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SEISMIC, TSUNAMI AND HURRICANE RISK OF HOSPITALS IN MEXICO

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ABSTRACT

In this work we present the estimation of losses for all hospitals in Mexico based on a full probabilistic risk assessment methodology for earthquakes, tsunamis and hurricanes. Results, shown in GIS maps and tables, exhibit clearly hazard and vulnerability differences for all hospitals built in Mexico. These results are being used by the health authorities to prioritize mitigation efforts. Results for the whole portfolio are also been used to better manage insurance contracts.

Introduction

After more than five years of collaboration between people from public hospitals in México, UNAM and the firm ERN, we are able now to compute losses and scenarios to present to the decision makers. This collaboration includes engineers, researchers, architects, physicians and administrative people, among others.

On one hand, we have been gathering information to create a database of all hospitals and clinics in México which we have concluded a few months ago. What we have now is the location (in terms of GIS systems), the number of stories, structural and contents value, structural type, year of construction (therefore, design building code) among others. As part of the Hospital Seguro (Safe Hospital) program, we also have detailed information of inspections and reports by local maintenance personal with information such as recent damage and behavior due to natural hazards.

We have been developing since 1996 full probability earthquake, tsunami and hurricane risk models to assess losses of structures, in this case hospitals and clinics (Ordaz, *et al.* 2007; Huerta *et al.*, 2006 and 2007). These models, developed at first for the insurance sector, have been very useful to draw maps of hazard and risk to point out those structures at the highest risk and, therefore, those that should be attended and retrofitted first. They include the earthquake hazard in terms of spectral acceleration, the tsunami hazard in terms of flooding areas and the hurricane hazard in terms of three internal hazards: wind, flood, and storm surge (to assess the hazard due to low frequent events and for non hurricane areas, other non hurricane wind, flood, and storm surge hazards has been included in the so called hurricane model).

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An issue of particular importance for hospitals is the seismic risk of their contents since its failure may put the whole hospital system at risk. We have included recent research to assess the risk of hospital contents in order to propose mitigation procedures and therefore reduce the risk.

The hazards

Hospitals in Mexico have been largely damage by earthquakes and hurricanes (mainly pluvial flood). Tsunamis and landslides (either caused by earthquakes or rain) are not a threat since hospitals are not built close to the see or near slopes. Fig. 1 shows some examples of geocoded hazard maps for some events.

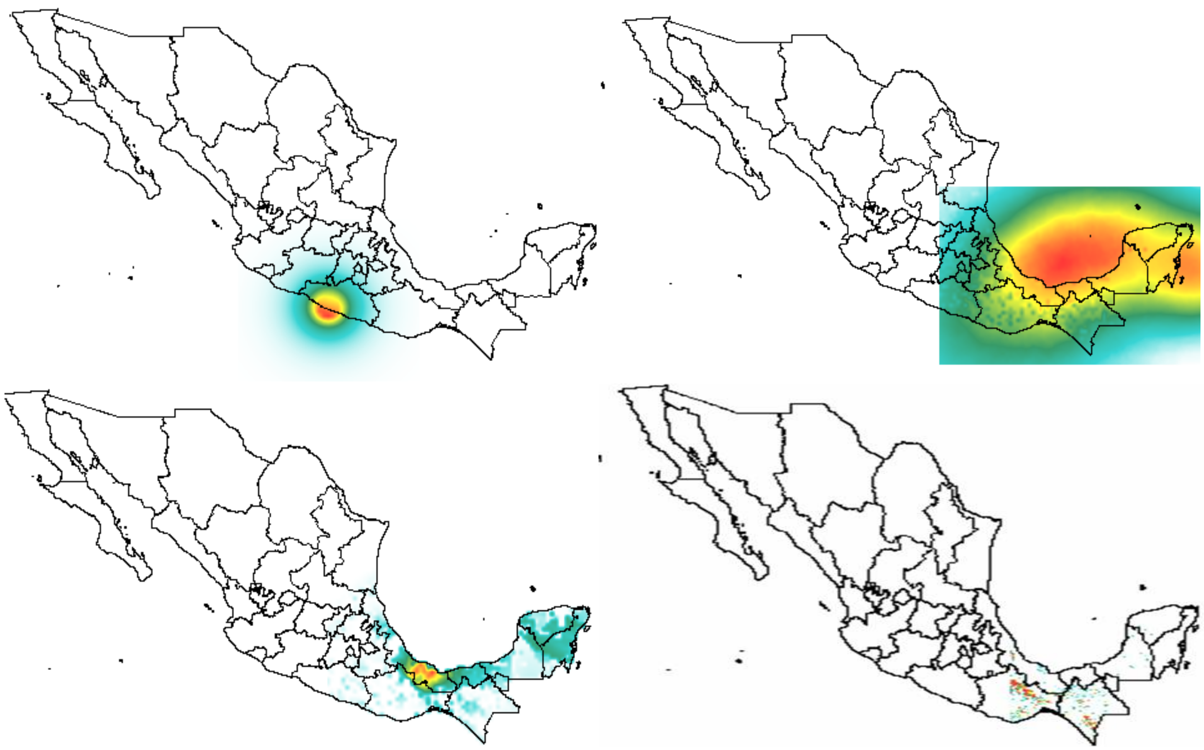


Figure 1. Examples of hazardous events included in the risk assessment: a) subduction earthquake M7.8, b) Hurricane Stan, c) flood associated to Hurricane Stan, d) landslides associated to Hurricane Stan.

Data base processing

The importance of a good quality structural and location data of the physical inventory for the estimation of losses was first discussed with the people in charge of the hospital units; representatives of the Federal Government in charge of the administration of the insurance policy (*Dirección de Seguros y Fianzas, SHCP*) were also present; this people was in charge of sending the proper official communications that trigger the gathering data process.

The requested information consisted on:

a) Location data:
- State, municipality, zip code and longitude and latitude; also, were applicable, the closest distance to the sea, lake, lagoon or river.
- Type of soil (rock, firm or soft). If this information was not provided, the risk assessment system contains a subroutine that computes it, especially at sites such as Acapulco and Mexico City with very well known site effects.

b) Replacement or Reconstruction Cost:
- Building or structure reconstruction value.

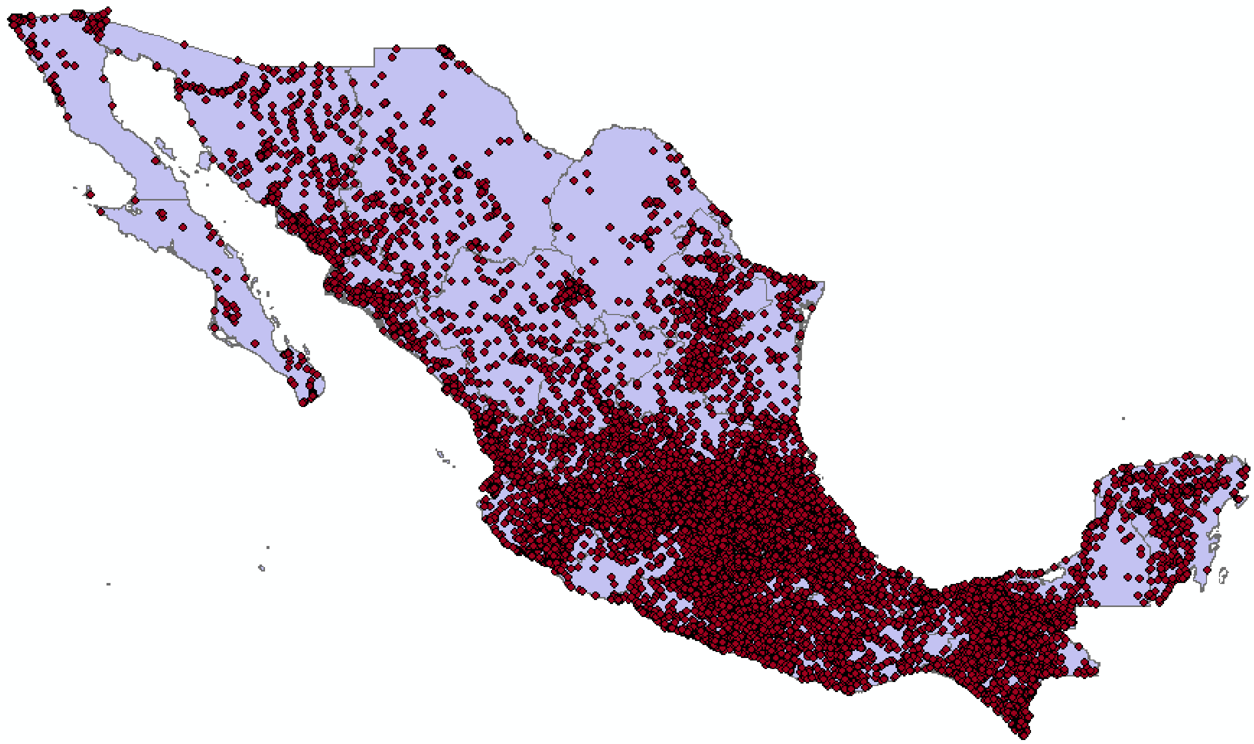
c) Use and contents:
- Number of beds.
- Equipment (e.g. fans or artificial climate, computers, projectors, power supplies, emergency plants).
- Special equipment and furniture (e.g. ultrasounds, defibrillators and operating rooms, among others).

The information on health infrastructure was requested from the Department of Health [*Secretaría de Salubridad y Asistencia*, SSA]. Information provided by SSA consisted of: i) inventory of medical clinics, health centers and hospitals; ii) movable assets (furniture, medical equipment and tools) for the three levels of government in México: municipality, state and federal. Figure 2a shows a map of Mexico with all 13,762 medical units' (red dots); as expected, there are more medical units in the central and coastal zones, where larger cities and towns are is located; Fig. 2b show the medical units in Mexico City where many units are located over the dark gray area, which is the lakebed zone that has large site amplification effects.

The SSA data base has a lot of information but very little can be used to characterized the structural type of each unit. The data base fields useful for our purposes are: the unit code, the unit location, the SSA typology, construction date, number of stories, construction area, number of consulting rooms, number of beds and the list of equipment each medical unit has.

Filling the lack of structural information

Very few medical units have all the structural information required in the fields described above, only large and important hospitals have it. For other units we had to find out a way to fill reasonably the missing information. Of course, there were some cases where in site inspections yield reliable information that was used to assess losses with less uncertainty.



(a)

(b)

Figure 2. Location of all medical units in a GIS database: (a) Mexico and (b) close-up to Mexico City, where dark gray color shows the lakebed zone where large site effects are present.

Number of storeys in medical units

Only 3.6% of all units have this information. We have assigned a number of storeys to each unit according to the medical unit typology and number of beds.

Medical units structural type

The SSA data base does not include information on medical unit's materials. Therefore, the structural type was grouped according to the medical unit typology. According to the Mexican typical construction, two types of structural systems were used:

- Confined masonry walls
- Concrete frames

Type of roof

This information is very important for hurricane risk. It was assumed that all units have reinforced concrete roof.

Construction year

The year of construction is strongly correlated with building codes and therefore structural behavior. However, more around 30% of medical units do not have this information. Figure 3 shows the percentage of units with a certain year of construction according to a decade. It was considered reasonable to assign 1985 as the default information assuming that the unit was build with pre 1985 standards.

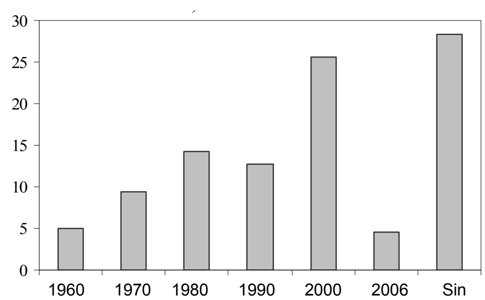


Figure 3. Construction year included in the database

Vulnerability Modeling

The formal way to quantify the vulnerability is using vulnerability functions that relate the probable consequences of a hazard, characterized by a parameter of intensity with engineering sense, on a given structural type. For earthquakes, the parameter that we use is the spectral acceleration, for hurricanes, wind speed, storm surge elevation and flood depth.

Additionally, there are other parameters that modify the structural behavior such as irregularities in plan and elevation, possibility of pounding, short columns, previous damages, differential settlements, etc. If known, they can be entered in the risk computation system, but only qualified engineers with onsite inspections are able to fill up this information.

Main structural types found in México for building hospitals are described as follows.

Steel frames

Some large hospitals have been built with steel frames according to the codes. The connections are particularly weak links in these constructions, but no evidence has been found that there is a large risk associated to potential failure of connections. An additional source of reduction in the structural integrity of these constructions is the potential for corrosion in the structural elements, so the lack of maintenance in these building in the long term can have consequences in the resistance, but this is difficult to expect in hospitals since there all times kept in good shape.

Concrete frames

The behavior is similar to the structures with steel frames. The most notable damages in this type of structures are related to an unsuitable detailing, mainly in the transversal stress, as well as the dimensions of the structural elements or an inappropriate configuration of the building. The natural decay of concrete is relatively slow; nevertheless, maintenance to the structural elements is necessary, though this factor is not so relevant, compared with steel constructions.

Flat slab systems

Very common in México, these structural systems have shown very large earthquake vulnerability. However, it is expected that very few hospitals were built with this structural system. Unfortunately, in the data base, it was impossible to gather this information; it is only possible to obtain it with qualified engineers thru site inspections.

Confined masonry walls

These are very rigid constructions, few storey high where walls are forced to behave in the way they are more competent, i.e. bearing lateral loads acting in its own plane.

Other structural systems

Unconfined masonry walls or weak material walls such as adobe are not used in Mexico for hospitals due to their very well known large vulnerability.

Results

Some illustrative results are shown as follows. Figure 4 shows losses of hospitals in México due to hurricane hazard (composed by wind, storm surge and flood), where dark blue shows those hospitals with expected annual losses larger than 0.2 per cent. Note that every dot in the map corresponds to an individual hospital. This attributes can also be shown in tables, which may be more practical in many cases.

For the earthquake risk, Fig. 5 shows losses for the same hospitals. Note that losses are concentrated in the subduction zone and in Mexico City (due to large site effects).

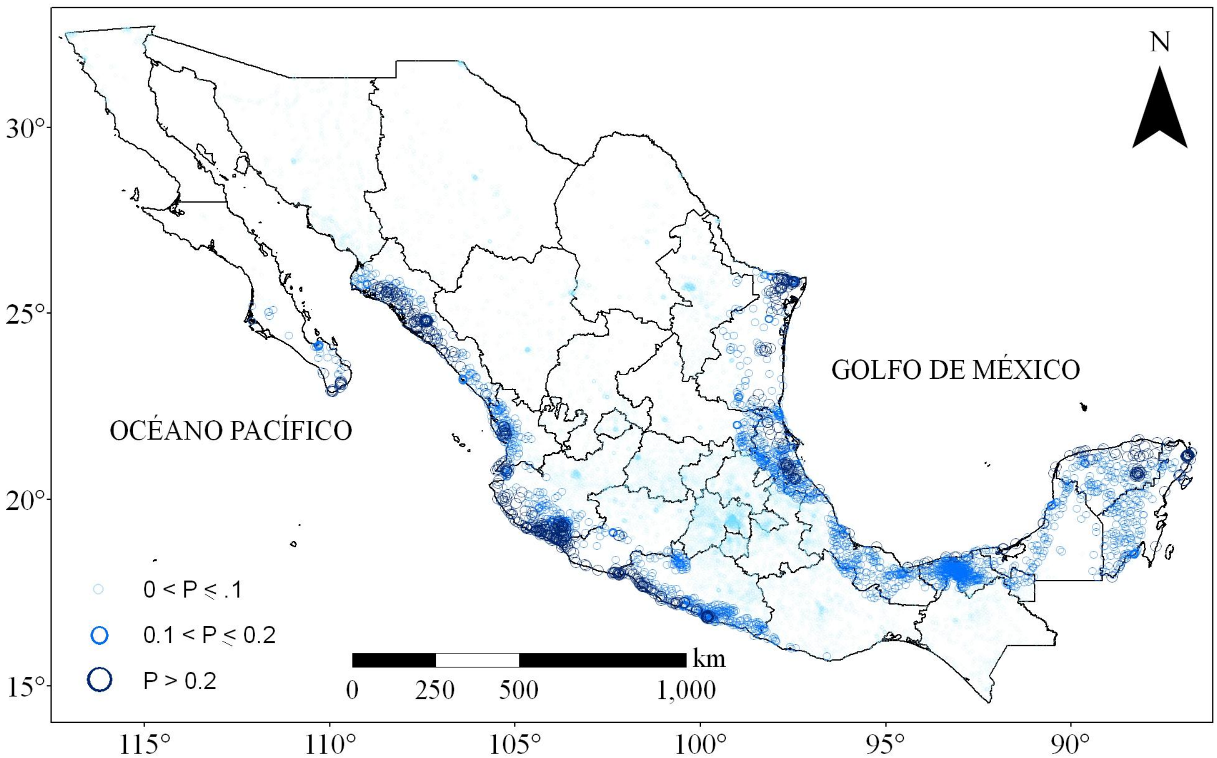


Figure 4. Losses of hospitals in México due to hurricane hazard (composed by wind, storm surge and flood), where dark blue shows those hospitals with expected annual losses larger than 0.2 per cent. Note that every dot in the map corresponds to an individual hospital.

Another way of seen portfolio losses is thru a return period loss estimation curve, shown in Fig. 6. Comparison of hospitals (SSA) is made with other portfolios such as roads and bridges (SCT), poor housing (SEDESOL) and schools (SEP). Expected losses for hospitals are much lower due to much better construction type and quality.

Finally, a comparison of expected losses due to earthquake and hurricane of a typical hospital located in many cities is shown in Fig. 7. This figure shows 20 cities in the country where a typical hospital two storeys high, made of concrete frames, was located and its annual expected losses drawn as an exercise to compare different risks for the same building. Note that even for ‘similar’ hazard zones results shown considerably differences since the full probabilistic risk assessment program consider all possible earthquakes occurrence.

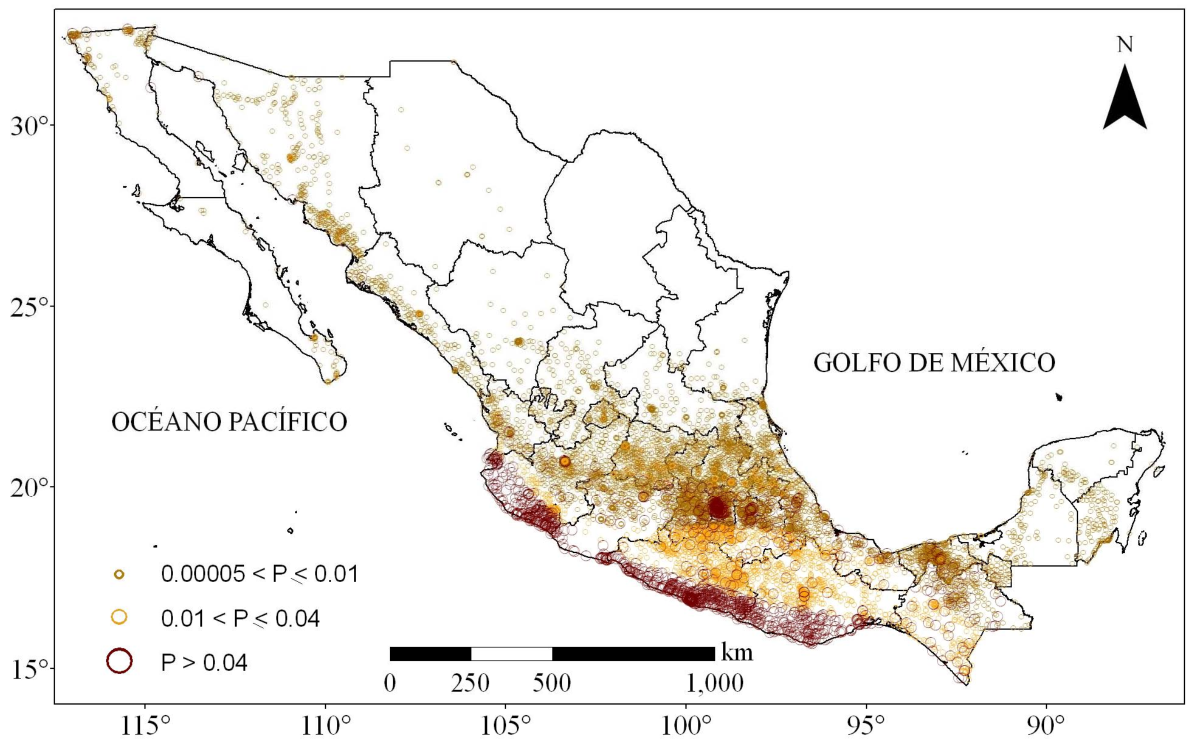


Figure 5. Losses for the same hospitals of figure 4. Note that losses are concentrated in the subduction zone and in Mexico City

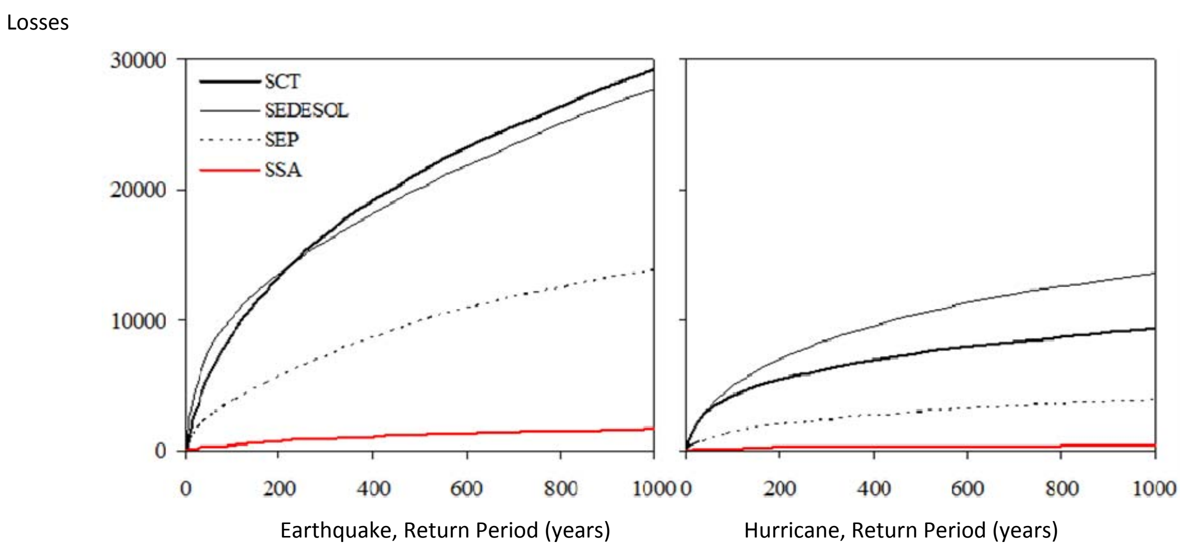


Figure 6. Losses for the whole portfolio for a given return period. Four portfolios are shown, hospitals (SSA), roads and bridges (SCT), poor housing (SEDESOL) and schools (SEP)

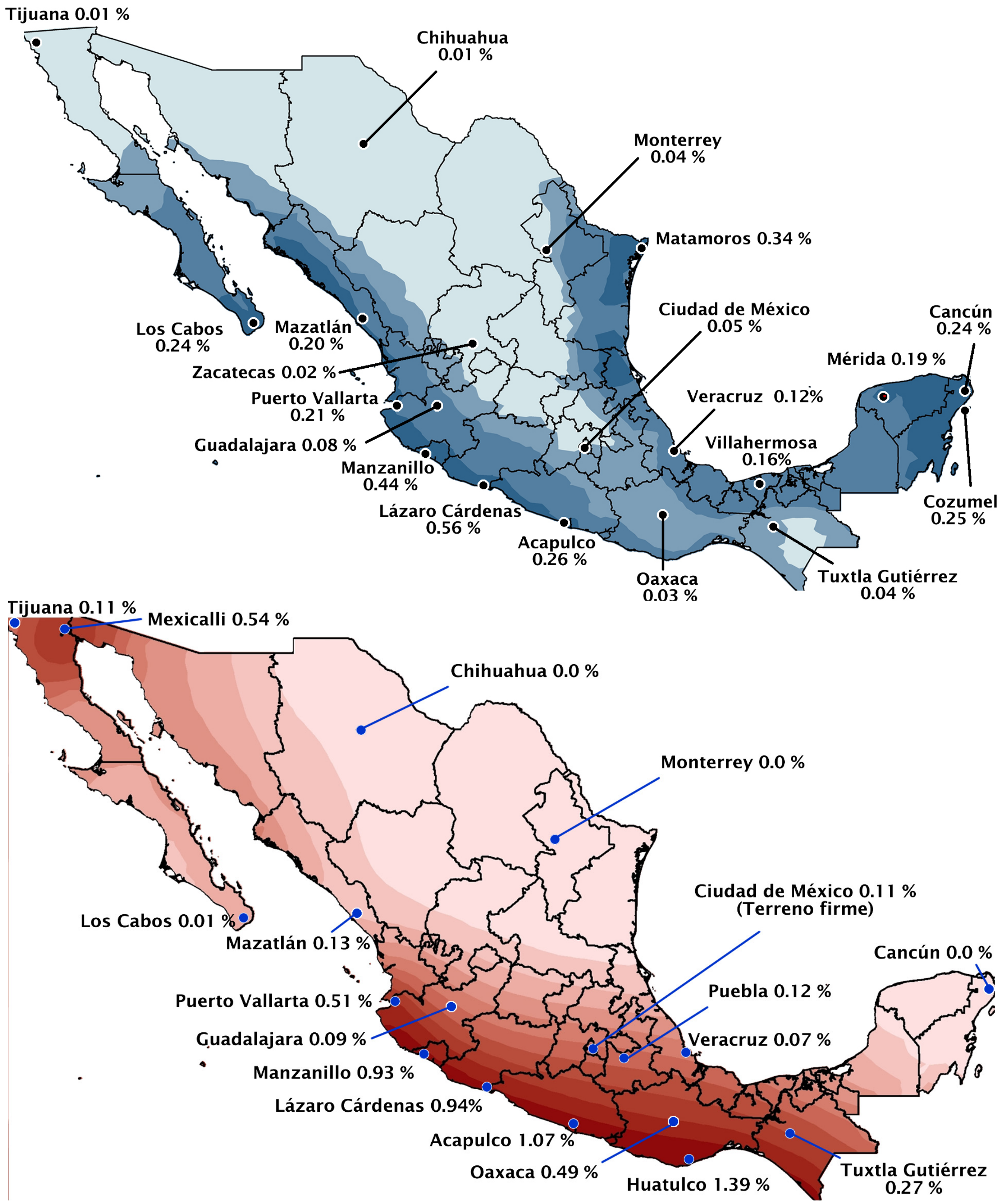


Figure 7. Twenty cities in Mexico where a typical hospital two storeys high, made of concrete frames, was located and its annual expected losses drawn as an exercise to compare different risks for the same building (hurricane, above, earthquake, bottom).

Conclusions

In this work we have presented annual expected losses for a portfolio of medical units in

Mexico due to earthquake and hurricane risk. This portfolio was built together with the medical administration authorities and it contains reliable information for every unit in the country, which makes the risk results useful for many purposes including insurance management.

Acknowledgments

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