at the individual building level. Such studies of individual buildings which can be geo-referenced would be included and permission to store and use in GEMECD will be sought by the consortium. If permission to use is not given, the data may appear in the GEMECD in an aggregated form and illustrated by an accompanying map (when this is available).

3.4. Tier 3: Location Overview

Selecting a survey location will bring the user to the third and final tier where the individual survey data for a particular location will be presented. The presentation of these data will be standardised according to pre-determined parameters harmonised with GEM Risk definitions and the GEM Ontology and Taxonomy. Each study to be shown in Tier 3 will be clearly accredited to its source (e.g. published paper, a report, a survey of proprietary data etc.).

A set of guidelines for the collection of the five categories of consequence data, with illustrative examples has been produced and the database platform is now being developed on the basis of these guidelines (Pomonis and So, 2012). The design of the GEMECD is well underway and is envisaged to be fully functional for data population and use by November 2012.

4. IN CLOSING

The legacy of the project will be a web accessible database for the on-going service of GEM users. For current events, GEMECD will serve as a clearinghouse of information, posted by users based on the standards and protocols set in the GEMECD documentation. In the long term, GEMECD will be a repository of the most relevant and validated data on consequences of the most significant events of the last 40 years around the world.

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