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SUMMARY

Socio-economic vulnerability is assessed for six locations, two in Norway and one each in Greece, Andorra, France and Romania. The purpose of the case studies has been to compare vulnerability levels and to test and possibly improve the methodology proposed in SafeLand Deliverable D2.6 titled *Methodology for evaluation of the socio-economic impact of landslides (socio-economic vulnerability).*

The indicators in the applied method represent five areas/components of vulnerability: (1) demographic, (2) economic and (3) social characteristics, (4) degree of preparedness and (5) recovery capacity for the locations in study. Each indicator was individually ranked from 1 (lowest vulnerability) to 5 (highest vulnerability) and weighted, based on its overall degree of influence. The final vulnerability estimate was formulated as a weighted average of the individual indicator scores.

The vulnerability scores obtained for the two locations in Norway and the locations in Andorra and France were similar (2.0 – 2.1). The vulnerability estimate for Grevena in Greece was higher (2.7), while the highest vulnerability among the analyzed location was Slănic in Romania (3.6).

In the assessment, both Skien and Stranda in Norway were ranked as municipalities with relative low vulnerability scores (2.0). Many of the indicators which contributed to the low vulnerability score are similar for the whole of Norway, including age distribution, personal wealth, urban population, insurance and disaster funds and quality of medical services. Andorra and Barcelonnette in France were ranked with a similar score as the Norwegian locations (2.0 – 2.1), even if there were differences for several of the individual indicator scores between the locations. Andorra scores relatively well on the economic and preparedness components, but poorly on the demographic, social and recovery components. Barcelonette scores relatively well on preparedness and recovery but less good on the economic component.

Grevena in Greece obtained a higher vulnerability score (2.7) and Slănic in Romania obtained the highest vulnerability score (3.6) among the analyzed locations. Grevena in particular scores poorly on the economic component as well as rather poorly on preparedness and recovery. Slănic has the highest vulnerability scores on all components except the social component, with particularly high scores on the economic as well as the preparedness and recovery components.

The case studies were repeated with an updated version of the method. The updated method resulted in a similar ranking of vulnerability for the case study locations as obtained with the original method.

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1 INTRODUCTION AND BACKGROUND

This report presents application of a method for assessing socio-economic vulnerability. The method is described in SafeLand deliverable D2.6 “Methodology for evaluation of the socio-economic impact of landslides (socio-economic vulnerability)”, Eidsvig and McLean et al. (2012). The method is briefly reviewed in Section1.1. The socio-economic vulnerability is assessed for two locations in Norway, and one location each in Greece, Andorra, France and Romania.

The case studies serve two purposes:

- Comparing the socio-economic vulnerability level for different communities throughout Europe
- Verification of the method:
    - Choice of indicators and vulnerability ranking for each indicator
    - Is the weighting of the indicators reasonable for landslides?
    - Do vulnerability levels for analyzed communities seem reasonable?

1.1 REVIEW OF THE METHOD

The proposed method is an indicator-based methodology to assess socio-economic vulnerability to landslides. The indicators represent the underlying factors which influence a community’s ability to deal with, and recover from the damage associated with landslides. The proposed method includes indicators which represent demographic, economic and social characteristics as well as indicators representing the degree of preparedness and recovery capacity. The purpose of the indicators is to set priorities, serve as background for action, raise awareness, analyze trends and empower risk management. Each indicator is individually ranked from 1 (lowest vulnerability) to 5 (highest vulnerability) and weighted, based on its overall degree of influence. The final vulnerability estimate is formulated as a weighted average of the individual indicator scores.

Table 1 shows the proposed socio-economic vulnerability model with suggested indicators, their corresponding weights, suggestions on where to collect the data and criteria for ranking of the indicators.

Table 1 Proposed vulnerability model

Indicators	Weights and means of data collection	Criteria for indicator ranking (1: Low vulnerability, 5: very high vulnerability)
Demographic Indicators		
Age distribution (see note 1)	2 Census	1: Uniform age distribution - less than 20% population is either between 0-5 years of age or over 65.
		2: 20-30% population is either between 0-5 years of age or over 65.
		3: 30-40% population is either between 0-5 years of age or over 65.
		4: 40-50% population is either between 0-5 years of age or over 65.
		5: Over 50% population is either between 0-5 years of age or over 65.
Rural population (see note 2)	2 Census	1: Less than 10% population is dependent on the land for primary source of income.
		2: 10-25% population is dependent on the land for primary source of income.
		3: 25-50% population is dependent on the land for primary source of income.
		4: 50-75% population is dependent on the land for primary source of income.
		5: Over 75% population is dependent on the land for primary source of income.
Urban population (see note 2)	1 Census	1: Population density is < 50 people/km^2
		2: Population density is between 50-100 people/km^2
		3: Population density is between 100-250 people/km^2
		4: Population density is between 250-500 people/km^2
		5: Population density is > 500 people/km^2
Economic Indicators		
Personal wealth	2 Census	*1:* GDP per capita > 50 thousand USD
		2: GDP per capita 30 – 50 thousand USD
		3: GDP per capita 20 – 30 thousand USD
		4: GDP per capita 10 – 20 thousand USD
		5: GDP per capita < 10 thousand USD
		1: The majority of constructions are of strong resistance, there are some or none of medium resistance and none of weak resistance.
		2: The majority of constructions are of strong resistance, there are some or none of medium resistance

Housing type (see note 3)	3 Census	and some of weak resistance.
		3: The majority of constructions are of medium resistance, there are some or none of strong resistance and some or none of weak resistance.
		4: The majority of constructions are of weak resistance, there are some or none of medium resistance and some of strong resistance.
		5: The majority of constructions are of weak resistance, there are some or none of medium resistance and none of strong resistance.
Social Indicators		
Vulnerable groups due to language or cultural barriers	1 Census	1: < 5% of the population is not familiar with majority language and culture
		2: 5-10% of the population is not familiar with majority language and culture
		3: 10-15% of the population is not familiar with majority language and culture
		4: 15-25% of the population is not familiar with majority language and culture
		5: > 25% of the population is not familiar with majority language or culture (indicative of a high percentage of tourists and/or recent immigrants)
Education Level	1 Census	1: > 30% of the eligible population (over 18 years of age) have attended, or are attending, a post-secondary education
		2: 20-30% of the eligible population have attended, or are attending, a post-secondary education
		3: 10-20% of the eligible population have attended, or are attending, a post-secondary education
		4: 5-10% of the eligible population have attended, or are attending, a post-secondary education
		5: <5 % of eligible population have attended, or are attending, a post-secondary education
Preparedness indicators		
Hazard evaluation (Lahidji, R., 2008)	3 Local government questionnaire	1: Detailed hazard maps available
		2: Basic hazard maps available
		3: Hazard mapping research ongoing (with some gaps)
		4: Basic assessment of direct impacts to exposed populations completed
		5: Incomplete assessment of direct impacts to exposed populations
		1: Stringent guidelines in place to ensure minimal risk to exposed population
		2: Consistent approach to the regulation of construction and land use on the basis of exposure to landslides

Regulation control (Lahidji, R., 2008) (see note 4)	3 Local government questionnaire	3: Fairly effective regulations for new developments, however, potential problems with older constructions
		4: Some consideration of risk during construction, but inadequate enforcement of regulations
		5: No consideration of risk in planning and construction
Emergency response (Lahidji, R., 2008)	2 Local government questionnaire	1: Permanent coordination between responders in communities; specialized equipment and well-trained rescue services available throughout the country
		2: Clear definition of roles and responsibilities at local level; proportionate allocation of resources
		3: Existence of an organization of emergency response, with coordination authority; adequate supplies of medical transport, communications and other specialized equipment in all important cities
		4: Professional search and rescue services, evacuation possibilities and central operation centers available in the most landslide-prone areas
		5: Fragmented organization and scattered resources; predominance of voluntary responders
Early warning system (Lahidji, R., 2008)	2 Local government questionnaire	1: Advanced early warning systems used in coordination with emergency response procedures
		2: Adequate early warning system coordinated with media announcements capable of reaching the majority of the population prior to the landslide
		3: Basic early warning systems available to the public
		4: Basic early warning system available to risk managers
		5: No early warning system
Recovery indicators		
Insurance and disaster funds (Lahidji, R., 2008)	2 Local government questionnaire	1: Extensive coverage for private and public buildings, existence of government-sponsored landslide funds
		2: Insurance coverage for the majority of private and public buildings, limited government-funding
		3: Widespread landslide insurance in development phase, but not yet accessible to everyone
		4: Incomplete support for victims of past landslide events
		5: Little or no insurance provided
Quality of medical services (see note 5)	1 Government data	1: > 4 hospital beds per 1 000 people
		2: 3-4 hospital beds per 1 000 people
		3: 2-3 hospital beds per 1 000 people
		4: 1-2 hospital beds per 1 000 people
		5: < 1 hospital beds per 1 000 people

Note 1: Age distribution

- The population of young children and senior citizens more vulnerable to harm in the event of a landslide is estimated by the percentage of people between 0-5 years of age or over 65. Since the average life expectancy in Europe is approximately 75 years, a uniform age distribution would indicate that 20% of the population is 'vulnerable' – this was used as the basis for the age distribution indicator scale.

Note 2: Rural/urban population

- Rural populations are highly vulnerable due to their lower incomes (on average) and dependence on the surrounding natural resources (e.g., farming, fishing) for sustenance. However, urban regions with very dense populations are more difficult to evacuate during emergencies (Cutter et al., 2003).

Note 3: Housing type

- Strong resistance refers to thick brick or stone wall and reinforced concrete constructions, medium resistance to mixed concrete-timber and thin brick-wall constructions and weak resistance to simple timber and very light constructions (Heinimann, 1999).

Note 4: Regulation control

- This indicator takes into account the quality of infrastructure in the region. If there is a significant amount of control over construction guidelines, the infrastructure is generally well-built and relatively resilient to landslides.

Note 5: Quality of medical services

- This indicator is categorized by the number of hospital beds per 100 000 people. The scale used is based on data provided by the European Commission Eurostat (2008).

Update of method:

In the revised version of report D2.6, the method was updated with 2-3 new indicators and the indicators were regrouped into 3 groups:

- Demographic and social indicators
- Economic indicators
- Preparedness, response and recovery indicators

The update of the method, including the new indicators with corresponding criteria for ranking and weighting, is described in section 8.3. The updated method is described in its entirety in Eidsvig and McLean et al. (2012).

2 SOCIO-ECONOMIC VULNERABILITY FOR SKIEN, NORWAY

Skien is a city on the Southern coast of Norway with about 50 000 inhabitants.

Figure 1 Location of Skien in Norway

The area is especially prone to clay landslide because of quick clay deposits. Quick clay is marine clay, where the salt content is reduced through flush of ground water. When quick clay is exposed to load or when moving, the clay may turn into a liquid.

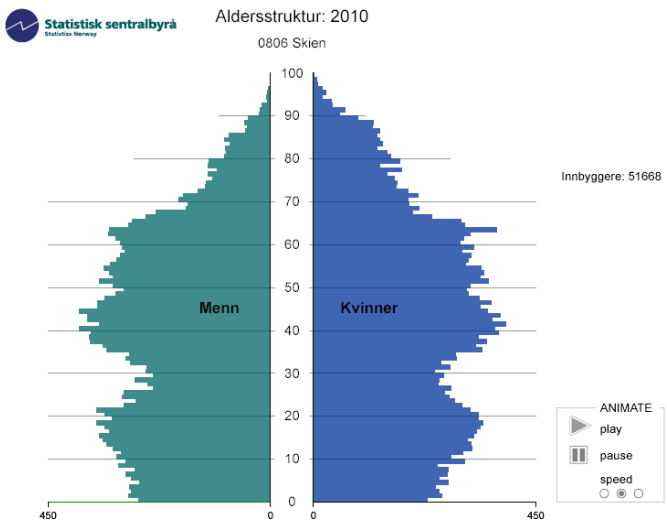
Risk mapping have been performed and several areas were classified as high risk areas, where mitigation actions were required. Mitigation actions have been performed to reduce the hazard. There are strict restrictions for construction work and other human activity which may trigger landslides in the quick-clay areas. No early warning system is established as most quick-clay slides are triggered by human activity.

Figure 2 Clay landslide by the Skiens river. Foto: Skien municipality.

2.1 INDICATOR RANKING

The data needed for the indicator ranking were obtained either from census data, interviews of people with knowledge about Skien and/or subjective judgment of the author. Table 2 summarizes the indicator and the description or reasoning for each indicator ranking.

Table 2 Summary of indicator ranking for Skien

	Result of analysis for Skien		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The ranking of the vulnerability was performed by looking into census data, see Figure 3. • Children 0-5 and age over 65 : About 9700 • 51700 inhabitants Fraction of population less than 5 years and above 65 years: 19%  *Figure 3 Age distribution in Skien.*	**1**
	Rural population	Preliminary vulnerability score (by judgment)	**2**
	Urban population	Preliminary vulnerability score (by judgment)	**1**
Economic	**Personal wealth**	Gross Domestic Product (GDP) for Skien = 87000$ (From census data)	**1**
	Housing type	A majority of the buildings in the area are wooden houses with reinforces concrete foundation walls, which would be classified as medium resistance houses.	**3**
Social	**Vulnerable groups**	Immigrant from other cultures: 7.8%. (From census data)	**1**

	Education level	22% have attended a post-secondary institution. (From census data)	**2**
Prepared-ness	**Hazard evaluation**	Basic hazard maps available.	**2**
	Regulation control	Consistent approach to the regulation of construction and land use on the basis of exposure to landslides.	**2**
	Emergency response	Clear definition of roles and responsibilities at local level; proportional allocation of resources	**2**
	Early warning system	No early warning system	**5**
Recovery	**Insurance and disaster funds**	Extensive coverage for private and public buildings, existence of government-sponsored landslide funds	**1**
	Quality of medical services	In census data not given number of hospital beds but number of medical doctors. Judgmental ranking.	**2**

2.2 VULNERABILITY CALCULATION

Table 3 shows the calculation of the socio-economic vulnerability score.

Table 3 Calculation of vulnerability score for Skien

Group	Indicator	Indicator score	Indicator weight	Weighted vulnerability score
Demographic (1.4)	Age distribution	1	2	2
	Rural population	2	2	4
	Urban population	1	1	1
Economic (2.2)	Personal wealth	1	2	2
	Housing type	3	3	9
Social (1.5)	Vulnerable groups	1	1	1
	Education level	2	1	2
Preparedness (2.6)	Hazard evaluation	2	3	6
	Regulation control	2	3	6
	Emergency response	2	2	4
	Early warning system	5	2	10
Recovery (1.3)	Insurance and disaster funds	1	2	2
	Quality of medical services	2	1	2
Total	$\frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**2.0**	**25**	**51**

The vulnerability score for Skien is 2.0, on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

3 SOCIO-ECONOMIC VULNERABILITY FOR STRANDA, NORWAY

Stranda municipality has about 4700 inhabitants and is located in western Norway. Åknes is a rock slope over a fjord arm in the Stranda municipality. There are continuous movements in the rock slope, which has a tsunamigenic potential if sliding into the fjord. A massive rockslide at Åknes would have dramatic consequences, as the tsunami triggered by the slide would endanger several communities around Storfjorden. The area is characterized by frequent rockslides, usually with volumes between 0.5 and 5 million m^3.

Figure 4 Location of Stranda municipality (left) and of the Åknes rock slope and municipalities along the fjord system (right).

Site investigations, monitoring and warning system for the potentially unstable rock slopes were implemented to reduce the hazard and risk. The Åknes/Tafjord project was initiated in 2005 by the municipalities, with funding from the Norwegian government, to investigate rockslides, establish monitoring systems and implement a warning and evacuation system to prevent fatalities, should a massive rockslide take place.

The situation for Stranda is not as for a typical landslide case as the danger is not in the rock slide itself, but in the tsunami generated by the rockslide. Thus, the consequences are at a larger scale than for typical landslide cases. Several municipalities along the same fjord system as Standa would be affected. Still Stranda is included as example, because it is a well known case in Norway and this case study could be used to demonstrate how awareness and preparedness affect the socio-economic vulnerability.

3.1 INDICATOR RANKING

The data needed for the indicator ranking were obtained either from census data, interviews of people with knowledge about Stranda and/or subjective judgment of the author. Table 4 summarizes the indicators and the description or reasoning for each indicator ranking.

Table 4 Summary of indicator ranking for Stranda

	Result of analysis for Stranda		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The ranking of the vulnerability was performed by looking into census data: • About 1000 inhabitants younger than 5 years or older than 65 years. • 4745 in total Fraction of population less than 5 years and above 65 years: 21% Vulnerability 2	**2**
	Rural population	Preliminary vulnerability score (by judgment)	**3**
	Urban population	Preliminary vulnerability score (by judgment)	**1**
Economic	**Personal wealth**	Gross Domestic Product (GDP) for Stranda = 96000$ (From census data)	**1**
	Housing type	A majority of the buildings in the area are wooden houses with reinforces concrete foundation walls, which would be classified as medium resistance houses.	**3**
Social	**Vulnerable groups**	Immigrant from other cultures: 4.7 %. (From census data)	**1**
	Education level	15% have attended a post-secondary institution. (From census data)	**3**
Prepared-ness	**Hazard evaluation**	Basic hazard map available	**2**
	Regulation control	Fairly effective regulations for new developments however, potential problems with older constructions	**3**
	Emergency response	Permanent coordination between responders in communities; specialized equipment and well-trained rescue services available throughout the country	**1**
	Early warning system	Advances early warning system used in coordination with emergency response procedures	**1**
Recovery	**Insurance and disaster funds**	Extensive coverage for private and public buildings, existence of government-sponsored landslide funds	**1**
	Quality of medical services	In census data not given number of hospital beds but number of medical doctors. Judgmental ranking.	**2**

3.2 VULNERABILITY CALCULATION

Table 5 shows the calculation of the socio-economic vulnerability score for Stranda.

Table 5 Calculation of vulnerability score for Stranda

Group	Indicator	Indicator score	Indicator weight	Weighted vulnerability score
Demographic (2.2)	Age distribution	2	2	4
	Rural population	3	2	6
	Urban population	1	1	1
Economic (2.2)	Personal wealth	1	2	2
	Housing type	3	3	9
Social (2.0)	Vulnerable groups	1	1	1
	Education level	3	1	3
Preparedness (1.9)	Hazard evaluation	2	3	6
	Regulation control	3	3	9
	Emergency response	1	2	2
	Early warning system	1	2	2
Recovery (1.3)	Insurance and disaster funds	1	2	2
	Quality of medical services	2	1	2
Total	$\frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**2.0**	**25**	**49**

The vulnerability score for Stranda is 2.0, on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

4 SOCIO-ECONOMIC VULNERABILITY FOR GREVENA, GREECE

Grevena is a town and municipality in Greece, capital of the Grevena Prefecture located on the NW part of Greece, see Figure 5. The town's current population is 10,177 citizens; it lies about 400 km NE from Athens and about 180 km SW from Thessaloniki. The municipality's population is 15,481 and the area is regarded as semi-urban. The population density was the smallest of the periphery of West Macedonia until the 1990s, while Grevena has had access to the Via Egnatia since the early 2000s, which now connects Igoumenitsa with the Evros of Alexandroupoli at the border with Turkey. The city is surrounded by mountains, while is situated by the river Greveniotikos, which itself flows into the main river Aliakmon. Figure 6 shows the geological map of Grevena basin with a representative NW–SE 2D cross-section (Pitilakis et al., SRM-DGC Final Report, Part A 2009).

Figure 5 Location of the city of Grevena in Greece

Landslide hazard mapping has been performed for the broader area of Grevena indentifying regions with high susceptibility to landsliding. Figure 7 and Figure 8 present the DEM and the spatial distribution of slope angles of the broader area of Grevena respectively. Hence, significant slope angles that range from 0^o to 90^o are presented even inside the city. The vulnerability assessment of different elements at risk (roads, pipelines) exposed to earthquake triggered landslides has been investigated in previous project. The results reveal that most of the expected damages are attributed to the occurrence of permanent ground deformations due to landsliding and not to the effect of ground shaking (Pitilakis et al., SRM-DGC Final Report, Part A 2009)

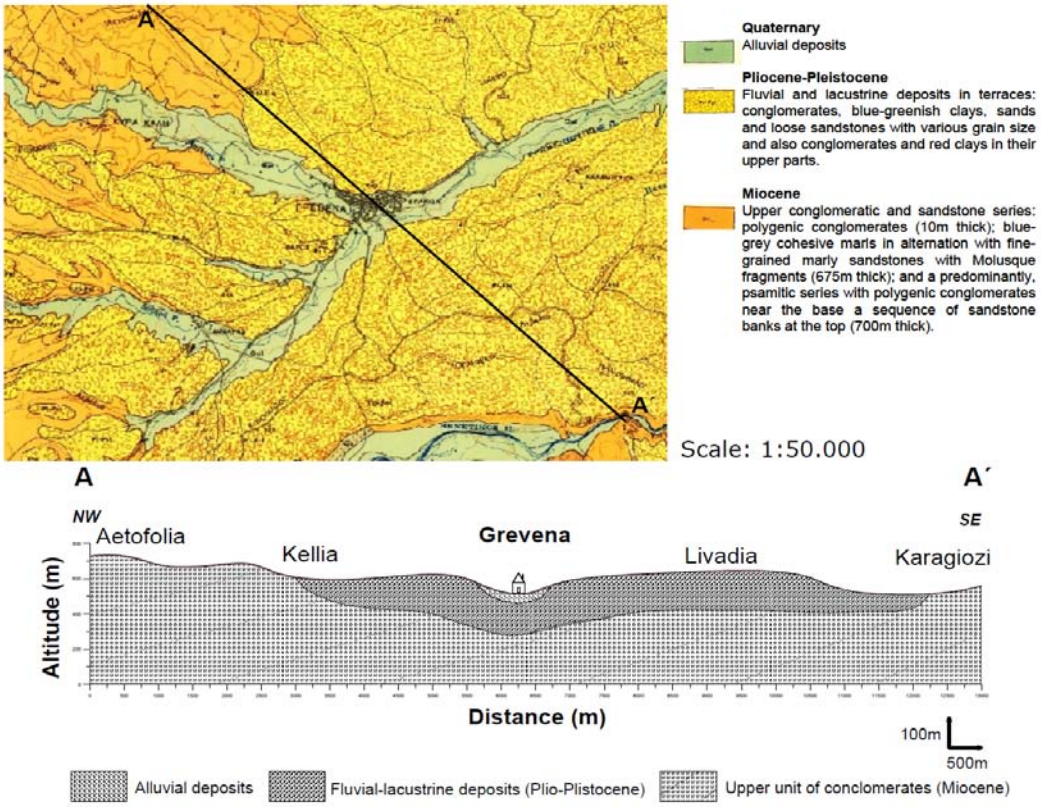


*Figure 6 Geological map of Grevena basin (I.G.M.E., 1972) and a representative 2D cross-section AA´aligned NW–SE direction (*Pitilakis et al., SRM-DGC Final Report, Part A 2009*).*

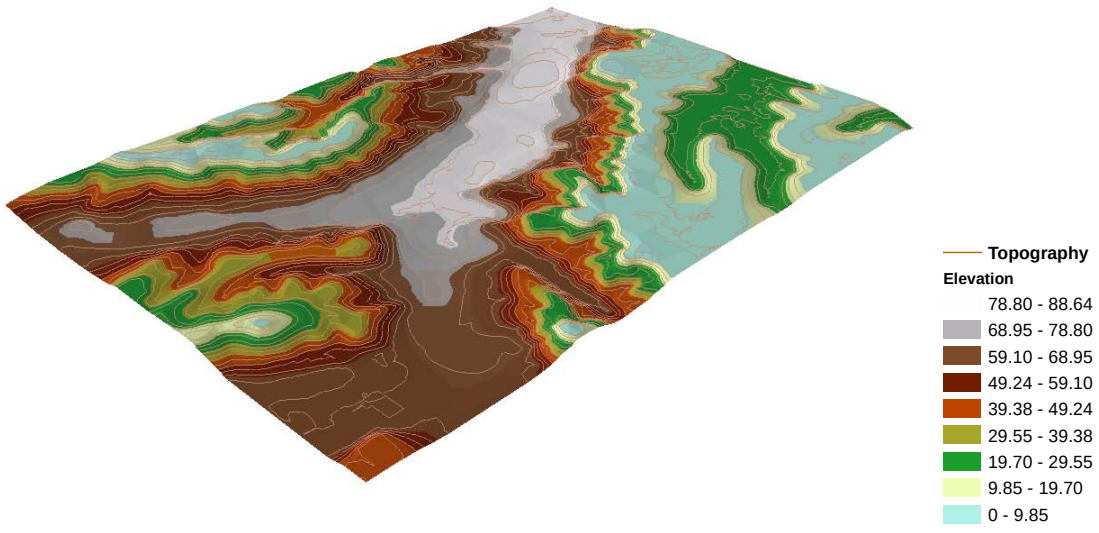


Figure 7 DEM for the broader area of Grevena

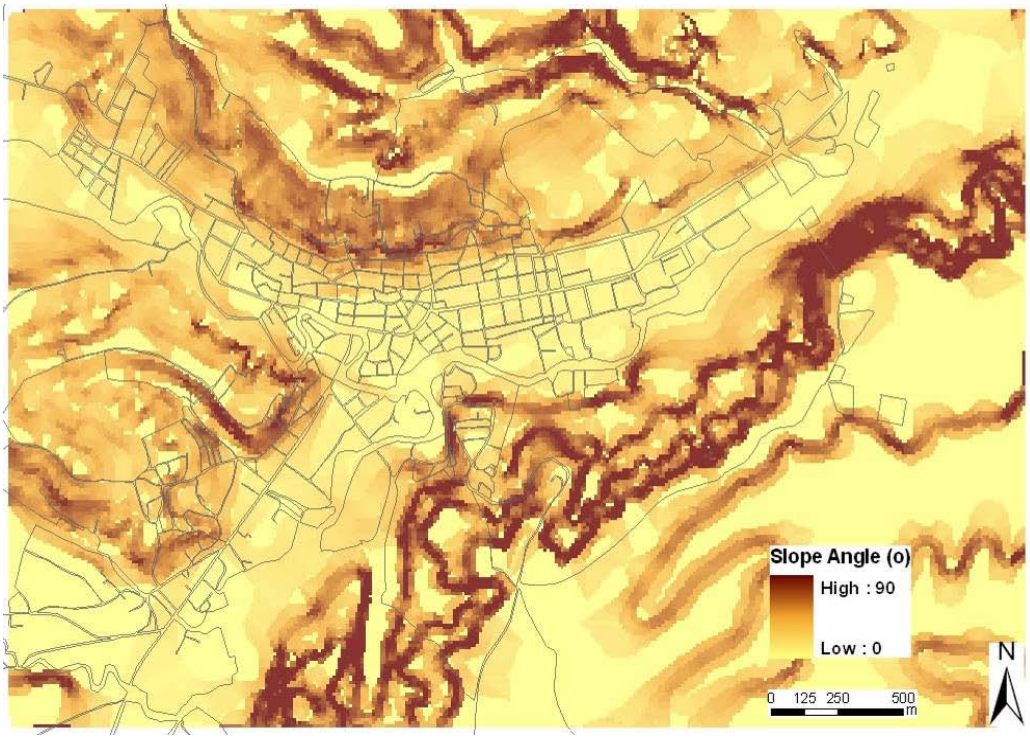


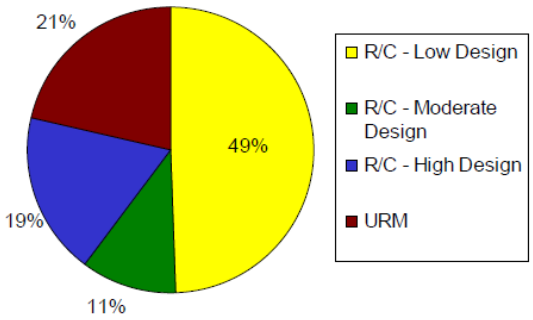
*Figure 8 Spatial distribution of slope angles of the broader area Grevena (*Pitilakis et al., SRM-DGC Final Report, Part A 2009)

4.1 INDICATOR RANKING

The data needed for the indicator ranking were obtained either from census data (Hellenic Statistic Authority), other sources (e.g. reports of past project, web pages) and/or estimations based on general information, experience and judgment of the authors. Table 6 summarizes the indicator and the description or reasoning for each indicator ranking.

Table 6 Summary of indicator ranking for Grevena

	Result of analysis for Grevena		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The ranking of the vulnerability was performed by looking into the National census 2001 data (Source: Hellenic Statistical Authority, www.statistics.gr). • Children 0-5 and age over 65 : About 2260 • 10,177 inhabitants in total Fraction of population less than 5 years and above 65 years: 22.2%	**2**
	Rural population	9.9% of the population is dependent on the land for primary source of income. (Source: http://hefaistos.anko.gr:7779/images/tabs/anko/HMERIDES/A-FASH.PDF)	**1**
	Urban	The Population density is 16.45 people /km ² <50	**1**

	population	people /km ^{2} (Source: http://www.mlahanas.de/Greece/Cities/Grevena.html)	
Economic	**Personal wealth**	Gross Domestic Product (GDP) for Greece = 12482.85€ (GDP per capita 10 – 20 thousand USD) (Source: Hellenic Statistical Authority, www.statistics.gr).	**4**
	Housing type	The building stock is governed by old (URM or 'low-code' R/C) buildings (21% URM and 49% 'low-code' R/C). (Source: Pitilakis et al., SRM-DGC Final Report, Part A 2009'.)  *Figure 9 Composition of the building stock of Grevena. Number of buildings per material – code design*	**4**
Social	**Vulnerable groups**	8.9% of the population is not familiar with majority language and culture (From census data) (Source: Hellenic Statistical Authority, www.statistics.gr)	**2**
	Education level	11.6% have attended a post-secondary institution. (Source: http://hefaistos.anko.gr:7779/images/tabs/anko/HMERIDES/A-FASH.PDF)	**2**
Prepared-ness	**Hazard evaluation**	Basic hazard maps available. (Source: Pitilakis et al., SRM-DGC Final Report, Part A 2009)	**2**
	Regulation control	Fairly effective regulations for new developments, however, potential problems with older constructions (Estimation based on general information, experience and judgment)	**3**
	Emergency response	Existence of an organization of emergency response, with coordination authority; adequate supplies of medical transport, communications and other specialized equipment in all important cities (Estimation based on general information, experience and judgment)	**3**
	Early	Basic early warning system available to risk	**4**

	warning system	managers (Estimation based on general information, experience and judgment)	
Recovery	**Insurance and disaster funds**	Widespread landslide insurance in development phase, but not yet accessible to everyone (Estimation based on general information, experience and judgment)	**3**
	Quality of medical services	314 hospital beds per 100 000 people. (Source: http://www.nosgrevenon.gr/)	**2**

4.2 VULNERABILITY CALCULATION

Table 7 shows the calculation of the socio-economic vulnerability score.

Table 7 Calculation of vulnerability score for Grevena

Group	**Indicator**	**Indicator score**	**Indicator weight**	**Weighted vulnerability score**
Demographic (1.4)	Age distribution	2	2	4
	Rural population	1	2	2
	Urban population	1	1	1
Economic (4.0)	Personal wealth	4	2	8
	Housing type	4	3	12
Social (2.0)	Vulnerable groups	2	1	2
	Education level	2	1	2
Preparedness (2.9)	Hazard evaluation	2	3	6
	Regulation control	3	3	9
	Emergency response	3	2	6
	Early warning system	4	2	8
Recovery (2.7)	Insurance and disaster funds	3	2	6
	Quality of medical services	2	1	2
Total	$= \frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**2.7**	**25**	**68**

The vulnerability score for Grevena is 2.7, on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

5 SOCIO-ECONOMIC VULNERABILITY FOR ANDORRA

Andorra is a mountainous country located in the Pyrenean Range between France and Spain with an average elevation of 1830 m. The rock fall activity in the area poses a continuous threat for persons and infrastructures. The capital of Andorra, Andorra la Vella and its neighboring urban area Santa Coloma are situated at the bottom of the Solà d'Andorra slope along some kilometers. In 1985 and 1997 rock falls impacted on buildings, in the second case causing the injury of a person. These events raised the public awareness of the risk and the local authorities were mobilized to take action against possible future rock falls.

Figure 10 Upper figure: Location of Andorra la Vella. Lower figure: The urban areas of Andorra la Vella and Santa Coloma and the rock fall-susceptible slope above them

5.1 INDICATOR RANKING

Table 8 summarise the ranking of the indicators. Not all indicators were ranked, see comments below the table.

Table 8 Summary of indicator ranking for Andorra

	Result of indicator ranking for Andorra		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The percentage between 0-5 years of age or over 65 is 19% (2009). (source: Department of statistics of the Govern of Andorra, http://www.estadistica.ad/)	**1**
	Rural population	In Andorra the rural population is approximately 11% (source: http://www.indexmundi.com for 2009). Given that the study-areas of Andorra la Vella and Santa Coloma are the main urban areas and the centers of financial activity for the country rather than rural areas, thus less than 10% population is dependent on the land for primary source of income.	**1**
	Urban population	2048 people/km2 (in 2007) (source: Department of statistics of the Govern of Andorra, http://www.estadistica.ad/)	**5**
Economic	**Personal wealth**	Given than Andorra la Vella is the centre of economical activity of Andorra, the most unfavorable case of GDP per capita 75-95% of the country average is assumed. GDP per capita: 39492 $ (source: http://www.tradingeconomics.com/)	**2**
	Housing type	The exposed buildings are reinforced-concrete or masonry structures. (from field-survey)	**1**
Social	**Vulnerable groups**	Assumption based on personal judgment, given the existence of many immigrants in the area over the last decades: 10-15% of the population is not familiar with language and culture	**3**
	Education level	Not evaluated, see comment below table	-
Prepared-ness	**Hazard evaluation**	Detailed hazard maps available The most important rock fall risk mitigation action carried out was the Rockfall Risk Management Master Plan of the Solà d'Andorra which was completed in May 1998. This Plan established restriction to the development in the most threatened sectors. The Plan gave also way to the implementation of protective works such as rock fall fences and concrete walls. The performance so far of the mentioned actions has revealed highly	**1**

		effective. The most important achievement is the change in the perception of risk by the stakeholders. The awareness of rock fall hazard has risen with the public audiences, the building codes and the control works. The Andorran administration is currently engaged in an ambitious program for rock fall risk mitigation with special interest in both the urban areas and the main road network.	
	Regulation control	Fairly effective regulation for new developments, however, potential problems with older constructions (Please see hazard evaluation)	**3**
	Emergency response	Clear definition of roles and responsibilities at local level; proportionate allocation of resources.	**2**
	Early warning system	Not evaluated, see comment below	**-**
Recovery	**Insurance and disaster funds**	Incomplete support for victims of past landslide events. The available information that we have is insufficient and this ranking was selected as the most-unfavorable one.	**4**
	Quality of medical services	3. 2,60 hospital beds per 1000 (year: 2006) (source: Instituto Nacional de Estadística, España)	**3**

Comments:

1. The educational level was not included because it is not always directly associated with the risk perception of the population, so its inclusion into the social indicators could possibly raise some doubts. Furthermore, no data are available.
2. For fast landslides (e.g. rock falls), due to the short reaction time, preparedness plays a minor role in comparison with the demographic indicators of the "housing type" and "population density". The social vulnerability in those cases is mostly determined by the buildings' resistance (building type) and the population density. Considering this, we propose the weights for these categories were adapted accordingly.
3. The following indicators were judgmentally developed due to lack of available data:
    a. Vulnerable groups due to language or cultural barriers.
    b. Emergency response (it is difficult to predetermine the response at the moment of the incident)

5.2 VULNERABILITY CALCULATION

Table 9 shows the calculation of vulnerability score for Andorra.

Table 9 Calculation of vulnerability score for Andorra

Group	Indicator	Indicator score	Indicator weight	Weighted vulnerability score

Demographic (1.8)	Age distribution	1	2	2
	Rural population	1	2	2
	Urban population	5	1	5
Economic (1.4)	Personal wealth	2	2	4
	Housing type	1	3	3
Social (3.0)	Vulnerable groups	3	1	3
	Education level	NA	1	NA
Preparedness (2.0)	Hazard evaluation	1	3	3
	Regulation control	3	3	9
	Emergency response	2	2	4
	Early warning system	NA	2	NA
Recovery (3.7)	Insurance and disaster funds	4	2	8
	Quality of medical services	3	1	3
Total	$\frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**2.1**	**22**	**46**

The vulnerability score for Andorra is 2.1 on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

6 SOCIO-ECONOMIC VULNERABILITY FOR BARCELONNETTE, FRANCE

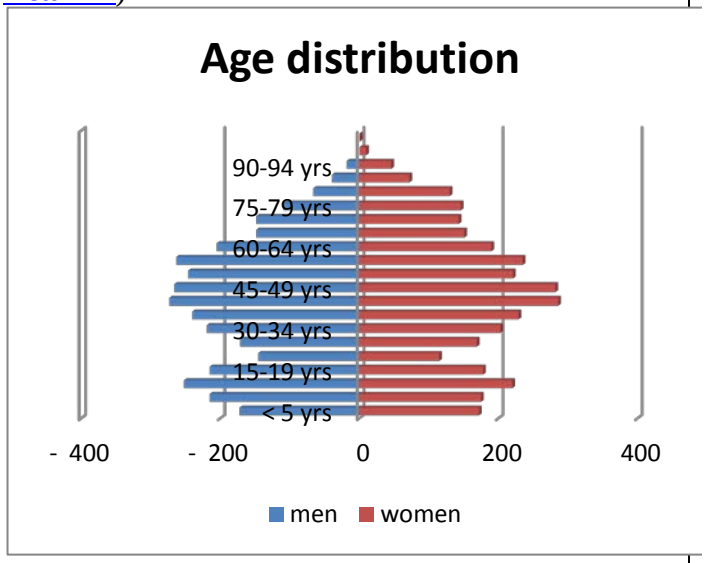
Barcelonnette is located in the Ubaye Valley, a wide and very fertile valley in the southern French Alps. In SafeLand, the Barcelonnette Basin is considered, which consists of 10 municipalities.

Figure 11 Location of Barcelonnette in France

Geomorphologic and climatic factors lead to various slope movements in the Barcelonnette Basin: gullies networks, landslides and debris-flow torrents. The La Valette mudslide (1986) and the two debris-flows which occurred in the Faucon torrent (1996, 2003) are some examples of the slope activity.

6.1 INDICATOR RANKING

	Result of analysis for Barcelonnette		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The ranking of vulnerability was performed by looking into census data, see Figure 1 • Children 0-5 and age over 65 : 1569 • 6782 inhabitants Fraction of population less than 5 years and above 65 years: 23.1 % 10500 inhabitants if you consider the Basin; the age distribution of the 10 municipalities is relatively	*2*

		similar to the municipality of Barcelonnette. (Source INSEE 2006 : http://www.recensement.insee.fr/tableauxDetailles.action?zoneSearchField=BARCELONNETTE&codeZone=0404-CV&idTheme=12&idTableauDetaille=44&niveauDetail=1)  *Figure 12: Age distribution in Barcelonnette*	
	Rural Population	3.7% of Barcelonnette municipality population is working in the agricultural sector. Over the Barcelonnette Basin, 9.8 % are working in the agricultural sector	1 .. or 2
	Urban population	Barcelonnette canton has a density of 6.8 inhabitants per km²	1
Economic	**Personal wealth**	GPD per habitant for Alpes de Hautes Provence area: 21 135€ -> USD 29200	3
	Housing types	The towns can be clearly divided into two groups with different characteristics: • Enchastrayes, Uvernet and Barcelonnette are characterized by large buildings, most of them comprising more than ten dwellings, constructed in the period 1957-1989. • Faucon-de-Barcelonnette, Jausiers, Saint-Pons, Méolans, Les Thuiles, La Condamine are characterized by small individual chalets that are either old (built before 1915) or built in the period 1957-1989. These chalets are expected to be less resistant than the larger constructions of Barcelonnette, Uvernet and Enchastrayes.	3

Social	**Vulnerable groups due to language or cultural barriers**	Less than 3.7% of Barcelonnette municipality inhabitants are immigrants; 2.7 % for the Barcelonnette Basin	1
	Education level	Only 1114 inhabitants have a post bacalaureat diploma, which represents 16.4% of the population Which population? Municipality or Basin?	3
Prepared-ness	**Hazard evaluation**	Existence of PPR, detailed local hazard maps for 8 out of the 10 municipalities	1
	Regulation control	Good because of the existence of the risk prevention plans	1
	Emergency response	Existence of preparedness (or local rescue) plans (called Plan Communal de Sauvegarde, PCS in France) in 2 out of the 10 municipalities; the 8 others municipalities have to prepare their PCS within the next 3 years. Rescue service based on civil protection, fireman and volunteers	3 or 4
	Early warning system	Early warning systems for 1 landslide site (La Valette), monitoring systems for 4 landslide, for flooding and for earthquake (no thresholds for alarm/alert defined), .	4 ?
Recovery	**Insurance and disasters funds**	Natural disaster decree (National funding)	1
	Quality of medical services	Local Hospital “Pierre Groues” has 64 hospital beds, which represents 943 hospital beds per 100 000 people	1

6.2 VULNERABILITY CALCULATION

Table 10 shows the calculation of vulnerability score for Barcelonnette.

Table 10 Calculation of vulnerability score for Barcelonnette

Group	Indicator	Indicator score	Indicator weight	Weighted vulnerability score
Demographic (1.6)	Age distribution	2	2	4
	Rural population	1.5	2	3
	Urban population	1	1	1
Economic (3.0)	Personal wealth	3	2	6
	Housing type	3	3	9
Social (2.0)	Vulnerable groups	1	1	1
	Education level	3	1	3
Preparedness	Hazard evaluation	1	3	3

(2.1)	Regulation control	1	3	3
	Emergency response	3.5	2	7
	Early warning system	4	2	8
Recovery (1.0)	Insurance and disaster funds	1	2	2
	Quality of medical services	1	1	1
Total	$\frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**2.0**	**25**	**51**

The vulnerability score for Barcelonnette is 2.0, on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

7 SOCIO-ECONOMIC VULNERABILITY FOR SLĂNIC, ROMANIA

Slănic locality is situated in the Subcarpathians, an area highly affected by landslide-related hazards. Shallow, recent landslides superposing on large, old and deep landslide bodies represent a real environmental problem for the local and regional development because the phenomena occurs almost on all hill slopes causing damages to infrastructure, lifelines, agricultural areas and settlements.

Figure 13 Location of Slănic locality (left) and settlements threatened by failure due to landsliding in Prahova County (right). Foto: geodin.ro

Figure 14 Earth flow triggered by heavy rainfall in Slănic locality (June 2010) Foto: R. Ciurean

The occurrence of landslides is related to the presence of salt breccia and clay schists within a NW-SE oriented syncline – the Slănic Syncline that is affected by longitudinal and transversal faults. Moreover, the slopes are affected by subsidence due to the lack of maintenance works and water infiltration in the old salt mine galleries (constructed for industrial salt exploitation).

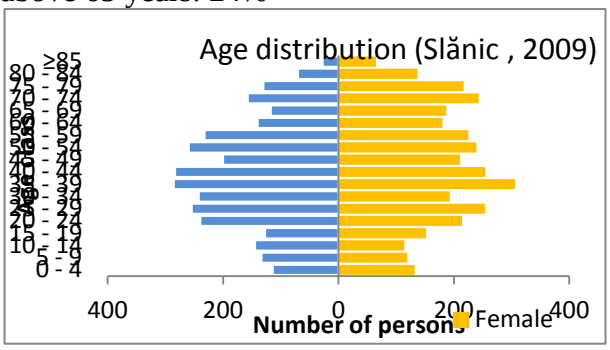
Several houses were partially or totally destroyed and 9 people were evacuated as a result of damages caused by landslides in April 2006 (Slănic Prefecture). The local authorities relocated the most affected families or gave compensations for some of the losses.

Although site investigations were performed in several critical points in Slănic, a systematic and long term plan of landslide hazard and risk reduction is still missing. The site, considered an important touristic attraction in the region, continues to pose a serious threat for the resident or non-resident population as well as for the quality of settlements and built environment due to landslide (and other related hazards) occurrence.

7.1 INDICATOR RANKING

The data used for the indicator ranking were obtained mainly from the National Institute of Statistics (http://www.prahova.insse.ro/main.php), questionnaires and interviews of people with knowledge about Slănic locality. The indicators assessed by subjective judgement were noted accordingly. Table 11 presents the list of used indicators along with the description or reasoning of each indicator ranking.

Table 11 Summary of indicator ranking for Slănic

	Result of analysis for Slănic		
Group	**Indicator**	**Description/reasoning for choice of indicator score**	**Indicator score**
Demographic	**Age distribution**	The ranking of the vulnerability was performed by looking into census data, see Figure below. • Children 0-5 and age over 65 : 1596 • 6595 inhabitants Fraction of population less than 5 years and above 65 years: 24%  *Age distribution in Slănic. Source: National Institute of Statistics*	**2**
	Rural population	Less than 5% of the total population on average is active in agriculture sector.	**1**
	Urban population	From census data	**3**
Economic	**Personal wealth**	91% of country average. (From census data) Gross Domestic Product (GDP) for Romania = 9290$ (http://www.globalpropertyguide.com/Europe/Norway/gdp-per-capita)	**5**
	Housing type	The majority of constructions are of weak resistance, there are some or none of medium	**4**

		resistance and some of strong resistance.	
Social	**Vulnerable groups**	Preliminary vulnerability score (by judgment).	**1**
	Education level	5% have attended a post-secondary institution. (From census data)	**4**
Prepared-ness	**Hazard evaluation**	Incomplete assessment of direct impacts to exposed populations	**5**
	Regulation control	Some consideration of risk during construction, but inadequate enforcement of regulations	**4**
	Emergency response	Existence of an organization of emergency response, with coordination authority; adequate supplies of medical transport, communications and other specialized equipment in all important cities	**3**
	Early warning system	No early warning system	**5**
Recovery	**Insurance and disaster funds**	Little or no insurance provided. The necessary resources to resist and recover from the impact are (in almost all cases) entirely state contributions, and generally estimated as insufficient.	**5**
	Quality of medical services	From census data	**1**

7.2 VULNERABILITY CALCULATION

Table 12 shows the calculation of the socio-economic vulnerability score.

Table 12 Calculation of vulnerability score for Slănic

Group	Indicator	Indicator score	Indicator weight	Weighted vulnerability score
Demographic (1.8)	Age distribution	2	2	4
	Rural population	1	2	2
	Urban population	3	1	3
Economic (4.4)	Personal wealth	5	2	10
	Housing type	4	3	12
Social (2.5)	Vulnerable groups	1	1	1
	Education level	4	1	4
Preparedness (4.3)	Hazard evaluation	5	3	15
	Regulation control	4	3	12
	Emergency response	3	2	6

	Early warning system	5	2	10
Recovery (4.0)	Insurance and disaster funds	5	2	10
	Quality of medical services	2	1	2
Total	$\frac{\sum \text{Weighted vulnerability score}}{\sum \text{Weights}} =$	**3.6**	**25**	**91**

The vulnerability score for Slănic is 3.6 on the proposed vulnerability scale, where 1 is the lowest possible vulnerability score and 5 is the highest possible vulnerability score.

Comments:
Generally, the vulnerability level for the analyzed community seems reasonable and the ranking for each indicator coherent.

In Romania, the Roma ethnic minority can be considered the most susceptible to potential losses from hazard events due to their dependence on social services, lack of quality housing and socioeconomic status. The vulnerability of this group is included through the indicators “housing type” and “personal wealth”.

8 CONCLUSIONS AND DISCUSSIONS

8.1 COMPARISON OF THE OBTAINED SOCIO-ECONOMIC VULNERABILITY RESULTS

The vulnerability score for all the case studies are summarized in Table 13. The colour scale shown at the bottom of the table is used to indicate relative vulnerability for each of the vulnerability components.

Table 13 Summary of the obtained results.

Location	**Skien, Norway**	**Stranda, Norway**	**Grevena, Greece**	**Andorra**	**Barcelonette, France**	**Slănic, Romania**
Demographic score	1.4	2.2	1.4	1.8	1.6	1.8
Economic score	2.2	2.2	4.0	1.4	3.0	4.4
Social score	1.5	2.0	2.0	3.0	2.0	2.5
Preparedness score	2.6	1.9	2.9	2.0	2.1	4.3
Recovery score	1.3	1.3	2.7	3.7	1.0	4.0
Vulnerability score	***2.0***	***2.0***	***2.7***	***2.1***	***2.0***	***3.6***

Relative vulnerability colour scale:

In the assessment both Skien and Stranda in Norway were ranked as municipalities with relative low vulnerability scores (2.0). Many of the indicators which contributed to the low vulnerability score are similar for the whole of Norway, including age distribution, personal wealth, urban population, insurance and disaster funds and quality of medical services.

Andorra and Barcelonnette in France were ranked with a similar score as the Norwegian locations (2.0 – 2.1), even if there were differences for several of the individual indicator scores between the locations. Andorra scores relatively well on the economic and preparedness components, but poorly on the demographic, social and recovery components. Barcelonette scores relatively well on preparedness and recovery but less good on the economic component.

Grevena in Greece obtained a higher vulnerability score (2.7) and Slănic in Romania obtained the highest vulnerability score (3.6) among the analyzed locations. Grevena in particular scores poorly on the economic component as well as rather poorly on preparedness and recovery. Slănic has the highest vulnerability scores on all components except the social component, with particularly high scores on the economic as well as the preparedness and recovery components.

To interpret the results individually one could define thresholds for division of the results into vulnerability classes like “Low”, “Medium” and “High”. The most obvious choice of threshold for vulnerability levels would be a linear scale:

- “Low vulnerability”: scores 1 – 2.33
- “Medium vulnerability”: scores 2.33 – 3.66
- “High vulnerability”: scores 3.66 - 5

According to such a definition, the locations in Norwegian, France and Andorra would have “Low” socio-economic vulnerability, Grevena in Greece would have “Medium” socio-economic vulnerability and, Slănic in Romania would have “Medium” to “High” socio-economic vulnerability. However, since the method is not based on disaster impact data, the abovementioned division into vulnerability classes is not scientifically reasoned. To improve the interpretation of the vulnerability score, the socio-economic vulnerability for a large number of locations could be assessed. Then it would be possible to analyze the results statistically to generalize and draw conclusions about interpretations of the individual vulnerability scores.

One needs to keep in mind that low socio-economic vulnerability doesn’t imply low risk. The risk depends also on hazard and all the locations selected for the case studies are high hazard areas.

8.2 EVALUATION OF THE METHOD

A key reason for carrying out the case studies was to gather experience on the use of the methodology and potentially make improvements. In particular, the following key features of the methodology were evaluated:

- Choice of indicators and vulnerability ranking for each indicator
- Is the weighting of the indicators reasonable for landslides?
- Do vulnerability levels for analyzed communities seem reasonable?

Below are some comments to the method regarding choice, ranking and weighting of indicators and some reflections on the results.

Comments to choice of indicators:

- Education level is not always directly related with the risk perception of the population

Comments to indicator ranking:

- Age distribution. Is it too strict to use 65 as the limit of “Being old”. : In Europe the life expectancy is high and being more than 65 is not equivalent to being old.

Comments to indicator weighting:

- Are preparedness indicators weighted too high? For fast landslides (e.g. rock falls), due to short reaction time, preparedness plays a minor role in comparison with other indicators. For the Andorra case study, one of the preparedness indicators was omitted from the study (i.e. “Early Warning System”). For further

development of the method it is recommended to adapt the weights to the landslide mechanism (slow moving or fast moving landslide) for specific indicators.

Evaluation of the results:

- The internal ranking, produced by the method, of the 6 locations in this study seems reasonable. For a better interpretation of the individual score values more case studies need to be performed or ultimately, the method should be calibrated against disaster impact data.

Other suggestions for improvement of the method:

- The socio-economic vulnerability is a time dependant parameter. For instance, more data for a specific community may become available (e.g. through acquisition of detailed hazard maps, updated census data etc.), some indicators may become more important than others etc. To this end, it would be advantageous to take into account the evolution of socio-economic vulnerability with time.
- The "Judgment of the analyst" associated with data unavailability may introduce bias on the vulnerability estimates. The incorporation of the proposed model within a probabilistic framework to account for various sources of uncertainty would comprise an interesting future extension.

8.3 UPDATE OF THE METHOD AND CASE STUDIES

Based on comments from the reviewer of report D2.6 and on experiences from the case studies, the vulnerability model has been extended by two indicators and slightly changed in a third indicator. The new indicators refer to critical infrastructure and risk awareness. 'Critical infrastructure' includes critical care facilities, critical facilities and lifelines. The 'Risk awareness' indicator considers the length of residence of the inhabitants in the risk area and the information status on hazard, risk and behavior in case of an emergency.

In addition to these new indicators, two preparedness indicators have been merged: 'Landslide hazard evaluation' and 'early warning system'. This is mainly to not overestimate the preparedness in the overall vulnerability analysis. The merged indicator is called 'Early warning capacity'. The new indicators and the corresponding criteria for ranking and weighting are shown in Table 14.

Table 14 Criteria for ranking and weighting of the 3 new indicators

Risk awareness	2 Local government questionnaire?	1: Stringent information campaigns on local risks in the community, in schools and for households, most of the residents have lived in the area for a long time
		2: Sporadic distribution of information material on local risk and risk management to households, information signs in the hazard zone
		3: Information on possible risks in the area are available on website and on signs in the hazard zone
		4: Information on hazard and risk available for experts, people have to look for information themselves, high fluctuation of population
		5: No information on hazard and risk in the area, high fluctuation of population
Early warning capacity	3 Local government questionnaire	1: Detailed hazard maps and advanced early warning systems used in coordination with emergency response procedures available
		2: Basic hazard maps available, hazard mapping research ongoing (with some gaps) and basic early warning systems available for researchers
		3: Hazard is a fast moving landslide, hazard maps and early warning system available
		4: Incomplete assessment of direct impacts to exposed populations, no early warning system
		5: Hazard is a fast moving landslide, no hazard maps and early warning system available
Critical infrastructure	3 Maps, Census	1: No critical care facilities and lifelines in the hazard zone
		2: Only few critical care facilities and no lifelines in the hazard zone
		3: Several critical facilities and lifelines in the hazard zone
		4: Important care facilities, such as hospitals, and major lifelines in the hazard zone
		5: All major critical care facilities and all lifelines in the hazard zone

These new indicators were ranked for the 6 case study locations in order to update the case studies. The result of the ranking is shown in Table 15

Table 15 Ranking of the 3 new/merged indicators for the 6 case study locations

Part I: Skien, Stranda and Grevena

Indicator	Skien, Norway	Stranda, Norway	Grevena, Greece
Risk awareness	**3** Information provided on the internet, e.g. skredatlas.nve.no, reports available from authorities online	**2** Internet and media presence	**4** Information on hazard and risk available for experts, people have to look for information themselves, high fluctuation of population
Early warning capacity	**2** Basic hazard maps available. No early warning system	**1** Basic hazard map available, advances early warning system used in coordination with emergency response procedures	**4** Incomplete assessment of direct impacts to exposed populations, no early warning system
Critical infrastructure	**3** Infrastructure affected: railway, major roads in Gråten, Borgestad, 2 schools in Skien, kindergarden Gråten, city centre Skien, one bigger care facility Skien	**4** Whole community would be affected	**3** Several critical facilities and lifelines in the hazard zone

Part II: Andorra, Barcelonette and Slănic

Indicator	Andorra	Barcelonette, France	Slănic, Romania
Risk awareness	**3** Information on possible risks in the area are available on website and on signs in the hazard zone	**4** Information on hazard and risk available for experts, people have to look for information themselves, high fluctuation of population	**4** Information about risk to different types of hazards (i.e. landslides, floods) is mostly available for experts and decision makers.
Early warning capacity	**4** Incomplete assessment of direct impacts to exposed populations, no early warning system	**3** (indicator description between score 2 and 4 suitable)	**3** Presently, there is no early warning system or landslide hazard map available for Slanic Prahova municipality and the assessment of direct impacts to exposed populations is incomplete.
Critical infrastructure	**2** Only few critical care facilities and no lifelines in the hazard zone	**2** Only few critical care facilities and no lifelines in the hazard zone	**3** Some of the touristic facilities are located in areas highly affected by landslides, suffusion and erosion. In April 2006, snow melting and high amounts of precipitation triggered a number of landslides which damaged transport lifelines and utility facilities (water distribution lines and electric power).

In the update of the method, the indicators were regrouped into 3 groups:

- Demographic and social indicators
- Economic indicators
- Preparedness, response and recovery indicators

The indicators in Table 15 belong to the group of preparedness, response and recovery indicators. Table 16 shows the results for the 3 groups of indicators and for the estimated vulnerability score.

Table 16 Results of case studies using extended model

Indicator score	Skien, Norway	Stranda, Norway	Grevena, Greece	Andorra	Barcelonette, France	Slănic, Romania
Demographic and social score	1.4	2.1	1.6	2.0	1.7	2.0
Economic score	1.9	1.9	3.7	2.1	2.4	4.6
Preparedness, response and recovery score	2.4	2.2	3.3	2.8	2.5	3.2
Vulnerability score	2.0	2.1	3.0	2.5	2.3	3.3

The ranking of the vulnerability for the study locations is similar to the previous case study results shown in Table 13.

Slănic in Romania and Grevena in Greece obtain the highest vulnerability score among the studied locations. These two locations score poorly on the economic component and on the preparedness, response and recovery component.

In Table 16, the French location Barcelonette and Andorra obtain slightly higher vulnerability scores than the Norwegian locations Skien and Stranda. This is mainly due to the preparedness, response and recovery component and partly due to the economic component.

Stranda obtains the relative highest score on the preparedness, response and recovery component. In Stranda, the Åknes/Tafjord project was initiated in 2005 by the municipalities, to investigate rockslides, establish monitoring systems and implement a warning and evacuation system to prevent fatalities, should a massive, tsunami-genic rockslide take place. On the other side, Stranda scores poorly on the critical infrastructure component, because a large amount of critical care facilities, critical facilities and infrastructure is located in the hazard zone.

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