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TESI MAGISTRALE:

Integrated environmental and socio-economic assessment of flood risk in a GIS context in the Vipacco basin'.

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“You do not really understand something

unless you can explain it to your grandmother”.

Non hai veramente compreso qualcosa fino a quando

non sei in grado di spiegarla a tua nonna

Albert Einstein (1879-1955)

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LIST OF ABBREVIATION

AC: Adaptive Capacity
AdB. Autorità di Bacino, Venezia
CBA: Cost-benefit analysis
CC: Coping Capacity
CEA: Cost-effectiveness analysis
CRED: Centre for Research on the Epidemiology of Disasters
DEFRA: Department for Environment, Food and Rural Affairs
DMs: Decision Makers
EEA: European Environmental Agency
GA: Geometric Average
GIS: Geographical Information System
GRASS: Geographic Resources Analysis Support System
IPCC: International Panel of Climate Change
ISPRA: Istituto superiore per protezione e la ricerca ambientale
ISTAT: Istituto nazionale di Statistica
KULTURisk: Knowledge-based approach to develop a cULTUre of Risk prevention
MCDA: Multi –Criteria Decision Analysis
MSs: Member States
NAM: Non-Additive Measures
RRA: Regional Risk Assessment
SERRA: Socio Economic Regional Risk Assessment
VSL: Value of Statistical Life
WA: Weighted Average

1) **INTRODUCTION**

"Flooding, along with related storms, is the most important natural hazard in Europe in terms of economic loss" (EEA, 2010 and CRED, 2009) and this is probably also the reason why a great interest is nowadays focused on flood risk mitigation and prevention.

Across Europe several catastrophic flood events happened in the last years: the flood of Po River in 2000 seriously affected all the northwest of Italy (Farinosi F. et al., 2012), "the disastrous summertime central European flooding in 2002" (Wilby R., et al., 2008) provoked huge inconveniences and the flood event in the Danube Basin in 2006 has particularly "revealed the vulnerability of the current society" (Danube Flood Risk, 2009).

It's hard to argue how much the intensity of the flood events is grown in the last years, but several scientific researchers have tried to demonstrate that flood risk will increase in the next years and they have tried to explain the reasons of this change.

Land use change, for instance, is considered as one of the main cause of the increasing severity of the flood and for instance Wheater and Evans (2009) have focused the attention on the urbanizations effects on fluvial floods. In particular they underline the problem of the waterproofing of the soils that "increases overland flow and reduces infiltration, bypassing the natural storage and attenuation of the subsurface. [..] The result is a greater volume of runoff, discharging in a shorter time, potentially leading to a dramatically increased flood peaks" (Wheater and Evans, 2009).

The waterproofing of the soils increases the risk mostly in the city center where the land is almost completely impermeable due to the presence of roads, industries and houses.

Another important issue concerning the intensity and the frequency of the floods is climate change. Milly et al. (2002), Wilby et al. (2008), DEFRA (2003) and IPCC (2007) affirm that in the next years, due to the global warming and consequently the change in the global water cycle, there will be an increase in flood risk in many part of the world. "The resulting increased flood risk poses challenges to society, physical infrastructure and water quality. It is likely that up to 20% of the world population will live in areas where river flood potential could increase by the 2080s" (Barker T., 2007).

At last, according to Zbigniew W.K. (?) the "socio-economic changes include increasing exposure and potential damage due to population growth and economic development in flood-prone areas". The higher the exposure is, the more dangerous could be the flood.

All these factors have led during the last years to an increasing interest for research in flood risk assessment. Risk analysis is a procedure used in many fields that goes from economy to social sciences and the purpose of this procedure is to find out the current risk in order to think about the possible risk reduction or mitigation methods. In particular, flood risk is usually calculated using the combination of three factors: hazard, vulnerability and exposure (Mojtahed et al., 2013 and DEFRA, 2003).

In this context, the European Union, in 2007, has drawn up the Flood Directive (2007/60/EC), which in article 2 defines flood risk as “the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event”. There’s in the Directive the explicit request to the competent authority of each Member States (MSs) to prepare flood risk maps and plans. Moreover it’s necessary to underline that Flood Directive suggests to the Member States (MSs) to “address all aspects of flood risk management focusing on prevention, protection, preparedness, including flood forecasts and early warning system and taking into account the characteristics of the particular river basin or sub basin” (Art. 7 Directive 2007/60/EC). This point is crucial for understanding the purpose of this research and, more widely, to link the Flood Directive with the KULTURisk (Knowledge-based approach to develop a cULTUre of Risk prevention) project in which this work is partially integrated.

KULTURisk is a research supported by the EU seventh framework programme and includes several European partners. Focusing on Italy there are involved two research groups of the University Ca’ Foscari of Venice (the Economic Department and the Environmental Science department) the Eastern Alps Hydrographic District (Basin Authority of Venice) and the University of Brescia.

KULTURisk, according to the previous mentioned Article 7 of the Flood Directive, aims to focus on risk prevention trying to integrate the physical-environmental component and the socio-economic factors of flood risk.

In the KULTURisk context, the physical-environmental component of the risk is assessed through a RRA (Regional Risk Assessment procedure) while the socio-economic factors are analyzed through a SERRA (Socio Economic Regional Risk Assessment) methodology (Mojtahed et al., 2013). SERRA is basically a procedure that considers the human component of vulnerability and the economic value of the exposed elements in the flood risk assessment. It aims to provide a monetization of the flood risk in the baseline scenario, that represents the current situation in the case study analyzed, and to propose a cost- benefit or cost-effectiveness analysis of the alternative scenario. Thanks to these analyses it can be considered as a useful instrument in the decision making process. Different measures might be taken in consideration in the alternative scenario, but in this work the attention is focused on EWS (Early Warning system). In particular, the aim of this work is to assess the socio-economic and physical environmental damages that could be provoked by a flood event through SERRA; it will be analyzed the Italian territory of the Vipacco river that corresponds to the municipality of Savogna d'Isonzo, a small area (16 km^2) at the border between Friuli Venezia Giulia and Slovenia.

The acquired data are stored in a GIS (Geographical Information System) and processed to produce maps in order to give to the reader and in case to the Decision Makers (DMs), a clear perception of the results. The risk assessment involved the complete monetization of the baseline scenario and the evaluation of EWS as alternative scenario. EWS is a non-structural risk reduction measure, while in the last 60 years the human defences from the flood were mostly realized through structural protection measure such as dams, dikes, river banks, detention basins, diversions and drainage channels (Ligato D. et al, 2004). These structures are mainly designed considering a certain flood intensity, that is usually 100 years old return time (AdB p.c.), but "no matter how high a design flood is, there is always a possibility of a greater flood occurring, inducing losses"(Zbigniew W.K., ?).

All the engineering structures aim to reduce the hazard component of the risk. On the other hand, the non-structural measures, such as the EWS, mostly act over the human component of vulnerability. The human vulnerability, within the SERRA methodology, is divided in Adaptive Capacity (AC) and Coping Capacity (CC) that respectively reflect the awareness of a population in case of flood and the capacity to react after it (Mojtahed et al., 2013). The human vulnerability corresponds to certain characteristics of the society that, in this works, will be analyzed through several indicators such as insurance density, dependency ratio, average income, number of people involved in the emergency and so on.

Other non-structural measures could have been analyzed like "zoning, economic instruments, flood related database [..] appropriate schemes of insurance", but the decision of considering EWS in this work was mainly due to the suggestions coming from the Basin Authority of Venice. They are currently working on the activation of an EWS called “AMICO”, which will be put in operation in the Vipacco sub-basin, the area of this case of study.

In this context, two receptors have been considered: people and buildings. The risk has been assessed following the SERRA methodology, mentioned in the KULTURisk presentation, and the damages have been calculated through depth damage functions taken from DEFRA (2003) for people and from Penning-Rowsell (2005) for buildings and reviewed by the KULTURisk working group. Depth damage functions create a relation between the economic damage of one receptor and a certain depth of the water. Thanks to these depth damage functions, at the end of the work it was possible to obtain a damage value of the baseline and alternative scenarios expressed in euro. The next step was analyzing these results through a cost benefit analysis. Concerning that, there’s still an open issue about the complete monetization provided by the functions used. This approach allows to assign a value in euro to all the receptors considered; in this case also deaths and injuries can be monetized; the value used to quantify a life of a person is the Value of statistical life (VSL) (OECD, 2012) and corresponds to about 3 million euro. From one point of view the complete monetization of the event makes easier the cost benefit analysis and the following possibly comparative choices of the decision makers; but on the other hand, does it make sense try to give a monetary value to the life of the people? Is three million of euro a reasonable amount? It is really hard to answer these questions and this is the reason why in this case it has been chosen to provide also a cost effectiveness analysis, where the value of the life of people doesn’t need to be monetized.

Three return times, suggested by the legislation and by the Eastern Alps hydrographic district, have been considered: 30, 100 and 300 years that correspond to high, medium and low probability of flood.

This work was mostly done in a GIS context, so that the results are displayed in several maps. Quantum GIS with the GRASS plug-in and the software GRASS 6.5 have been used, mostly because they are both free and open source. The spatial data used in this work mainly derived from the Eastern Alps hydrographic District that was responsible for the RRA application in the same area. They have provided depth and velocity raster maps that have been used in the risk calculation through depth damage functions. On the other hand the social indicators derive from several sources such as ISTAT (Istituto nazionale di statistica), Health Minister, Civil Protection and others. All the data have been imported in a GIS context and then analyzed with the GIS tools.

The structure of the thesis follows the different steps accomplished during the work.

Firstly, in the section "Data and methodology" it is presented an explanation of the methodology and of the spatial analysis.

In particular, the first paragraph, reports a brief introduction of the normative context, considering both European and Italian legislation in force. Furthermore, it is shown how the KULTURisk project is linked with the Flood Directive.

In the second paragraph a wide presentation of the KULTURisk project is provided; both RRA and SERRA have been treated. Moreover, there are introduced some methodological adaptations that have been applied to the case of study. At last the GIS instruments, operations and the principal technical issues implemented in the GIS are presented, as a sort of 'GIS manual' for future applications in the same field.

In the second part of the first section the spatial analyses concerning Vipacco area are described. Starting from the process of data collection, this paragraph explains how these data have been analyzed. In particular a great attention is given to normalization and aggregation procedures of the data that have permitted to compare them to each other.

At last there are the maps and the discussion of the results visualized in the GIS. There are reported several maps describing the baseline and alternative scenario with different return times. The discussion of these maps allows drawing the conclusions of the work.

There's a concept, introduced by Donald Wilhite in the mid 80's and mentioned by Zbigniew W.K. in his lessons, called the ' hydro-illogical cycle' that well explains the vicious turn of events in a flood area. "The return period of a destructive flood is usually much greater than the political horizon of decision makers and the electorate", so that after a time without flooding people and authorities forget what happened and "the willingness to pay for flood preparedness decreases sharply and projects are downscaled or suspended" (Zbigniew W. K.). This 'hydro-illogical cycle', in my opinion, explains in a very good way the floods problem nowadays. Due to the probability of increasing intensity and frequency of flood, in the next years there must be a behavioural change in the population and authorities. This is probably the only way to try to minimize flood risk.

2) DATA AND METHODOLOGY

2.1 NORMATIVE CONTEXT

2.1.1 Flood Directive 2007/60/EC

Following the classification of CRED (Centre for Research on the Epidemiology of Disasters) the natural disasters can be classified into the following categories:

a) geophysical: earthquake, volcano and dry mass movement;

b) meteorological: storm;

c) hydrological: flood and wet mass movement;

d) climatological: extreme temperature, drought and wildfire;

e) biological: epidemic, insect infestation and animal stampede (CRED, 2012).

CRED defines a disaster as “a situation or event which overwhelms local capacity, necessitating a request to a national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering” (CRED, 2012). Moreover, to define an adverse event as a disaster, there should be more than 10 victims or 100 people affected, declaration of emergency state or a call for international help (CRED, 2012).

There is an increasing discussion of climate change and natural disaster all around Europe and world. In the past few years tsunami (Indonesia 2006 and Japan 2011), earthquake (Iran 2013 and Italy 2009), flood (central Europe 2002, Veneto 2010) and other natural phenomena have affected people all around the world.

This work is going to focus on risk and damages due to flood. In particular in this chapter I’m going to address the in force legislations in Europe and Italy and compare them. This analysis is concerned with receptors, deadlines and aim of several laws. After that I will introduce the KULTURisk project (a European project focusing on flood), which is correlated with the law in force.

The European Directive gives to the MSs (Member States) the guideline to proceed in order to minimize flood impacts, while the national legislation shows the way to follow. KULTURisk tries to give another viewpoint introducing the social dimension in flood prevention, but it has to be consistent with the law to actually be able to help the MSs.

A definition of flood according to the European Directive 2007/60/EC is: “the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses and floods from the sea in coastal areas, and may exclude floods from sewage system” (Flood Directive, 2007).

According to the EEA (European Environment Agency) technical report “flooding, along with related storms, is the most important natural hazard in Europe in terms of economic loss” (EEA, 2010 and CRED, 2009). In the 2010 report EEA have analyzed the flood disasters between 1998 and 2009 and, “according to EM-DAT 2010 floods have produced more than 1100 fatalities and affected more than 3 million people”. An estimation of the direct economic losses in the same period are calculated around 60 billion euro (EEA, 2010).

Focusing on Italy, in this century several catastrophic events occurred between north and south of the country. The data of the most dangerous events occurred from 1950 are recorded by SICI (Sistema Informativo sulle Catastrofi Idrogeologiche). In particular the project AVI aims to collect all the available data about hydrogeological events (floods and mass movement) in the 20^{th} century. In the 1951 the overflow of Po River near Rovigo provoked 123 casualties and harshly damaged the economic and agricultural activities of the region. The dramatic flood of river Arno in 1966 is sadly famous due to all the cultural heritage losses of the city of Florence. In addition in the region of Tuscany there were 48 deaths and huge damages due to the extreme meteorological conditions, occurred in all north of Italy. Between the 2^{nd} and the 6^{th} of November 1994 in the north west of Italy strong meteorological events provokes flood and mass movement and in the Piedmont region several municipality remained isolated for several days, there were 78 deaths and about 10 000 people evacuated. There were numerous estimations of cost and the amount varies between 15 000 and 25 000 billion lire equal to 1.4% of the total GDP of Italy in 1994 (SICI). At the end, one of the biggest recent flood events is the 2010 flood in Veneto that damaged several provinces and in particular the city of Vicenza. The Bacchiglione River overflowed in the centre of the city causing damages to houses, enterprises, cars and infrastructure. The evaluation of the cost for the Vicenza municipality is about 150 million of euro (AdB Venezia, p.c.).

The reasons why floods seem to be every time more devastating than before is still uncertain but climate change, land use change, expansion of impervious land and changes in the river flows may increase the intensity of the adverse event. Although floods are natural events mainly due to the meteorological and climate conditions, "flood disasters are the results of the interaction between hydrologic floods and societal systems" (EEA, 2010).

The increasing severity of the flood event in Italy and Europe led the governments to analyze and manage the phenomena in a more accurate way.

At the beginning of the new century, in 2000, the European Commission stipulated a comprehensive document that tried to summarize and analyze the status of the water in each country (Directive 2000/60/CE). The directive 2000/60/EC of the European Parliament and of the council established a framework for community action in the field of water policy. In this direction, in 2007 European Parliament published a document that tried to give a useful guideline to all the Member States about the flood risk management (Directive 2007/60/CE). The Directive revolved around the prevention, protection and mitigation of flood. "According to European Commission, the Flood Directive has to be seen in the context of the Water Framework Directive and an integrated approach for the implementation of both directives should be promoted in order to maximise synergies" (Bakker M.H.K. et al., 2013).

For instance, as mentioned in the directive 2000/60, the assignment of drafting the river basin management plan is given to the competent authority that should be indicated by the MSs (Member States). In the first step the authorities should identify the areas, in their river basins, for which flood risk exists. In particular, the article 4 of the Directive offers the guidelines to draft a preliminary Flood Risk Assessment. After that each Member State shall, at the level of river basin district, or unit of management, prepare flood hazard maps and flood risk maps; in Italy this work belongs to the Basin Authorities. As specified in the Chapter 3 of the Directive, "Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:

a) floods with a low probability, or extreme event scenario;
b) floods with a medium probability (likely return period ≥ 100 years);
c) floods with a high probability, where appropriate". (Flood Directive,2007)

Moreover in each map some elements like flood extent, water depths and flow velocity shall be represented. Concerning flood risk maps, there are some elements that obviously have to be taken into account. It's easily understandable that there's no risk perceived without an exposed receptor and in this case the receptors, as it's shown in article 5 chapter 3 that shall be considered are:

a) " the number of inhabitants potentially affected;
b) the type o f economic activity present in the area at risk;
c) IPPC (integrated pollution prevention control) installations, which may cause environmental pollution in case of flooding;
d) other information which MSs considers useful such as the indication of areas where floods with a high content of transported sediments and debris flow can occur and information on other significant sources of pollution" (Flood Directive, 2007).

After the maps, the unit of management should study the possible measures to reduce the risk writing a flood risk management plan. The plan shall take into account relevant aspects such as "cost and benefits, flood extent and flood conveyance routes and areas which have the potential to retain flood water, such as natural floodplains, the environmental objectives of Article 4 of the Directive 2000/60/EC, soil and water management, spatial planning, land use, nature conservation, navigation and port infrastructure" (Flood Directive, 2007).

Different measures should be taken into account such as structural and non-structural intervention. In this context the Directive recommends the Member State to focus on the non-structural measures. Prevention, protection and preparedness are the points discussed in Article 7. Unit of Management should think about Early Warning System (EWS) and about the social component of a precise area. Each basin at risk should not be managed in the same way; on the contrary the risk should be studied in regional areas because of its peculiar characteristics that change the possible mitigation measures in the different regions.

Two principles are considered and mentioned in this directive: the subsidiarity and solidarity principles. The first principle underlines the sovereignty of each Member State in its territory. All the European Directives give the guideline to achieve a common aim, but the Member States can operate in the best way they believe. EU should only be involved in international issues and only if it can be more efficient than the MSs.

Solidarity refers to the obligation of MSs not to take in place actions that can increase the risk in other MSs, on the contrary MSs are encouraged to cooperate in order to achieve the best results (Bakker M.H.N. et al, 2013). Article 7.4 of the directive underlines that " Flood Risk Management Plans established in one MSs shall not include measures which, by their extent and impact, significantly increase flood risks upstream or downstream of other countries in the same river basin or sub- basin unless these measures have been coordinated and an agreed solution has been found among the member state concerned" (Flood Directive, 2007).

Indeed, another focal point concerns the trans boundary floods. Several big rivers flow in Europe and in some cases they also pass through more than one country. In this case it should be useful to draft an International Flood Risk Management Plans in order to divide the responsibilities and share the information and data about the possibilities of flood (Bakker M.H.N. et al, 2013). The FD does not explicitly refer to 'public participation' that is one of the most important points in the EU legislation (Aarhus Convention, 1998). However, while drafting the Flood risk management plans the competent authorities deal with stakeholders and end-users in order to better understand the real issues of the region.

The important deadlines for the MSs are:

a) preliminary flood risk assessment in December 2018;
b) flood hazard maps and risk maps by December 2019;
c) flood risk management plan by December 2021 (art 14 Flood Directive).

2.1.3 Legislative decree n 49/2010

Concerning Italy, the art 4 of D.lgs 10 December 2010 n.219 has conferred to the Basin Authorities of national relevance and to the Region the assignment to carry out the coordination function in their river basin district (Ministero dell'Ambiente, 2013). The implementation of the Directive 2007/60/CE is contained in D.Lgs n 49/2010. The aim of this decree is to define shared procedure to produce homogeneous risk maps all around the country. The competent authorities should refer to this document in the drafting of the Maps and the Management Plan requested by the 2007/60.

In this direction, ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) have developed guidelines with methodology and criteria to be used by the Italian Basin Authorities in the Risk Assessment. This study took in consideration the different ways of considering exposure, vulnerability, hazard and risk.

In order to integrate the methodology, the Decree 49/2010 suggests the sources that should be considered for the needed data. For instance, concerning the exposure, the number of potentially affected inhabitants is easily findable in ISTAT (Istituto Statistica) census. In addition to that the Decree offers data sources regarding infrastructure, cultural heritages and environmental systems.

One of the differences in the implementation of the directive is concerning the receptors that should be considered. As already said, the directive 2007/60 (Art 5 Chapter 3) considers people, economic activities and IPPC installations as receptors. In the Italian law (Art 6 49/2010) the following macro-categories are considered:

a) people;
b) strategic structures and infrastructures;
c) cultural heritages and environmental ecosystems;
d) economic activities;
e) installations described in the attached I of DLgs n°59 del 18.2.2005 and the protected area of the attached 9 of the DLgs 152/2006
f) other useful information

Later, in a document of June 2012 written by ISPRA these categories are summarized in 4 receptors easily comparable to the receptors described by EU. These receptors are: population, economic activities and cultural and environmental heritages.

The most important difference between Italian and EU legislation is in regards to the damage concept.

The technical steps about risk calculation will be discussed in the methodology in the next chapter.

Concerning the maps, in the Decree 49/2010 the indication on the return time and the mandatory elements to be shown is perfectly consistent with Directive 2007/60.

The Decree 49/2010 proposes the following deadlines:

a) preliminary risk assessment: 22 September 2011;
b) hazard and risk maps: 22 June 2013;
c) flood management plan: 22 June 2015;
d) following update: 2019-2021.

2.1.4 Comparison between normative context and KULTURisk

Different types of risk could have been considered but, at first, KULTURisk has studied flood risk assessment. The aim of the project is to assess the possible physical, environmental, social and economic losses produced by a flood with a shared methodology that is composed by two parts, RRA (Regional risk Assessment) and SERRA (Social Economic Regional Risk Assessment).

Different research groups have developed this methodology and later on the partners of the project have applied it at the regional level in different case studies. In order to get consistent and useful results for the project, the Directive 2007/60/EC has a great relevance. For this reason it’s crucial to compare the different elements requested by the project and the Directive.

Regarding receptors, the Directive considers the number of inhabitants, the economic activities, the IPPC and other possible useful information. KULTURisk considers the following:

a) people (number of inhabitants)
b) economic activities (in particular buildings, infrastructure and agriculture)
c) cultural heritage
d) natural and semi-natural system

Regarding the first two points, they are completely consistent with the normative. Moreover, cultural heritage and environment are explicitly mentioned in the article 1 of the chapter 1 of the Directive as one of the elements that should be protected.

The project doesn’t mention the IPPC as one of the elements to be taken into account. Nevertheless, in the application of the methodology these types of installations are certainly studied. Indeed, SERRA aims to consider the direct and indirect damages produced by a flood, which should consider also the losses and the costs due to a possible pollution. Concerning receptors, as explained above, the two approaches are perfectly consistent. Furthermore, the elements that must be represented in the maps such as flood extent, water depth and flow velocity, are also in the project, the first necessary step to calculate the risk.

Another crucial issue that perfectly links the project with the normative is about prevention and cost-benefit analysis. The Directive (Chapter IV, Article 7) underlines the importance to take into account, in the drafting of Flood risk management plans, some aspects such as cost and benefits, prevention, protection, preparedness and early warning system (EWS).

This is probably the most significant common ground between the Directive and the project. Risk assessment in KULTURisk project is just the first step to get a more comprehensive study. Prevention, social preparedness and EWS are considered in different alternative scenarios and each one is studied using a cost benefit or cost effectiveness analysis.

In conclusion the project and the European law seem to be perfectly compatible and this is the base for a reasonable and consistent application of the methodology.

2.2 The KULTURisk approach

In the previous chapter I introduced the KULTURisk (KR) project and I compared with the European legislation. This section will analyze in depth the aims and the methodology of the project.

In this chapter I will present the theoretical methodology for the regional risk assessment RRA and the socio-economic regional risk assessment SERRA; nevertheless the application of the methodology in Vipacco case study has required interpretations and modifications and adaptations.

The KULTURisk project was initiated due to the increasing need of dealing with natural catastrophes such as earthquakes, floods or extreme meteorological events. In this context this is part of a bigger European program: the Seventh Framework Programme (http://www.kulturisk.eu/).

In particular, the KULTURisk project intends to develop a risk assessment methodology that allows estimating the benefits offered by several prevention strategies that could be proposed to the decision makers. In this direction the priority purpose is to integrate "the environmental risk assessment made by the experts with a socio-economic assessment that permits to associate a cost-benefit analysis to each of the proposed mitigation strategies" (Mojtahed V., 2013). The decision makers could use the results as an integrated and efficient instrument to optimally choose the best option.

The methodology has been developed by two research groups of the University Cà Foscari of Venice; in particular the department of environmental sciences has elaborated the Regional Risk Assessment (RRA) and the department of economics focused on the Socio-Economic Regional Risk Assessment (SERRA).

To better explain the methodology it is useful to describe the framework presented in the deliverable 1.6 of Work Package (WP1) of the project (Fig.1) (Balbi S., 2012).

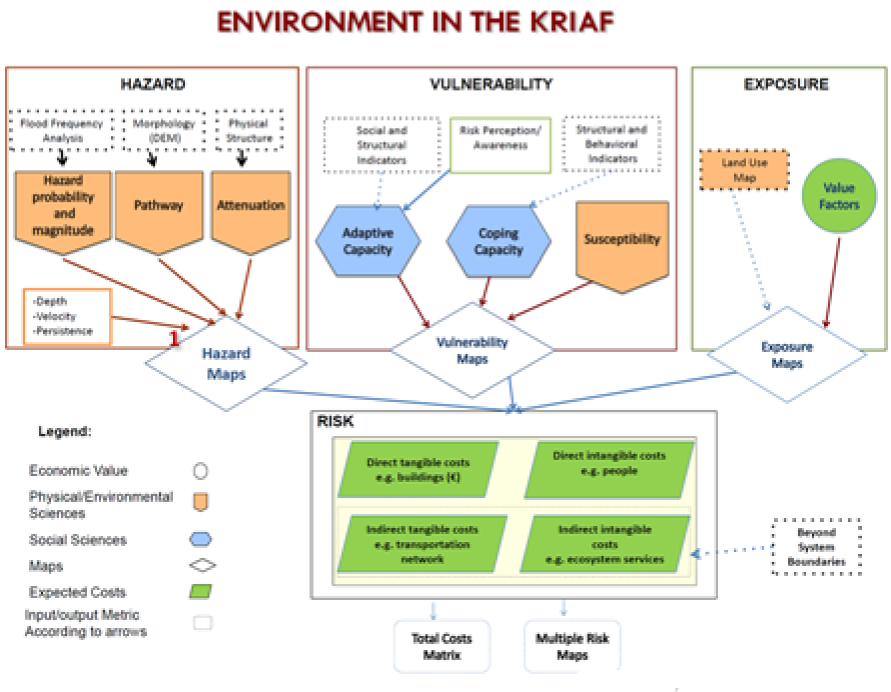


Fig.2.1 KULTURisk Framework (Balbi et al., 2012).

At first it's important to clearly define the concept of risk. " Risk is the possibility that a natural or man-made phenomenon may cause damage to the population, inhabitants, production areas and infrastructures in a given area in a certain period of times" (Protezione Civile); or following the definition of the IPCC "the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery" (IPCC-SREX,2012).

Concerning risk all the modern approaches agree on considering three factors to calculate it: hazard, exposure and vulnerability. Risk is therefore expressed by the formula proposed by various authors and authorities (IPCC, Eastern Alps Hydrographic District) and by KR WP1 Team (2012):

$$R = H * V * E$$

where:

H is = Hazard as: "the probability that a phenomenon of a certain intensity occurs in a certain period of time, in a certain area" (Protezione Civile); or "the potential occurrence of a natural or human induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources" (IPCC-SREX, 2012).

V is = Vulnerability as: "vulnerability of an element (people buildings, infrastructures, businesses) is the potential for damage following vibration caused by an event of a certain intensity" (Protezione Civile) and "is consisted of susceptibility as the P/E component and adaptive & coping capacities as the social component" (Mojtahed V. et al., 2013).

E is = Exposure or Exposed value as: "is the unit number (or 'value') of each of the elements at risk in a given area, like human lives or inhabited areas" (Protezione Civile); or "the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected" (IPCC-SREX, 2012).

These factors represent three out of the four components of the flowchart. The fourth derives from these three components and represents the economic quantification of the risk associated with different scenarios; for each component we can create a map which is used for a clearer visualization of the results.

In this work, regarding RRA, I will propose the methodology used by Eastern Alps hydrographic District that is partially different from the one proposed by the WP1 in the KR framework, but it was used in the case study presented in the following chapter and it's perfectly consistent with the methodology of the KR project.

RRA is represented in the flowchart by the orange boxes, whereas SERRA part is described in the blue boxes (social component) and in the green one (economic).

RRA is not part of the application of this study, but it will be presented to have a comprehensive framework of the work and in this case the procedure described is proposed by the Basin Authorities to calculate the hydrologic risk in their district.

The first frame concerns hazard. It is strictly connected with the physical characteristics of the area of study. Hydraulic experts are in charge of creating hazard map.

On the other hand, vulnerability derives from the interaction between physical-environmental and social component; the physical-environmental part of vulnerability is called susceptibility, whereas the social component will be divided into adaptive and coping capacity (Balbi S. et al., 2012). In the case of flood event, the social component could be represented by "the perception or awareness of the society of the possibility that a negative event occurs and by its capacity to react" (Mojtahed V. et al., 2013).
In this context social vulnerability is divided into:

a) Adaptive Capacity (AC): "the combination of the strengths, attributes, and resources available to an individual, community, society, or organization (ex-ante hazard) that can be used to prepare for an undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities" (IPCC-SREX, 2012 and Mojtahed V. et al., 2013);
b) Coping Capacity (CC): "the ability of people, organizations, and systems, using available skills, resources, and opportunities, to address, manage, and overcome (ex-post hazard) adverse conditions" (IPCC-SREX, 2012 and Mojtahed V. et al., 2013).

The social component of vulnerability is one of the focal points of the SERRA approach. The other modification made by SERRA is the Value Factor. "This is a set of several factors such as value of statistical life, willingness to pay or accept number of direct or indirect users" (Mojtahed V. et al., 2013). These factors support the decision makers in monetizing the damages and classifying them according to Mertz et al. (2010) in:

a) "direct tangible costs: the costs due to the damages provoked by the hazard and which occur during physical event, which can be easily specified in monetary terms;
b) direct intangible costs: value lost during physical event, which cannot, or are difficult/ controversial to be monetized because they are non-market value;
c) indirect tangible costs: damages and relative costs induced by the hazard but occurring, in space or time, outside the physical event, easily specified in monetary terms.
d) indirect intangible costs: damages and relative costs induced by the hazard but occurring, in space or time, outside the physical event, that are controversial to be monetized" (Mojtahed V. et al., 2013).

Value factor is one of the components of the exposure frame; the other one is the physical component of the exposure that is concretely represented by the land use. The RRA and SERRA methodologies will be exhaustively presented in the following section.

2.2.1 RRA

Hazard

As already mentioned, article 6 of 2007/60/CE identifies 3 scenarios which assess the hydraulic hazard:

a) " floods with a low probability, or extreme event scenario;
b) floods with a medium probability (likely return period ≥ 100 years);
c) floods with a high probability, where appropriate" (Flood Directive, 2007).

According to D. Lgs 49/2010 the return period associated to the scenarios are 30, 100 and 300 years.

Hydraulic engineers develop through hydraulic models the values *h* of maximum water depth and *v* of maximum flow velocity that occur during an overflow event in each point. The values given to the hazard are always normalized and included between 0 and 1. The reason why is given this type of value is to be able to combine these indices each other using different measure units into one non dimensional index. In this direction, it will be explained later on that all the values of the factors analyzed will be normalized in order to get a number between 0 and 1.

The concept of hazard only depends on the characteristics of the river basin. For this reason hazard could only be reduced using structural measures that change something in the river flow.

The methodology used by the Eastern Alps hydrographic District leads to obtain 3 hazard classes that are summarized in a unique values (between 0 and 1), giving different weights to the different return time (p.c.).

The receptors considered in the RRA are:

1) people (art.6-5 2007/60/CE) ;
2) economic activity (art.6-5 2007/60/CE) ;
3) environment and cultural heritages (art.6-5 2007/60/CE).

Vulnerability

Vulnerability is calculated for each of these receptors. In this context the physical-environmental component of vulnerability will be called susceptibility.

Susceptibility is defined as “the likelihood that receptors could potentially be harmed by any hazard given their structural factors, typology of terrain and characteristics (in physical and non-monetary terms” (IPCC 2012 and Mojtahed V. et al., 2013).

Obviously the safety of people is the most important aspect for any decision maker or stakeholder. Floods cause many injuries and fatalities, sometimes due to the lack of good emergency measures and a low level of preparedness of the population (EEA, 2010). In the explanation of the social vulnerability these elements will be examined and, in particular for people, turn out to be essential.

Regarding the physical factors, the Eastern Alps hydrographic District considers vulnerability connected to the Flood Hazard Rate (FHR). FHR is an index that considers the height (*h*) of the water, the velocity (*v*) and the debris factor (DF). According to Ramsbottom et al. (2004) and the project “Flood Risk to people” of the Department for environment, Food and Rural Affair (DEFRA, 2006), FHR is calculated using the following formula:

$$FHR = h\,(v + 0.5) + DF$$

The values of DF strictly depend on *h* e *v* and are in function of the land use. In particular the relation among these factors is represented in Tab 2.1.

Depths	Pasture/Arable	Woodland	Urban
0 to 0.25m	0	0	0
0.25 to 0.75m	0	0.5	1
d>0.75m	0.5	1	1

Tab 2.1 DF values (DEFRA).

At this point a vulnerability index (between 0 and 1) is given to different scenarios in relation to FHR values (Tab 2.2).

DESCRIPTION	FHR FIELDS	V_p
Caution: "flooded area by flowing water with low depth or stable but deep water "	FHR < 0.75	0.25
Hazard for someone (child): "flooded area by deep water or high velocity flow."	0.75 ≤ FHR < 1.25	0.75
Hazard for everyone: "flooded area by deep water or with high velocity flow"	FHR ≥ 1.25	1

Tab 2.2 Vulnerability values in function of FHR fields (AdB, Venezia).

This index represents the susceptibility value that will be used to calculate the total vulnerability index, taking into account the social component of vulnerability, represented by adaptive and coping capacity.

The economic activities, that are the second receptor considered, are divided in 3 sub-classes:

a) buildings (art. 6.5 D. Lgs. 49/2010) ;
b) infrastructure (art. 6.5 D. Lgs. 49/2010) ;
c) agriculture and natural and semi-natural environment (art. 6.5 D. Lgs. 49/2010).

The three macro-categories are better classified in the land use classes reported in Tab. 2.3.

COD	DESCRIPTION
1	Residential
2	Hospital, social assistance structures
3	Public buildings
4	Commercial and craft
5	Industrial
6	Agricultural
7	Agricultural not defined such as forest, grassland, grazing land, cemeteries, urban parks.
8	Touristic-entertaining
9	Unproductive
10	Skiing area, Golf camp, Riding stables
11	Camping
12	Transport and communication network: primary road
13	Transport and communication network: secondary road
14	Railway zone
15	Touristic area; Collective equipment area; Collective equipment area over municipality, Collective equipment in the subsoil.
16	Technologic and service infrastructures
17	Structure to support communication and transport network (airports, harbours, service area., parking)
18	Energy production area
19	Landfills, Waste treatment plants. Extractive areas, Waste water treatment plant
20	Area with installation explained in the legislative decree 18 February 2005, n. 59
21	Cultural-historical and archaeological relevant area.
22	Environmental heritages
23	Military zone.

Tab 2.3 Land use classes (Adb, Venezia).

In case of flooding, the buildings could collapse due to the water pressure or the undermining of foundation. The resistance of a building strictly depends on its own characteristics. Age, material and type (single or multi-storied) are the main properties considered in this work (Mojtahed V., 2013).

Eastern Alps hydrographic District assigns vulnerability index in relation to the values of h and v, according to Clausen and Clark (1990) (Tab. 2.4).

DESCRIPTION	***h* and *v* FIELDS**	V_E
Damages similar to that produced by a natural low depth flood.	if h < 0.5	0.25
Moderate damages, as doors and windows thrown to the ground, partial damages to “internal goods” and small damages to the main structural elements of buildings.	v < 2 m/s if 0.5 ≤ h < 2 m; v ≥ 2 m/s if h · v < 4 m^2/s and h ≥ 0.5	0.75
Total collapse or major damages to buildings that need demolition and rebuilding.	v < 2 m/s if h ≥ 2 m; v ≥ 2 m/s if(h · v) ≥ 4 m^2/s	1

Tab 2.4 Assignment of vulnerability to buildings (AdB, Venezia)

Damage to the infrastructures is crucial to consider not only because of the possible direct economic losses, but also because an inundated road causes the interruption of the service. The consequences of this interruption have repercussions for the emergencies measures, the local economy and the citizen’s or commercial transportation. Based on empirical experiments of the *Australian Rainfall and Runoff (AR&R) Project n 10* (2011), it has been adopted the vulnerability function presented in Tab. 2.5.

DESCRIPTION	***h* and *v* FIELDS**	V_E
Possible low damages to vehicle whose stability is not affected; restricted inconvenience in the use of the infrastructure.	v < 1 m/s if h < 0.3 m; v ≥ 1 m/s if h · v < 0.3 m^2/s	0.25
Possible partial damages to vehicle whose stability is in critical condition; possible inconvenience in the use of the infrastructure.	v < 1 m/s if 0.3 ≤ h < 0.5 m; v ≥ 1 m/s if 0.3 ≤ h · v < 0.5 m^2/s	0.75
The vehicle lost the stability condition and relevant damages occur that compromise the future of the vehicle; the infrastructure cannot be used (is not practicable)	v < 1 m/s if h ≥ 0.5 m; v ≥ 2 m/s if h · v ≥ 0.5 m^2/s	1

Tab 2.5 Assignment of vulnerability to infrastructures (AdB, Venezia).

The last macro-category considered is agriculture. Floods can produce serious damage to agriculture (Carrera et al., 2012) and consequently to the agricultural workers and the relative economy. According to Citeau (2003), different types of cultivation have different tolerance levels in relation to the height and the velocity of water. For instance, maximum height and velocity tolerate by an orchard are 1 m 0.5 m/s respectively for vineyard and maximum velocity varies from 0.25m/s for land vegetables to 0.5 m/s for orchard. In the following Tables (from 2.6 to 2.9) vulnerability values associated with different *h* and *v* and different cultivation types are presented.

DESCRIPTION	*h* and *v* FIELDS	V_E
Tolerable height and velocity for a specific agricultural land.	if $v \leq 0.25$ m/s and $h \leq 0.5$ m	0.5
Not tolerable height and velocity for a specific agricultural land	Otherwise	1

Tab2.6- Assignment of vulnerability to vineyards (AdB, Venezia).

DESCRIPTION	*h* and *v* FIELDS	V_E
Tolerable height and velocity for a specific agricultural land	if $v \leq 0.5$ m/s and $h \leq 1$ m	0.5
Not tolerable height and velocity for a specific agricultural land	Otherwise	1

Tab2.7- Assignment of vulnerability to orchard and olive trees (AdB, Venezia).

DESCRIPTION	*h* and *v* FIELDS	V_E
Tolerable height and velocity for a specific agricultural land.	if $v \leq 0.25$ m/s	0.5
Not tolerable height and velocity for a specific agricultural land	Otherwise	1

Tab2.8- Assignment of vulnerability to vegetables (AdB, Venezia).

DESCRIPTION	*h* and *v* FIELDS	V_E
Tolerable height and velocity for a specific environment	if $v \leq 0.5$ m/s and $h \leq 1$ m	0.25
Not tolerable height and velocity for a specific environment	Otherwise	0.5

Tab2.9- Assignment of vulnerability to natural and semi-natural environment (AdB, Venezia).

Directive 2000/60 and Italian law consider the environment and the cultural heritage as the last receptor. However, it's not easy to define a clear vulnerability function for this category of receptors. Regarding the environment, the Eastern Alps hydrographic District, according to Habitat Directive (92/43/CEE) and Birds Directive (79/409/CEE), assigned vulnerability equal to 1 to that area of the network Nature 2000 where IPPC or other relevant pollution sources are present. If not, the values associated to the environment correspond to the values presented in Table 2.9 for the natural and semi-natural environment. Cultural heritage's vulnerability is even harder to define and maybe there are not enough cognitive and scientific elements to establish a specific vulnerability value. For this reason the Eastern Alps hydrographic District has chosen to associate to those elements a vulnerability index equal to 1.

Exposure

“The potential for a hazard to cause a disaster mainly depends on how vulnerable an exposed community is to such hazards” (EEA, 2010). For this reason, after the discussion over vulnerability, the calculation of exposure must be presented.

Exposure, as vulnerability, refers to people, economic activity and environment and cultural heritages.

Concerning people, in the approach of the Basin Authority of Venice, exposure is characterized by two factors:

a) number of people located in an area expressed by a density factor (Fd)
b) the duration of human presence, represented by the duration factor (Ft). Ft is a quotient between the supposed duration permanence in a place and the 24 hours of a day (PGUAP- Provincia Autonoma di Trento- DPR 15/02/2006).

In Table 2.10 there are summarized the Ft values referred to the different land uses.

COD	DESCRIPTION	F_t
1	Residential	1
2	Hospital, social assistance structure	1
3	Public buildings	1
4	Commercial and craft	0.5 ÷ 1
5	Industrial	0.5 ÷ 1
6	Agricultural	0.1 ÷ 0.5
7	Agricultural not defined such as forest, grassland, grazing land, cemeteries, urban parks.	0.1 ÷ 0.5
8	Touristic-entertaining	0.4 ÷ 0.5
9	Unproductive	0.1
10	Skiing area, Golf camp, Riding stables	0.3 ÷ 0.5
11	Camping	1
12	Transport and communication network: primary road	0.5
13	Transport and communication network: secondary road	0.5
14	Railway zone	0.7 ÷ 1
15	Touristic area; Collective equipment area; Collective equipment area over municipality, Collective equipment in the subsoil.	1
16	Network infrastructure, Communication infrastructure.	0.3 ÷ 0.5
17	Structure to support communication and transport network (airports, harbours, service area., parking)	0.7 ÷ 1
18	Energy production area	0.4
19	Landfills, Waste treatment plants. Extractive areas, Waste water treatment plant	0.3
20	Area with installation explained in the legislative decree 18 February 2005, n. 59	0.9
21	Cultural-historical and archaeological relevant area.	0.5 ÷ 1
22	Environmental heritages	0.5 ÷ 1
23	Military zone.	0.1 ÷ 1

Tab 2.10 Assignment of Ft values to several land use classes (AdB, Venezia).

The total exposure for people (Ep) is calculated by:

$$Ep = Fd * Ft$$

Flood Directive and Italian normative require the description of the type and the spatial allocation of the economic activities in the flooded area. The relative exposure (Ee) will be also used in the SERRA methodology as physical exposure of the receptors. The following table presents the Ee values adopted by the Eastern Alps hydrographic District.

COD	DESCRIPTION	E_E
1	Residential	1
2	Hospital, social assistance structure	1
3	Public buildings	1
4	Commercial and craft	1
5	Industrial	1
6	Agricultural	0.3 ÷ 1
	Agricultural not defined such as forest, grassland, grazing land, cemeteries, urban parks.	0.3
8	Touristic-entertaining	0.5
9	Unproductive	0.1
10	Skiing area, Golf camp, Riding stables	0.3 ÷ 1
11	Camping	0.5
12	Transport and communication network: primary road	1
13	Transport and communication network: secondary road	0.5 ÷ 1
14	Railway zone	1
15	Touristic area; Collective equipment area; Collective equipment area over municipality, Collective equipment in the subsoil.	0.3
16	Network infrastructure, Communication infrastructure.	1
17	Structure to support communication and transport network (airports, harbours, service area., parking)	1
18	Energy production area	1
19	Landfills, Waste treatment plants. Extractive areas, Waste water treatment plant	0.5
20	Area with installation explained in the legislative decree 18 February 2005, n. 59	1
21	Cultural-historical and archaeological relevant area.	1
22	Environmental heritages	1
23	Military zone.	0.1 ÷ 1

Tab 2.11 Assignment of Ee values to several land use classes. (AdB, Venezia).

At last, to define the exposed value of an environmental or cultural component, the procedure is similar to the ones already seen. They’ve considered the different land use classes and the possible modification induced by a flood, giving an Een (exposure environment) value to each cod class (Tab. 2.12).

COD	DESCRIPTION	E_{EN}
1	Residential	1
2	Hospital, social assistance structure	1
3	Public buildings	1
4	Commercial and craft	0.8
5	Industrial	0.3 ÷ 1
6	Agricultural	0.7
7	Agricultural not defined such as forest, grassland, grazing land, cemeteries, urban parks.	0.7
8	Touristic-entertaining	0.1
9	Unproductive	0.3
10	Skiing area, Golf camp, Riding stables	0.3
11	Camping	0.1
12	Transport and communication network: primary road	0.2
13	Transport and communication network: secondary road	0.1
14	Railway zone	0.7
15	Touristic area; Collective equipment area; Collective equipment area over municipality, Collective equipment in the subsoil.	0.3
16	Network infrastructure, Communication infrastructure.	0.1
17	Structure to support communication and transport network (airports, harbours, service area., parking)	1
18	Energy production area	1
19	Landfills, Waste treatment plants. Extractive areas, Waste water treatment plant	1
20	Area with installation explained in the legislative decree 18 February 2005, n. 59	1
21	Cultural-historical and archaeological relevant area.	1
22	Environmental heritages	1
23	Military zone.	0.1 ÷ 1

Tab 2.12 Assignment of Een values to several land use classes (AdB, Venezia).

Risk

As already seen at the beginning of this section the formula to calculate the risk is:

$$R = H * V * E$$

It's possible to calculate it for each receptor considering the specific values of vulnerability and exposure:

$Rp = H * Vp * Ep$

$$Re = H * Ve * Ee$$

$$Ren = H * Ven * Een$$

Once the specific risk determination is concluded, the way in which the Eastern Alps hydrographic District calculates the total risk is by assigning a weight to each specific risk. The highest value is given to the 100 years return time scenario. Considering that each component has a value between 0 and 1, the total Risk also assumes a value in that interval.

In order to define risk classes, there are 4 intervals identified; each one belongs to a different risk category as shown in Table 2.13.

R INTERVALS	**DESCRIPTION**	**Risk category**
$0.1 < R \leq 0.2$	Moderate Risk for which relative social economic and environmental damages are negligible or nulls.	R1
$0.2 < R \leq 0.5$	Medium Risk for which are possible minor damage to buildings, infrastructures and environmental heritage that do not compromise people safety, buildings use and economic activities functionality.	R2
$0.5 < R \leq 9$	High Risk for which is possible problems for people safety, functional damages to buildings and infrastructures, interruption of socio economic activities and damages to environmental heritage.	R3
$0.9 < R \leq 1$	Very High Risk for which there are possible loss of human lives and serious injuries to people, serious damages to buildings, infrastructures and environmental heritage and the destruction of socio economic activities.	R4

Tab 2.13 Definition of risk classes (AdB, Venezia).

2.2.2 SERRA

Social-RRA

In the previous section it has been presented the physical dimension of vulnerability. In this part the attention will be focalized over the human and physical dimension of vulnerability (Mojtahed V.et al., 2013).

SERRA tries to offer a new methodology to assess the social and economic consequences due to an adverse event. The main problem results in the vulnerability assessment. As already seen in the framework, SERRA will be used in the evaluation of the human dimension of vulnerability (Adaptive Capacity and Coping Capacity), and in the calculation of costs, considering the Value Factor as exposure.

Vulnerability derives from different social and ecological variables and this cannot be objectively measured by "using a well-defined static or dynamic model" (Giupponi et al., 2012). SERRA methodology has created a subjective way to estimate it through the use of indicators, normalization, weighting and aggregation.

The selection of the indicators is the first step of the analysis. The choice strictly depends on the application context. Another focal point is the type of event that is studied. Obviously the indicators for assessing floods are different from the indicators of earthquake risk (Mojtahed V. et al., 2013). The deliverable 1.6 of KR-FWK provides the preliminary list of the indicators chosen for adaptive and coping capacity, selected based on the literature e.g. Cutter et al. (2003), Cutter and Finch (2008), Steinführer et al. (2008), MOVE (2011).

The list of the indicators used in this work is available in Appendix 1. The list presents the three components to evaluate: AC, CC and susceptibility. The indicators are brought together into variables that represent different characteristics of the system.

The receptors considered are: population (P), economic activities, natural and semi-natural system and cultural heritages (CH). In particular "the economic activity is classified into building (B), infrastructure (I), agriculture (A). Buildings are of 2 types: residential (R) and commercial and industrial (CI) which are further classified into three categories: structure (S), content (C), business activity (B)" (Mojtahed V. et al., 2013). Natural and semi-natural systems are not considered as receptors because in this case the human component of vulnerability seems to be not relevant.

After the selection of the indicators and the data collection, all the data must be normalized weighted and aggregated by several existing procedures of weighting and aggregation. In this section it is useful to give a brief description of these procedures that will be analyzed deeply in the case study.

Normalization "is the procedure of transforming indicator values with different units of measure into a dimensionless number" (Mojtahed V. et al., 2013). The aim is to obtain values between 0 and 1 in order to get a total vulnerability value that belongs to the same interval. Several normalization techniques exist in literature (OECD, 2008 and KR WP1, 2012) but the Value function is the one chosen in this context. "Value functions are the mathematical representations of human judgements, which offer the possibility of treating people's value and judgements explicitly, logically and systematically" (Beinat, 1997 and Mojtahed V. et al., 2013). In the case study, a designed questionnaire should be given to the experts in order to obtain a function with upper and lower thresholds. The lowest value will be normalized as zero, which represents no vulnerability; on the other hand the highest value will assume a value equal to 1 and will represent a fully vulnerable situation. All the values in between will be normalized following the function.

The next step, after normalization procedure is the weighting. Not all the indicators contribute the same to the aggregated vulnerability index of a certain receptor. For this reason, they need to be weighted and aggregated "in accordance with the logical conceptual model, but also according to the elicited preferences of the Decision Makers (DMs)" (Mojtahed V. et al., 2013).

Three most common aggregation methods are the following:

a) weighted averages (WA);
b) geometric averages (GA);
c) non-additive measures (NAM).

In this study only two of these methods will be used: the WA and the NAM. In both the methodologies stakeholders need to be involved in order to obtain their opinion over the proposed indicators. Once the results of the questionnaires will be analyzed, according to the stakeholder's preferences, a weight will be assigned to each indicator following different methodologies.

At this point, an aggregated vulnerability index per receptor will be obtained and the relative value is included between 0 (not vulnerable) and 1 (fully vulnerable).

As already seen in the RRA methodology, also SERRA needs to be applied for each receptor. A brief description of this application will be now presented to better understand the procedures used in the case study.

People is the first receptor considered; the people's vulnerability "is determined by the characteristics of susceptible buildings where they live and the available social capacities to cope and adapt with the flood hazard" (Mojtahed V. et al., 2013). In the case of people the social preparedness is a crucial topic. While building cannot be moved from one place to another even if there is an optimal emergency measures, people can easily be protected by improving EWS, emergency measures and insurance coverage. The adaptive and coping capacity could be improved with minimum effort and sometimes the results obtained could be greater than the results obtained using some structural intervention. In this case, building properties are considered as susceptibility and represent the physical dimension of the total people vulnerability while the human component of vulnerability is calculated through several social indicators. The first step is the collection of the data and then they need to be normalized and aggregated. In the Fig. 2.2 it's represented an example of aggregation structure.

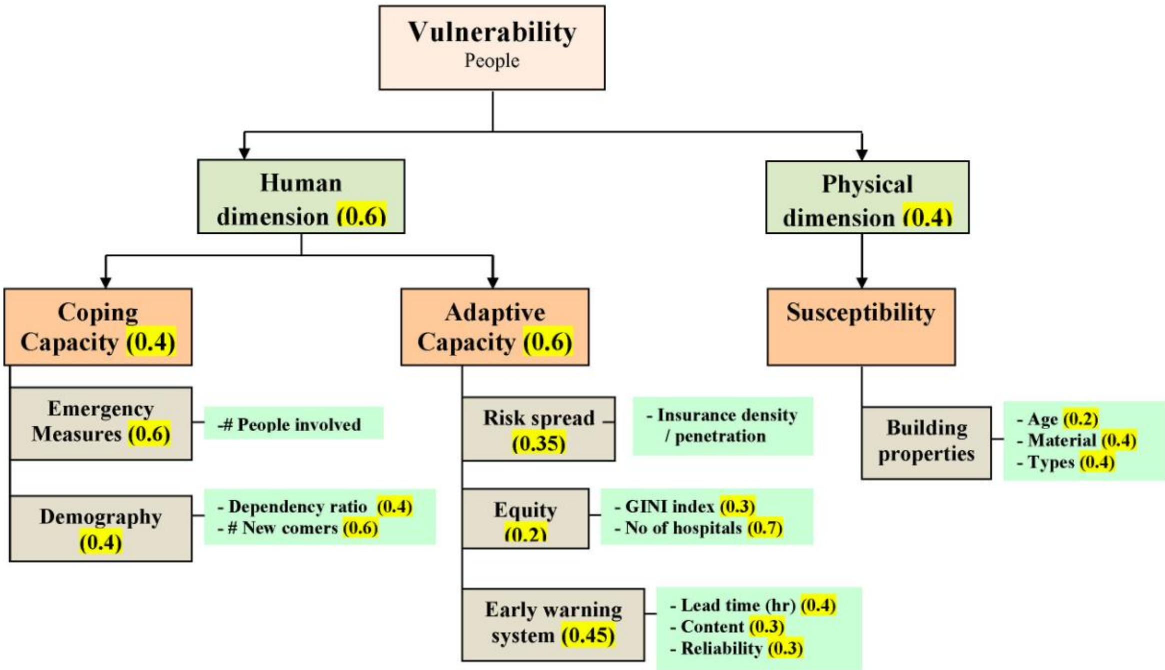


Fig.2.2 Hierarchical combination of indicators with relative weights highlighted (Mojtahed V. et al., 2013).

The weights given for each indicator should derive from the analysis of the questionnaire of the stakeholders, but in this work weights are choose thanks to expert's consultation. The principle aim of this procedure is assigning a value between 0 and 1 to the people vulnerability, considering the relative weight of each indicator.

The same procedure that considers the convergence nodes and weights for the indicators will be applied for the other receptors.

Economic activity is the second receptor taken into account and it is divided in:

a) buildings;
b) infrastructures;
c) agriculture (Mojtahed V. et al., 2013).

Regarding buildings, this category is further divided in 3 sub receptors: structure, content and business activity. Concerning structure and content, susceptibility, as in the case of people, is represented by the building properties (age, type and material), while the susceptibility of business activity takes also into account the broad economy considering interconnectivity and specialization as useful indicators for the physical dimension. Adaptive and coping capacity present different indicators depending on the characteristics of the receptors. Obviously the number of people involved in the emergencies has no relevance in the vulnerability of the building structure, whereas it assumes a big importance in the vulnerability of the building content and business activity. A detailed discussion over the indicators will be treated in the application case study. The following figures (Fig. 3, 4, 5) show the hierarchical combination of thee indicators in the theoretical framework.

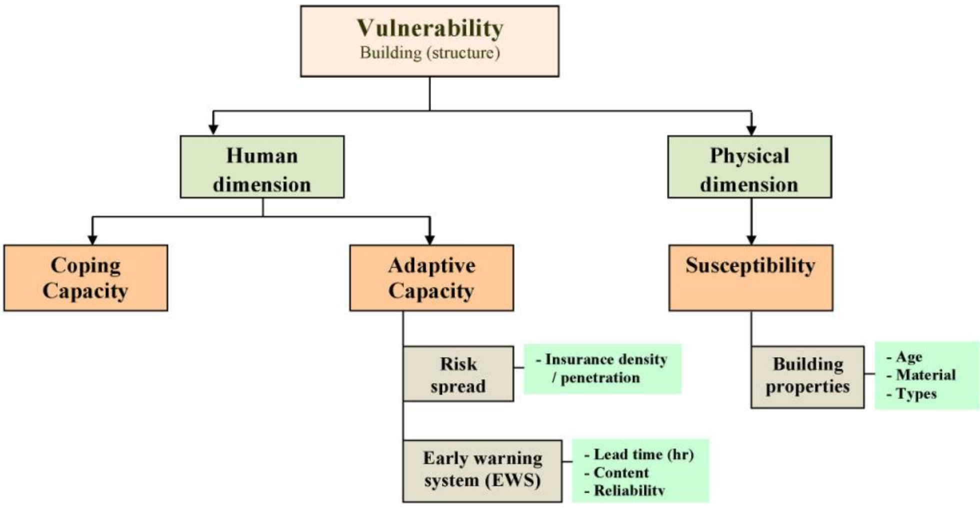


Fig. 2.3 Hierarchical combination of indicators for the structure of buildings (Mojtahed et al., 2013).

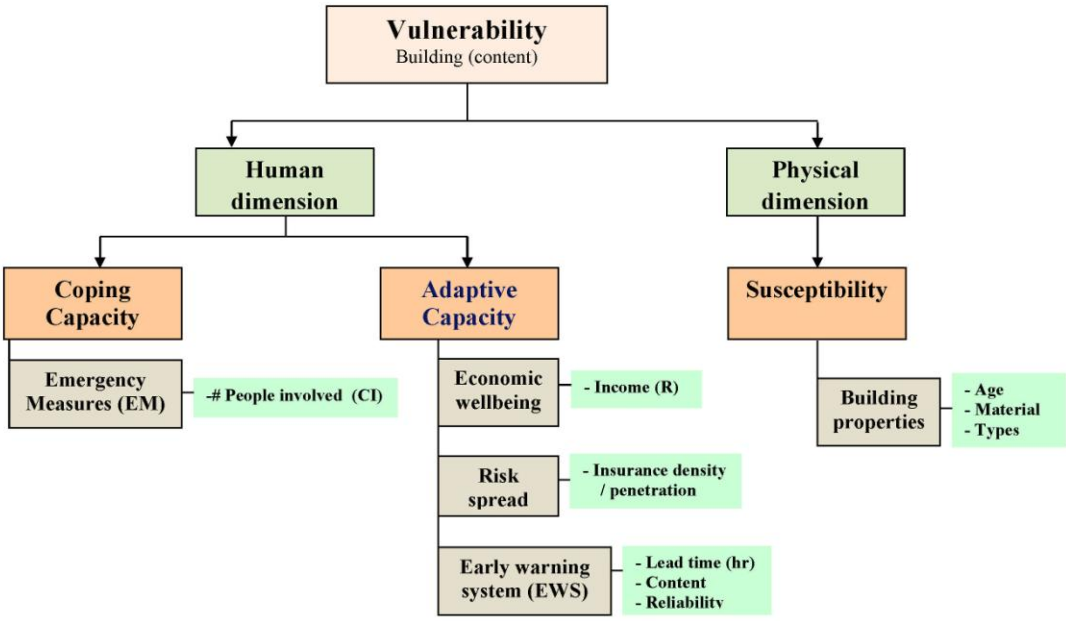


Fig. 2.4 Hierarchical combination of indicators for the content of buildings (Mojtahed et al., 2013).

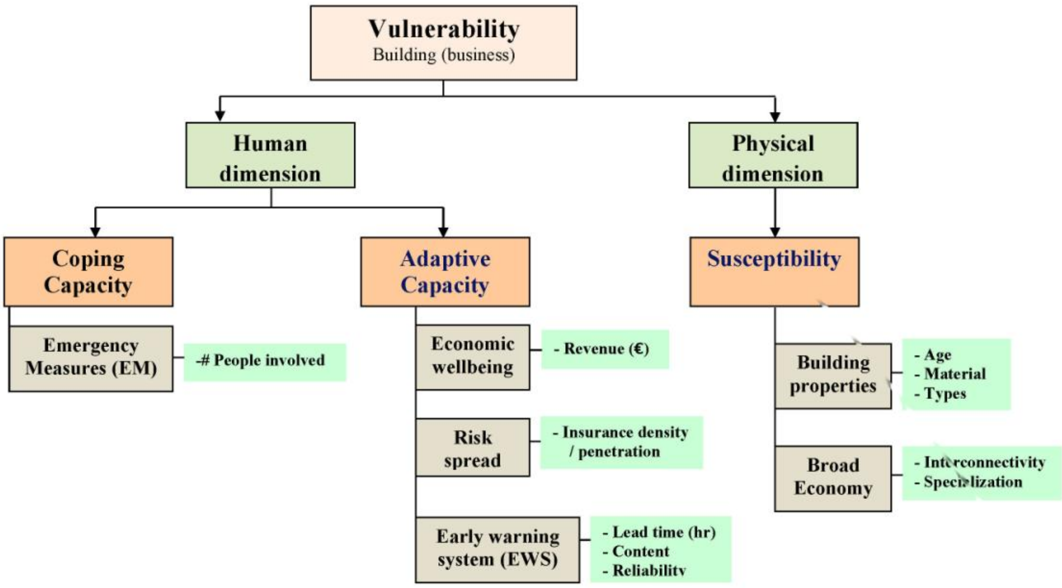


Fig. 2.5 Hierarchical combination of indicators for the business activity (buildings) (Mojtahed et al., 2013).

Infrastructure is the following receptor to be considered. The transport of the goods is a focal point in the economy. If the flood damages the infrastructure the interconnectivity and the network properties will be seriously affected. These indicators indeed represent the susceptibility while adaptive and coping capacity only take into account emergency measures and EWS. Also in this case the weight will be given according to stakeholder's preferences.

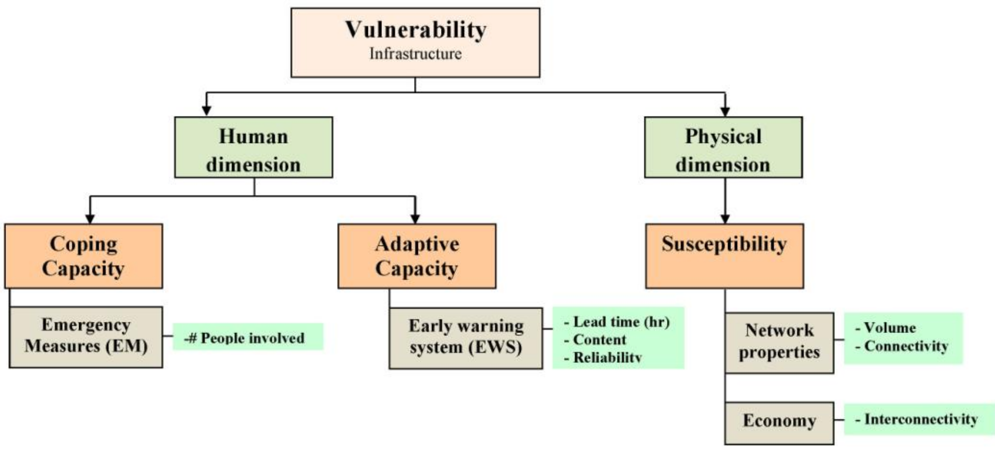


Fig 2.6 Hierarchical combination of indicators for Infrastructure (Mojhated et al., 2013)

Agriculture is the last receptor considered in the economic activities. Losses in this sector strongly affect the economy and the wellness of the population. For this reason the vulnerability assessment assumes a particular relevance. The susceptibility is represented by flood timing (season and inundation duration) and economy, whereas adaptive and coping capacity are characterized by emergencies measure, EWS and risk spread.

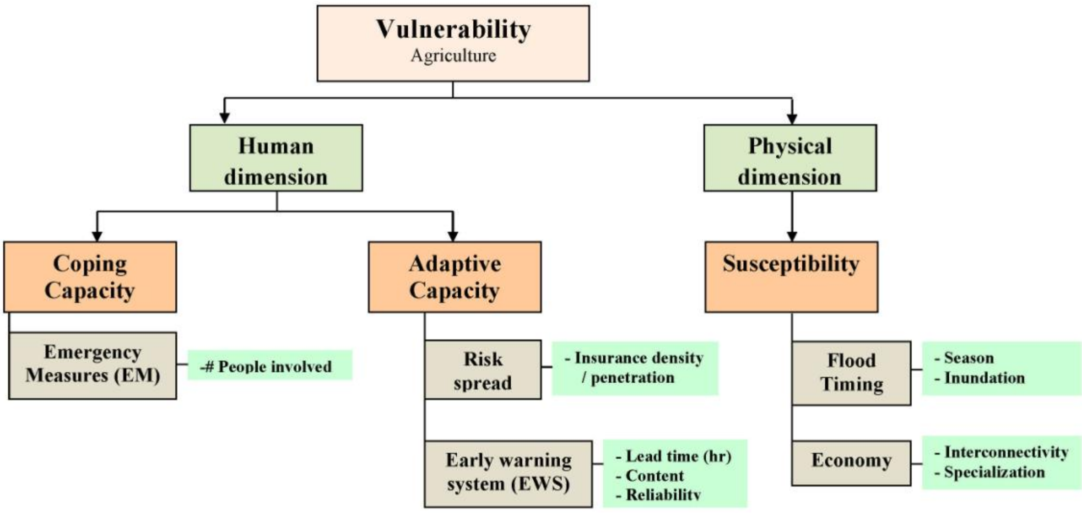


Fig. 2.7 Hierarchical combination of indicators for Agriculture (Mojhated et al., 2013).

Concerning natural and semi-natural system, the physical vulnerability is considered enough, whereas for the cultural heritage it's also taken into account the social vulnerability. Susceptibility is described by building properties and adaptive and coping capacities are quantified through emergency measures and EWS. The figure (Fig. 2.8) below shows this combination.

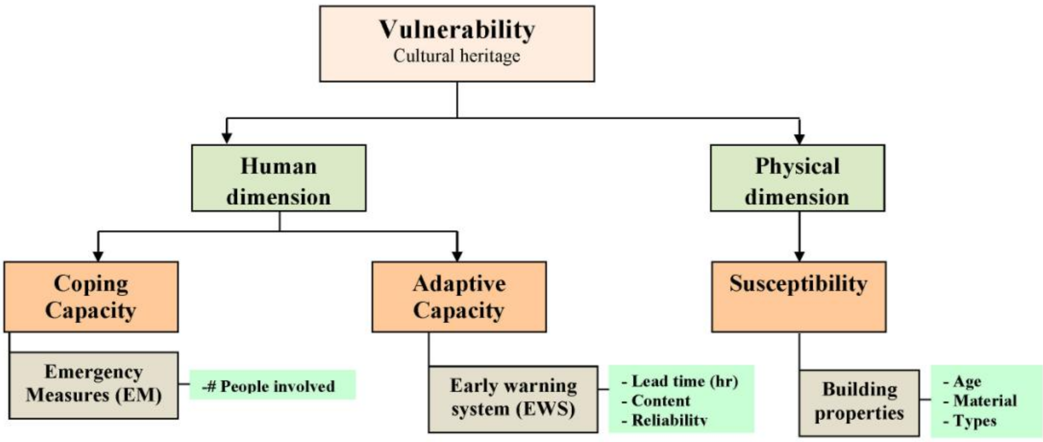


Fig. 2.8 Hierarchical combination of indicators for Cultural heritage (Mojtahed et al., 2013).

Once all the receptors will be analyzed, the vulnerability values will be used in the calculation of the total flood risk. In the application of the methodology something could be subjected to change due to lack or inconsistence of some data.

Economic-RRA

The economic approach of the SERRA methodology is probably the most important because it helps the DMs to choose the best option, focusing the different scenario.

The first step of the economic analysis consists of identifying the costs due to a flood event of a given hazard in a given space. This evaluation allows the decision makers and the stakeholders to know which are the costs associated with a flood event of a precise intensity without any prevention measure. This preliminary study will be called *baseline scenario*. Further, there will be considered several possible preventive measures that represent the different *alternative scenarios.* In this case the evaluation of costs will take into account also the costs of the preventive measure itself so that, calculating the difference between the *baseline* and the *alternative scenario*, the decision makers could understand the benefit derived from each option.
As explained in the Deliverable 1.6 of the KULTURisk project, SERRA aims to obtain not only the direct tangible costs, but also the indirect and intangible costs “in view of providing a comprehensive quantification of risk” (Balbi et al., 2012).
In particular, in the Deliverable 1.6 is presented the Total Cost Matrix (Fig. 2.9) that considers all the direct, indirect, tangible and intangible cost.

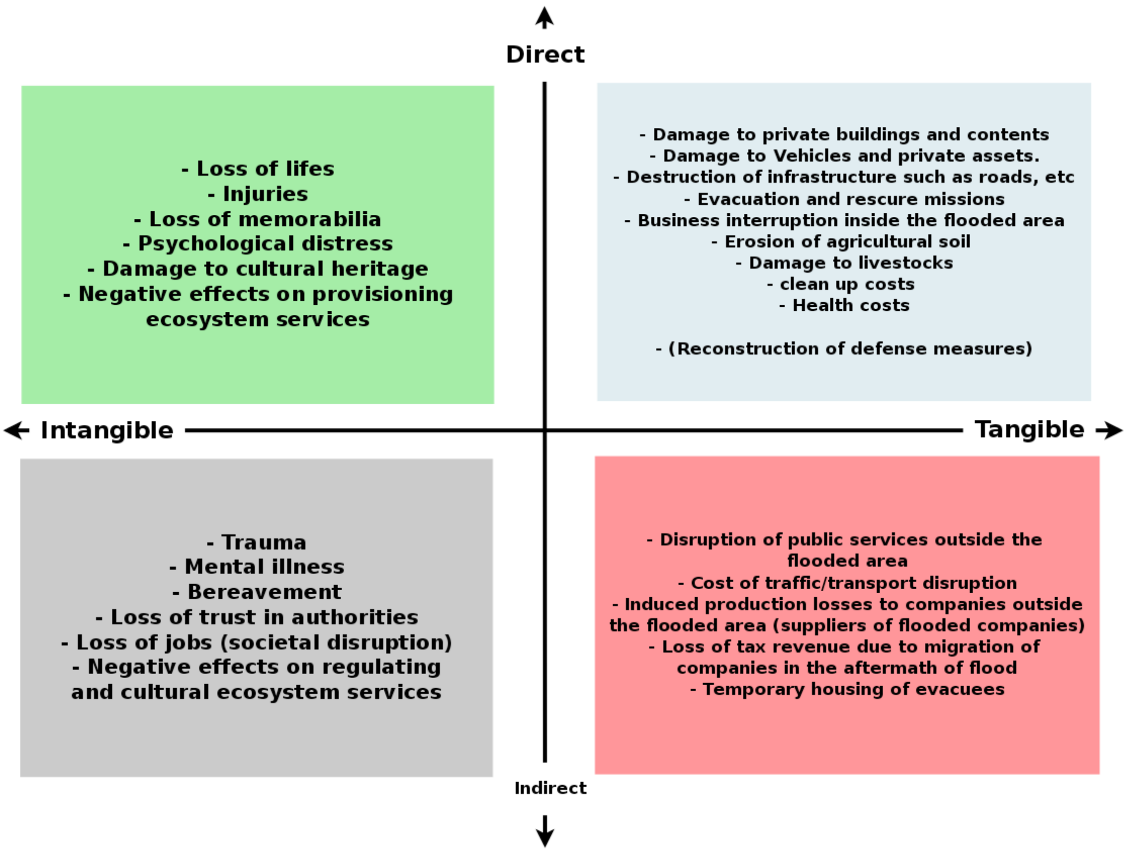


Fig. 2.9 The Total Cost Matrix, adapted from: Penning-Rowsell et al. (2003), Jonkman et al. (2008), and Merz et al. (2010).

In the deliverable 1.4 of the KULTURisk project is widely presented the theoretical economic evaluation. The identification and the monetization of tangible costs is not a trivial task. "Tangible costs derive from the impacts on the economic system. Economic cost can be generally broken down into damage costs (or losses), adaptation costs and residual damage costs" (Balbi et al., 2012). On the other hand, the fully quantification and monetization of the intangible costs is quite difficult to accomplish; firstly because it's not easy to identify them and secondly because even if they have been recognized it's quite hard to monetize them. The reason why the monetization is so controversial is due to the ambition to give a monetary value to things such lives, psychological trauma or injuries that assume a value that obviously go beyond the simple economic evaluation. Nevertheless, to obtain a comprehensive and realistic vision of the problem it's necessary to try to overcome this issue. Furthermore, the quantification of indirect and intangible cost assumes a big importance in the evaluation of the non- structural measures; for instance EWS "could only partially reduce the amount of direct tangible costs, but it can:

a) save the lives of many people (direct intangible costs);

b) change behaviour of people by avoiding long lasting trauma (indirect intangible costs)
c) prevent evacuation costs (indirect tangible costs)" (Balbi et al., 2012)

As already specified above, the costs analysis should include the evaluation of costs of the *baseline scenario* and *alternative scenarios* in order to give to the DMs all the elements needed for a comprehensive comparison of the risk prevention measures. The decision makers can use several methods for the appraisal of measures and projects; in this study three of those methods will be discussed:

a) cost-benefit analysis (CBA);
b) cost-effectiveness analysis (CEA);
c) multi-criteria analysis (MCA) (Balbi et al., 2012).

The main difference among these three methods regards the type of income data requested and the outcome solution proposed. CBA is particularly useful when "objectives and impacts (..) can be stated in monetary terms" (Balbi et al., 2012). On the other hand, CEA and MCA are appropriate when the impacts and the objectives are not expressed in monetary terms. Anyway, CEA and MCA could be used also if all the elements assume an economic value, whereas CBA could not be used if there are some non-monetary values (Balbi et al., 2012). The decision criteria in a CBA are three different types: net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) (Kruschwitz, 2003 and Balbi et al., 2012). The first one is define as "the difference between the discounted benefits and the discounted costs of a project". If the difference shows a positive value it means that the project is favourable and convenient. The second method considers the ratio between the discounted benefit and the discounted costs of a project. If the BCR is higher than 1 the project should be considered advantageous (Bründl et al., 2009). The last "criterion is the internal rate of return (IRR), which is the rate of return that renders an NPV equal to zero. The internal rate of return is that interest rate, at which discounted benefits and costs of a project are equal. A project is recommendable, if the IRR is higher than the level of a certain reference interest rate" (Balbi, et al, 2012).

CEA procedure begins with the goal analysis. Despite of the CBA, the CEA can distinguish several goals and objectives and it is able to analyze it separately. The partial effects could be measured in a qualitative way, using evaluation categories such "satisfying/unsatisfying", or classified in ordinary category like "higher, equal, lower". To obtain a concrete difference among the alternatives analyzed, the effects have to be quantified through cardinal scale. In this way it is achievable not only the information about the most effective alternative but also a numeric difference between one and another scenario. After this step the results are represented in a matrix with the different alternatives. For each partial goal it is shown the costs and the respective effectiveness. Only if one alternative project proves to be superior to all the other alternatives in all the partial goals, can be judged as the best one. In the other cases, two or more alternatives will be presented to the DMs.

The third instrument is the multi-criteria analysis. As in the CEA, also MCA considers different goal and objectives and tries to find the best alternative among the project proposal. The main difference regards the solution provided to the DMs. While a cost effectiveness analysis is not always able to point out the best option, through MCA a weight is given to the different partial goal and it let to obtain the best alternative. The sub-goals may take less or more importance according to the different weight assigned (Boardman et al., 2001).

The weight can be chosen through direct or indirect approaches; the direct approaches are mainly represented by questionnaire provided to different experts or stakeholders such as members of Parliaments, civil servants, other political responsible representatives and so on. The indirect approach is chiefly based on historical data. The assignment of the weight is the focal point in the MCA, since the weights given to the different partial goals change the final results (Balbi et al., 2012).

In this case study there will be used both the costs-benefit and the costs-effectiveness analysis. The costs-benefit considers the total costs of the baseline in relation with the total cost of the alternative scenario. As the alternative scenario considered consist in the EWS, the analysis takes into account the installation costs, the probability of false and missed alarms and the difference between the EWS and the baseline scenarios. After the explanation of the different methods used to appraise the cost and the benefit derived from the different alternative scenario, now the attention will be focus on the characterization of "the set of value factors and the methods for systematically assessing each type of damages for receptors" (Mojtahed et al., 2013). Basically in this work I have used depth damage functions that correlate the economic damage with the water depth.

In particular there are analyzed people and buildings that are the receptors considered in the case study; at last there are presented also the analysis of the other receptors in order to give a complete framework of the SERRA aims.

People

Also in this case people is the most important receptor that has to be considered. The SERRA methodology has not only the aim to estimate the number of possible deaths, but also to evaluate psychological trauma and injuries caused by a flood event. In order to calculate the number of people at risk SERRA uses two functions that need to be introduced: the Flood Severeness (FS) and the Vulnerability index (Vi). Flood Severeness is defined as "a function of flood frequency (P), flow velocity (FV), inundation depth (ID) and presence of Debris Factor (DF)"(Mojtahed et al., 2013).

$$FS = f(P, FV, ID, DF)$$

The vulnerability index it's a product of People Vulnerability (PV) and Area Vulnerability (AV). The people vulnerability is a value derived from all the evaluation presented in the social section of SERRA, while area vulnerability depends on EWS, speed of onset, and type of buildings.

To have a comprehensive view of this function the KR WP1 Team has made a comparison of DEFRA and SERRA methodology. Indeed DEFRA methodology was widely used in the RRA development. The relationship found between DEFRA and SERRA methodology was considered consistent , but further study are necessary on this point. As seen in the vulnerability assessment in the RRA explanation, the formula of HR proposed by DEFRA is:

$$HR = d * (v + 0.5) + DF$$

Once the hazard and the vulnerability are calculated, SERRA proposed the following equation to obtain the number of people at risk (n.p.r) :

$$n.p.r = n * FS * Vi$$

where n is the number of people in the flood zone, FS is the flood severeness and Vi the vulnerability index.

At this point two indexes called α and β must be introduced to quantify the possible death and injuries among the total number of people at risk. In SERRA methodology α and β has respectively a value equal to 1 and 1.5. Alpha and Beta are calibrated based on historical data events.

The following formula express the number of possible injuries (n. Inj.) and death (n.dth.) people in relation with FS, Vi and the α and β coefficients.

$$n.inj = (n.p.r. * \alpha * Vi)$$

that combined with the previous one:

$$n.inj = n * FS * \alpha * (Vi)^2$$

and

$$n.dth = \frac{n.inj * \beta * FS}{10}$$

that becomes:

$$n.dth = \frac{n * (FS)^2 \ * \alpha * \beta * (Vi)^2}{10}$$

These formula represent the number of hypothetic death and injuries in case of a flood of given intensity in a given time and space. With this values is possible to calculate the total costs; for possible death this value is multiplies for the value of statistical life (VSL) (e.g OECD, 2012) that corresponds to € 3.1 M; and for injuries the value is estimated as VSL*0.02.

Economic activities are the second receptors considered in a economic assessment. As in the social part this receptor is further categorized in: buildings, infrastructure and agriculture.

Buildings

Buildings are, in turn, divided in contents and structures. The first step is to quantify the flooded area of the buildings considering that in this case the damage mostly depends on water depth, flood duration and debris factor (Mojtahed et al., 2013).

In the practical application of the building damage after the quantification of the area of buildings affected by the flood event, the damage costs are calculated using a depth damage function proposed by Penning Rowsell (2005) and then adapted thanks to Mojtahed (p.c). The depth damage function used in this work considers a relationship between the depth of the water in each pixel of the GIS map and the relative building damage. For practical reasons in this work buildings structure and contents are considered together.

The formula used to calculate the building damage (structure and contents) for square meter is :

$$87.422 * \ln(x) + 515.14$$

This formula was imported in the GIS context and then the values have been recalibrated in relation to the dimension of the pixel. Indeed the results of this formula give a value in €/m^2 while each pixel in this phase of the work has an area of 58 m^2. The results of the damage function will be multiplied per 58 in order to obtain the real value. Another important issues are the damages considered as indirect tangible costs. About people it was quite hard to try to quantify the indirect costs because they are mainly intangible, while in case of economic the indirect costs could be easier to identify and quantify. After a flood, business activities could be subject to losses, but also, delay in the delivery, deferability of production, all processes that affect also other economic activities and may create damages also far away from the flood. In the Del. 1.7 two more indirect tangible costs are discussed: the loss of tourism and the loss of tax revenue. The length of the period in which business returns to normal activity, is the first variable to consider in order calculating the indirect tangible cost. In this work, due to lack of information the intangible costs will not be considered.

Other receptors

Infrastructures such as airport, railway, road, electrical power, natural gas and communication network are just some of the strategic node of a developed society. The interruption of these services creates many inconveniences for the population, the economic traffic and so on. The costs of the recover, and the impacts of this interruption need to be studied in this context. For instance the interconnectivity of the economy is highly connected to the transport infrastructure and in some case also the presence of secondary road is an important task during the emergency.

In this case the costs can be divided in direct tangible (clean up and replacement of traffic systems and lifeline systems) and indirect tangible (disruption to the users of the lifeline systems and traffic disruption) (Mojtahed et al.,2013).

The last receptor of the three categories of economic activities is agriculture. As already seen in the social part, damage to crops mainly depends on the type of crops, height of the water and duration of the event. Moreover, according to the season, the different crops are at different growth phases and could be less or more resistant the flood event. For this reason Mojtahed et al. (2013) suggest also to consider calendar dates and season in the assessment of agriculture damages. In particular, “once the type of crop is known and depending on the month when flood happens one can look for the respective phase of cultivation and estimate the cost associated to that phase only” (Mojhated et al., 2013). The costs considered include: cultivation costs, harvesting costs, establishment costs and the loss of gross income. Regarding agriculture, the disruption to potential dependent industries is considered as an indirect tangible cost, while the costs of cleaning up, crop damage and erosion of agriculture soil are direct tangible.

At least it is introduced the environmental and cultural heritage costs assessment. The environmental effects of a flood are mainly due to the interruption of some services that the environment provide to the human being. According to Mojtahed et al. (2013) “three main habitats can be affected by the flood: freshwater, intertidal wetlands and terrestrial habitat”. Actually this procedure can be separated in three steps:

1) identification of the environmental affected area and type of habitat;
2) quantification of environmental effects;
3) assignment of economic value to the environmental effects through literature case studies and estimation of value transfer (Mojtahed et al., 2013).

In this last step we can refer to EFTEC-Handbook for the environment Agency of England and Wales that provides the economic value for different habitats. As already explained in the social methodology it seems that no change in adaptive capacity neither in coping capacity can improve the resistance of a habitat. It is also possible to identify the direct, indirect and tangible and intangible costs. For instance the prohibition of freshwater consumption and the interruption of the service after a flood event can be considered as a direct and tangible cost, while the devastation of an inhabited recreational park can be seen as a direct intangible cost (Mojtahed et al., 2013).

Cultural heritage is another trivial task in the economic assessment because the cultural and emotional value are not easily quantify because they don’t have a market price. Nevertheless, there’s a way to try to solve this issue and mostly the solution is using the

Willingness to pay (WTP) to restore a damage cultural site. This value depends on the amount of visitors, age and other peculiar component of each site and can be based also on the data collected through questionnaires. As explained for the environmental heritage the economic value can be found in the EFTEC-Handbook for the environment Agency for England and Wales and adaptive and coping capacity are not considered in this case. The only direct tangible costs that can be analyzed are for the cleanup and restoration. Loss of cultural heritage is considered as direct tangible or intangible.

2.2.3 GIS

As explained in the previous chapter one of the main objective of this work is to visualize the results in maps. This is the main ambition of this particular research in the KULTURisk general framework. For reaching this aim, Quantum GIS has been used with the introduction of the GRASS (Geographic Resources Analysis Support System) plug-in and of the GRASS GIS 6.5 software. The principal reason of this choice is that there are both open source Geographic Information System (GIS).

The reason why the visualization of the results in a GIS context is so important is mostly depending on the characteristics of the flood risk. As already presented in the normative context flood risk maps are requested by the European Union and also in Italy the urban and environmental planning are mostly based on the risk maps given to the Region or to the municipality by the competent authorities. In Italy for instance the construction of residential or industrial building is limited by the risk category of the land. This is true for different types of risks such as seismic, volcanic and also flood risk.

The new vision in this work, thanks to the KULTURisk framework, is that in the maps there will be not only the physical/environmental components of the risk, but also the social and economic factors.

Indeed the purpose, at the end of this research, is to create a map that, considering social and physical vulnerability, displayed the economic value of the damages.

To reach this aim all the data used in this work need to be geo-referenced. The meaning of this operation is to find in the right geographical context for each data through a coordinate reference system. According to Hill L. (2006), “whatever occurs, occur in space and time and can be visualized, explained and understood in those terms”.

A map could be considered as an interface between the human perception and the real environment. Consulting a map the information need to be clear and immediate. The user must perceive what the map aims to communicate.

The geographical position must help to better understand the meaning of the information content. Hence, in this context some social indicators such as the unemployment ratio or the average income, do not assume any value if they are not referred to a specific geographic area.

First of all, GIS is an informative system, able to memorize and elaborate the spatial data and one of its peculiar and most useful characteristics is the capability of using different types of data such as digital and cartographic sources (Favretto A., 2000).

GIS systems are quite popular since the beginning of the 90’s and nowadays are used in a lot of fields, such as agriculture, economy, engineering, architecture, urban planning, municipality plan, environmental sciences and so on. The interdisciplinary approach and the variety of users of this type of software make it really difficult to clearly define. Several definitions have been given to the GIS and, for instance, it is described as “a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world” (Burrough P.A., 1986).

Furthermore it can be defined as “a decision support system involving the integration of spatially referenced data in a problem solving environment” (Cowen D.J., 1984). With this meaning it’s really useful in this context. The map displayed in a GIS context could be shown to the Decision Maker’s in order to make the results more understandable and deducible. The visualization of the results in a map is one of the crucial points of this work. The decision makers, end users or anyone that has some interest in this research will be able to see the cost of a flood event in each part of the municipality considered. This map can immediately give an idea of the size of the damage just using different colours; red mostly stands for upper damages, while green or white represent lower costs.

The GIS software has several functions such as the introduction and the management of the data, the possibility of creation of database, the use of several analysis procedures, the graphical representation of the data and their transformation. It is really hard to try to summarize the GIS function because this software is really versatile and could be used for the most different application.

Concerning this work it is quite simple to identify the GIS functions used. Mostly they regard map processing and overlaying.

“In map processing each data set is represented as a map (also called layer, theme or coverage)” (Maguire D.J., 1991) and these layers can be added, multiplied and managed in several other ways, if they are in a raster format. The output is another map with new values.

To explain better which operation has been done in this work, firstly it is necessary to present the types of data considered in this research.

They can be divided in: vector, raster and social indicators.

Vector and raster are the two typical GIS data types, while social indicators do not present spatial information and they have different unit of measure. Vector and raster are typical spatial data and include the coordinates and the symbols that are displayed in a map (Favretto A., 2000).

Vector is usually represented in the GIS with points, lines and polygon or area; for example the municipality area or the census tracks borders. Linked to the spatial data in a vector format there is a table of attribute. Attribute has the function to show the characteristics of the spatial data. In this table there are presented several characteristics of the layer such as some geometrical properties (area, perimeter, length and so on), codes (land use code, ISTAT code) economic value and all the attribute refers to the spatial layer that the user want to input.

Raster data are instead made of pixel. A pixel is the littlest and indivisible part of a raster image. Several pixel create a grid with different spatial resolution; the dimension of the pixel defines the spatial resolution. In this work all the data containing the information about depth and velocity of the water obtained by the Eastern Alps Hydrographic District are in a raster format. In particular the resolution of this layer is of 10*10 meter that means that each cell (pixel) has an area of 100 m^2.

Both vector and raster have pros and cons. For instance vector displayed better the boundaries of an entity, while raster could present mixed pixel in the borderline. Moreover with vector it is possible to edit the attributes and they generally represent the spatial entity in a clear way. On the other hand raster files allow spatial elaboration and they present a compact and simple structure. In addition to that the overlay of several raster layer and the possibility of concluding any type of operation among them, make raster files the best option to use in this work. In particular there was the issue to multiply and add different layers. If they are simply overlaid in a raster format (for instance .rst) the software can generate a new map calculating the product in each pixel. This means that the value of the pixel in the output map is generated considering the overlaying of two or more pixel.

This is mostly the reason why in this work all the vector data have been rasterized in Q GIS. A raster layer can be also multiplied by a scalar number or function. During normalization and aggregation procedure this is exactly what it was done in the GIS context.

During the work several technical issues have been faced and a different solution was found for each of them. In this part of the GIS methodology there will be presented some issues and the procedures used to solve them.

The first step to do after the data collection, it was to input them in directory and sub directory in order to make them easily available in a GIS context

Data Input in QuantumGIS

As briefly mentioned in the previous paragraph, the types of data input in this research are: vector raster and social indicators.

Vector and raster are easily displayed in QuantumGIS; they just need to be added through the command “Add Vector” or “Add raster” in the layer menu or with the appropriate illustrated command.

This command open a window that let the user chose the data inside several directories. Where the file that the user wants to open is shown in the window, he just has to click the “open” key (Fig 2.10).

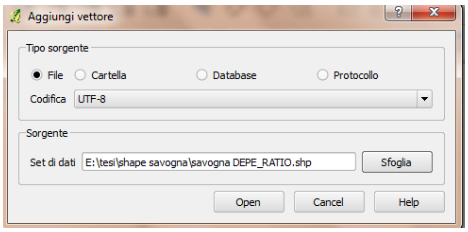


Fig. 2.10 QGIS open layer window.

In case of social indicators the procedure is a little longer. The data need to be added in the table of attribute of the layer. After the opening of a layer in QGIS this appears in the column on the left of the display. To visualize the table of attributes there are two ways: the right click on the name of the layer (that give also the possibility to do other operation), or press the button on the top with the specific image.

Once the table is open in the display it is necessary to set up the edit manner (the pencil button) and then press "new column" and manually insert the name of it and the relative number (Fig. 2.11). This operation must be repeated for all the indicators. Each time the municipality is 'cut' from the map of municipalities of the Friuli Venezia Giulia region using a tool of the vector menu. Each new layer of Savogna has the same borders, but it has different attributes.

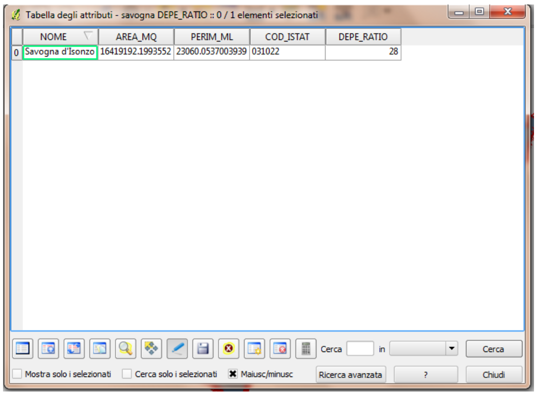


Fig. 2.11 QGIS Vector layer and relative table of attribute

Vector to raster in QGIS

Once all the data have been imported in the software they need to be rasterized. The reason of that is, as explained before, that any overlaid operation need to be done in a raster format.

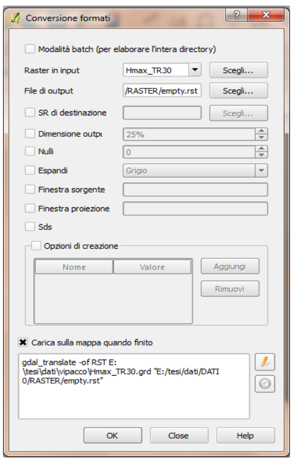


Fig. 2.12 QGIS conversion format

Firstly to rasterize a vector file it must be created an empty raster with the grid dimension of a reference raster. To do that there's a command in the raster menu that is called "Conversion"; "Format Conversion". The window asks to set the input raster, the output raster, the reference systems and other options. As input it might be insert a raster of the case study area with a precise grid value; as output, a name for the empty

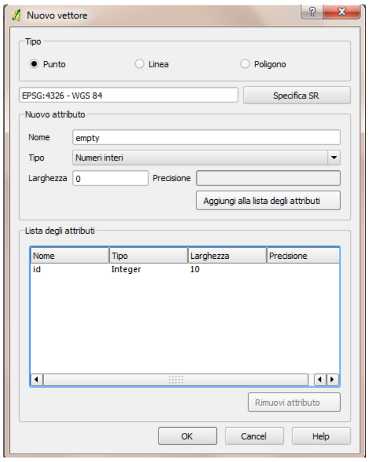


Fig. 2.13 QGIS New shapefile window

Fig 2.14 QGIS empty shapefile.

raster file and as reference system the one chose in the project (Fig. 2.12). This operation creates a raster file with the same characteristics of the input file; in order to obtain an empty raster, it might be created an empty vector layer, that it will be used as base for the following step. The vector layer must have the same dimension of the raster layer just created. There's a proper key in the menu called "New shapefile" that allows the user to create a new vector file with the dimension and the attribute that he prefers. In the window (Fig. 2.13) called "NewShapefile" the user can choose the type of file (point, line, polygon), the reference system and can input a list of attribute. In this case we want to create a polygon and put in the attribute table an id equal to 0 in order to get an empty vector file. The image here are just an example to help the user. Once the user has

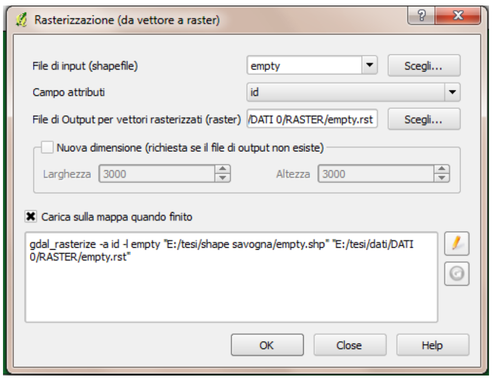


Fig. 2.15 From Vector to Raster

visualized the new layer in the box layer in the left of the QGIS screen, he has to design it using the dedicated edit function.

The new vector layer will have in all the area the same value equal to 0 (Fig 2.14).

At this point this vector file must be rasterized using the reference raster already created. The output will be a raster file with the same dimension of the reference raster, but with all the values of the cells equal to 0. To make this step the user has to go on “Raster Menu”; “Conversion”; “Rasterize” (Fig. 2.15).

The input file in the empty.shp and the attribute is the id (in this case 0); in the output file the user has to insert the raster empty file created before that will be overwritten with the new information (Fig. 2.16).

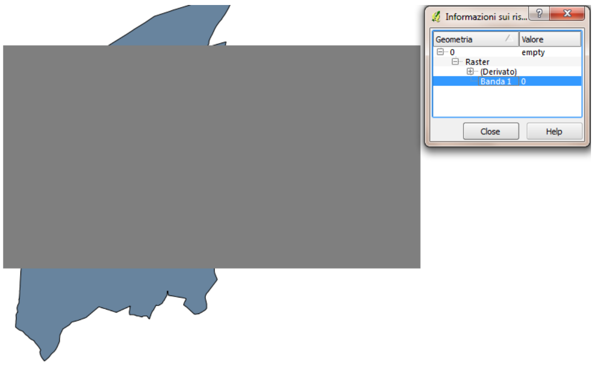


Fig. 2.16 QGIS Empty raster

This will be the base raster for all the shape file that the user needs to rasterize; the procedure described might be followed from the beginning until the end for each vector layer . It is really important to remember to realize the first step of conversion, and it is useful to use the empty raster as an input and also assign to the raster output the name of the vector layer that the user needs to convert.

GRASS plug-in and software

In this research the most used software is Quantum GIS, but for some issues has been easier find solutions with the GRASS plug-in and GRASS 6.5 software. GRASS is actually a “complete and free open source Geographic Information System (GIS)” (grass.osgeo.org) and is also really used as a plug-in for Quantum GIS. It’s quite easy to find and install the GRASS plug-in in Quantum GIS and it is really useful becomes familiar with the plug in because it is a good way to get to know the GRASS software that allows the user to make a huge amount of operations. First of all, it might be created a directory called “grassdata”, then go in the QGIS toolbar at the “Plugin” menu; “Plugin management”.

Here the user can choose to install GRASS. A toolbar with the available grass instruments emerges in QGIS.

Fig. 2.17 GRASS Instruments toolbar.

In GRASS the data must have a precise organization. A data schema must be created before the use of GRASS instruments. As already explained “grassdata” is usually the name of the main directory that contains all the data. This is usually divided in two sub-directory; the first one could take the name of the location and it is useful to divide the data according to the different geographical location. The second one is called Mapset and is used to further categorize the data. In Fig. 2.18 it is shown the example of grass data categorization used in this research.

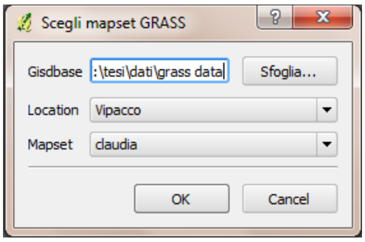


Fig. 2.18 GRASS mapset.

After this step, the data need to be imported in grass.

Import of data in GRASS

When a layer is open in QGIS, it is easy to import it in grass. After the opening of the grass mapset, it might be used one of the GRASS instruments called r.in.gdal.qgis or v.in.ogr.qgis, depending on the type of the data (vector or raster). Actually there are many functions to import data that include: import and create a new location, import from a data source and link it to a grass data and so on, but in this context there will be analyzed just the basic command.

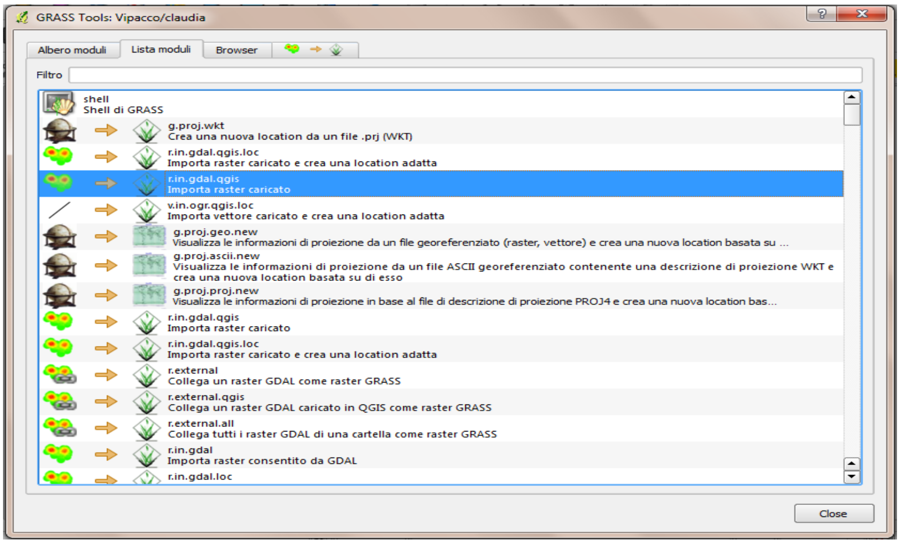


Fig 2.19 GRASS Tools.

After the module has been chosen, the user has just to use the raster in QGIS as raster input and put a name to the raster output that will be part of the grass database. Notice that the GRASS module that include raster and vector analysis, 3D visualization, projection management and more work only with GRASS data. Therefore any time that it is necessary to use a GRASS module, the user might check if the data requested are already part of the GRASS database.

GRASS r.recode

At a certain point of this work it was indispensable try to recode some raster layer. In this context recode means that the software "creates an output raster map by recoding input raster map based on recode rules" (grass.os.geo). To better explain this procedure it will be reported an example.

The first step is obviously open the raster file in the grass context; then in the list of module it might be found the r.recode module. In this window (Fig. 2.20) it is requested the name of the raster that the user wants to recode, a file containing the recode rules and the name of the raster output.

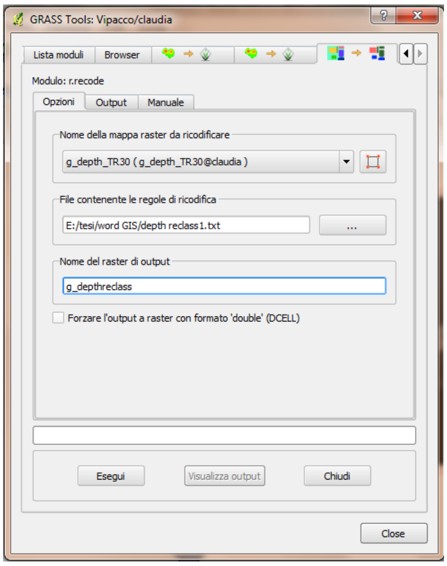


Fig. 2.20 GRASS r.recode.

In this example it is used as an input a raster file containing the water depth in case of flood with 30 years return time. The rules to recode must be written in a .txt file and in a proper way. For instance in this case the rules are:

0:0.25:0

0.25:0.75:10

0.75:*:20

The meaning of these numbers is easy to understand: all the pixel that present a depth values that go from 0 to 0.25 will assume a value equal to 0 in the output map; the values from 0.25 to 0.75 will become 10 and those bigger than 0.75 will be recoded as 20.

There are many cases in which this procedure is really useful and the process is always the same.

GRASS r.mapcalculator

At the beginning of this paragraph it was explained that the entire vector layer must be rasterized in order to do some operation among them. The module used to do is called r.mapcalculator and it works in a really simple way.

Once the raster are opened in GRASS, they could be used for much arithmetical or geometrical operation. To let the user better understand it the example will present a simple multiplication among layers. The idea is that each pixel of the raster map will be multiplied for the overlaid pixel of the other maps.

The window of the r.mapcalculator asks to input the layers to combine, the formula that might be used and the name of the output map (Fig. 2.21).

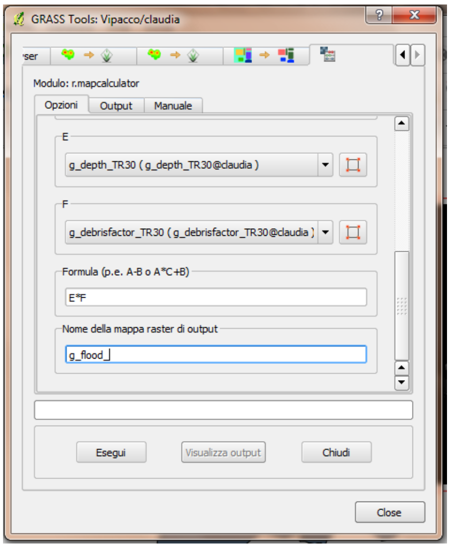


Fig. 2.21 GRASS r.mapcalculator

The r.mapcalculator was widely used because each type of function can be calculated with it. The procedures of normalization and aggregation of the data, for instance, have been mostly done with this module.

Obviously, some other operations have been made during this work with Quantum GIS or GRASS, but those that have been presented were probably the most critical.

2.3 SPATIAL ANALYSIS

2.3.1 Vipacco

The methodology explained in the previous section will be now applied to a particular case study. In this work the area of study is a small portion of land in Friuli Venezia Giulia, near the border with Slovenia and in particular most of the data used in the application belongs to the municipality of Savogna d'Isonzo. The name of this town derives from a river that passes nearby and that is called Isonzo. According to the Eastern Alps hydrographic District, Isonzo is a river 134 km long and the spring is located in the Jalovec Mountain, a mountain in the Slovenian Julian Alps (AdB, Venezia. p.c.) while the mouth is in the Trieste Gulf, Italy. Actually Savogna d'Isonzo is not crossed by Isonzo, but by Vipava-Vipacco, a smaller river that flows into Isonzo near Savogna. Also Vipacco is a trans-boundary river and it flows in Italy only for 12 km in a karst area of eastern Friuli Venezia Giulia. Only this part of the river basin is going to be subjected to the study. In September 2010 the municipality of Savogna d'Isonzo was protagonist of a flood event that caused damages to the buildings and infrastructures and several problems to the population. The flood was provoked by intense rain events that happened during 18th and 19th of September 2010. The water dropped not only in the land of Savogna municipality but there were strong storms also in Slovenia, in the previous section of the river. The accumulation of rainwater was probably not the only factor that provoked the flood; the civil protection did some inspections the day after the event and they discovered that the bed of the river was full of vegetation and detrital material nearby road or other infrastructures. Moreover in those days also the river Isonzo had a water level higher than normal and this situation increased the hazard of a flood event (www.protezionecivile.fvg.it). The Friuli Region has quantified the total costs of the damages for that event at 888 thousands of euro. This amount was supposed to be given to the population and to the economic activities to refund the losses provoked by the flood event (Regione Friuli venezia Giulia).

It was presented the last serious flood event in the area to let better understand the reason why was chose that part of the region to apply the methodology.

In the Savogna municipality lives 1739 people (demo.istat.it, 2010) but only a part of that are at risk in case of a flood event. The municipality has an extension of 16,8 square km and it is mainly divided in two zone: a flat country between the Isonzo and Vipacco river and a hill part that presents the peculiar characteristics of a karstic land (Comune di Savogna)

The RRA analysis was made by the Eastern Alps hydrographic District that shared the results (such as height and speed of the water) with the Department of Economics of University Cà Foscari of Venice in order to apply the SERRA methodology.

2.3.2 Data

The social data needed for a comprehensive application of SERRA are already presented in the Appendix 1. The physical/environmental are the set of data used in the RRA, but they assume a great importance also in this part of the work. The results of the RRA have needed sometimes to be disaggregated in the several indicators used to calculate it. The reason of this disaggregation is that SERRA uses the height and speed of the water to quantify the damage, while in the RRA these values appear in an aggregated way.

The first part of the work has involved the collection of data of the area of study. This was not an easy task because the area it's quite small so that not all the data requested were available and some of that were considered not relevant for the case of study. This part of the study was conducted together with the Eastern Alps hydrographic District and it started analyzing the data that they have used in the RRA.

The data types are of different format. Some of them are in a raster or vector format and others are numeric values collected in excel table. This work aims to present a spatial representation of the results in a GIS context. GIS is a Geographical Information System that allows having a cartographic representation of the area of study. The vector or raster file are easily displayed while the excel table need to be processed. The discussion over the construction of the map will be presented in the next section.

Physical indicators

Component of the physical/environmental RRA	Indicator	Data source (map name, scale, authors, year).
Flood hazard	Water depth (m)	☑ AdBV
	Flow velocity (m/s)	☑ AdBV
	Flood extension (Km^2)	☑ AdBV
Exposure	Presence of people in residential areas	☑ AdBV
	Presence of buildings	☑ Regione Friuli Venezia Giulia
	Presence of infrastructures	☑ MOLAND
	Presence of agricultural typologies	☑ MOLAND, CORINE
	Natural & semi-natural systems	☑ MOLAND,CORINE
	Presence of cultural heritages	Not relevant
Susceptibility	Vegetation cover	☑ MOLAND,CORINE
	Slope	Not relevant
	Soil type	☑ MOLAND,CORINE
	Wetland extension	Not Relevant

Tab. 2.17 Physical/environmental data (KR Project, author's elaboration).

There are presented the physical/environmental indicator, which are divided in 3 component:

a) flood Hazard;
b) exposure;
c) susceptibility;

as explained in the KULTURisk flowchart.

Firstly, in order to identify the area of study we have taken the Savogna d'Isonzo borders from a map of all the Friuli Venezia Giulia's municipalities. This map was taken from the website of the Region that present a catalogue of all the land and environmental data.

Water depth and flow velocity were both elaborated by AdB through hydrological model and they are presented in raster format. Extension is obviously limited by the water depth boundaries. Both these values are necessary to understand the entity of the damages for the different receptors (People, Buildings, infrastructures and agriculture).

Exposure is defined by the effective presence of the receptors in the area of study. Concerning agriculture and environmental heritage, the CORINE land cover maps usually exhaustively represent these data. CORINE maps represent the different type of land use, in particular “the land cover project is part of the CORINE programme and is intended to provide consistent localized geographical information on the land cover of the 12 Member States of the European Community”(EEA, 2007). Nevertheless in this study it’s possible to use also MOLAND map that seem more precise in some point of the area.

Regarding people, we have to know the number of people that effectively live in one or in another part of the city. This process was possible thanks to the use of CTR (Carta Tecnica Regionale) and census tracts. The CTR tell us where exactly the residential and commercial building are located in the area, whereas the census tracts are necessary to calculate the number of people that live in each part of the town. The elements of CTR are easily findable in the Friuli Venezia Giulia (FVG) website and the CTR used in this work are in scale 1.5000. To calculate the number of residents, the Eastern Alps hydrographic District has given us an excel table with a lot of information about the population divided for census tracts and the shape file of these tracts; from this point, in order to display the people localization in the map, it was only necessary to put the information in the attribute table of the tracts shape file.

As just explained all the information about the buildings exposure is contained in the CTR. In particular the number of the map used in this work have the following codes: 088030, 088070, and 088110,088120.

MOLAND and CORINE are also used in the evaluation of the location of the infrastructures, vegetation cover and soil type. The FVG Region presents in the environmental catalogue all the information about the presence of infrastructure such as roads and railways, land use or presence of river.

Slope and wetland extension are considered not relevant in this context.

The following part is a matter of the social indicators considered and the relative data collection that are presented in Tab. 2.18.

Social Indicators

Components	Variables	Indicators	Data Sources (map name, scale, authors, year) or link
Adaptive Capacity (AC)	Economic wealth	Income/Revenue (Yearly)	Immobiliare.it
	Risk spread	Insurance density/ penetration	IVASS
	Equity	GINI index	ISTAT
		No. of beds of hospital per 1000 people	Ministero della salute
	Early warning system (EWS)	Lead-time (hr)	AdBV
		Information Content (qualitative; very good, good, bad, very bad)	
		Reliability (qualitative; very good, good, bad, very bad)	
Coping capacity (CC)	Demography	Dependency ratio (%)	Comuni Italiani.it
		Newcomers (#)	Excel file, ISTAT
		Unemployment Rate	Excel file, ISTAT
	Emergency management (EM)	People involved (# of fire fighters or other people)	Protezione Civile p.c.
Susceptibility (SUS)	Building properties	Age (years)	AdBV
		Materials (Concrete, brick or wood)	
		Types (single or multi-storey)	
	Business properties	Types (private, public, industry, corporate or trade)	Not relevant
		Size of the Business (number of employee)	Not relevant
	Economy	Inter-connectivity (# commuters per day)	Not relevant
		Specialization (Herfindahl index◊)	Not relevant
	Network	Importance / volume (no. of passengers per day, per type of transport system)	Not relevant
		Connectivity (number of routes of the zone)	Not relevant

Tab 2.18 Social Data (KR Project, author's elaboration).

In this case was harder to find out all the needed data. The reason was that these information are less available and more dispersed in different public or private authorities.

Anyway , at the end, we achieve to collect most of the data request.

As already explained in the methodology, vulnerability is divided in social vulnerability and susceptibility. Social vulnerability is further categorized

a) AC: Adaptive Capacity
b) CC: Coping capacity

In a paper entitled *"Social Vulnerability to Environmental hazards"* (Cutter S. et al.2003), the authors introduce the concept of vulnerability paradox. They underline that the importance of social vulnerability is widely recognized as a fundamental parameter in the calculation of risk but nevertheless there are still a few studies about these themes and our knowledge is quite inadequate. The social indicators are actually hard to quantifying and they need all the normalization and aggregation processes presented in the previous chapter. Therefore the data collection and analysis of the indicators of social vulnerability is one of the most delicate and critical point of this work.

To enter in the detail, we can start considering Adaptive capacity that is divided in 4 indicators:

a) economic wealth;
b) risk spread;
c) equity;
d) EWS.

The first variable considered for AC is the Economic Wealth. Clearly this value influences the social capacities. A wealthy society has much more possibilities to face the emergency and to react after the adverse event. In this part of the work is really important to obtain data not only for the Savogna d'Isonzo municipality, considered as our area of study, but also the data needed for the normalization procedure. In this direction we've collected all Italian provincial income average. The average income per municipality is achievable from ISTAT (Comuni Italiani.it).

Almost all the indicators used in the adaptive and coping capacity present numeric value. The aim of this work is also trying to display these values, their elaboration and the final results in a GIS context. The way I've found to solve this problem is to take the shape file of the Savogna d'Isonzo municipality from the website of the FVG Region and, for each indicators, create a shape file with that numeric value as an attribute.

Risk spread is the second indicator analyzed. Obviously an higher value of insurance density leads to increase adaptive capacity. To find out these data we've contacted the IVASS (Istituto per la Vigilanza sulle Assicurazioni) where we find the provincial density value of insurance. Also in this case we could found the value for the municipality and in order to normalize it we've collected the insurance data of all Italian provinces.

After that Equity needs to be analyzed. This is described through 2 indicators:

a) GINI index
b) N° of beds in Hospital per 1000 people

According to the World Bank GINI index is "a coefficient of inequality this is the most commonly used measure of inequality. The coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, all others have none). Graphically, the GINI coefficient can be easily represented by the area between the Lorenz curve and the line of equality" (World bank website).

In Italy ISTAT (Istituto nazionale di Statistica) provides only the regional GINI index values; for our purpose we've taken the Friuli Venezia Giulia value and the regional value for normalization procedure. In this case the higher is the inequality among the residents lower it will be their adaptive capacity.

The n° of bed per 1000 people is a value that described how the emergency could be managed. Obviously higher the n° of bed, higher it will be the Adaptive Capacity of the people. In this case the value is provided by the Ministero della Salute. Also in this case only the regional values are easily achievable, reason why we've used the Friuli's one.

At this point we consider EWS that is the most important variable in the alternative scenario. It is really controversial to assign a value to the three indicators mentioned in the Deliverable 1.7. What we've obtained at the end was a informal judgement of some experts (Eastern Alps Hydrographic Disctrict and University of Brescia) that have provided us a qualitative value for the information content, lead time and reliability. To calibrate it they have used information derive from other EWS already installed.

Regarding Coping Capacity, the variables that are taken into account are demography and emergency management. All the indicators that describe demography are elaborated by ISTAT. In particular we've found regional value for dependency ratio, newcomers and unemployment rate. The ways in which these indicators affect CC are different.

For instance it is supposed that higher is the dependency ratio and lower should be the coping capacity. This value represents the ratio between the sum of very young people (lower than 15 years) and old people (higher than 65 years) divided per the total amount of the population. Child and aged people are surely more vulnerable in case of emergency due to the lack of feeling of danger or in the case of very little child and old people due to a difficult mobility. Concerning newcomers and unemployment rate, both decrease the coping capacity. The first because newcomers are supposed to be more vulnerable in an emergency case and in the second one because it could be difficult to react to some damages without the income of a work.

The emergency management is an important issue and in Italy the responsible in this field is the Protezione Civile. The civil protection (Protezione Civile) is a public administration that manages a lot of natural emergency situation in Italy (earthquakes, flood, forest fire) and it's composed by volunteers and employees. To assess how many people are involved in the emergency in our area we've directly contacted the responsible of protezione civile of the municipality. The normalization procedure in this case was quite hard due to the lack of data, as explained in the dedicated paragraph.

The last component to consider is susceptibility and we are supposed to take in consideration 4 indicators:

a) building properties;
b) business properties;
c) economy;
d) network.

The first one regards the intrinsic characteristics of the buildings as the age, the materials and the type. We've found all this information in an excel table given to us by the Eastern Alps Hydrographic District. Very old buildings are highly susceptible to flood risk. Concrete structures are more flood-resistant than brick or wood and single-storied buildings are more susceptible to flood than multi-storied.

Business properties present a deeper characterization; it is divided in types (such as private, public, industry or corporate) and size of business that depends on the number of employee. The economy would consider the inter-connectivity with the near town and the Herfindhal index, an index that describes the market concentration and it is based on the economic competition (U.S. Department of Justice). At last, the indicator called network contains the importance and volume of transport and the connectivity, interpreted as number of route per zone. In this work business properties and inter-connectivity are considered not relevant mostly because the area of study is a very small town where are not located such big industries or commercial traffic. Furthermore it is very complicated obtaining this data.

After making all these considerations it is clear that susceptibility, in this context, can be summarized just considering building properties.

Economic indicators

Indicator	**Data source** (Scale, authors/institution, year) or link	**Receptor**
Average monthly household rent (€/month)	Immobiliare Gorizia	People
Average dimension of households (#)	Not found	
Average evacuation costs of households per Km^2	Not found	
Average value of each types of utility service per day (€/day)*	Value transfer	
Average structure value per unit floor area per each residential building type	Multicolour manual	Residential
Average value of contents of a residential building per unit of house	Multicolour manual	
Average number of vehicles per household	Not relevant	

Tab 2.19 Economic Data (KULTURisk Project, author's elaboration).

The economic damage considered in this work are referred just to people and buildings. For people I've used the VSL, while for building a depth damage function derived from Multicolour Handbook (Pennig-Rowsell E. et al. 2005).

2.3.3 Metadata and INSPIRE

The word metadata was firstly used in the USA, where the Federal Geographic Data Committee (FGDC) established a standard for the description of the geographical database (Faggioni R. and Cadoni F., 2000).

"Metadata is information and documentation which describes the content, quality, origin etc. and makes data understandable and shareable between users and receivers over time" (EIONET, 2013). In plain words metadata are data that concern other data. There's a very current discussion nowadays about metadata; system such as Internet or some other software can collect information about all type of data. There are several articles (Lanier J., 2013 and Iannaccone S., 2013) that talk about the potential power of metadata. The scandal of the huge amount of data collected by governments over the citizen has focus the popular attention of what metadata are and which is their potential. Anyway, in this context we are going to present spatial data and all the spatial data need to be described by metadata.

In a document published by ESRI (Economic and Social Research Institute) there is the specific description of what metadata are and why they are so useful and there is underline the importance of a link between metadata and GIS system. Concerning the format metadata can be stored in a text file, Extendible Markup Language (XML), or database record. Moreover they are easier shareable that data because they have a smaller size. "Metadata can describe GIS data, a GIS Web service, or an online metadata catalogue" (ESRI, 2002).

They may include different information that portraits several characteristics of the data. In this case metadata may include the location, the language, the format, the scale, the last updating and other descriptive information (Teare K. et al., 2000). After the standard definition of FGDC several national and international authorities have introduced analogous standard, but a few database responsible have followed it. Probably the reason of this incongruity is the lack of a recognized scheme that has carried various organizations to propose different standard such as: FGDC; CEN/TC 287; Open GIS Consortium; ISO/TC 211(Faggioni R. and Cadoni F., 2000).

In this context in the 2007 the European Commission has issued the Directive 2007/2/EC of the European Parliament and of the Council that establish an Infrastructure

for Spatial Information in the European Community (INSPIRE). The implementation of the Directive will go on for several years, but the full implementation is required by 2019.
The main purpose of this Directive is to create a database for sharing the spatial information across Europe following some standards.
In the first consideration of the Directive the European Community declare to aim to an high level of environmental protection, taking into account the differenced among the several MSs. In this context the spatial information is needed to formulate and realize several European political strategies and “it is necessary to establish a measure of coordination between the users and providers of the information so that information and knowledge from different sectors can be combined” (Directive 2007/2/EC).
The aim of the Directive is clearly expressed in the Article 1 and “is to lay down general rules aimed at the establishment of the Infrastructure for Spatial Information in the European Community (INSPIRE)”. In the following article the Directive gives the guideline concerning different area such as: metadata (Chapter 2, Art.5), interoperability of spatial data sets and services (Chapter 3, Art.7), network services (Chapter 4, Art.11), data sharing (Chapter 5, Art.17) and coordination and complementary measures (Chapter 6, Art.18).
Focusing the attention on metadata they “shall include information on the following:
(a) the conformity of spatial data sets with the implementing rules provided for in Article 7(1);
(b) conditions applying to access to, and use of, spatial data sets and services and, where applicable, corresponding fees;
(c) the quality and validity of spatial data sets;
(d) the public authorities responsible for the establishment, management, maintenance and distribution of spatial data sets and services;
(e) limitations on public access and the reasons for such limitations, in accordance with Article 13.” (Directive, 2007/2/EC).
In the document “*Reporting of Spatial data for the Floods Directive* ” (Part II), it is actually presented the connection between the INSPIRE directive and the flood directive. Effectively the report gives some guidelines to implement INSPIRE. In this context there will be available “the following operation:

a) Get View Services Metadata: get metadata about a specific view service

b) Get map: returns a map for a specified area

c) Link View Service: allows the linking of view services together" (EIONET, 2013) .

The metadata are supposed to be in an xml. format and the full implementation of INSPIRE is expected for the 22/12/2019.

In Quantum-GIS, the open source GIS program used in this research, metadata are visualized in the table of properties and include coordinates, extension, source and other information.

In this work there was made a metadata table in excel, trying to use the INSPIRE classification of spatial data. Not all the information were available, so the table in the Annex B presents several empty spaces. Anyway, there are described the spatial data considering several categories as: identification, classification and services, keywords value, geographic location, temporal reference, quality and validity, conformity, constraint related to access and use, organization responsible, metadata of metadata, data type, distribution format and reference system.

2.3.4 Normalization Procedure for selected indicators

The data regarding social indicators present several units of measurement and this characteristic makes them very difficult to compare to each others. Normalization procedure allows to transforming indicator values with different measurement units into a dimensionless number (Mojtahed et al., 2013). In this way it assumes sense to compare, add or multiplying them.

Several normalization techniques exist in literature (Mojtahed et al., 2013), but the choice among them depends on the indicators and the willingness of the stakeholders. The normalization algorithms could be really different and could use several formulas: Min-Max, 0-Max but in general they refer to a value function (Mojtahed et al., 2013). In the SERRA methodology several value functions have been used, one for each indicator. The determination of those functions strictly depends on the type of the data that could be quantitative but also qualitative. In each case it is necessary to apply a value functions, it must be collected not only the value itself, but "an upper and lower threshold and a series of values representing different significant levels of performance with reference to defined goal" (Mojtahed et al., 2013).

In this study the upper and the lower thresholds do not always belong to the same geographical reference system; according to the availability of the data, some of the value functions have been produced using the European values, some others through the regional data, and someone with the Italian provincial values.

For the value function used for each indicator I will refer to an internal document of the KULTURisk research group about the normalization procure adopted in this context and all the data sources have already been presented in the Tab. 2.18 and in the following description. It will be now exposed a presentation of the value functions used to normalized the social indicators in the case study.

Dependency Ratio (DR)

Dependency Ratio can be considered as a measure showing the number of dependents (aged 0-14 and over the age of 65) to the total population (aged 15-64), also referred to as the "total dependency ratio".

For instance, considering the Savogna d'Isonzo Municipality the Dependency Ratio is calculated as followed:

Residents aged 0-14 = 202

Residents aged > 65 = 186

DR = (202+186)/1334 = 0.28 * 100= 28%

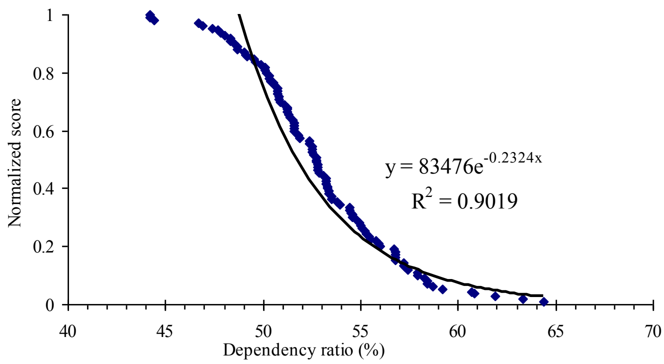
For normalizing DR, we compare available observed data of 27 European Countries and 110 Italian Provinces. The results (Tab. 2.20) demonstrate that maximum and minimum value of EU dataset does not incorporate the heterogeneity of micro-level (Province) data of Italy. In addition, the Italian number of samples is higher than the European data set. Therefore, we develop value function based on observed data of 110 Italian Provinces.

	EU Dataset	DR of Italian Provinces
Maximum	54.2 (France)	64.4 (Trieste)
Minimum	38.1 (Slovakia)	44.2 (Olbia-Tempio)
Median	47.5	52.7

Tab 2.20 Comparison of Dependency Ratio between EU and Italy (by Province).

As population with higher DR leads to decrease coping capacity, the province with highest DR is considered as 0 and the province with lowest DR is considered as 1. DR for other provinces are distributed in the descending order and mathematical function is generated based on best fitted distribution, which is shown below.

$$\begin{cases} y = 1; & if\ x \leq 49 \\ y = 83476e^{-0.2324x}; & if\ 49 < x < 64.5 \\ y = 0; & when\ x \geq 64.5 \end{cases}$$



Graph 2.1 DR normalization function

This function has been used in Quantum GIS to normalize the DR. The normalized value is equal to 1 and it means that contributes to increase the CC.

Unemployment rate (UR)

The Unemployment rate is a measure of the prevalence of unemployment and it is calculated as a percentage by dividing the number of unemployed individuals by all individuals currently in the labour force.

In the Savogna case study we have used the regional value, because more precise data were not available. In the Friuli Venezia Giulia, ISTAT (2011) has calculated the unemployment rate equal to 5.2 %.

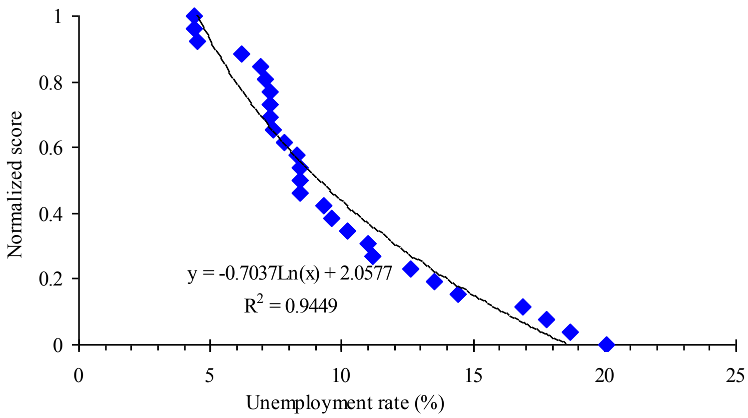
For normalizing UR, we compare available observed data of 27 European Countries and 22 Italian Regions. The results (Tab. 2.21) demonstrate that maximum and minimum value of EU dataset incorporate the heterogeneity of micro-level (region) data of Italy. In addition, the number of samples is high for EU data compared to Italian data set. Therefore, we develop value function based on observed data of 27 European Countries.

	EU Dataset	DR of Italian Regions
Maximum	20.1 (Spain)	14.7 (Sicilia)
Minimum	4.4 (Austria)	2.7 (Bolzano/Bozen)
Median	8.4	6.5

Tab 2.21 Comparison of Unemployment Rate between EU and Italy (by region).

As population with higher UR leads to decrease coping capacity, the country with highest UR is considered as 0 and the country with lowest UR is considered as 1. UR for other countries are distributed in the descending order and mathematical function is generated based on best fitted distribution, which is shown below.

$$\begin{cases} y = 1; & if\ x \leq 4.4 \\ y = -0.7037Ln(x) + 2.0577; & if\ 4.4 < x < 20 \\ y = 0; & when\ x \geq 20 \end{cases}$$



Graph 2.2 UR normalization function

The normalized value is 0.89.

New comers

It is supposed that a society with a high numbers of foreign migrants is less reactive after a flood event and during the emergency, maybe due to the different language or cultural tradition.

In this case we've found the number of newcomers that have arrived in Friuli Venezia Giulia in the 2011 (13.817) and then we've supposed that the distribution of migrants was equally distributed in the entire region. According to that, we have simply done a proportion:

N° migrants in FVG: inhabitants of FVG = n° migrants in Savogna d'Isonzo: inhabitants of Savogna d'Isonzo

13.817: 1219356 = X: 1722 X= 20

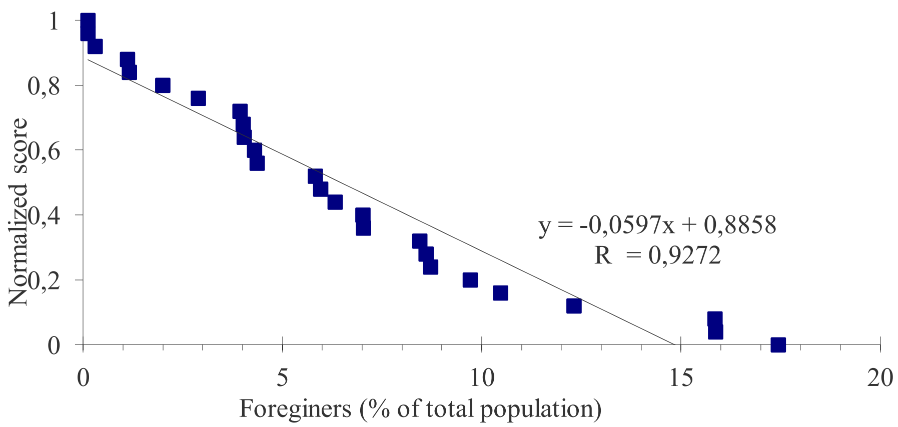
For normalizing new comers (foreigners), we compare also available observed data of 27 European Countries and 22 Italian Regions. The results (Tab 2.22) demonstrate that maximum and minimum value of EU dataset incorporate the heterogeneity of micro-level (region) data of Italy. In addition, the number of samples is high for EU data compared to Italian data set. However, compared to other European countries, the percentage of foreign people is very high in Luxemburg. Therefore, we develop value function based on observed data of 26 European Countries (except the value of Luxemburg).

	EU Dataset	DR of Italian Regions
Maximum	43.0 (Luxemburg)	11.3 (Emilia-Romagna)
Minimum	0.1 (Poland)	2.3 (Puglia or Sardegna)
Median	6.1	8.6

Table 2.22 Comparison of percentage of foreign people between EU and Italy (by region)

Similar to above procedure, the country with highest number (among 27 EU countries) of foreigners is considered as 0 and the country with lowest no. is considered as 1. Numbers of foreigners for other countries are distributed in the descending order and mathematical function is generated based on best-fitted distribution which is shown below.

$$\begin{cases} y = 1; & if\ x = 0 \\ y = -0.0597x + 0.8858; & if\ 0 < x < 15 \\ y = 0; & when\ x \geq 15 \end{cases}$$



Graph 2.3 Newcomers normalization function

In the normalization function the value must be express in percentage. So that in case of Savogna can be approximated to 0 and the normalized value is equal to 1.

Economic wealth, income

The economic wealth will be expressed in this work by the GDP per capita.

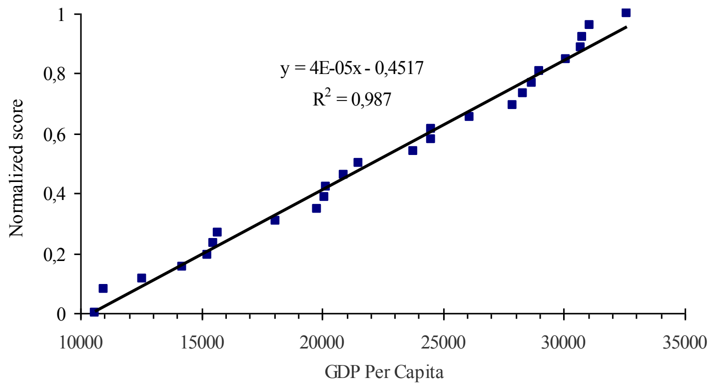
In Savogna the average income is about 21.000 euro. For normalizing GDP per capita, we compare also available observed data of 27 European Countries and 22 Italian Regions. The results (Tab. 2.23) demonstrate that maximum and minimum value of EU dataset incorporate the heterogeneity of micro-level (region) data of Italy. In addition, the number of samples is high for EU data compared to Italian data set. However, compared to other European countries, the percentage of foreign people is very high in Luxemburg. Therefore, we develop value function based on observed data of 26 European Countries (except the value of Luxemburg).

	EU Dataset	GDP of Italian Regions
Maximum	67,000 (Luxemburg)	27,169 (Bolzano)
Minimum	10,600 (Bulgaria)	12,776 (Campania)
Median	23,800	21,362

Table 2.23 Comparison of GDP per capita between EU and Italy (by region)

Similar to above procedure, the country with highest value of GDP (among 27 EU countries) is considered as 1 and the country with lowest value is considered as 0. GDP (per capita) for other countries are distributed in the ascending order and mathematical function is generated based on best-fitted distribution which is shown below.

$$y = 1; \qquad if\ x \geq 32000$$
$$y = (4E - 5 * x) - 0.4517; \qquad if\ 10000 > x > 32000$$
$$y = 0; \qquad when\ x \leq 10000$$



Graph 2.4 GDP normalization factor

The normalized value is 0.3883.

GINI index

The Gini coefficient or Gini index is a measure of statistical dispersion developed by the Italian Statistician and Sociologist Corrado Gini. The Gini coefficient is a measure of the social inequality, calculated considering the values of frequency distribution. In this context we are going to examine the GINI index relative to the income distribution. If the Gini index is equal to 0 it means that there's a perfect equality among the population; in other word, concerning the income, it means that all the people has the same economic wealth. On the other hand, a coefficient equal to 1 expresses the maximum inequality among the inhabitants.

For the GINI index we have found only the regional value that for Friuli Venezia Giulia is equal to 0.265; expressed in percentage it becomes 26.5%.

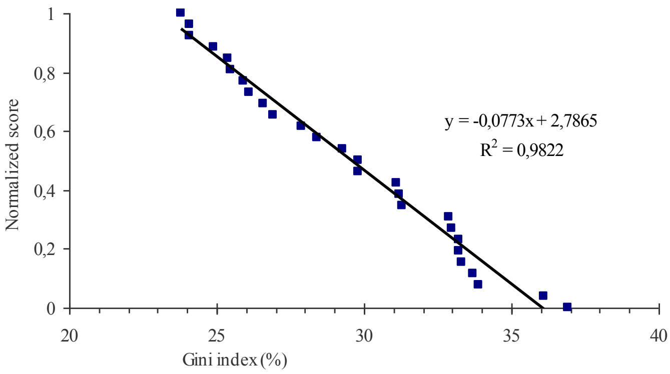
For normalizing GINI Index, we compare also available observed data of 27 European Countries and 22 Italian Regions. The results (Tab. 2.24) demonstrate that maximum and minimum value of EU dataset incorporate the heterogeneity of micro-level (region) data of Italy. In addition, the number of samples is high for EU data compared to Italian data set. Therefore, we develop value function based on observed data of 27 European Countries.

	EU Dataset	GINI index of Italian Regions
Maximum	36.9 (Lithunia)	34.3 (Sicilia)
Minimum	23.8 (Slovenia)	25.5 (Trento)
Median	29.8	28.6

Tab 2.24 Comparison of GINI index between EU and Italy (by region)

Normalizing Gini Index, we analyze census data of 27 EU countries. The country with highest Gini coefficient is considered as 0 and the country with lowest coefficient is considered as 1. Coefficients for other countries are distributed in the descending order and mathematical function is generated based on best fitted distribution which is shown below.

$$
\begin{aligned}
y &= 1; && if\ x \leq 24 \\
y &= -0.0773x + 2.7865; && if\ 24 < x < 36 \\
y &= 0; && when\ x \geq 36
\end{aligned}
$$



Graph 2.5 GINI index normalization function

The normalized value of the GINI index is equal to 0.7381 and expresses a quite good equality among the inhabitants of the area considered.

Hospital bed density for 1000 people

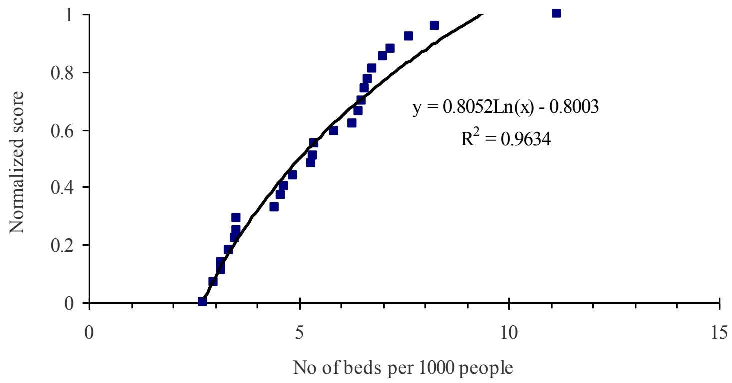
The indicator hospital bed density refers the number of hospital beds per 1,000 people. The high value of hospital bed density indicates refers that the society has more coping capacity for post-disaster emergency services that reduces the vulnerability.

Also in this case we have only found a regional value for the hospital bed and in Friuli Venezia Giulia there are 4 beds each 1000 people.

Normalizing hospital bed density, we analyze census data of 27 EU countries. The country with lowest density is considered as 0 and the country with highest value is considered as

1. Coefficients for other countries are distributed in the ascending order and mathematical function is generated based on best fitted distribution which is shown below.

$$\begin{array}{ll} y = 0; & if\ x < 3 \\ y = 0.8052Ln(x) - 0.8003; & if\ 3 < x < 10 \\ y = 1; & when\ x \geq 10 \end{array}$$



Graph 2.6 N ° beds for 1000 people normalization function

The normalized value is 0.316and it's under the average of the EU countries.

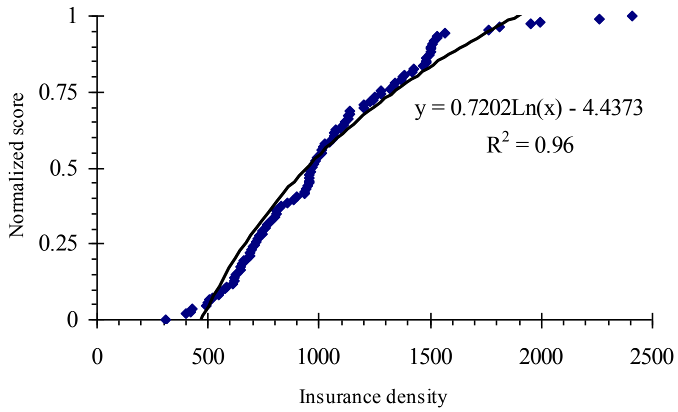
Insurance density

Insurance density is calculated as the ratio of total insurance premiums (in €) to total population (Lenzi and Millo, 2005). Values with higher insurance density lead to increase adaptive capacity. In this case, life insurance density is considered as indicator.

Savogna shows an insurance density equal to 901

Normalizing Insurance density, we analyze census data of life insurance for Italian provinces. The province with highest insurance density value is considered as 1, whereas the province with lowest coefficient is considered as 0. Insurance densities for other provinces are distributed in the ascending order and mathematical function is generated based on best fitted distribution which is shown below.

$$\begin{array}{ll} y = 0; & if\ x < 400 \\ y = 0.7202Ln(x) - 4.4373; & if\ 400 < x < 1900 \\ y = 1; & when\ x \geq 1900 \end{array}$$



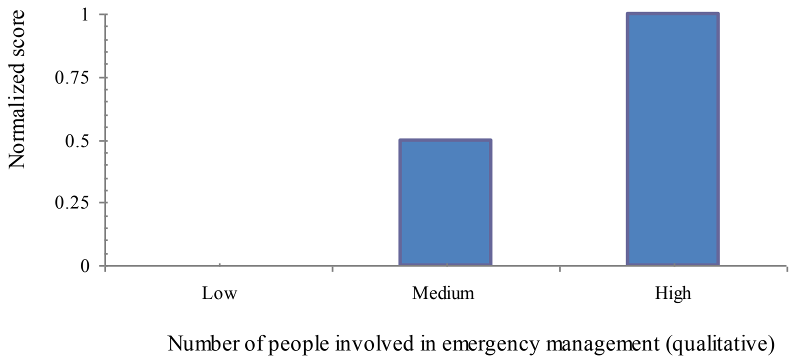
Graph 2.7 Insurance density normalization function

The normalized value of insurance density is equal to 0.463

People involved in the emergency

The number of people involved can be approximated by the number of fire fighters and Red Cross and the number of trained volunteers; contacting the office of "Protezione Civile" in Savogna we have found the value of people involved that are about 30.

In this case was quite hard to find European or Italian value to create a value function so that this factor has been normalized in a qualitative way.



Graph 2.8 Number of people involved normalization function

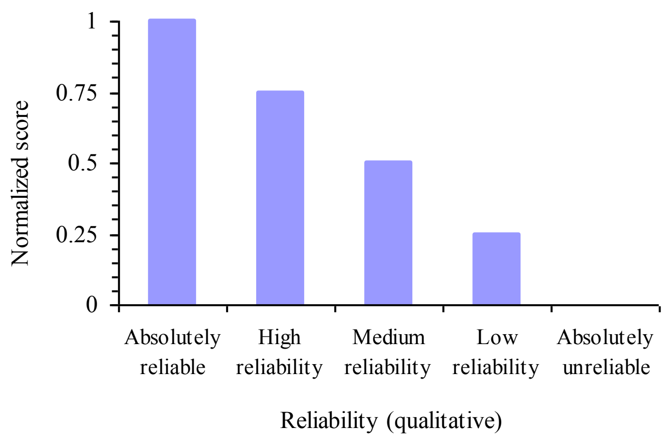
We have decided that 30 can be considered as medium level of protection (0.5 normalized value).

EWS

EWS is considered as part of Adaptive Capacity and it's divided in three components: reliability, lead time and information content. All the values used in this work were provided by the Eastern Alps hydrographic District and by the University of Brescia as personal communication.

Reliability

Reliability is an important factor of the EWS; a false alarm might provoke inconveniences and damages for people and economic activities and after that people could not trust any more in the integrity of the information. The alarm is given to the population after a serious control of the hydrological and weathers models and forecasts made by the competent authorities. The problem is mostly due to the uncertainty of these models (Schröter K., et al., 2008). From an expert opinion (Ferri M., AdB Venezia p.c), a probability of fail of 25% is reasonable for an hydrological model; moreover the model's results are reviewed and analyzed by the experts that can understand if there are some fail in the model and correct the information. Concerning this work, we can say that an alarm given in the Vipacco area is very reliable. This is mainly due to the small dimension of the area that allows having good and almost completely reliable information. Difficult decision about the reliability of the alarm obviously happens in a border situation where the models give a peak value that is really near to the flooding value.

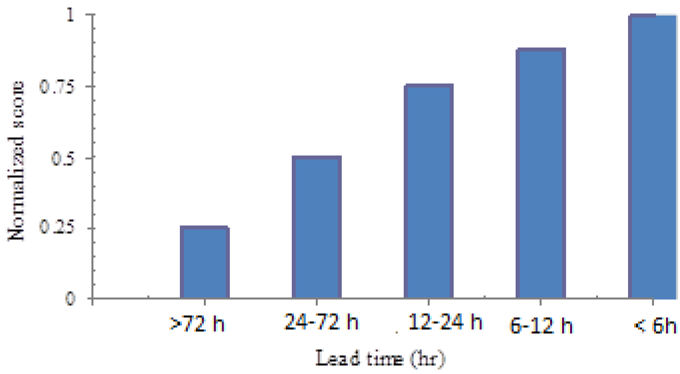


Graph 2.9 EWS Reliability normalization function

After the considerations previously presented in the Savogna d'Isonzo municipality the reliability of an EWS is normalized at 0.75 (high reliability).

Lead Time

The information about a possible dangerous situation starts to arrive to the competent authorities three days before the river peak (Basin Authority of Venice, p.c.). At that point the information isn't really credible, but from 24 hours before the events it begins to become more and more reliable. In the Vipacco zone 12 hours is a reasonable time to put in alert the population.

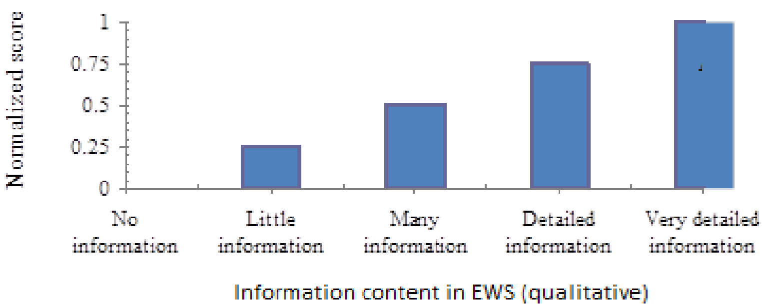


Graph 2.10 EWS Lead Time normalization function

The normalized value is 0.75

Information content

The information content can include several information such as peak water level and time, area at risk, safety area where is possible to go, information about emergency measure and so on.



Graph 2.11 EWS Information content normalization function

The information content of the EWS provided form Eastern Alps Hydrographic District can be considered sufficiently detailed, hence the normalize value is equal to 0.75.

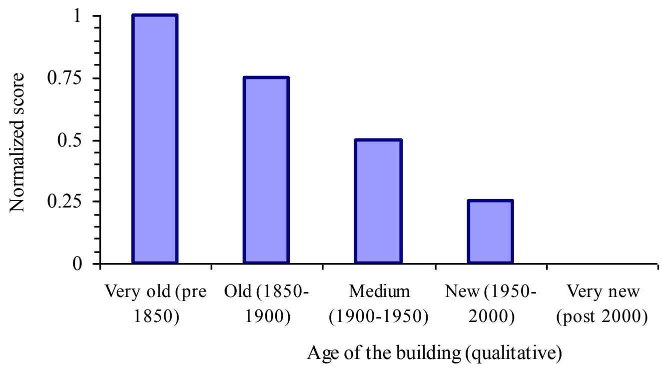
Building properties

Building properties are the only indicators that we have considered to assess susceptibility. It is divided in age, material and type of the building.

All the information we found about buildings was given us from the Eastern Alps hydrographic district in a excel table format. This is the only indicator that presents data divided for census track, so that we could make a differentiation inside the municipality. In this case the data have been collected in a qualitative way and then they have been normalized through qualitative judgement similar to Mertz et al. (2010).

Age

Very old buildings are highly susceptible to flood risk. Therefore, buildings constructed before 1960 were considered as 1. Similarly, very recently (after 2010) constructed buildings are considered as 0, as they are less susceptible. Other qualitative benchmarking is given below.

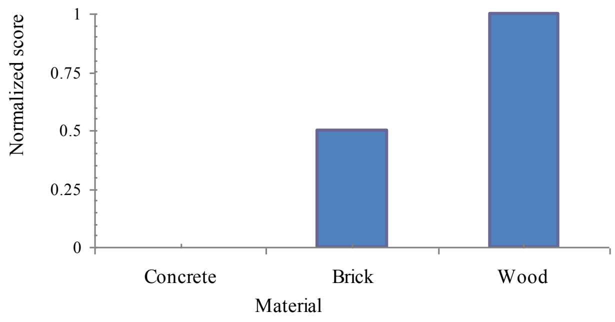


Graph 2.12 Building age normalization function

In order to normalize the age of the building we have calculated the average age for the buildings located in each census track. According to the average age a normalized value between 0 and 1 was assigned to each census track.

Materials

Concrete is more flood resistant than brick or wood. Therefore, buildings made up with wood and brick are highly susceptible to flood than buildings made up with concrete. Qualitative benchmarking is given below.

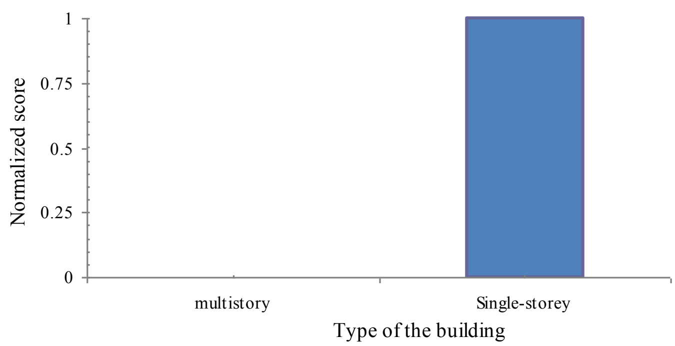


Graph 2.9 Building material normalization function

All the buildings in Savogna d'Isonzo are made of concrete so that all the municipality assumes a value equal to 0.

Types

Single storied buildings are highly susceptible to flood than multi-storied.



Graph 2.13 Building Type normalization function

Also in this case we have calculated the average type of buildings in each census track. In this way some part of the municipality result highly susceptible (census tracks with more multi-storey buildings) and others completely non susceptible (census tracks with more single-storey buildings).

2.3.5 Aggregation procedure

Among the different procedures mentioned in the previous chapter in this work the procedure that is used is the weighted average (WA). At the beginning it was thought to use also the NAM (non additive measures), but at the end the questionnaire prepared by the KULTURisk research group was not given to the stakeholder for some practical issues, so that it was not possible to elaborate the results. Anyway it is presented, as an example, in the Appendix 3.

Anyway, the weights chosen in the baseline scenario are elicited from the KR research group opinions, presented in the Del 1.7.

The given weights have been elaborated by experts in different fields such as economics, social and environmental sciences and engineering. Concerning early warning system during the work it was necessary try to make some changes in the relative weight in order to assign it a consistent value. In the discussion of the results it will explained how this operation was made.

3) RESULTS AND GIS MAPS

3.1 Baseline scenario

3.1.1 People

People at risk return time 30 years

Map 1 People at risk baseline scenario TR 30 (Author's elaboration).

People at risk return time 100 years

Map 2 People at risk baseline scenario TR 100 (Author's elaboration).

People at risk return time 300 years

Map 3 People at risk baseline scenario TR 300 (Author's elaboration).

In the following table there are reported the number of people at risk and the relative costs for people in each return time considered in the baseline scenario.

	TR 30	TR100	TR300
N people at risk	0.86	3.25	7.1
N of injuries	0.37	1.58	3.58
Injuries damages	229.400 €	976.600 €	2.219.600 €
N of death	0.08	0.28	0.68
Death damages	244.900 €	868.000 €	2.108.000 €
Total costs people	474.300,00 €	1.847.600,00 €	4.327.600,00 €

Tab 3.1 Total costs for people in the baseline scenario (Author's elaboration)

3.1.2 Buildings

Buildings at risk return time 30 years.

Map 4 Building at risk baseline scenario TR 30 (Author's elaboration)

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Buildings at risk return time 100 years

Map 5 Building at risk baseline scenario TR 100 (Author's elaboration).

Buildings at risk return time 300 years

Map 6 Building at risk baseline scenario TR 300 (Author's elaboration).

The table 3.2 presents the associated costs to buildings for each probability analyzed in the baseline scenario.

	TR 30	TR100	TR300
Residential buildings tot pixel	1.425 €	22.192 €	38.626 €
Industry (CAUDEK) tot pixel	10.065 €	10.879 €	11.292 €
Total costs for buildings Adaptation to pixel 58 m^2	666.420 €	1.918.118 €	2.895.244 €

Tab 3.2 Total costs for buildings in the baseline scenario (Author's elaboration).

3.2 Alternative scenario EWS

In this section of the results it will be firstly presented the alternative scenario considering an early warning system with the relative weight assigned to it in the methodology; later on it will be reported an example with changed weights. For the alternative scenario it will be presented only the 300 years return time because it is considered the most illustrative.

3.2.1 People

People at risk return time 300 years EWS using the SERRA's weights

Map 7 People at risk alternative scenario (EWS) TR 300 (Author's elaboration).

People at risk return time 300 years EWS implementing SERRA (first approximation changing the weights)

Map 8 People at risk alternative scenario (EWS), SERRA implementation (Author's Elaboration).

The following table (Tab3.3) presents a comparison of the total costs related to people in the different alternative scenarios analyzed

	TR 300 SERRA EWS WEIGHTS	**TR300 EWS SERRA IMPLEMENTATION**
N. of people at risks	5.54	4.22
N of injuries	2.19	1.24
Injuries costs	1.357.800 €	768.800 €
N of deaths	0.41	0.24
Death costs	1.271.000 €	744.000 €
Total costs	2.628.800 €	1.512.800 €

Tab. 3.3 Total costs for people in the alternative scenarios (Author's elaboration).

3.2.2 Buildings

Building at risk return time 300 years EWS

Map 9 Buildings at risk alternative scenario (EWS) (Author's Elaboration).

The table 3.4 presents the associated costs to buildings in 300 years return time scenario, considering the EWS.

	TR 300 EWS
Residential buildings tot pixel	35.675 €
Industry (CAUDEK) tot pixel	9.217 €
Total costs for buildings **Adaptation to pixel 58 m²**	2.603.736€

Tab. 3.4 Total costs for buildings in the alternative scenario (Author's elaboration).

3.3 Cost-benefit analysis

The costs of the baseline and the alternative scenario (EWS) derive from the depth damage functions used in this case study. Moreover, to have an idea of the effective benefit that a EWS can give in a flood event, I've considered the possibility of false and missed alarm. To obtain a proper data about the probability it should be used a hydrological model and further study of the uncertainty is needed. Due to the lack of time and experience, the data used and reported in the Table 3.5 derive from some expert's judgement (Eastern Alps Hydrographic District and University supervisor). Mostly based on a EWS already installed in the Bacchiglione River (a river that crosses

Vicenza) the probability of a false alarm is calculated as 25%, while the probability of a missed alarm is considered about 5%. To obtain the cost I've multiplied the data of evacuation cost (Dr. Paolo Nonino, responsible of the technical area of Savogna d'Isonzo p.c.) for the probability of a false alarm; while in case of missed alarm I've considered all the baseline costs multiplied per the probability of a missed alarm.

	TR30	TR100	TR300
TOTAL BASELINE	1.140.720 €	3.765.718 €	7.222.844 €
TOTAL EWS	803.518 €	2.825.428 €	5.232.536 €
COST FALSE ALARM	500 €	500 €	500 €
COST MISSED ALARM	57.036 €	188.286 €	361.142 €
INSTALLATION COSTS	5.000 €	5.000 €	5.000 €
COST BENEFIT	274.666 €	746.504€	1.623.666€

Tab 3.5 Cost benefit analysis. Baseline scenario and EWS considering SERRA weights (Author's elaboration).

After the calculation of the results, it was clear that the weight given to the EWS in the methodology was well-calibrated concerning buildings, while regarding people it was probably underestimated. In particular in this case study, where the area is really small and the number of people at risk is also little, it is reasonable to think that a reliable EWS can actually be more effective. For this reason, in this context it was necessary trying to change the weights in the hierarchical combination of indicators of the people vulnerability, assigning to the EWS and the human component of vulnerability a higher value. This is just a first approximation, further research is needed to try to assess and recalibrate the weights of the EWS in the SERRA methodology. In Table 3.6 it's presented a comparison between the total costs of EWS using the SERRA weights and the total costs of EWS with reviewed weights. The new values of the weights were chosen in collaboration with some experts (Ferri M., Autorità di Bacino, University Supervisor and other flood risk experts of the University) and they are reported in Appendix 2.

	TR 300 BASELINE	TR300 EWS	TR300 TEST
N OF PEOPLE AT RISK	7,1	5,54	4,22
N OF INJURIES	3,58	2,19	1,24
INJURIES COSTS	2.219.600€	1.357.800 €	768.800 €
N OF DEATH	0,68	0,41	0,24
DEATH COSTS	2.108.000 €	1.271.000 €	744.000 €
TOTAL COSTS PEOPLE	4.327.600 €	2.628.800 €	1.512.800 €

Tab 3.6 Comparison of the different scenario considering people at risk TR300 (Author's elaboration).

3.4 Cost effectiveness analysis

The complete monetization of the people's damage is a trivial task. Assigning a value to the life of people that change from country to country opens an ethic issue. To avoid this it is following proposed a cost effectiveness analysis regarding people.

In the Table 3.7 it is reported a cost effectiveness analysis of the different scenarios analyzed (baseline, EWS with SERRA weights and EWS changing the SERRA weights) for the return time considered. The costs of EWS partially change with the return time considered due to the inclusion of the probability of missed alarm in the calculation. The total amount of one scenario multiplied per the probability of missed alarm (5%) it's added at the cost of installation of EWS and the false alarm. Also to calculate the costs of false alarm it is used a probability value (25%) that is multiplied for the total value of evacuation costs (about 2000 euro, p.c). The following tables summarized the rounded off values of people at risk in the different situation and the EWS total costs. While in the costs-benefit analysis it's finally presented a benefit expressed in euro, in this case, the task to decide which could be the best solution is totally given to the Decision maker's.

	TR30	TR100	TR300
n of people at risk/BASELINE	1	4	8
n of people at risk/EWS 1	1	3	6
n of people at risk /EWS2			5
n of injuries/ BASELINE	1	2	4
n of injuries/EWS1	1	1	3
n of injuries/EWS2			2
n of death	0	1	1
n of death/EWS1	0	1	1
n of death/ EWS2			1

Tab. 3.7 Effectiveness of EWS regarding people (Author's elaboration).

	TR30	TR100	TR300
COST FALSE ALARM	500 €	500 €	500 €
COST MISSED ALARM	57.036 €	188.286 €	361.142 €
INSTALLATION COSTS	5.000 €	5.000 €	5.000 €
TOTAL EWS	62.536 €	193.786 €	366.642 €

Tab. 3.8 Total costs for EWS in each TR (Author's elaboration).

4) DISCUSSION OF THE RESULTS AND CONCLUSIONS

The baseline scenario shows the flood risk in the Italian part of the Vipacco's Basin in the current situation considering the SERRA approach, while the EWS scenarios illustrate the possible risk reduction situations.

In particular the results illustrate the number of people at risk in each return time considered, the number of possible injuries and death, the building exposed to risk and the complete monetization of this entire factor.

Looking at the Table 3.1 and 3.2 reported in the results, it's clear that the relative costs of a flood obviously increase when the severity of the flood increases.

In a case of a complete monetization of injuries and deaths in all the return times considered the values of injuries and death damage are bigger than the buildings damages, even if for the 100 years scenario these values are quite similar.

The Table 3.5 reports the complete cost-benefit analysis, considering people and buildings, for the three return times in the baseline and in the first alternative scenario.

The weights used in this alternative scenario have been presented in the SERRA methodology explanation (Paragraph 2.2.2). In the entire flood probability considered (30, 100 and 300 years) there is an economic benefit from installing a EWS. Thanks to this risk reduction measure the people can be put in a safe place, the buildings' structure can be protected by sand bags and the building content can be moved away from a dangerous place.

Another important thing to notice is that an increasing intensity of the event (that is reflected in a higher return time) increases the benefit derived from a EWS. Since the intensity and the frequency of the flood is subjected to increase in the next years, mostly due to climate change (IPCC, 2007) and an increasing number of exposed people (Zbiegniew W.K.), it' s really important for the DM's considered the benefit provided by EWS in an extreme event.

Anyway, analyzing the number of people at risk (considering possible injuries and death) and thinking about the peculiar characteristics of the area of study, the results offered by the weights used in the SERRA methodology seems to be overestimated. The municipality taken into account has about 1800 inhabitants mostly dislocated in all the area of the municipality; the real number of people at risk is quite small and in a case of evacuation there would not be traffic problems such as in a bigger city. For all these reasons, talking with flood experts, we've decided to change the SERRA weights for the EWS regarding people. This is just a first approximation, where I've used the same hierarchical combination of the indicators, changing only the relative weights. In the Appendix 2 the new weights used in the test are reported. Anyhow, further studies are needed for the re-calibration of the weights of the SERRA methodology, whenever the analyses would be moved to different areas of study

The results of this first approximation are reported in Tab. 3.6. and they are focused on a return time of 300 years. The comparison with the other scenarios clearly shows the benefit obtained from an economic point of view; anyway the number of people at risk is still quite high and further research need to be done to produce operational applications.

In regard to the costs-effectiveness analysis the number of people that can be saved by an early warning alarm is estimated in comparison to the costs of this risk reduction measure. The decision makers should choose if it is worth or not spending that amount of money to try to save people from injuries or death.

The first general consideration about the results concerns the dimension of the area of study and its relative importance. As already explained Savogna d'Isonzo is a really small municipality and, as the results have revealed, the number of people at risk is quite low in absolute terms; in the worst case there are just 8 people at risk. On the one hand, for these reasons, it was quite easy during the work making consideration over the data and assessing if the results were consistent or not. In a small area like Savogna d'Isonzo it's clear that a good communication system (alarm, SMS, web) can easily reach all the inhabitants and the evacuation procedures and the emergency measures should work well. Reading the report of the case study of the Danube basin made by a partner of the KULTURisk project, it was immediately clear the different approach in the work. Danube is the second largest river basin in Europe and it crosses 19 countries. In such a huge basin, it's harder to think about a good communication system that can provide reliable and accurate information in all the 19 countries crossed. Moreover, even if the alarm could reach all the inhabitants of the river basin, it should be considered the possible infrastructure's congestion due to high number of inhabitants in the flooded area. Furthermore in a case of a bigger river's basin it would not be easy to find and compare

the data, making assumption and analyzed the results. Obviously the collection and the precision of the data are really different. In the Danube case study a lot of data were based at national scale and they can change really much from one country to another. These data produce a different vulnerability in each country of the area of study. Consequently in that case it should be more visible the role of the human vulnerability in the risk calculation. On the other hand, in a little area of study like Savogna d'Isonzo, the spatial differentiation of the risk was mostly due to different depths and velocities of the water during a flood event and the relative land use. The social indicators were considered homogeneous in all the area so that there was not a differentiation in the human vulnerability inside the municipality considered. The only characteristic that changed among the municipality is the susceptibility, due to the different characteristics of the buildings in the census tracks. Another big issue to take into account in a river basin is the increasing uncertainty of the hydrological model. It's clear that for a small river basin the meteorological conditions and the peak flow forecast should be more precise and reliable. Nevertheless it should be necessary in each case study trying to assess the uncertainty of the prevision's model, but it was not possible in this context.
The second issue has emerged during the results analysis. As already explained, the assignment of the weights in the aggregation procedure of SERRA was made in a first approximation consulting expert's opinion. During this work it was thought to give a questionnaire (Annex A) to the stakeholders in order to use their opinion to recalibrate the weights. The Nam measure (NAM) with the Choquet integral was chosen as aggregation procedure (Mojtahed et al., 2013). In the middle of the discussion over implementation of the normative, it was not possible to propose the questionnaire to the stakeholders; therefore I've used the weights derived from expert's opinion. The results of the baseline seem to be consistent with a possible flood event, while the EWS results seem to be overestimated. This is the reason why it was done one SERRA implementation, changing the relative weights of EWS, adaptive capacity and human vulnerability in the hierarchical combinations of the indicators (Appendix 2). This is just a first approximation and further studies are needed in this context.
Another consideration, as already advanced in the introduction, regards the ethical question about the complete monetization of the people's life. According to Biausque (2010) VSL can be calculated using different parameters like the willingness to pay, the

human capital and the cost of indenisation. For this reason, this value is not equal for all the human being around the world, but changes from country to country. For instance, Miller (2000) has collected the results of many different researches and he has reported the VSL for different countries expressed in thousands of 1995 U.S dollar. Just to give an idea of the differences among countries, the value of life of a Japanese was considered as about 8 million dollar, while the life of a South Korean's was estimated at about 620 thousands of dollar. There's nowadays a living matter about this question and in particular I want to report the case of two journal's article that dissert overt this theme. At the end of April 2013, after the disaster happened in one Bangladesh factory, Maha Rafi Atal has written an article on "The guardian" on line journal about the differences between the cost of living and the costs of life. She affirms that "if the cost of living varies from place to place, the cost and value of a life should be the same everywhere" (Rafi Atal M., 2013). Tim Worstall, a few days later, has replayed to her with a post on the "Forbes" supporting the theory that it's theoretically right the principle that each human being life has the same value, but not in economic terms; and it depends mostly on the average income and economic situation of the country of origin.

In this context it makes sense to consider the VSL if we want to compare the cost of a risk prevention measure with the total cost of the flood event, but the decision makers should look also at the cost effectiveness analysis that counts the effective number of people. In my opinion, looking just at the final cost-benefit analysis (Tab.3.5) they could not notice the differences between people and building at risk and they could take a decision just based on the amount of losses without giving the right value to the citizens' life.

One of the most ambitious purposes of SERRA methodology is involving several disciplines in the study. It is not easy trying to put in communication to each other so many different approaches; SERRA has incorporated through a trans-disciplinary approach several experts from economic to social science and from environmental sciences to hydraulic engineering. This communication among different fields allows to go beyond the traditional risk reduction measure and makes SERRA a good instrument in the decision making process.

The last and the most important reflection induced by this study concerns the risk prevention measure, in particular EWS. Even if further research is necessary to assess the right weight for the EWS in the aggregated vulnerability, the importance and the possible effectiveness of a non-structural risk prevention measure clearly come out from this work. People's life can be saved with a proper alarm system installed and also the economic losses induced from buildings can be partially reduced.

The following step in the flood risk reduction analysis is the communication of the decision to the stakeholders, in particular to the population, the municipality, the emergency measures' responsible, the people involved in emergency and so on. Flood risk reduction must involve the citizen in a participatory process; the stakeholder needs to be informed by the experts and a great interest should be focus on the population's preparedness, attitude and behaviour.

Prevention measures need to be increased and improved, instead of spending a large amount of resources to response to the natural hazard. One of the aims of the KULTURisk project was to create a culture of risk prevention, considering several types of risk. Through a questionnaire written by the environmental sciences research group of Ca' Foscari (Ronco P., Torresan S. et al. 2013), the KULTURisk group could collect opinion of experts of several natural hazards, such as volcano, earthquake and windstorm. The results were discussed at the KULTURisk workshop in Venice on 19-20 September 2013. It has emerged that are necessary further studies in the adaptation of Coping and Adaptive capacity and in the risk calculation, but the general methodology was considered good or excellent suitable for seismic and wind storm risks and far suitable for volcanic and avalanches risk assessment (Ronco P., 2013). An improvement of human component of vulnerability could be one of the right choices considering a multi-hazard approach. No matter which type of risk is affecting a population, it's important that people are prepared to promptly react to it. "Building disaster resilient communities means that disaster reduction is everyone's responsibility. A disaster reduction strategy is a global challenge that involves communities, schools, the media, researchers, scientists, nongovernmental organizations, various sections in governments and regional and international organizations including many agencies and programmes of the UN system"(Briceño S., 2005).

Probably, only a good and coordinated work of this big chain of subjects involved could really help communities all around the world to face in a sustainable way all the type of natural hazards.

Appendix 1

Social Indicators

Components	Variables	Indicators	Definition and notion	Further Details	Sources
Adaptive Capacity (AC)	Economic Wealth	Income	People with higher number of per capita income lead to increase AC, decreasing Vulnerability (VUL).	Per capita income/GDP	Immobiliare.it
	Risk Spread	Insurance density	Higher insurance density lead to increase AC and decrease VUL	Ratio of total insurance to total population	IVASS
	Equity	GINI Index	Measure of statistical dispersion about the income of the population	A value with 0 expresses perfect equality, whereas 1 expresses maximum inequality	ISTAT
		No of Hospital	Higher number decreases vulnerability		Health Minister
	Early Warning System (EWS)	Lead Time	EWS with high lead time, enough information content and reliable warning lead to decrease VUL	Requires information about the EWS in place. The indicator can be approximated assigning a score to each of the four dimensions	AdB Venice
		Information Content			
		Reliability			
Coping capacity (CC)	Demography	Dependency Ratio	Population with higher DR leads to increase vulnerability	It is an age population ratio of those typically not in the labour force and those typically in the labour force	ISTAT
		New comers	Population with higher number of migrants leads to increase vulnerability	Percents of recent immigrants	ISTAT
	Emergency Measure	People involved	Higher number of people involved decreases VUL	Per capita number of volunteers and number of people of fire-fighters and civil protection	Civil protection
Susceptibility	Building Properties	Age	Old buildings are more vulnerable	Requires the breakdown of buildings into categories and relative % of concentration.	AdB Venice
		Material	Concrete is more resistant than brick and wood		
		Type	Single Storied Buildings are more vulnerable than multisotried		

Appendix 2

SERRA weights and first approximation

VULNERABILITY										
				0,4172564						
Human vulnerability										Susceptibility
			60%							40%
			0,362094							0,5
Coping capacity				Adaptive Capacity						
40%				60%						
0,7				0,59651						
Demography		Emergency Measures		Risk Spread	Equity		EWS			
40%		60%		35%	20%		45%			
1		0,5		0,463	0,4848		0,75			
Dependency Ratio	New comers	People involved		Insurance density	GINI index	Hospital bed	Lead	Content	Reliability	
50%	50%	100%		100%	40%	60%	30%	40%	30%	
1	1	0,5		0,463	0,738	0,316	0,75	0,75	0,75	

SERRA weights

VULNERABILITY										
				0,30085655						
Human vulnerability										Susceptibility
			90%							10%
			0,27873							0,5
Coping capacity				Adaptive Capacity						
5%				95%						
0,7				0,72239						
Demography		Emergency Measures		Risk Spread	Equity		EWS			
40%		60%		5%	5%		90%			
1		0,5		0,463	0,4848		0,75			
Dependency Ratio	New comers	People involved		Insurance density	GINI index	Hospital bed	Lead	Content	Reliability	
50%	50%	100%		100%	40%	60%	30%	40%	30%	
1	1	0,5		0,463	0,738	0,316	0,75	0,75	0,75	

SERRA first approximation, changed weights

Annex A

Questionnaire for the stakeholders

Different order Interaction: Aggregation of 4 indicators

<u>1. First order interaction: only additive</u>
Aggregating four nodes in the first order interaction, the question is very simple.

<u>Question:</u> We consider 'adaptive capacity' as an example which can be assessed by focusing in particular on the performances of four indicators:
Economic Wealth (EconW): refers to the abundance of valuable resources. Economic Wealth (EconW) is considered here as per capita income. A higher number of index value –value at "best"- leads to increase adaptive capacity.
Risk Spread (RS): refers to spread or transfer of risks. Insurance is considered as risk transfer mechanism. Insurance density is considered as specific indicator for measuring insurance. A higher number of index value –value at "best"- leads to increase adaptive capacity.
Equity (EQ): refers to equal opportunity, in a safe and healthy environment. In this study, equity is the aggregated notion of proxies of GINI Index and availability of medical treatment (number of beds per 1000 population). A higher number of index value –value at "best"- leads to increased adaptive capacity.
Early Warning System (EWS): is the aggregated notion of lead time, reliability and information supplied. A higher number of index value –value at "best"- leads to increased adaptive capacity.

Consider the relative importance of each indicator. Please allocate 100 points among them

Indicators	*Parameters*	*Values*
EconW	μ(1)	
RS	μ(2)	
EQ	μ(3)	
EWS	μ(4)	
Total		*100*

In order to simplify the implementation of the procedure, the parameters of the Möbius transform are later calculated. There is a two-way relation between the measures (μ), i.e. the elicited measures, and the Möbius coefficients (m):

$$m_\mu(S) = \sum_{T \subseteq S} (-1)^{s-t} \mu(T)$$

[1]

In the example with four nodes the Möbius coefficients are:
m(1) =μ (1); m(2) =μ (2); m(3) =μ (3); m(4) =μ (4)
m(1,2) = 0; m(1,3) = 0; m(1,4) = 0; m(2,3) = 0; m(2,4) = 0; m(3,4) = 0
m(1,2,3) = 0; m(1,2,4) = 0; m(1,3,4) = 0; m(2,3,4) = 0
m(1,2,3,4) = 0

Using the Möbius coefficients, given that the Choquet integral is computable as:

$$C_\mu(x_1, x_2, .., x_n) = \sum_{T \subseteq N} m_\mu(T) \min_{i \in T} \{x_i\}$$

[2]

with four modes (x1, x2, x3, x4), the Choquet integral is calculated as follows:

Cm(x1, x2, x3, x4) = m(1) • x1 + m(2) • x2 + m(3) • x3 + m(4) • x4

2. Second order interaction:

Aggregating four nodes in the second order interaction, the questionnaire can be designed following the example below.

Question: *We consider 'adaptive capacity' as an example which can be assessed by focusing in particular on the performances of four indicators: (1) Economic Wealth (EconW); (2) Risk Spread (RS); (3) Equity (EQ); (4) Early Warning System (EWS).*

For each indicator, there are two extreme cases which will be called "best" and "worst" and below we offer a matrix containing possible coalitions of the indicators chosen. The values for each of the rows may lie between 0 and 100, but need to respect monotonicity principle.

	EconW	RS	EQ	EWS	Values
μ(1)	Best	Worst	Worst	Worst	
μ(2)	Worst	Best	Worst	Worst	
μ(3)	Worst	Worst	Best	Worst	
μ(4)	Worst	Worst	Worst	Best	
μ(1,2)	Best	Best	Worst	Worst	
μ(1,3)	Best	Worst	Best	Worst	
μ(1,4)	Best	Worst	Worst	Best	
μ(2,3)	Worst	Best	Best	Worst	
μ(2,4)	Worst	Best	Worst	Best	
μ(3,4)	Worst	Worst	Best	Best	

In order to simplify the implementation of the procedure, the parameters of the Möbius transform are later calculated. There is a two-way relation between the measures (μ), i.e. the elicited measures, and the Möbius coefficients (m):

$$m_{\mu}(S) = \sum_{T \subseteq S} (-1)^{s-t} \mu(T) \quad [3]$$

In the example with four nodes the Möbius coefficients are :

m(1) =μ (1); m(2) =μ (2); m(3) =μ (3); m(4) =μ (4)

m(1,2) = μ (1,2) – [μ (1) + μ (2)]
m(1,3) = μ (1,3) – [μ (1) + μ (3)]
m(1,4) = μ (1,4) – [μ (1) + μ (4)]
m(2,3) = μ (2,3) – [μ (2) + μ (3)]
m(2,4) = μ (2,4) – [μ (2) + μ (4)]
m(3,4) = μ (3,4) – [μ (3) + μ (4)]

As there is no third order interaction,
m(1,2,3) = 0;

However, parameters of third order can be elicited using below equation

$$\mu(S) = \sum_{T \subseteq S} m(T) \quad [4]$$

$$\mu(1,2,3) = m(1) + m(2) + m(3) + m(1,2) + m(1,3) + m(2,3) + m(1,2,3)$$

$= \mu(1) + \mu(2) + \mu(3) + [\mu(1,2) - (\mu(1) + \mu(2))] + [\mu(1,3) - (\mu(1) +$
μ3]+[μ2,3−μ2+μ3]+0
Therefore, $\mu(1,2,3) = \mu(1,2) + \mu(1,3) + \mu(2,3) - \mu(1) - \mu(2) - \mu(3)$

Similarly,
m(1,2,4) = 0; $\mu(1,2,4) = \mu(1,2) + \mu(1,4) + \mu(2,4) - \mu(1) - \mu(2) - \mu(4)$
m(1,3,4) = 0; $\mu(1,3,4) = \mu(1,3) + \mu(1,4) + \mu(3,4) - \mu(1) - \mu(3) - \mu(4)$
m(2,3,4) = 0; $\mu(2,3,4) = \mu(2,3) + \mu(2,4) + \mu(3,4) - \mu(2) - \mu(3) - \mu(4)$

m(1,2,3,4) = 0;

$$\mu(1,2,3,4) = m(1) + m(2) + m(3) + m(4) + m(1,2) + m(1,3) + m(1,4) + m(2,3) + m(2,4) + m(3,4) + m(1,2,3) + m(1,2,4) + m(1,3,4) + m(2,3,4) + m(1,2,3,4)$$
$$= m(1) + m(2) + m(3) + m(4) + m(1,2) + m(1,3) + m(1,4) + m(2,3) + m(2,4) + m(3,4)$$
$$= \mu(1) + \mu(2) + \mu(3) + \mu(4) + [\mu(1,2) - (\mu(1) + \mu(2))] + [\mu(1,3) - (\mu(1) + \mu(3))] + [\mu(1,4) - (\mu(1) + \mu(4))] + [\mu(2,3) - (\mu(2) + \mu(3))] + [\mu(2,4) - (\mu(2) + \mu(4))] + [\mu(3,4) - (\mu(3) + \mu(4))]$$
$$\mu(1,2,3,4) = \mu(1,2) + \mu(1,3) + \mu(1,4) + \mu(2,3) + \mu(2,4) + \mu(3,4) - 2\mu(1) - 2\mu(2) - 2\mu(3) - 2\mu(4)$$

where the coalition coefficient m(T) can be either positive, negative or null; if positive, it means that there is synergic interaction between the criteria (indicators) belonging to the coalition T while if negative, there is redundancy interaction (or conflicting). If null, no interaction exists.

Using the Möbius coefficients, given that the Choquet integral is computable as:

$$C_\mu(x_1, x_2, .., x_n) = \sum_{T \subseteq N} m_\mu(T) \min_{i \in T} \{x_i\}$$

with four sub-domains (x1, x2, x3, x4), the Choquet integral is calculated as follows:
Cm(x1, x2, x3, x4) = m(1) • x1 + m(2) • x2 + m(3) • x3 + m(4) • x4 + m(1,2) • min(x1, x2) + m(1,3) • min(x1, x3) + m(1,4) • min(x1, x4) + m(2,3) • min(x2, x3) + m(2,4) • min(x2, x4) + m(3,4) • min(x3, x4)

<u>3. Third order interaction:</u>
Aggregating four nodes in the second order interaction, the questionnaire can be designed following the example below.

<u>Question:</u> We consider 'adaptive capacity' as an example which can be assessed by focusing in particular on the performances of four indicators: (1) Economic Wealth (EconW); (2) Risk Spread (RS); (3) Equity (EQ); (4) Early Warning System (EWS).

For each indicator, there are two extreme cases which will be called "best" and "worst" and below we offer a matrix containing possible coalitions of the indicators chosen. The values for each of the rows may lie between 0 and 100, but need to respect monotonicity principle.

	EconW	RS	EQ	EWS	Values
μ(1)	Best	Worst	Worst	Worst	
μ(2)	Worst	Best	Worst	Worst	
μ(3)	Worst	Worst	Best	Worst	
μ(4)	Worst	Worst	Worst	Best	
μ(1,2)	Best	Best	Worst	Worst	
μ(1,3)	Best	Worst	Best	Worst	

μ(1,4)	Best	Worst	Worst	Best	
μ(2,3)	Worst	Best	Best	Worst	
μ(2,4)	Worst	Best	Worst	Best	
μ(3,4)	Worst	Worst	Best	Best	
μ(1,2,3)	Best	Best	Best	Worst	
μ(1,2,4)	Best	Best	Worst	Best	
μ(1,3,4)	Best	Worst	Best	Best	
μ(2,3,4)	Worst	Best	Best	Best	

In order to simplify the implementation of the procedure, the parameters of the Möbius transform are later calculated. There is a two-way relation between the measures (μ), i.e. the elicited measures, and the Möbius coefficients (m):

$$m_{\mu}(S) = \sum_{T \subseteq S} (-1)^{s-t} \mu(T)$$

[3]

In the example with four nodes the Möbius coefficients are :

m(1) =μ (1); m(2) =μ (2); m(3) =μ (3); m(4) =μ (4)

m(1,2) = μ (1,2) – [μ (1) + μ (2)]
m(1,3) = μ (1,3) – [μ (1) + μ (3)]
m(1,4) = μ (1,4) – [μ (1) + μ (4)]
m(2,3) = μ (2,3) – [μ (2) + μ (3)]
m(2,4) = μ (2,4) – [μ (2) + μ (4)]
m(3,4) = μ (3,4) – [μ (3) + μ (4)]

m(1,2,3) = μ (1,2,3) – [μ (1,2) + μ (1,3)+ μ (2,3)] + [μ (1) + μ (2)+ μ (3)]
m(1,2,4) = μ (1,2,4) – [μ (1,2) + μ (1,4)+ μ (2,4)] + [μ (1) + μ (2)+ μ (4)]
m(1,3,4) = μ (1,3,4) – [μ (1,3) + μ (1,4)+ μ (3,4)] + [μ (1) + μ (3)+ μ (4)]
m(2,3,4) = μ (2,3,4) – [μ (2,3) + μ (2,4)+ μ (3,4)] + [μ (2) + μ (3)+ μ (4)]

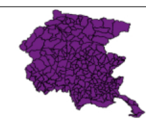
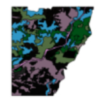
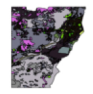
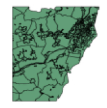
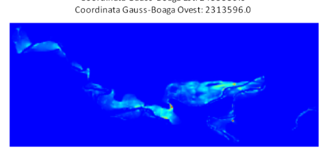
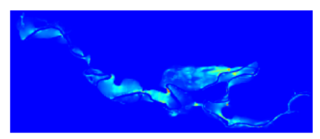
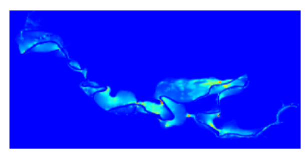
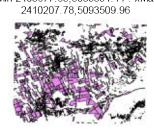
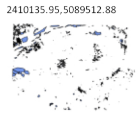
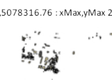
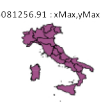
m(1,2,3,4) = μ (1,2,3,4) – [μ (1) + μ (2) + μ (3) + μ (4)] + [μ (1,2) + μ (1,3) + μ (1,4) + μ (2,3) + μ (2,4)+ μ (3,4)] – [μ (1,2,3) + μ (1,2,4) + μ (1,3,4) + μ (2,3,4)]

where the coalition coefficient m(T) can be either positive, negative or null; if positive, it means that there is synergic interaction between the criteria (indicators) belonging to the coalition T while if negative, there is redundancy interaction (or conflicting). If null, no interaction exists.
Using the Möbius coefficients, given that the Choquet integral is computable as:

$$C_{\mu}(x_1, x_2, .., x_n) = \sum_{T \subseteq N} m_{\mu}(T) \min_{i \in T} \{x_i\}$$

with four sub-domains (x1, x2, x3, x4), the Choquet integral is calculated as follows:
Cm(x1, x2, x3, x4) = m(1) • x1 + m(2) • x2 + m(3) • x3 + m(4) • x4 + m(1,2) • min(x1, x2) + m(1,3) • min(x1, x3) + m(1,4) • min(x1, x4) + m(2,3) • min(x2, x3) + m(2,4) • min(x2, x4) + m(3,4) • min(x3, x4) + m(1,2,3) • min(x1, x2, x3) + m(1,2,4) • min(x1, x2, x4) + m(1,3,4) • min(x1, x3, x4) + m(2,3,4) • min(x2, x3, x4) + m(1,2,3,4) • min(x1, x2, x3, x4)

Annex B *Metadata table*

IDENTIFICATION					PATIAL DATA AND SERVIC	KEYWORDS VALUES	GEOGRAPHIC LOCATION	TEMPORAL REFERENCE				CONFORMITY		CONSTRAINT RELATED TO ACCESS AND USE		ORGANISATIONS	METADATA ON METADATA					
Resource title	Resource abstract	Resource type	Resource locator	source langua	Topic category (ISO 19115 category)	Keywords	Geographic bounding box	Temporal extent	Date of publication	Date of cration	Acquisition date	Specification	Degree	Conditions applying to access and use	Limitation on public access	Responsible party	Metadata point of contact	Metadata date	Metadata language	Distribution format	Data type	Reference system
COMUNI_FVG_2009 polygon	Limiti amministrativi dei Comuni della Regione Friuli Venezia Giulia aggiornati a seguito dellafusione tra i Comuni di Campolongo al Torre e Tapogliano nel nuovo Comune denominato Campolongo	dataset	regione FVG	Italian	003 boundaries	comunità urbana , giurisdizione amministrativa , amministrazione , confine amministrativo , livellocomunale , comune , competenza amministrativa , ente locale , organo amministrativo	 Ambito territoriale: Regione - Friuli Venezia Giulia coordinate Gauss-Boaga Nord: 5168505,0 ; Sud: 5048187,0; Est : 2435539,0; Ovest: 2313596,0		01/01/2009		18/05/2013			public use	public	irdat@regione.fvg.it	irdat@regione.fvg.it	01/02/2009	Italian	.shp	vector	roma40/est
clc_2006_Clip	Raccolta di documenti esplicativi sul progetto Corine Land Cover (Guide tecniche, note, legende).	dataset	European Commision Centre for the observation of the earth	English	carte di base, pianificazione e catasto	uso del suolo , suolo , copertura del suolo , occupazione del suolo , carta del suolo , risorse del suolo	 xMin, yMin 383786.15,5078408.90 : xMax,yMax 394675.95,5091938.52	01/01/2000	01/01/2002		18/05/2013			copyright in some document	public	http://directory.eoportal.org/info_ETCLCEuropeanTopicCentreonCORINELandCover.html	irdat@regione.fvg.it	01/01/2006	Italian	shp.	vector	roma/40 est
land_use_2000_Clip	Uso del suolo aggiornato all'anno 2000 realizzato nell'ambito del Progetto "MOLAND FVG -Consumo ed uso del territorio del Griuli Venezia Giulia" (2001-2002)	dataset	regione FVG and European Commision. Institute for the environmet and the sustainability	English	pianificazione e catasto	uso del suolo , inquinamento del territorio , classificazione dell'uso del territorio , uso del territorio ,territorio (geografia), sviluppo del territorio, territorio (ecologia), assetto del territorio	 Ambito territoriale: Regione - Friuli Venezia Giulia coordinate Gauss-Boaga Nord: 5168505,0 ; Sud: 5048187,0; Est : 2435539,0; Ovest: 2313596,0	01/01/1980-01/01/2000		01/01/2001	18/05/2013			public use	public	http://www.jrc.ec.europa.eu and irdat@regione.fvg.it	irdat@regione.fvg.it	13/11/2007	Italian	shp.	vector	roma/40 est
sez_031_l_Clip		dataset	ISTAT	Italian	003 boundaries	confine amministrativo	 xMin, yMin 383786.16,5078408.90 : xMax,yMax 394673.81,5091938.46				18/05/2013			public use	public	http://dawinci.istat.it				shp.	vector	WGS84
sez_031_p_Clip		dataset	ISTAT	Italian	003 boundaries	confine amministrativo	 xMin, yMin 383786.15,5078408.90 : xMax,yMax 394673.81,5091938.52				18/05/2013			public use	public	http://dawinci.istat.it				shp.	vector	WGS84
Ferrovia_e_superfici_annesse_2000_Clip	Rappresentazione grafica delle linee ferroviarie della Regione Friuli Venezia Giulia, aggiornata al 2000, nell'ambito del progetto MOLAND FVG	dataset	regione FVG and European Commision. Institute for the environmet and the sustainability	English	Trasporti	trasporto , trasporto via terra , trasporto ferroviario , ferrovia , rete ferroviaria	 Ambito territoriale: Regione - Friuli Venezia Giulia Coordinata Gauss-Boaga Nord: 5168505.0 Coordinata Gauss-Boaga Sud: 5048187.0 Coordinata Gauss-Boaga Est: 2435539.0 Coordinata Gauss-Boaga Ovest: 2313596.0	01/01/1980-01/01/2000		01/01/2001	18/05/2013			public use	public	http://www.jrc.ec.europa.eu and irdat@regione.fvg.it	irdat@regione.fvg.it	13/11/2007		shp.	vector	roma/40 est
velocità_TR30		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/08/2013			restricted						grd.	raster	WGS84
velocità_TR100		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/08/2013			restricted						grd.	raster	WGS84
velocità_TR300		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/08/2013			restricted						grd.	raster	WGS84
tirante_TR30		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/08/2013			restricted						grd.	raster	WGS84
tirante_TR100		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/08/2013			restricted						grd.	raster	WGS84
tirante_TR300		dataset	Autorità di Bacino Venezia	Italian			 xMin;yMin 386750.3804;5081402.3790 xMax;yMax : 393630.3804;5085082.3790				29/082013			restricted						grd.	raster	WGS84
AREA_088030	Aree di copertura dei lotti di produzione della seconda edizione in aggiornamento della Carta Tecnica Regionale Numerica in scala 1:5000	dataset	regione FVG	Italian	Carte di base	cartografia , mappa , carta (geografia)	 xMin, yMin 2403677.65,5089394.44 : xMax,yMax 2410207.78,5093509.96	01/01/2003		01/05/2007	25/05/2013			public use	public	irdat@regione.fvg.it	irdat@regione.fvg.it	08/05/2007	italian	shp.	vector	monte mario 3003
AREA_088070	Aree di copertura dei lotti di produzione della seconda edizione in aggiornamento della Carta Tecnica Regionale Numerica in scala 1:5000	dataset	regione FVG	Italian	Carte di base	cartografia , mappa , carta (geografia)	 xMin, yMin 2403586.43,5083859.04 : xMax,yMax 2410135.95,5089512.88	01/01/2003		01/05/2007	25/05/2013			public use	public	irdat@regione.fvg.it	irdat@regione.fvg.it	08/05/2007		shp.	vector	monte mario 3003
AREA_088110	Aree di copertura dei lotti di produzione della seconda edizione in aggiornamento della Carta Tecnica Regionale Numerica in scala 1:5001	dataset	regione FVG	Italian	Carte di base	cartografia , mappa , carta (geografia)	 xMin, yMin 2403507.28,5078316.76 : xMax,yMax 2410475.44,5083947.13	01/01/2003		01/05/2007	25/05/2013			public use	public	irdat@regione.fvg.it	irdat@regione.fvg.it	08/05/2007		shp.	vector	monte mario 3003
AREA_088120	Aree di copertura dei lotti di produzione della seconda edizione in aggiornamento della Carta Tecnica Regionale Numerica in scala 1:5002	dataset	regione FVG	Italian	Carte di base	cartografia , mappa , carta (geografia)	 xMin, yMin 2410011.91,5081256.91 : xMax,yMax 2412098.44,5083834.09	01/01/2003		01/05/2007	25/05/2013			public use	public	irdat@regione.fvg.it	irdat@regione.fvg.it	08/05/2007		shp.	vector	monte mario 3003
reg2011		dataset	ISTAT	Italian		cartografia , mappa , carta (geografia)	 xMin, yMin 313361.00,3933878.18 : xMax,yMax 1312106.50,5220491.20				18/06/2013			public use	public					shp.	vector	ED50/UTM 32N

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