Nat. Hazards Earth Syst. Sci. Discuss., 2, 3615–3657, 2014
www.nat-hazards-earth-syst-sci-discuss.net/2/3615/2014/
doi:10.5194/nhessd-2-3615-2014

Natural Hazards and Earth System Sciences
Discussions
Open Access

Assessing residential buildings value in Spain for risk analyses. Application to the landslide hazard in the Autonomous Community of Valencia

I. Cantarino[1], F. J. Torrijo[1], S. Palencia[2], and E. Gielen[2]

[1]Departament of Land Engineering, Polytechnic University of Valencia
[2]Departament of Urban Planning, Polytechnic University of Valencia

Received: 11 February 2014 – Accepted: 6 April 2014 – Published: 22 May 2014

Correspondence to: I. Cantarino (icantari@trr.upv.es)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

This paper proposes a method of valuing the stock of residential buildings in Spain as the first step in assessing possible damage caused to them by natural hazards. For the purposes of the study we had access to the SIOSE (the Spanish Land Use and Cover Information System), a high-resolution land-use model, as well as to a report on the financial valuations of this type of buildings throughout Spain. Using dasymetric disaggregation processes and GIS techniques we developed a geolocalized method of obtaining this information, which was the *exposure* variable in the general risk assessment formula. If hazard maps and risk assessment methods – the other variables – are available, the risk value can easily be obtained. An example of its application is given in a case study that assesses the risk of a landslide in the entire 23 200 km^2 of the Valencia Autonomous Community (NUT2), the results of which are analyzed by municipal areas (LAU2) for the years 2005 and 2009.

1 Introduction

Concern for the damage caused by geo-hydrological processes such as earthquakes, floods and landslides has been on the increase in recent years at both local, regional and national levels, mainly due to the wide coverage given to the subject by the media. This concern has given rise to an increase in the number of studies focused on identifying the areas susceptible to such processes, as well as the adoption of risk management policies and many regions have increased their budgets to mitigate the effects of natural disasters on the urban areas and on their inhabitants.

One of the consequences of this movement has been the introduction by the government of measures to predict, prevent and mitigate these events. In addition, the population growth that inevitably involves a higher demand for residential buildings, together with the corresponding need for larger infrastructures, means that the population expansion spreads to areas that are often liable to suffer the effects of geo-hydrological events.

The Autonomous Community of Valencia (Spain) has adopted a firm position as regards preventing natural or induced hazards, as reflected in Article 14 of Law 4/2004 (30 June) relating to Land Planning and Protection of the Landscape (LOTPP in Spanish), also in the decree issued on 13 January 2011 by the Council of Valencia concerning the Territorial Strategy of the Community of Valencia (ETCV). As laid down by the LOTPP, the latter is the basic land planning instrument of the Community; it fixes action plans, initiatives and guidelines for the development of the region while at the same time respecting the environment with special emphasis on natural hazards.

Among the guiding principles laid down by the ETCV is that of encouraging future urban and regional developments to take place in risk-free zones or, in cases where the risks can be justified, in minimum-risk zones. It also proposes actions to improve the management of natural and induced hazards in the form of Territorial Action Plans (PAT), including one with measures to reduce the occurrence and improve the landslide risk management.

In the context of the above-mentioned regulations, in which adequate land planning and management are considered to be among the most important non-structural measures, there is a clear need for the creation of a risk-mapping system. These maps are an aid to regional planning as they accurately define any risk areas and compel the adoption of specific constructional measures in these zones, while at the same time they help to create legislation to regulate these activities (Palencia and Gielen, 2010).

In order to assess and compare the costs of damage caused by the different natural hazards described above, one of the basic requirements is to have access to a wide and detailed data base. In addition, in order to make full use of this data it is essential to have maps showing the location of the different data (dangers, land use and occupation, etc.) to enable the application of tools and processes associated with Geographical Information Systems (GIS) for the purpose of drawing risk maps.

NHESSD
2, 3615–3657, 2014

However, this type of map has never been fully developed, mainly due to the difficulty of obtaining information on the elements they contain. Of the few that exist, most are restricted to the susceptibility to hazards and mainly analyze the characteristics of the process without paying too much attention to the possible damage to the elements exposed to the hazards (Corominas et al., 1998). However, they can be useful for purposes of land planning and mitigating hazards (Mejía-Navarro and García, 1996), as well as for reducing any possible future damage to the minimum.

As regards the European perspective, both the European Environmental Agency (EEA) and the European Territorial Cooperation Programmes (ESPON: European Observation Network, Territorial Development and Cohesion) have drawn up natural hazard maps. The EEA (2010) has compiled an exhaustive list of different types of hazards and technological accident risks of places for which maps were subsequently made. One of the reports issued by ESPON (2006) analyzed the hazards and risks but did not estimate the damage in financial terms, producing qualitative scale maps at the provincial level (NUT3).

The present paper deals with risk-mapping with regard only to the damage caused to buildings, as will be explained in Sect. 2. The proposed method of estimating the value of residential buildings is offered as the first step in assessing the risk associated with processes of any other type. As an example of its use, the method is then applied to a complete procedure for assessing the risk of landslides within the Valencia Community (NUT2, *Autonomous Community*) at the end of this paper.

2 Natural hazards and risks

2.1 Terminology

In general terms, risks can be defined as the interaction that takes place between the threat or danger, the elements exposed to them (people, buildings, etc.) and the severity of the damage these objects may sustain. Risk assessment is normally divided into three phases:

a. Analysis of risk factors such as hazards, exposure and vulnerability.

b. Risk assessment by calculating or estimating probable losses, usually in financial units.

c. The analysis and design of risk mitigation measures.

This paper deals with the first two phases, leaving the design and adoption of damage mitigation measures to the land planners. Our main objective is to arrive at a quantitative evaluation of risks, i.e. one that has been calculated from quantitative values of the above risk factors by the well-known general risk equation, based on the classic definition of the Office of the United Nations Disaster Relief Organization (UNDRO, 1979)

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability} \quad (1)$$

– HAZARD meaning the probability of occurrence, within a specific period of time in a given area, of a potentially damaging natural phenomenon.

– EXPOSURE or ELEMENTS AT RISK meaning the population, buildings and civil engineering works, economic activities, public services, utilities and infrastructure, etc. . . at risk in a given area. may be expressed either in deterministic or probabilistic terms.

– VULNERABILITY meaning the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from (no damage) to 1 (total loss).

NHESSD
2, 3615–3657, 2014

2.2 Methodology applied for risk assessment

In this paper, we apply the risk assessment to landslides, natural geomorphic process occurring at locations characterized by specific environment conditions. Our principal goal is mapping the risk value in a wide given area by application of the Eq. (1) and by using technics based in GIS software. In this case, the main problem is finding homogeneous data for across the chosen area. For this reason, amongst many others, there are only few quantitative maps on risk landslide in Spain (Bonachea, 2006) and it would interesting exploring this way. The entire process of our methodology is shown in the Fig. 2 (Sect. 4.4).

In the first place, for estimating hazard we start from a landslide vectorial map formed by a regional Government Department for our complete selected area. However, this map only gives some certain estimation of the real value of the landslide probability occurrence. Unfortunately, no specific data of quantitative hazard exists for the entire area under study, and we should be able to extract all the information from this map, despite the uncertainty created.

Vulnerability is the third member of the Eq. (1), and likely, the most difficult to obtain, due the complexity and the wide range of variety of landslide processes (Glade, 2003). This element has been calculated from the data on type of building in a land cover model and the intensity of landslide, following the cited authors in Sect. 4, where this term will be fully dealt with.

Finally, exposure is, of course, somewhat difficult to put a value on human lives and economic activities (the value of a person, if such a thing existed, would depend on various factors such as age, employment and wage level, etc.) not to mention the difficulty of representing these values graphically, since they are not static elements. This is why most of the studies carried out are limited to material elements (Bonachea, 2006).

In the present study only residential buildings and its direct structural damages are considered as assets exposed to the landslide processes, together with the functional

NHESSD
2, 3615–3657, 2014

elements that give them a market value, ignoring all other types of elements on risk. We do not use the reconstruction cost value for the given area, since it is really difficult to find in Spain this type of data from insurance companies or municipalities (Bonachea, 2006). The method applied to estimate building values is dealt with in detail in the following section and is considered to be the essential first step in assessing exposure to any type of natural hazard.

3 Valuing residential dwellings

As the starting point of the valuation process we used the Albert and Uriel Report (2012) carried out for the *Fundación BBVA* (FBBVA), which contains estimates of the values of housing assets and other structures in Spain, together with their distribution around the country. The values in this report were based on detailed breakdowns of housing selling prices and built-up areas, and thus included the value of both buildings and ground.

With this information, an assessment of the value of a residential dwelling can be made by a disaggregation of dwelling prices in a process based on the location of the different residential areas. This type of mapping information is called dasymetric mapping and traces back to the paper of Wright (1936), the most well-known example of these early developments. Dasymetric mapping can be defined as a cartographic technique whereby ancillary thematic data is used to refine the geographical representation of a quantitative variable reported at coarse spatial aggregations.

In our case, the quantitative variable is the housing value, and the ancillary data are the polygons that include areas with types of buildings. Building types can be identified from land use models or from cadastral data, although the latter option involves considerably more work, due to the volume and segmentation of the data and is normally used only in studies on a limited number of municipal areas.

The most similar work to estimate building values for risk assessment is made by Kleist et al. (2006) within of project “Risk Map Germany”. This is done on the basis of the Corine Land Cover dataset and a dasymetric mapping approach, and provides a uniform database on the reconstruction cost of potentially risk-exposed residential buildings in Germany on the community level.

Another similar study was developed in Italy by Luino et al. (2009). In this paper, the authors expose a model for flood damage estimation based on a GIS software. In this case, estimation of the value of buildings and contents was based on knowledge of the type of structure and its use. For this, the study area data base required a layer designed to contain the information and characteristics of all buildings. The estimation of a building's unit value is based, first, on a real estate and property price database, and after, on its geographical location, usage and typology.

3.1 Land use models: SIOSE

As is well known, great advances have been made in the definition and presentation of land mapping in the last decade. In Spain, the two most important projects on land use are the *Corine Land Cover* (CLC) and the *Land Use and Cover Information System of Spain* (SIOSE). Both projects present very different concepts, even though both were carried out under the direction of the National Geographical Institute (IGN in Spanish).

In spite of the fact that the CLC represents a great advance as the first data base on land use in Europe during a prolonged period of time, its lack of resolution in certain key aspects means that information has to be sought from other sources, at least on a national scale (Valcárcel, 2011). In 2005 therefore the IGN set up the SIOSE, whose aim was to generate a land use data base for the entire country on a scale of 1 : 25 000 with reference images from the year 2005 (SIOSE2005). However, although the data on land occupation has been widely developed and published, that on land use is still being worked on.

At the present time, only data on the SIOSE2005 is available for the entire country, while SIOSE2009 is still being compiled, and an update is expected for 2014, to coincide with a new version of the CLC. The SIOSE2005 was therefore used as the data base in this work. Its main technical characteristics are compared to those of the CLC in Table 1, below.

In the SIOSE model, each polygon is defined by a land cover that may be one of two types:

- Simple coverage: uniform over the entire polygon.
- Composite coverage: (found in most cases) a variety of simple or even composite coverages within a polygon.

In addition, covers can be characterized by attributes or parameters that provide further information.

Of 86 possible covers, residential buildings are included in a composite coverage known as *Composite Artificial* within the *Mixed Urban* class. It includes the simple artificial cover *Buildings*, characterized by a distinguishing attribute of the series of building types used in this study, details of which can be seen in Table 2 (IGN, 2010).

3.2 Method applied to the valuation of dwellings

The steps involved in valuing residential dwellings in SIOSE polygons are described below. A flow diagram is given in Sect. 4.4.

3.2.1 Disaggregation of residential dwellings

In order to consider different land values, the FBBVA Report stratified areas into *urban* and *rural.* Municipal areas were also classified by size, province, and whether they were *inland* or *coastal*, giving a total of 451 strata or areas.

The breakdown of municipal areas in each province is therefore as follows:

- inland municipal areas of up to 2000 inhabitants
- inland municipal areas of between 2000 and 5000 inhabitants

- inland municipal areas of between 5000 and 10 000 inhabitants
- inland municipal areas of between 10 000 and 25 000 inhabitants
- coastal municipal areas of less than 25 000 inhabitants
- municipal areas with more than 25 000 inhabitants

To georeference the values given in the tables of the FBBVA report, a dasymetric disaggregation was carried out in accordance with the definition of residential buildings in the SIOSE land use data model. The different types of building as defined by the model's attributes for *Buildings* cover are given in Table 2:

For each stratum in the FBBVA Report we can thus obtain the built-up surface for each of the SIOSE building types, such as Sbu (i). It is important to remember, for a given polygon, that this area does not necessarily coincide with the surface area of the polygon that defines it (see Table 3), since it may be composed of compound cover. According to the SIOSE, a polygon may contain various types of cover with their corresponding percentage of occupation. Built-up surface is calculated according to the ratio between this percentage and the total surface area.

The distribution of residential buildings in the whole of Spain in accordance with the four building types defined by SIOSE can be seen in Table 3.

It is interesting to note the large area occupied by detached single-family dwellings, which is due to the different types included in this category, e.g. villas, country houses, etc., while the others are more specific. On the provincial level, these dwellings are widely dispersed. In some coastal provinces single-family dwellings form a large majority.

The polygons containing isolated buildings are the smallest (see column Stot), unlike their built-up area, which is taken up by detached single-family types (see Sbu), these naturally occupy larger areas. However, the terraced houses, due to their better layout, occupy the largest sites (Stot), although their built-up area is equal to that of block of flats, though both are similarly constructed.

3.2.2 Estimating the number of floors in each type of building

After obtaining information on the built-up area, the next step is to estimate its gross floor area, named equivalent dwelling surface area (Sed) for each SIOSE building type, which will mainly depend on the average number of floors above ground, and which logically must be characteristic of each building type. This will make it possible to equate total dwelling surface area to a single localized value in SIOSE with the value of the residential dwellings in the FBBVA Report, to finish off the dasymetric process.

Unfortunately, the SIOSE does not provide any information on the number of floors in each type of building. The only way to obtain this data is indirectly from the census information available on the numbers of buildings and their floors from the web page of the National Statistics Institute (INE). The number of above-ground floors for buildings devoted mainly to dwellings can be obtained from the 2001 INE census, which makes a distinction only between single-family dwellings and other types of residential buildings (multi-family). According to the SIOSE disaggregation, these would consist of isolated buildings, blocks of flats and terraced houses, which means the SIOSE type of detached house can easily be identified and then applied the typical number of floors from the INE census.

Although there is a time difference between the 2001 census and SIOSE2005, this is not significant, since there were no substantial changes in building types in Spain between these two dates. It should also be pointed out that the latest SIOSE land use data for Spain also dates from 2005, but as the construction rate since that time has slowed down considerably more up-to-date statistics would not significantly affect these results.

The built-up area in SIOSE can be expected to be in direct proportion to the number of buildings per type of dwelling, i.e. to equate the number of buildings with the built-up area we must assume similar surface areas in each of the four types of dwelling. For example, single-family dwellings could be either modern villas or traditional country houses, but the built-up surface can be assumed to be close to the average in both cases (see Table 4).

Thus, in the case of single-family detached houses, according to the INE information 94.25 % have one or two floors. Assuming similar floor areas, to calculate the average number of floors, weights can be applied for the number of floors per building, to obtain the weighted mean number of floors $\mathrm{NF_m}$ by applying the following formula:

$$\mathrm{NF_m} = \sum(\mathrm{NF}_j \times \mathrm{NB}_j)/\sum \mathrm{NP}_j \qquad (2)$$

where NB is the total number of buildings with their corresponding number of floors; NF, j being this number of floors, which, according to the INE, in the case of these buildings, is between 1 and 6. The result is *1.57*, and is the value that can be applied to all the SIOSE built-up surface (Sbu) to obtain the gross floor area, or the estimated surface area of dwelling (*Sed*) in this category:

$$\mathrm{Sed} = \mathrm{Sbu} \times \mathrm{NF_m} \qquad (3)$$

According to the SIOSE, isolated buildings make up 7.3 % of the total of multi-family dwellings (calculated from the data in Table 3, column Sbu), while they are 8.63 % (100–91.37 %, see Table 4) of the number of buildings with seven or more floors. In accordance with our assumption of homogeneity between the number of buildings and the surface they occupy, these seven floors could be taken as the threshold indicator of the number of floors for the SIOSE detached buildings. Calculating the weighted average height of blocks of flats by Eq. (2), an average of *8.61* floors is obtained.

It is a somewhat more complicated task to separate dwellings in blocks of flats from terraced houses. The following premises can be assumed:

- Terraced houses will always have fewer than four floors.

- Block of flats will have more than one floor (in the smaller villages this is not the case, but the numbers here are small).

NHESSD
2, 3615–3657, 2014

- The SIOSE ratio of terraced/block of flats surface is maintained with respect to the number of buildings.

From the above premises, we can estimate solutions which optimize the difference of squares between the SIOSE surface percentages by using the MS – Excel Solver option. One of the best results is the following distribution:

- 1 floor: 100 % terraced houses.
- 2 floors: 79.6 % terraced houses; 20.4 % blocks of flats.
- 3 floors: 32.5 % terraced houses; 67.5 % blocks of flats.
- 4–6 floors: 100 % blocks of flats.

Applying these coefficients and the Eq. (2), the mean number of floors for each SIOSE building type can be calculated (see Table 5).

The values shown here are the mean for the whole of Spain and of course vary according to the geographic location and population of the municipal area in which they are situated. The mean surface area in terraced and semi-detached houses can be said to be similar, as can be seen from the Sbu(m) in Table 3, which also shows that the plots are understandably larger for the semi-detached houses (see Stot(m)), as they are in more densely populated zones provided with better roads, parks, etc.

In the absence of definitive conclusions and considering population size as one of the variables with the strongest influence on the height of buildings, an analysis was carried out with INE tables that break down data on building heights according to municipality size into eight different population levels between less than 100 and more than 500 000 inhabitants.

The results of applying the same type of distribution as the exposed coefficients for terraced/blocks buildings to each population level can be seen in Fig. 1, below.

In accordance with the data from this graph, it can be concluded that:

– In isolated buildings the number of floors ranges from 7.6 to 8.7. This variance is not important, especially as it involves a limited number of buildings.

– In blocks of flats it lies between 2.5 and 4.9. The variance here is wider and due to the number of buildings involved this is where the figure should be adjusted for size of municipality.

– In detached single-family houses floors vary between 1.8 and 1.5. This is the only type of building with a tendency to decrease, although it is fairly stable in the municipal areas with higher populations.

– In terraced houses the figure is between 1.6 and 2.0, which is a not a highly significant variation.

3.2.3 Adjusting housing value for type of building

It should not be forgotten that when valuing a housing we must bear in mind not only its surface area but other specific criteria related to its type, location, use, quality, etc. We therefore gave a weighting to the calculated surface (Sed) according to these characteristics to obtain the equivalent dwelling surface (Sevd) related to its value.

The Spanish Colleges of Architects make use of formulas to calculate the Reference Building Cost (RBC) according to a Basic Module Building (BMB in € m^{-2}). We adopted the RBC recommended by the Valencia Building Institute (IVE), an organization belonging to the Government of Valencia (IVE, 2012).

$$\mathrm{RBC} = (\mathrm{BMB} \times \mathrm{Ct} \times \mathrm{Ch} \times \mathrm{Cu} \times \mathrm{Cnv} \times \mathrm{Cs} \times \mathrm{Cc}) \times \mathrm{Sc} \quad (4)$$

Where,

RBC = Reference Building Cost (€)

BMB = Basic Module Building (€ m^{-2})

Ct = Type of building

Ch = Number of floors above ground

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

Cu = Location in historic centre
Cs = Useful living area (predominant size)
Cv = Number of dwellings per unit
Cc = Quality of finish
Sc = Built-up surface (m^2)

We used the most significant and applicable coefficients, so that the surface equivalent to the value of the dwelling (Sevd) could be expressed by the following formula:

$$\text{Sevd} = (\text{Ct} \times \text{Ch} \times \text{Cv} \times \text{Cc}) \times \text{Sed} = \text{Cg} \times \text{Sed} \quad (5)$$

In which Cg is the general weighting coefficient of the value of the building per SIOSE type (see Table 6).

3.2.4 Calculating value of SIOSE residential polygons.

According to the preceding sections, it is possible to calculate the equivalent surface of a dwelling from its Sevd value in m^2 for any given polygon p defined by SIOSE with a determined building type i, with a certain constructed surface area Sbu (m^2) together with a mean number of floors NF_m. This is expressed by the following equation from Eqs. (3) and (5):

$$\text{Sevd}(p) = \text{Sbu} \times NF_m(i) \times \text{Cg}(i) \quad (6)$$

For a given layer e of the 451 defined in the Albert and Uriel Report (2012, see Sect. 3.2.1) the total surface area of dwellings *Sevd*, including all SIOSE building types, will be:

$$\text{Sevd}(e) = \sum \text{Sevd}(i) = \sum \text{Sbu}(i) \times NF_m(i) \times \text{Cg}(i) \quad (7)$$

With this figure, the value of dwellings per surface Vds(e) is calculated in € m^{-2} for each layer e, according to the value of total dwellings Vdt(e) as established by the cited

FBBVA Report.

$$Vds(e) = Sevd(e)/Vdt(e) \quad (8)$$

It is now possible to perform a dasymetric distribution of the total value of dwellings among the different residential building polygons with the attribute *i* as defined by SIOSE, Vd(*p*). For each polygon *p*, this value will be defined by the specific value Vds(*e*) of the layer *e* to which it belongs and its equivalent surface area Sevd(*p*), according to:

$$Vd(p) = Vds(e) \times Sevd(p) \quad (9)$$

In other words, a financial value is assigned to each SIOSE residential polygon according to the number of dwellings it contains. This information is of great interest since it forms the basis required to assess the exposure to any type of risk.

4 Case study: assessment of landslide risk in the Community of Valencia

We considered it to be of great interest to carry out a specific application of the proposed method of valuing housings to assessing a certain natural hazard within a given region. The threat selected was the land movement processes and the region selected was the Community of Valencia (NUT2, *Autonomous Communities*), composed of the three provinces of Alicante, Castellón and Valencia (NUT3, *Provinces*) and making up 5 % of the surface (22 200 km^2) and 11 % of the population of Spain. The results are given by province and municipalities (LAU2, *Municipalities*).

Our selections were based mainly on three reasons:

- Availability of the necessary maps: landslide susceptibility in the whole of the Valencia Community (COPUT, 1998) and two versions of the SIOSE model, as this was also available this Community in 2009. The same calculation process was therefore carried out for two years, thus giving an assessment of the evolution of risk for the period 2005–2009.

– The three provinces had been described as being areas of "high hazard" for landslides in the above-cited ESPON Report (2006), although it did not specify the areas in which they could occur.

– The need to identify the trouble spots in the territory and draw up detailed maps, proposing both structural and land planning measures. This is an explicit approach related to Objective 8 of the above-mentioned ETC risks.

Exposure was to be assessed in accordance with the process described in the preceding section. Still to be defined are *hazard* and *vulnerability*, which will be dealt with in the following section.

4.1 Exposure

Almost all authors (Varnes, 1984; UNDRO, 1991) agree as to the elements to be considered as being affected by landslides. However, each author has a distinct way of dealing with the different types of elements, as will be seen below when we consider *vulnerability*, as the *elements exposed to risk* and *vulnerability* are directly related to each other.

In this work we dealt only with residential buildings exposed to the landslides in accordance with the method described in the preceding section. One of the important questions was the calculation of the distribution of the number of floors. For terraced buildings, which show the greatest variance, as can be seen in Fig. 1, a special study was carried out. Such as we have exposed in Sect. 3.2.2., with population size data for the municipal areas of Valencia (from the INE Census for 2001) we obtain the Table 7.

As can be seen in Fig. 1, the value of the number of floors in the remaining building types show little variation with population size and were thus assumed to be constant in all municipal areas, coinciding with the mean given in Table 5 (Sect. 3.2.2).

NHESSD
2, 3615–3657, 2014

4.2 Hazard

For this work, spatial hazard data were taken from a 1 : 50 000 scale vector format landslide map drawn up from a Regional Department of Public Works of the Valencia Government in the project entitled *Lithology, exploitation of industrial rocks and landslide risk in the Valencian Community* (Thematic Mapping Series, COPUT, 1998), using geological and geotechnical maps from the Spanish Geomining Technical Institute (ITGME), 1 : 50 000 scale topographical maps from the Army Geographical Service, as well as aerial photographs available at that time. Use was also made of specialist bibliography and field surveys to observe morphology, lithology, structure, slopes, vegetation, etc.

The landslide-risk zoning process consisted of combining the main risk factors and features to identify and assess unstable zones, which included lithology, petrographic composition, tectonic structure, topographical slopes, relief contours and rainfall. By this means, the COPUT has obtained a "risk" map with scores assigned to zones according to their probability of a landslide occurring. Human activity was taken into account to assign an instability score and the zones were divided into low, medium and high risk, but were not given a numerical value. However, for the purposes of the hazard assessment, low was considered as 0.25, medium 0.50 and high 0.75.

It should be pointed out here that most landslide risk maps (and this is the case) in fact show terrain susceptibility, i.e. the "spatial probability" or possibility of a landslide occurring, without analyzing the time factor or when these events are likely to happen. In our case, neither do these values correspond to specific probabilistic values, but rather to the characteristics of susceptibility to landslides. However, due to the absolute lack of further explanatory data, this information should be considered as a first reference or approximate results.

NHESSD
2, 3615–3657, 2014

4.3 Vulnerability

Varnes (1984) was one of the first authors to use the term *vulnerability* in a review of the different aspects involved in risks due to different natural or technical phenomena. He considered vulnerability to be the degree of potential damage, expressed from 0 to 1, sustained by an exposed element or group of elements as a result of a natural phenomenon of a given intensity. This definition has been almost universally accepted by later researchers in the field of landslides, most of whom refer to the cited work (Brabb, 1984; Alexander, 1993; Fell, 1994; Leone et al., 1996; Leroi, 1996; IUGS, 1997; Dai et al., 2002).

However, the intensity of a landslide is somewhat difficult to quantify in practice, since it depends largely on the nature and the intensity of the mechanical forces generated by the landslide (differential movements in the terrain, subsidence, thrusting force, load, specific weight, depth, etc.) and the vulnerability characteristics of the exposed elements (Leone, 1996). It is also difficult to separate vulnerability from hazard and risk, since these concepts are intimately interrelated in a complex way (Alexander, 2000).

It is therefore difficult to design a standard and complete method of assessing vulnerability. According to Bonachea (2006) in a review of the problem, few studies have been published to date on the subject, and most of them use highly subjective methods that are impossible to reproduce or are only applicable to specific zones.

At present, there is an ongoing debate regarding the definition of vulnerability. Scientists with various scientific backgrounds have a different understanding of what vulnerability is (Glade, 2003). In a recent review of existing vulnerability assessment methodologies for alpine hazards (landslides, rock falls, debris flows, and snow avalanches), Papathoma-Köhle et al. (2011) suggest that there is neither a common definition for vulnerability nor a standard methodology for vulnerability assessment. This author recorded a range of methodologies by reviewing 41 vulnerability assessment methodologies for alpine hazards. Most of them took into consideration only one vulnerability indicator which was mostly the building type. Scientists often develop vulnerability

NHESSD
2, 3615–3657, 2014

curves, in other words, functions that express the relationship between the degree of loss and the intensity of the process. One recent example of this research we can see in Papathoma-Köhle (2012).

Consequently, according to Leone (1996) and some others authors (see Papathoma-Köhle, 2011), two vulnerability factors have to be considered in the residential dwellings: the intensity of the landslide and the structural sensitivity of the building. The former of these factors is usually badly defined due to the complexity of the parameters involved, although many of them are implicitly included in heuristic methods of assessing landslide risks. In the absence of other data sources, for the present study we use the hazard values given by the COPUT cited reference maps.

As regards the sensitivity of buildings to landslides, we use the four types of buildings cited by the SIOSE classification. Although no specific data is available on their characteristics, information is obtainable pertaining to their building types, number of floors and whether detached or non-detached, which can be equated with one of the four types proposed by Leone (1996, p. 142), between B1 (highly vulnerable) and B4 (least vulnerable). See Table 8.

It is now possible to carry out a classification similar to that proposed by Leone (1996, p. 140–141) with structural damage matrices that consider landslide intensity and the characteristics of the asset exposed to hazard. Table 9 gives the results of the final vulnerability assessment by a simplified method according to intensity and building type. This author classifies damage according to a certain vulnerability interval, included as a reference.

The damage levels are really the factors that determine vulnerability and the numerical values are an indication of the loss of value of a building after suffering the effects of a landslide. In our case, these numerical values were difficult to calculate directly as there were no data bases available on the market value of affected buildings.

NHESSD
2, 3615–3657, 2014

4.4 Assessing risk

After defining exposure, hazard and vulnerability, all the elements to assess the risk according to the Eq. (1) are avalaible. The assessment was performed using ESRI ArcGIS 10.1 software, automated by routines written in Python with an ArcPy geoprocessor.

Figure 2 shows the flow diagram of the process. In the final step the risk values were divided into administrative units in order to carry out a provincial (NUTS3) and municipal (LAU2) analysis (see Sect. 4.5).

4.5 Results

As the SIOSE land use data are available for 2005 and 2009, partial and complete calculations were carried out for these years on all areas subjected to landslide hazards according to the COPUT maps. The hazard values are shown in Table 10, in which it can be seen that the estimated surface area covered by dwellings (Sed) under high risk is relatively small (around 12 % for both years), although their incidence on risk values is more than one quarter (26 and 28 %). The greatest hazard and vulnerability of these areas justify these results and highlight the need to act on them.

Total risk increased by almost 25 % (€ 439 million) between the years 2005 and 2009, even though Table 10 shows that the dwelling area (Sed) is practically the same. The analysis of this table makes it clear that the increased risk is not due to increased construction levels in the high risk zones during the study period, but to the higher values of the dwellings, since the values of the exposed elements increased much more than the residential surface area affected. It is worth remembering at this point that 2009 marked the end of the housing boom in Spain in which housing prices moved continually upwards.

As regards the provincial values as given in Table 11, it can be clearly seen that Alicante is the province most affected by absolute risk, with more than 1000 million euros in both 2005 and 2009. This is chiefly due to the coastal zones in the north-west

NHESSD

2, 3615–3657, 2014

of the province (Marina Alta and Marina Baixa areas; see Fig. 3), with a high demand for housing, being hilly regions susceptible to higher landslide risks.

The Valencia Community is divided into 542 municipalities, more than half of which (268) are affected to a greater or lesser degree by risk of landslides (see Table 12). The risk-assessment ranges adopted coincide with the percentiles 20-40-60-80 for the total data, with limits of € million 2.5-55.0-102.9, respectively.

Furthermore, the group or layer of municipalities with the highest risk is that with less than 25 000 inhabitants in the coastal regions of Alicante. Finally, 23 municipalities were found to have between 90 and 100 % of their dwelling surface area exposed to risk of a landslide.

Figure 3 shows the map of the results by municipalities and risk level for the entire Valencia Community for the year 2009.

5 Discussion

The application of the above methodology has achieved results at the provincial and municipal levels on the whole Valencian Community in two dates. Analysing those results, they seem entirely consistent with the knowledge we have of Valencia on land use, hazard and property market. The knowledge of the area in terms of land use and hazard can explain the results for each one of the areas (provinces, municipalities). The resulting hierarchy was the expected and therefore it is demonstrated that the methodology used is valid at least in comparative terms. Furthermore, the knowledge we have about the evolution of the real estate market also validates the trends noted by the variation of the results between 2005 and 2009.

To interpret these results, it must be remembered that the methodology has been framed within the territorial scope of the Valencian Community. It aims to raise a generalist modelling tool, for comparing different levels of condition that could be easily repeated and will serve as an indicator for more accurate models. A first approximation to the problem under study requires a territorial or regional planning at specific scale.

NHESSD
2, 3615–3657, 2014

Furthermore, a local scale will be used to the definition of specific measures and their economic value in detail. Basically, what we want are results for comparing the level of risk posed by different administrative domains. Thus, the primary aim is to manage and prioritize investment in research to more precise scales, allowing the adoption of concrete measures. Therefore, the result obtained is useful in the management by the regional and local administrations.

The scale used corresponds to territorial or regional planning, which in this case is defined as macro-scale. According to this scale, damage assessment has been conducted at the municipal administrative unit level (Meyer and Messner, 2006). The methodological development and the scale used justify a low level of accuracy in the results (in million Euros) and the amount of resources required per unit area and the input data required.

However, the availability of more accurate data, such as land use according to SIOSE (data 1 : 25 000) do not undermine the results, but allow to have higher level of accuracy in terms of buildings susceptible to damage.

All the used data come from official public sources. These data have been developed by different administrations of national and regional level, and they give particular strength to the methodology proposed, ensuring repeatability and consistency of the calculations of the results. Perhaps, the landslide hazard mapping prepared by the Regional Administration 1 : 50 000 (COPUT), is the more limited data source, with greater uncertainty and therefore the one that defines the scale of the work.

The methodology developed for the assessment of buildings is one of the processes that gives added value to this research. Based on the market value obtained from the FBBVA Report (Albert and Uriel, 2012), we have disaggregated local units in smaller units, associated with the classification type of residential buildings defining by SIOSE land cover model. This methodology allows to estimate the value of the dwelling associated with SIOSE polygons, more accurate than the average given by the FBBVA Report. To perform the disaggregation, we have used official and public sources of information (see Fig. 2). All these sources have allowed to adjust the value of the build-

NHESSD
2, 3615–3657, 2014

ing for each polygon SIOSE, adding again at municipal level the value of the dwellings affected by landslide hazard. This methodology ensures the homogeneity of the generated data and an easy updating in future time periods.

A limitation that we have encountered is the absolute lack of a regional database on the valuation of vulnerability of buildings to landslides. This fact is a well-known and widespread problem, and it hindered to apply the intensity/degree of loss curves methodology. This situation has been resolved by using a simple damage matrix with theoretical values, as shown in Table 9. Our calculation of the loss in market value of the buildings is an estimation of the direct and tangible damage, that does not necessarily require to determine the other ones (indirect or intangible). The purpose of this work is to establish a methodology to support decision making, so we do not need a detailed analysis of damages and specific measures to minimize them.

In any case, the damage value obtained by municipality is not an absolute value, due to the uncertainty it may have. Nevertheless, the comparison between values of different administrative units is one of the greatest interests of this paper. Therefore, these values were reclassified by intervals at different risk levels (low, medium and high), being able to establish a clear hierarchy of municipalities.

6 Conclusions

This is a novel work in the ambit of risk assessment in that it proposes a direct general assessment method for geolocalized dwellings capable of being unrestrictedly applied to any area in Spain. Detailed land use maps, such as those offered by the SIOSE model, are absolutely essential as a dasymetric variable for the breakdown of the original data.

A landslide risk assessment model was designed to use easily available official data compiled by public organizations, which also happens to be the only available for the total area of this field. It has to be admitted that landslide risk maps need to be updated, and especially improved, both conceptually to clearly include the probabilistic variable, and as regards questions of scale, even though at the present time we can see little likelihood of this being carried out.

As we now have the entire automated assessment process available in Python routines in ESRI ArcGIS 10.1, this will make it possible to implement any update or modification with ease. Our next objective therefore is to carry out a similar assessment of dwellings for the whole of Spain, including the entire affected population according to the population grid available for 2005 and 2010 (Goerlich and Cantarino, 2013). Furthermore, the process has been designed in such a way that it can be applied to other geographical areas, provided the appropriate hazard maps are available.

The results obtained on landslide risk assessment in the Valencia Community make it possible to compare different zones; they can also be used as the basis for detailed studies, and offer local authorities objective indicators to help in making decisions on advisable actions. However, bearing in mind the scale of the work, the area of the analyzed territory, the method used and the input data, these results should not be assumed to be definitive, but rather as a first step in the right direction. Neither, of course, should they be allowed to alarm local populations by assigning quantitative values to specific areas.

From the land planning perspective, the results obtained can be considered satisfactory as a response to the rational use of residential land in municipal districts or even larger areas. Indeed, this work has created a method that accurately uses local data sources to assist municipal authorities in taking the appropriate decisions according to the landslide risk evaluated. In fact, specifying the appropriate measures to be adopted could be regarded as an important new line of study.

Acknowledgements. The authors are grateful to the BBVA Foundation and to Carlos Albert and Ezequiel Uriel, the authors of the report on the Spanish housing stock, for making available to them original data from their report. The translation of this paper was funded by the Universidad Politécnica of Valencia (Spain).

References

Alexander, D.: Natural Disasters, University College London Press, London, 632 pp., 1993.

Alexander, D.: Confronting Catastrophe, Oxford University Press, New York, 288 pp., 2000.

Albert, C. and Uriel, E.: El stock de capital de viviendas (1990–2010) y en otras construcciones (1990–2009) en España, y su distribución territorial, Fundación BBVA, available at: http://www.fbbva.es/TLFU/dat/el%20stock%20de%20capital%20en%20viviendas%20(1990-2010)_web.pdf, 2012.

Bonachea, J.: Desarrollo, aplicación y validación de procedimientos y modelos para la evaluación de amenazas, vulnerabilidad y riesgo debidos a procesos geomorfológicos, Ph.D. Thesis, Universidad de Cantabria, avalaible at: http://www.tdx.cat/handle/10803/10610, 2006.

Brabb, E. E.: Innovative approaches to landslide hazard and risk mapping, in: Proceedings of the Fourth International Symposium on Landslides, Canadian Geotechnical Society, Toronto, Canada, Vol. 1, 307–323, 1984.

COPUT: Litología, aprovechamiento de rocas industriales y riesgo de deslizamiento en la Comunidad Valenciana, Conselleria d'Obres Publiques, Urbanisme i Transports (COPUT), Gobierno Valenciano, 1998.

Corominas, J., Moya, J., Ledesma, A., Gili, J. A., Lloret, A., and Ruis, J. (Eds.): New technologies for landslide hazard assessment and management in Europe (NEWTECH), Contract ENV-CT96-0248, final report, European Commission: Environment Programme, 1998.

Dai, F. C., Lee, C. F., and Ngai, Y. Y.: Landslide risk assessment and management: an overview, Eng. Geol., 64, 65–87, 2002.

EEA: Mapping the impacts of Natural Hazards and technological accidents in Europe, EEA Technical Report, no 13, 2010.

ESPON: The Spatial Effects and Management of Natural and Technological Hazards in Europe – ESPON 1.3.1, 2006.

Fell, R.: Landslide risk assessment and acceptable risk, Can. Geotech. J., 31, 261–272, 1994.

Glade, T.: Vulnerability assessment in landslide risk analysis, Erde, 134, 121–138, 2003.

Goerlich, F. J. and Cantarino, I.: A population density grid for Spain, International Journal of GIS, 27, 2247–2263, 2013.

IGN (National Geographic Institute): Land Cover and Use Information System of Spain (SIOSE) Technical document Version 2.0, Madrid, 2010.

NHESSD

2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

IUGS Working group on landslides-Committee on Risk Assessment: Quantitative risk assessment for slopes and landslides, in: Landslide Risk Assessment, edited by: Cruden, D. and Fell, R., Balkema, Rotterdam, 3–12, 1997.
IVE (Instituto Valenciano de la Edificación): Coste Unitario de Ejecución Edificación Residencial: Gobierno Valenciano, available at: http://www.five.es/inicio/economia/457.html, 2012.
Kleist, L., Thieken, A. H., Köhler, P., Müller, M., Seifert, I., Borst, D., and Werner, U.: Estimation of the regional stock of residential buildings as a basis for a comparative risk assessment in Germany, Nat. Hazards Earth Syst. Sci., 6, 541–552, doi:10.5194/nhess-6-541-2006, 2006.
Leone, F.: Concept de vulnérabilité appliqué à l'évaluation des risques générés par les phénomènes de mouvements de terrain, Ph.D. thesis, l'Université Joseph Fourier, Grenoble, I., 1996.
Leone, F., Asté, J. P., and Leroi, E.: L'évaluation de la vulnérabilité aux mouvements de terrains: pour une meilleure quantification du risque, Revue de géographie alpine. 1996, Tome 84 N° 1, 35–46, 1996.
Leroi, E.: Landslide hazard – risk maps at different scales: objectives, tools and developments, in: Landslides – Glissements de Terrain, edited by: Senneset, K., Trondheim, Norway, Balkema, Rotterdam, 35–51, 1996.
Luino, F., Biddoccu, M., Cirio, C. G., Agangi, A., Giulietto, W., Godone, F., and Nigrelli, G.: Application of a model for the evaluation of flood damage, GeoInformatica, 13, 339–353, 2009.
Messner, F. and Meyer, V.: Flood damage, vulnerability and risk perception – challenges for flood damage research, flood risk management: hazards, vulnerability and mitigation measures, NATO Science Series, 67, 149–167, 2006.
Palencia, J. S. and Gielen, E.: La importancia de la vulnerabilidad frente a inundaciones como criterio de buen gobierno en materia de ordenación territorial, VI Congreso Internacional de Ordenación del Territorio, Pamplona, 27, 28 y 29 de octubre de 2010, 81–95, 2010.
Papathoma-Köhle M., Kappes, M., Keiler, M., and Glade, T.: Physical vulnerability assessment for alpine hazards: state of the art and future needs, Nat. Hazards, 58, 645–681, 2011.
Papathoma-Köhle M., Keiler, M., Totschnig, R., and Glade, T.: Improvement of vulnerability curves using data from extreme events: a debris flow event in South Tyrol, Nat. Hazards, 64, 2083–2105, 2012.
UNDRO: Natural Disasters and Vulnerability Analysis, Report of Expert Group Meeting Geneve, 1979.

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

UNDRO: Mitigation Natural Disaster: Phenomena, Effects and Action – a manual for Policy makers and Planners, Office of the UN Disaster Relief Coordinator, Geneva, 1991.
Valcárcel, N.: Comparison and parameterization between SIOSE and CLC, 6th EAGLE meeting and Joint Meeting EAGLE-Geoland2, June 2011, Málaga, Spain, avalaible at: http://sia.eionet.europa.eu/EAGLE/EAGLE_6thMeeting_g2_Malaga/04a_CLC-Attribution_NV_Homework.pdf, 2011.
Varnes, D. J.: Landslide Hazard Zonation: a Review of Principles and Practice, UNESCO, Paris, 63 pp., 1984.
Wright, J. K.: A method of mapping densities of population with Cape Cod as an example, Geogr. Rev., 26, 103–110, 1936.

NHESSD
2, 3615–3657, 2014

I. Cantarino et al.

Table 1. Characteristics of the CLC and SIOSE models.

	CLC	SIOSE
Area	Europe	Spain
Scale	1 : 100 000	1 : 25 000
Minimum Mapping Unit (MMU)	25 ha	0.5 ha: wetlands, beaches, riverside vegetation and sea cliffs. 1 ha: Urban fabrics, coastal and sheets water bodies. 2 ha: Agricultural land, forests and natural zones.
Minimum width of linear elements	100 m	15 m
Data Model	Hierarchic: 44 classes at level 3 and 58 classes at level 4.	Object-oriented: 40 simple classes and 46 predefined composed classes, attribute types not included.

NHESSD
2, 3615–3657, 2014

Table 2. Attributes of the SIOSE simple cover "*Buildings*".

SIOSE building type	Attribute	Notes	Abbreviation
Isolated Building	21	Compact block of apartments	Isolated
Block of Flats	22	In urban area, non isolated	Block
Single-Family Detached Home	23	Single family dwelling	Detached
Terraced House	24	Houses in rows. Includes semi-detached houses	Terraced
Factory or Warehouse	25	Non residential	–
Under Construction	28	Not occupied	–

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

Table 3. Summary of SIOSE building and surface types for Spain.

SIOSE Building type	No of polygons	%	Stot (ha)	%	Stot(m) (ha)	Sbu (ha)	%	Sbu(m) (ha)
Isolated (21)	7732	4.6	40 683.3	3.7	5.3	13 871.1	4.0	1.8
Blocks (22)	27 562	16.3	166 189.8	15.1	6.0	92 734.5	27.1	3.4
Detached (23)	108 035	63.9	707 000.7	64.2	6.5	151 513.9	44.2	1.4
Terraced (24)	25 871	15.3	187 811.5	17.0	7.3	84 380.9	24.6	3.3
TOTAL	169 200		1 101 685.3			342 500.4		

Stot: Total Polygon Surface Area; Stot(m): Mean Polygon Surface Area; Sbu: Total Built-Up Surface Area; Sbu(m): Mean Built-Up Polygon Surface Area.

Table 4. Number of floors in residential buildings in Spain according to data from the INE 2001.

Number of floors (NF)	Number of detached houses	Percentage Accumulated (%)	Remainder of residential buildings	Percentage Accumulated (%)
1	3 264 826	48.86	254 857	13.20
2	3 033 813	94.25	601 473	44.35
3	375 321	99.87	327 932	61.33
4	5442	99.95	251 742	74.37
5	2104	99.98	211 503	85.33
6	1085	100.00	116 607	91.37
7	0	100.00	58 652	94.40
8	0	100.00	60 241	97.52
9	0	100.00	10 109	98.05
12	0	100.00	37 709	100.00
TOTAL	6 682 591		1 930 825	

NHESSD
2, 3615–3657, 2014

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

Table 5. Summary of results per building type.

SIOSE building type	Built-Up SIOSE Surface Sbu (ha)	Total Number of Buildings (INE 2001)	Average Surface per Building (m^2)	Average Number of Floors NF_m
Isolated	13 871.14	166 711	832	8.61
Block	92 734.50	923 690	1004	3.98
Detached	151 513.85	6 682 591	227	1.57
Terraced	84 380.91	840 424	1004	1.82

Table 6. Coefficient of increase in building's value (Cg).

SIOSE building type	Ct	Ch	Cv	Cc	*Cg*
Isolated	1.050	1.025	1.000	1.000	*1.076*
Block	1.000	1.000	1.000	1.000	*1.000*
Detached	1.150	0.975	1.100	1.200	*1.480*
Terraced	1.100	0.975	1.100	1.100	*1.298*

NHESSD
2, 3615–3657, 2014

Table 7. Mean number of floors per layer for block of flats.

FBBVA Report Layer	Mean number of floors for blocks (NF_m)
Inland municipalities up to 2000 inhab.	3.1
Inland municipalities between 2000 and 5000 inhab.	3.4
Inland municipalities between 5000 and 10 000 inhab.	3.6
Inland municipalities between 10 000 and 25 000 inhab.	3.7
Coastal municipalities with less than 25 000 inhab.	4.0
Municipalities with more than 25 000 inhab.	
Up to 50 000 inhab.	4.0
Up to 100 000 inhab.	4.3
Up to 500 000 inhab.	4.6
> 500 000 inhab.	5.0

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

Table 8. Assigning building types according to Leone (1996).

SIOSE Building Type	Characteristics	Leone Type (1996a)
Isolated	Good quality construction, $NF_m = 8$, modern, detached.	B3, B4
Block	Widely variations in quality and age. $NF_m = 4$. Non-detached.	B2
Detached	Generally good structural quality, age variable. $NF_m = 1$. Detached.	B3
Terraced	Good structural quality. $NF_m = 2$. Modern. Non-Detached.	B4

NHESSD
2, 3615–3657, 2014

Table 9. Assessment of vulnerability according to type of building and landslide intensity. Damage estimates according to Leone's associated interval (1996).

Intensity		Building type 22	23	21	24	Structural damage
1	Low	0.35	0.30	0.25	0.20	Cracks in walls that do not affect stability. Repairs not urgent. [0.20–0.30]
2	Medium	0.55	0.50	0.45	0.40	Marked deformations, large breaches in walls, cracks in supporting structures, stability affected, evacuation necessary. [0.40–0.60]
3	High	0.85	0.80	0.75	0.70	Structural damage, partially destroyed, evacuation inevitable, reconstruction of affected parts. [0.70–0.80]

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

Table 10. Surface area of affected dwellings and total risk according to hazard.

Hazard	Surface Area of Affected Dwellings Sed(km^2)		Total risk (€ million)	
	2005	2009	2005	2009
Low	20.1	20.7	351	415
Medium	18.8	19.7	971	1189
High	5.6	5.7	471	628
TOTAL	44.5	46.1	1793	2232

NHESSD
2, 3615–3657, 2014

Table 11. Surface area covered by dwellings, exposed elements and risk by province.

	Surface Area of Affected Dwellings Sed(km^2)		Exposed Elements (€ million)		Total risk (€ million)	
	2005	2009	2005	2009	2005	2009
Alicante	23.6	24.3	5966	6569	1088	1216
Castellón	6.6	7.1	1171	1753	236	352
Valencia	14.3	14.7	2044	2862	469	664
TOTAL	44.5	46.1	9181	11 184	1793	2232

NHESSD
2, 3615–3657, 2014

Table 12. Risk ranges by municipality (€ million).

Province (NUT3)	RISK RANGE	2005 No LAU2	2005 RISK (€ M)	2009 No LAU2	2009 RISK (€ M)
Alicante	1	12	1	11	1
	2	9	7	10	8
	3	18	42	16	37
	4	20	125	20	116
	5	31	912	34	1054
Total	**–**	**90**	**1087**	**91**	**1216**
Castellón	1	8	1	8	1
	2	20	15	12	7
	3	11	28	14	29
	4	13	75	16	99
	5	7	118	11	216
Total	**–**	**59**	**237**	**61**	**352**
Valencia	1	27	3	22	2
	2	25	17	23	15
	3	27	57	28	61
	4	22	126	23	134
	5	18	267	24	452
Total	**–**	**119**	**470**	**120**	**664**
TOTAL		**268**	**1794**	**272**	**2232**

NHESSD
2, 3615–3657, 2014

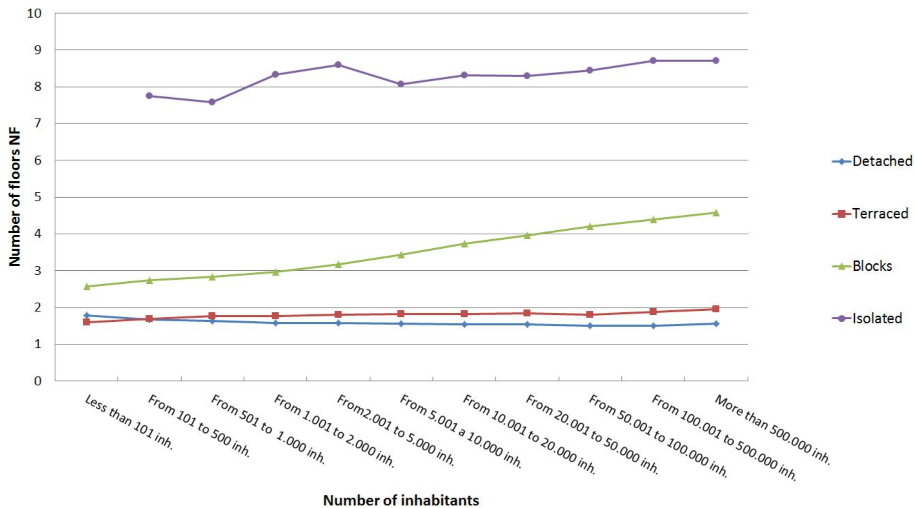

Figure 1. Variation in number of floors per type of building and municipality size.

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

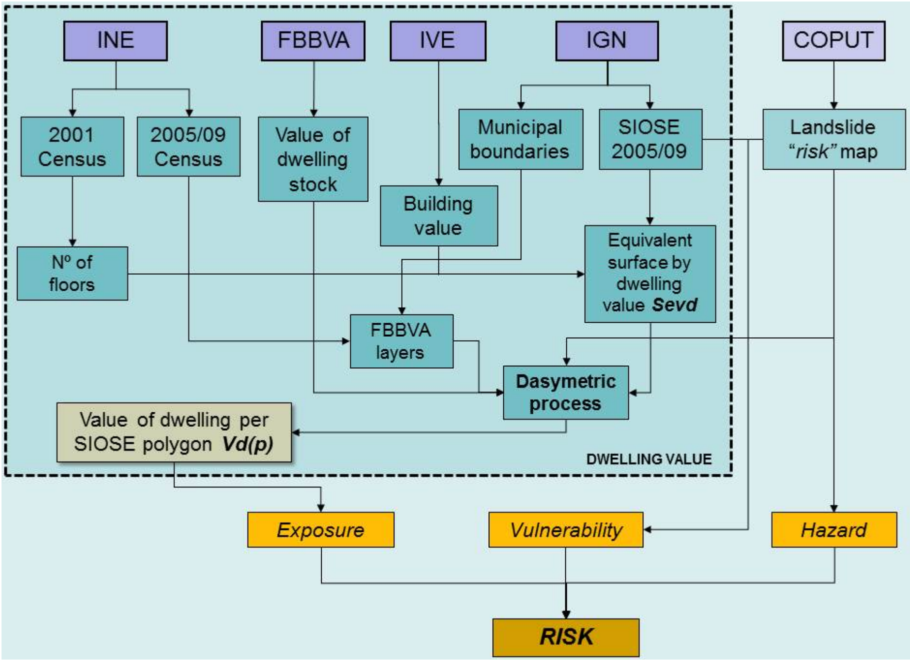

Figure 2. Flow diagram. INE: Spanish National Statistics Institute. FBBVA: Foundation of the BBVA bank. IVE: Building Institute of Valencia (Valencia Government) IGN: Spanish National Geographical Institute. COPUT: Department of Public Works, Town Planning and Transport: Valencia Government.

NHESSD
2, 3615–3657, 2014

Assessing residential buildings value in Spain for risk analyses

I. Cantarino et al.

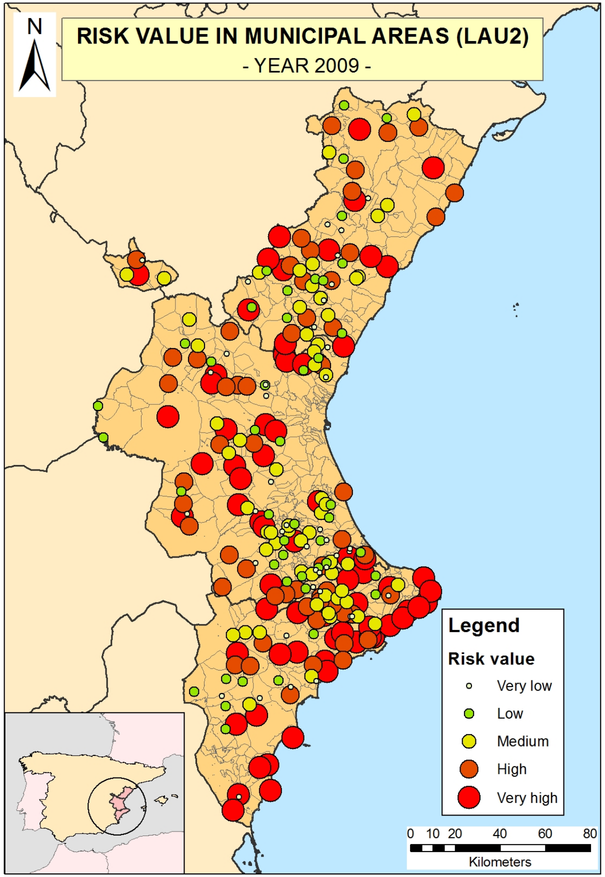

Figure 3. Location and quantification of risk value by municipality in the Valencia Community.