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LARGE-SCALE PROBABILISTIC ASSESSMENT OF SEISMIC RISK – APPLICATION FOR THE COMMUNITY OF AGGLOMERATION NICE CÔTE D'AZUR (CANCA)

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ABSTRACT

This study focuses on large-scale assessment of seismic risk. In this context is provided a seismic risk assessment for the Community of Agglomeration Nice Côte d'Azur (CANCA) (27 municipalities 512 000 people). First, a census is conducted on data available for large scale assessment: 1 - geographical data of the BD-TOPO (IGN, 2005), providing the outline of each building, their height and location, 2 – statistical data of INSEE from 1999 censuses at the scale of district (INSEE, 1999). The buildings vulnerability is then estimated based on those two data types. The probabilistic seismic risk is estimated from probabilistic seismic hazard curves based on intensity and specifically calculated to take into account the local hazard. It leads to an assessment of the annual probability of different damage levels, the annual probability of individual mortality and the expected number of casualties. The results obtained following the two approaches are compared and analysed.

INTRODUCTION

This study focuses on large-scale assessment of seismic risk; a seismic risk assessment for the Community of Agglomeration Nice Côte d'Azur (CANCA) is provided in this context. This agglomeration, in the south east of France covering an area of 394 square kilometres including the City of Nice and its hinterland, is made up of 27 districts experiencing a large economic and demographic expansion with, at this time, 512 000 people. At the scale of the surveyed area, the purpose is to apply methods to estimate the risk based on available data, in order to test them and check their domain of validity.

First, a census is conducted on data available for large scale assessment. Two data types are examined: on the one hand, geographical data of the BD-TOPO (IGN), providing the outline of each building, their height and location, allows the consideration of local hazard and vulnerability into geographical areas. On the other hand, statistical data of INSEE from 1999 censuses at the scale of district allows an analysis using a homogenous statistical distribution of the buildings.

Then, the buildings vulnerability is estimated based on those two data types. For the building analysis, vulnerability is obtained from the distribution of the buildings into neighborhood of similar vulnerability (downtown, village center, residential areas) based on studies of aerial photos. For the statistical analysis at the city scale, vulnerability is obtained from types of construction considering the age and the height of the buildings and also the type and size of the town (city, village).

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Finally, the probabilistic seismic risk is estimated from probabilistic seismic hazard curves computed in intensity Evaluation of the annual probability of different damage levels, annual probabilities of individual mortality and the expected number of casualties are so determined. The results obtained following the two approaches are compared and analysed, in particular human losses and possible damage probabilities.

AVAILABLE DATA

Data of INSEE censuses

INSEE (National Institute of Statistical and Economic Studies) censuses provide, among other things, information on people, housing and real estate. Those statistical data are available for municipalities or by IRIS (areas containing about 2000 people, for municipalities with a population exceeding 5,000 persons). The database does not allow locating buildings or population in the municipality's area but provides the following information for seismic risk analysis (1999 census):

- The quantity and type of housing (individual or multiple dwellings);
- The number of buildings in the town;
- The age of housing and buildings;
- The number of floors of the buildings.

The population of each building can be deducted considering an average number of occupants per housing.

Data of the BD-TOPO

It's the most complete and accurate database of the IGN (National Geographic Institute) (IGN, 2005). It provides a precise description of the landscape, the composition of the territory and infrastructures. All buildings are modeled in three dimensions (contour and height). The database is exploitable on scales ranging from 1:5,000 to 1:50,000 and takes the form of topics: territory, infrastructures, transportation lines, energy networks, hydrography, vegetation, activity and building areas, public facilities, administrative borders… themselves divided into subcategories. For the buildings, regardless their function (housing, businesses, industry, administrations…), the data which can be used for the risk assessment are:

- The geographical positioning and the outlines of the buildings;
- The height of the structure, which assesses the number of stories.

In relation with the age of the building, the number of stories can be deducted from the height of the structure considering, for example 3 meters per floor. The number of occupants can also be estimate with a population's statistical distribution in each building based on the number of floors.

CALCULATION

Hazard

An intensity model of the seismic hazard in France (Martin et al, 2008) is used for this survey. For each municipality, a seismic hazard curve represents the probabilities of intensity exceeding (Figure 1). The hazard curves are modulated considering local specificities of the study area: topography or possible site effects induced by soil characteristics (composition and mechanical properties). The hazard curves are modulated by increment of intensity considering local seismic hazard (Figure 2, Table 1). The evaluation of the probabilistic seismic local hazard is made by defining annual rates of occurrence of ground motion parameters.

Table 1. Local seismic hazard level considering subsoil characteristics and topography.

Topography and geology of the studied area	local sieismic hazard	intensity increment
bedrock	nil to negligible	0
effects of topographic situation: scree slope, stiff soils, marly lands...	low	0.2
Site effects associated with shallow valleys (high topographic effects). Alluvial layer <50m, soil with medium mechanical characteristics.	moderate	0.4
Site effects related to deep valleys, alluvial layer> 50m, low mechanical properties of the soil.	high	0.6

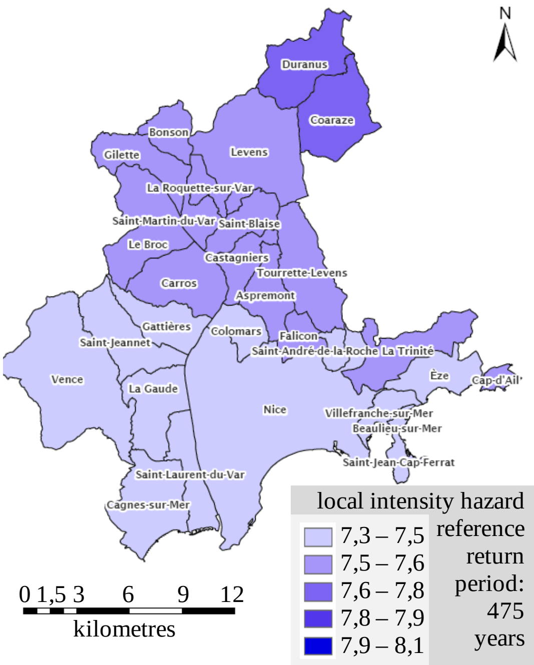


Figure 1. Regional seismic hazard map of the CANCA territory, described in intensity for a return period of 475 years.

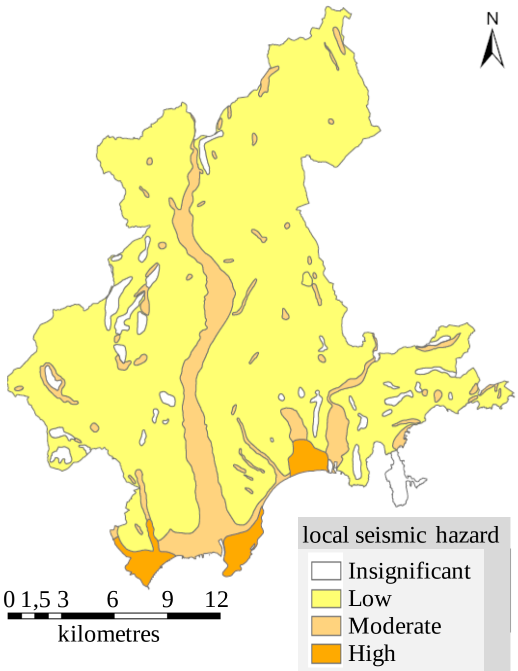


Figure 2. Local seismic hazard map of the CANCA territory.

Vulnerability

Tow avenues have been pursued to assess the vulnerability. For the first one, a geographical approach, based on vulnerability areas considering the type of urbanization and the location of the buildings is taken into account. For the second, a statistical approach, based on typologies depending on characteristics from the census (number of stories, date of construction) is adopted. The vulnerability is estimated using Risk-UE method (2003) through the assignment of vulnerability classes:

- High vulnerability: vulnerability index of 0.8;
- Medium vulnerability: vulnerability index of 0.6;
- Low vulnerability: vulnerability index of 0.4;
- Negligible vulnerability: vulnerability index of 0.2.

Geographical vulnerability

The vulnerability of municipality belonging to the CANCA, except Nice, is analyzed from the delimitation of areas of similar construction type. Most municipalities that compose the CANCA grew up around very old villages (11th or 13th centuries), to which new districts were added with the urban expansion. This development of cities by time period, creates specific construction typologies for each district and geographical area.

In those municipalities, the subdivision into districts is designed by using the IGN maps to assess the spacing of buildings, and by using aerial photos to identify the typology of the concerned buildings. So, it is possible to define 7 different areas of uniform typology and the corresponding vulnerability classes:

- Village centre/terraced houses, narrow streets: high vulnerability;
- City center/spaced houses: medium vulnerability;
- Commercial areas (along the river Var): medium vulnerability;
- Residential areas, subdivisions: low vulnerability;
- Coastal areas with old constructions: medium vulnerability;
- City center of larger cities/municipalities with old buildings: high vulnerability;
- Non-urbanized areas (scattered housings including less than 10% of the buildings of the city): negligible vulnerability.

In the case of Nice municipality, the analysis is based on the vulnerability areas defined during the Risk-UE project (2003).

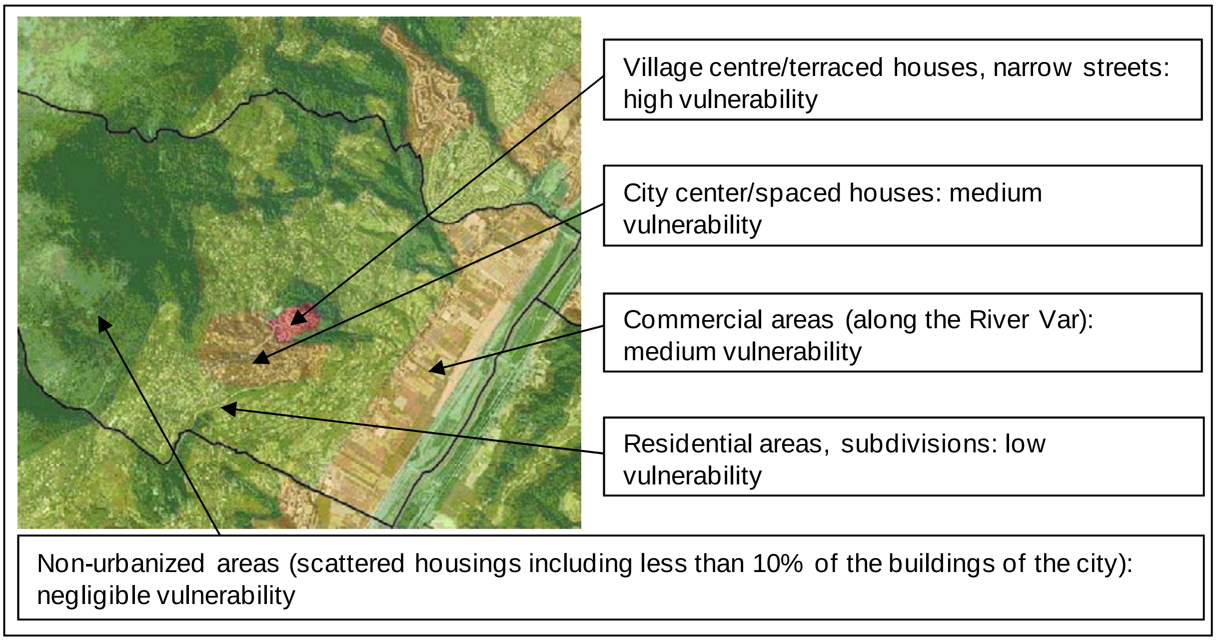


Figure 3. Determination of vulnerability classes and delimitation of geographical areas by the observation of aerial photos (example of Gattières municipality).

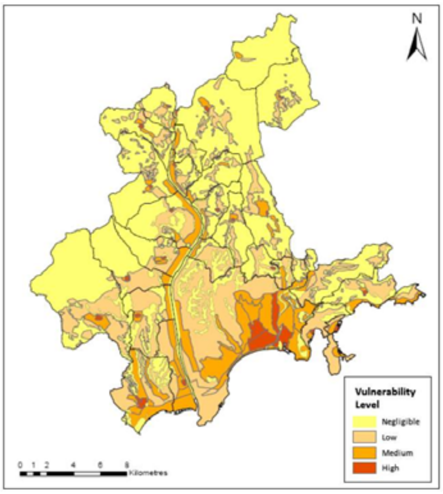


Figure 4. Seismic vulnerability on CANCA territory based on the analysis of the urbanization.

	Typology		vulnerability level		
	number of storeys	years of built	less than 600 building municipalties	mid size municipalities	Nice
individual dwelling	1 to 2	< 1915	moderate	moderate	moderate
		1915 - 1948	moderate	moderate	moderate
		1949 - 1967	moderate	low	low
		1968 - 1974	low	low	low
		1975 - 1981	low	low	low
		1982 - 1989	low	low	low
		>1989	low	low	low
appartment buildngs (more than single dwelling)	1 to 5	< 1915	high	high	high
		1915 - 1948	high	high	moderate
		1949 - 1967	moderate	moderate	moderate
		1968 - 1974	moderate	moderate	low
		1975 - 1981	low	low	low
		1982 - 1989	low	low	low
		>1989	low	low	low
	6 to 9	< 1915		high	high
		1915 - 1948		high	high
		1949 - 1967		moderate	moderate
		1968 - 1974		moderate	moderate
		1975 - 1981		moderate	moderate
		1982 - 1989		low	low
		>1989		low	low
	> 9	< 1915		high	high
		1915 - 1948		high	high
		1949 - 1967		moderate	moderate
		1968 - 1974		moderate	moderate
		1975 - 1981		moderate	moderate
		1982 - 1989		low	low
		>1989		low	low

Table 2. Seismic vulnerability levels considering typology, height, age and techniques of construction for different size municipalities.

Statistical vulnerability

The data of INSEE censuses allows classifying buildings according to the following parameters:

- The number of housings: single residential unit (individual building) or multiple dwelling (more than one housing according to the INSEE definition);
- The height of the buildings: distribution of multiple dwellings by number of stories (ground floor to 4 floors, from 5 to 8 floors and more than 9 floors);
- The completion date of the building (distribution by periods): before 1915, from 1915 to 1948, from 1948 to 1967, from 1968 to 1974, from 1975 to 1981, from 1981 to 1990 and after 1990.

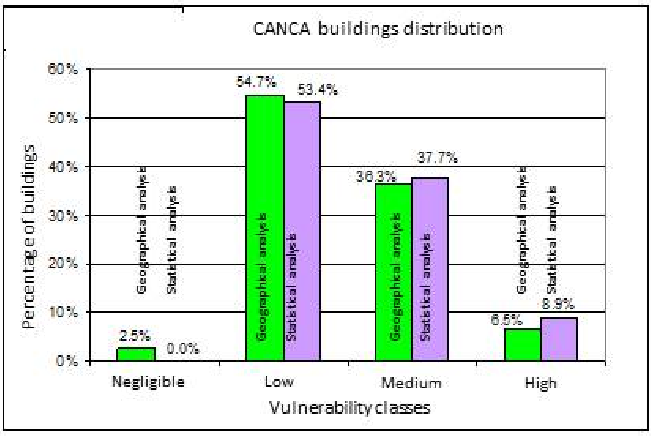
By combining this classification with an analysis of the surveyed area urbanization, vulnerability classes can be assigned to buildings (Table 2).

Comparison of the vulnerability

The consistency between the two approaches of the vulnerability was assessed by comparing the amount of buildings in each vulnerability class. For the whole surveyed area, differences in distribution depending on the two approaches (geographical and statistical) remains very low considering the number of buildings regarded. Indeed, these are below 3% (Figure 5). However, some cities can show more significant gaps reaching 30%. Those differences result from the nature of the processed data:

- The data of the BD-TOPO take into account all buildings whereas the INSEE censuses count only residential buildings considered as main home;
- The BD-TOPO ignores buildings in poor conditions (temporary or ramshackle buildings...) while these are taken into account by the INSEE censuses;
- The BD-TOPO does not distinguish terraced buildings (as in the city center) whereas the INSEE censuses consider one building for each stairwell.

This comparison shows that the vulnerability assessment according to the two approaches converges for a significant number of municipalities.



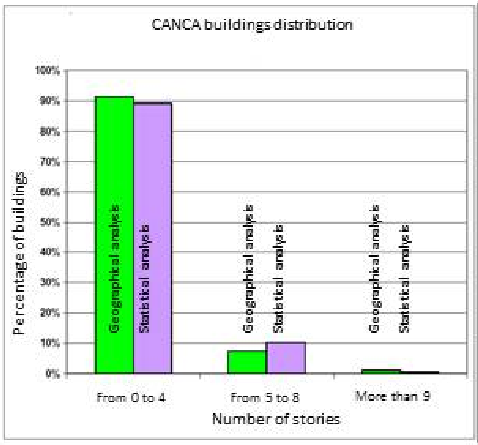


Figure 5. Comparison of the number of buildings for (left) different vulnerability classes (right) different number of stories.

Losses

The surveyed area is made up of 27 municipalities, with varied dimensions and types, whether it is the surface or the number of buildings or the type (coastal city or village high in the hills). The number of buildings studied varies according to the database and the definition of buildings:

- 66,747 buildings with the IGN data from the BD-TOPO database;
- 72,450 buildings with the 1999 INSEE census data.

The difference in the number of buildings can be explained by the nature of data (see previous paragraph). The evolution of loss in buildings is analyzed in terms of damage grades, ranging from D0 to D5 of EMS-98 scale with a probabilistic approach (Grunthal and Levret, 2001).

Risk

Seismic risk is assessed by developing a probabilistic approach by convolution of the curves of hazard, vulnerability and losses. Unlike deterministic scenarios (based on the consequences of earthquakes of predefined characteristics), this approach allows to estimate the real risk considering probabilities of occurrence for all intensities (from the lowest to the highest). The risk is evaluated in several stages, hazard assignation and damage calculation.

The hazard is attributed to each building in relation to its position for the geographical approach and each municipality is divided into similar hazard areas; the buildings are distributed considering a single density of buildings for each municipality for the statistical approach.

The calculation of probabilities of each damage grade is expressed in annual probabilities of occurrence (convolution of hazard and vulnerability).

Thus results for each building in the geographical approach is obtained, and also by building types and hazard area with the statistical approach. Under both approaches an average is calculated for all buildings in each municipality.

RESULTS

The calculation of risk on the scale of the surveyed area under both approaches shows that the annual probability that there is no damage is of the order of 0.97, that the annual probability of collapsing is of the order of 10^{-5} (Figure 6) and that the annual individual death rate is of the order of 10^{-6}. Those average values show some variability of two orders of magnitude depending on the municipality (Figure 7), considering hazard, vulnerability and losses.

The geographical approach is appropriate for an analysis on the city scale, as it allows locating the most vulnerable districts in the various hazard areas. However this approach requires an amount of time more important than the statistical approach for the establishment and the calculation. Indeed, it is necessary to interpret maps and aerial photos and to design the outlines of vulnerability areas.

The comparison of the results under both approaches (geographical and statistical) for the whole surveyed area leads to averages results of a similar level (Figure 7). However significant variations can be observed for some municipalities. Those variations express the difference in the hazard consideration and the vulnerability evaluation. For a larger scale analysis, the results of the two methods point in the same direction, showing that the surveyed area for the statistical approach must be sufficiently large to ensure results to be valid.

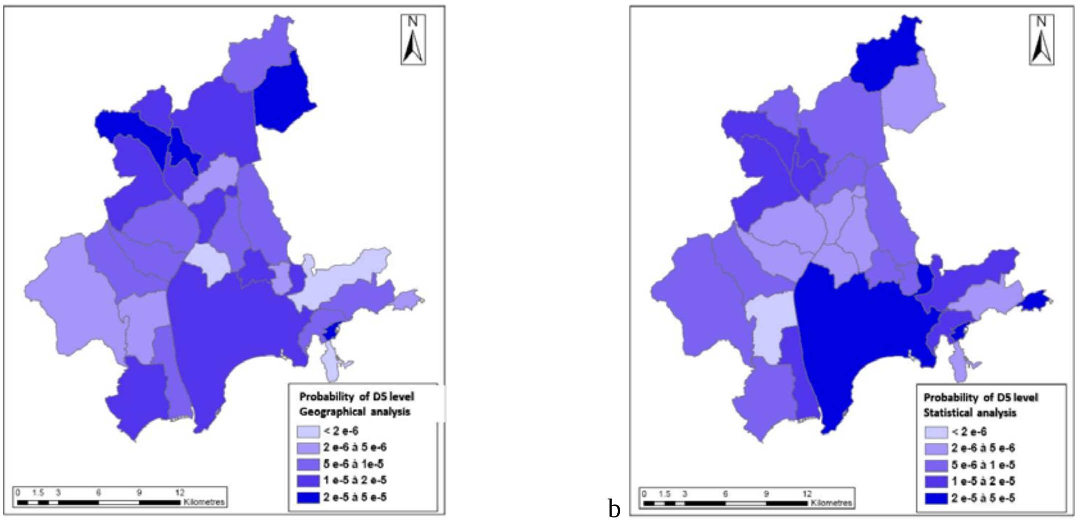


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Figure 6. Comparison of results obtained by: a) geographical and b) statistical approaches for D5 damage.

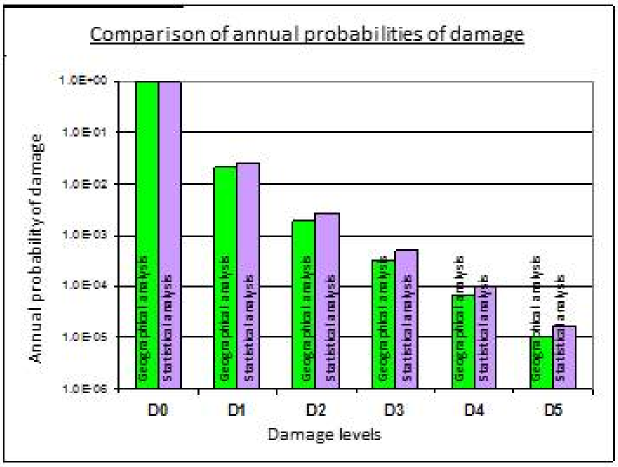

Figure 7. Comparison of damage annual probabilities for both approaches (geographical and statistical).

CONCLUSIONS

The proof of applicability of the seismic risk method at the large scale (tens of thousands of buildings or more common) has been presented. This verification was conducted by the confrontation of two vulnerabilities assessment based on the exploitation of existing data methods. These methods were applied on the territory of the Community of Agglomeration Nice Côte d'Azur, that is an important territory with 512 000 inhabitants in 27 municipalities.

Hence, the results show that at the scale of all municipalities, the annual probability to observe any damage is around 0.97, and the annual probability of collapse is around 10-5 and the rate of individual annual mortality of about 10-6. These average values show variability following municipalities according to their hazards, vulnerabilities and respective issues. Also, the geographical analysis based on the definition of homogeneous vulnerability areas leads gave efficient results across the county. This approach requires a significant time setting up. Moreover, this approach allows a geographical interpretation of the results at municipal infra scale. The statistical analysis based on the definition of types of vulnerability versus the age and number of floors of buildings leads to valid results at the scale of several commons.

This study shows the feasibility of probabilistic risk researches on large scales from existing data. Analytical methods may beings adapted according to the objectives and resources available, however it is necessary to respect their validity domain's as concerning any application.

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