RAIN – Risk Analysis of Infrastructure Networks in Response to Extreme Weather

Project Reference: 608166

FP7-SEC-2013-1 Impact of extreme weather on critical infrastructure

Project Duration: 1 May 2014 – 30 April 2017

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The evaluation is:

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- **The content is not related to general outcomes as dissemination or communication**
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Methodology for measuring societal vulnerability due to failure of critical land transport infrastructure elements

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1. Executive summary

Extreme weather events reflect in the transport sector immediately, intensively and with massive negative consequences: they lead to the increase of freight transport time, prolongation of traveling and the rise of accident probability. Except for the direct above mentioned extreme weather impacts on transport infrastructure, there are also consequential negative societal and economic impacts in population which are caused by the disfunctionality of transport infrastructure. Among the most serious impacts on population are: unavailability of ambulance and rescue services which causes higher damage of health and loss of lives of a population, unavailability of essential food and goods, problems with providing massive evacuation, insufficient security of population and public order, transport inaccessibility of employer, i.e. longer way to work place.

Deliverable D 3.4 "Methodology for measuring societal vulnerability due to failure of critical land transport infrastructure elements" is dealing with identifying, measuring and assessing societal vulnerability caused by impacts of extreme weather events on critical land transport infrastructure.
It is divided into two basic parts. The first part (Section 4) "Research of the societal vulnerability concepts and societal vulnerability components" (security, economic, social) is dealing with theoretical aspects of vulnerability. It includes defining vulnerability, vulnerability concepts, core factors and key dimensions of vulnerability, resilience and survey of some models of risk and vulnerability assessment. The second part (Section 5) "Development of approach to measure societal vulnerability" includes results of our research in the form of proposed methodology for measuring societal vulnerability due to extreme weather impacts on critical transport infrastructure. Our approach is based on multilevel approach to societal vulnerability measuring. The measure of Societal Vulnerability is expressed through Vulnerability Index (VI) calculated on the basis of selected vulnerability indicators. The higher VI value the higher societal vulnerability.

In addition to this approach a specific application for measuring vulnerability and resilience from a user perspective was developed within the Objective Ranking Tool. This additional work related to the DoW was done based on the remarks from reviewers that the potential innovation lies in the development of a unified framework for evaluating critical infrastructure, identifying natural hazards and assessing risks in order to make effective decisions on the mitigation of negative impacts from extreme weather. Further improvements to make this analyses more user-oriented (i.e. providing more practical outputs) were recommended. This specific ORT-application was developed as a response to these remarks.

This specific ORT-application is a tool for self-evaluation by local authorities at different levels and their stakeholders. Within this application it is possible for them to assess their performance and preparedness to different types of extreme weather events. This assessment expresses elements of vulnerability as such but also allows the identification of the quality of preparation in terms of resilience. Having seen a clear picture of their strength and weaknesses in the face of extreme weather they can act to improve their resilience.

The outcome of the described two basic –more theoretical - parts was used as input to develop specific criteria to evaluate the vulnerability and resilience of the community within the ORT-application. The ORT-application on vulnerability and resilience to extreme weather events might be seen as a practicable, easy to use, assessment for any local authority. Within the tool it is possible to compare the outcomes of different local assessments and to decide on regional level where to improve preparation or where investments will have the best improvements in terms of preparedness.

2. Glossary

Risk – the combination of the probability of an event and its negative consequences (UN/ISDR, 2009).

Vulnerability - the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UN/ISDR) (2009).

Exposure - the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (IPCC, 2012).

Susceptibility- characterizes the predisposition and likelihood to suffer harm when a hazard strikes a community or a system is exposed. It is revealed within physical, social, environmental, cultural and institutional dimensions (Birkmann, 2013).

Adaptive capacity - the combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities (IPCC, 2012).

Resilience –- a concept related to a system's ability to perform the critical functions required for its mission efficiently, even in the event of disruptive actions, e.g., natural, accidental or malevolent events. Resilient systems can maintain their performance through (Biringer, 2013):

- prevention or absorption of a disruption impact,
- reconfiguration and adaptation from normal operating procedures to a different set of operations,
- restoration or recovery the system quickly and efficiently.

3. Introduction

Functional transport infrastructure is the core of any developed country. Its disruption due to extreme weather events can cause major problems for the functioning of the whole society and also lead to an increased vulnerability. In recent years disruption of transport infrastructure, due to extreme weather events, has increased significantly. The impact of these events varies between regions depending on geographic risk exposure and the level of socio - economic development.

In many cases disturbance of line transport constructions means barred access to the basic life needs and disturbance to the traffic requirements of the target area. Such disruption can have an economic impact on the whole region or state, on its economic growth, can have a significant social impacts on the population, their health, standard of living, security or public order. Elements of transport infrastructure also have a major role in facilitating assistance during various crisis situations and also in ensuring a mass evacuation.

Within the deliverable D 3.4 “Methodology for measuring societal vulnerability due to failure of critical land transport infrastructure elements “ the work is concentrated on development of an understanding how failure of critical land transport infrastructure leads to societal vulnerability. From a literature review, dealing with measuring vulnerability to extreme weather events, follows that a common methodology to identify and measure risk and vulnerability to extreme weather events in order to define disaster-risk management and disaster-relief priorities is still not sufficiently developed. Also for this reason our effort was concentrated on research how to measure vulnerability to be usable for improving risk reduction and preparedness to extreme weather events and how to propose and develop relevant indicator approaches for specific purposes.

4. Research of the societal vulnerability concepts and societal vulnerability components (security, economic, social)

4.1 Defining vulnerability

Societal vulnerability is a part of a disaster risk assessment and crucial information necessary for supplementing hazard and mitigation assessments. Identification and assessment of various vulnerabilities of societies, economies, institutional structures and environmental resource bases are the basic information necessary for improving risk reduction and preparedness to natural hazards. Assessing vulnerability does not mean only to capture the human vulnerability but also to assess the resources available for dealing with the adverse event.

Assessing and measuring vulnerability in the context of extreme weather events requires foremost a clear understanding of the vulnerability concepts and what vulnerability is (Luskova, 2015).

The concept of vulnerability has been emerged, discussed and continuously developed over the almost past five decades especially in the fields of geographic development and poverty research, and hazard and disaster risk research. In the 1970s, research focused on disasters and crises associated with droughts in Africa, significantly contributed to the development of social vulnerability concept in geographic development and poverty research. Hazard and disaster risk research associated with disaster risk reduction started in the 1980s. In the last two decades vulnerability has become also a key topic in the climate change science.

The term “vulnerability” is used very loosely in dependence on an individual’s background and the applied context.

The scientific communities and stakeholders apply different vulnerability definitions. According to Birkmann (2013), the current literature encompasses more than 30 different definitions, concepts and methods to systematize vulnerability (Byrtusova et al, 2015). There is no consensus about the precise meaning of the term vulnerability in the scientific literature, and it seems to be open to interpretation.

In the ISO/IEC 27000:2016, vulnerability is defined as “a weakness of an asset or control that can be exploited by one or more threats”. A control is measure that is modifying risk, threat is potential cause of an unwanted incident, which may result in harm to a system or organization (ISO/IEC 27000:2016).

Cannon et al. (2003) says that: “ Vulnerability (in contrast to poverty which is a measure of current status) should involve a predictive quality: it is supposedly a way of conceptualizing what may happen to an identifiable population under conditions of particular risk and hazards. It is the complex set of characteristics that include a person's:

- initial well-being (health, morale, etc.),
- self-protection (asset pattern, income, qualifications, etc.),
- social protection (hazard preparedness by society, building codes, shelters, etc.),

- social and political networks and institutions (social capital, institutional environment, etc.)”.

United Nations International Strategy for Disaster reduction (UN/ISDR) (2009) defines vulnerability as follows: “Vulnerability is the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard”. The comment describes that there are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include poor design and construction of buildings, inadequate protection of assets, lack of public information and awareness, limited official recognition of risks and preparedness measures, and disregard for wise environmental management. Vulnerability varies significantly within a community and over time (UN/ISDR, 2009).

Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as follows:

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007).

The main difference in the UN/ISDR and IPCC definitions of vulnerability is in their second parts, where the IPCC definition includes also characteristics of the hazard phenomena (magnitude, rate of climate change) what tends predominantly to focus on impacts. In this context the analytic power of vulnerability in terms of showing the social construction of disaster risk is undermined (Byrtusova et al, 2015).

It can be said that specific definitions imply different views what results in different priorities in vulnerability assessments. Although there are different schools of vulnerability research a consensus can be seen in the fact that nearly everyone views vulnerability as an “internal side of risk” (UN/ISDR 2004).

At present vulnerability is viewed as multidimensional, differential and dynamic phenomena and it can be misleading to establish a universal definition of vulnerability (Birkmann, 2013).

4.2 Vulnerability concepts development

In the 1970s and early 1980s vulnerability was associated especially with physical fragility (e.g. the likelihood of a building to collapse due to the fire). During the last two-three decades the concept of vulnerability has been continuously developed and broadened towards a more comprehensive approach encompassing susceptibility, exposure, coping capacity and adaptive capacity, as well as different thematic areas, such as physical, social, economic, environmental and institutional vulnerability (Luskova, 2015). Fig.1 illustrates development and widening of the vulnerability concept that contributed to enhancing the vulnerability understanding (Byrtusová, 2015).

Amost all vulnerability concepts in disaster risk research consider vulnerability as an „internal side of risk“ and the conditions of the exposed subject or object (its susceptibility) at risk form the core characteristics of vulnerability (the first circle in Figure 1).

An extension of this view represents definitions of vulnerability that understand under vulnerability the likelihood of injury, death, loss and disruption of livelihood in extreme event. According to this definition the main vulnerability elements are conditions which increase the likelihood of human death, injury and loss and disruption of livelihood in extreme event.

The third circle represents the „dualistic structure of vulnerability "focusing on susceptibility and unusual difficulties in coping and recovery capacities of individuals or communities exposed to adverse consequences. So coping and recovery capacities are part of vulnerability.

The fourth circle means extension of the vulnerability from a double structure to a multi-structure which include exposure, susceptibility, coping capacity, adaptive capacity.

The last fifth circle indicates the need to consider various dimensions of vulnerability represented by physical, economic, social, institutional and environmental aspects.

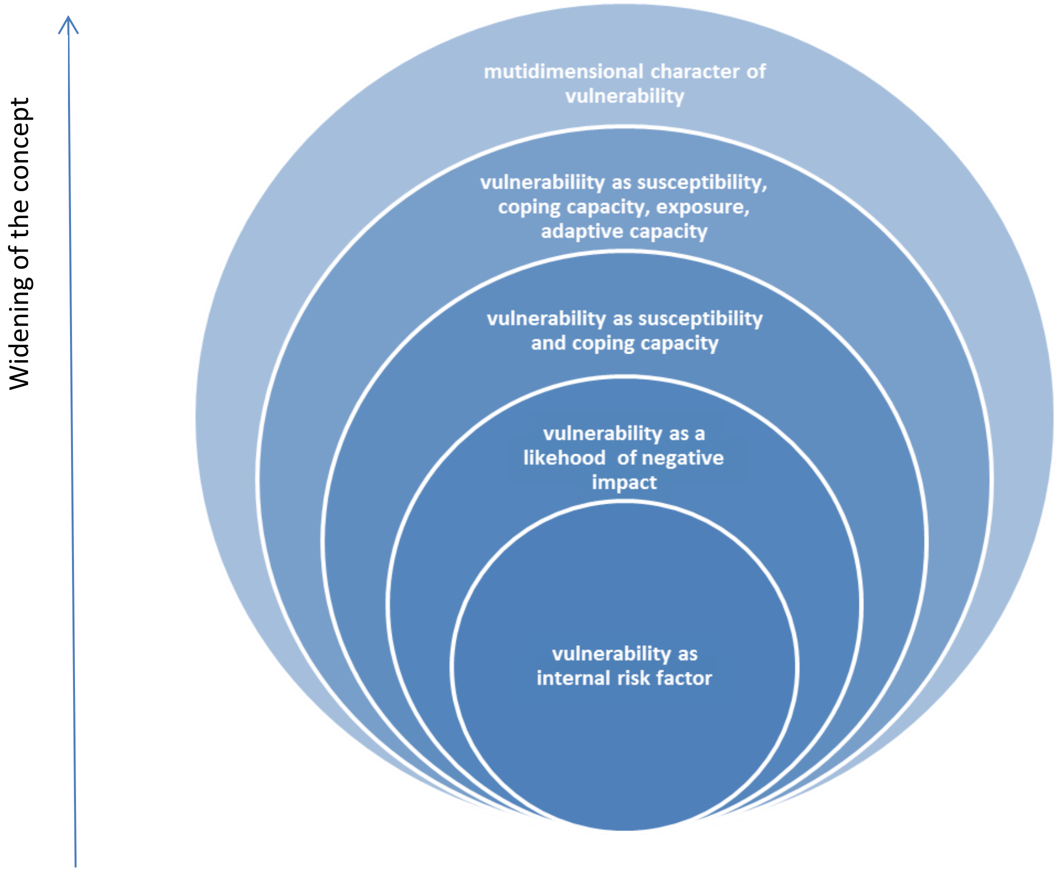


Figure 1. Key spheres of vulnerability (Birkmann, 2013)

4.3 Core factors of vulnerability

Various authors and scientific communities define core factors of vulnerability differently.

Core factors of vulnerability can include susceptibility, sensitivity or fragility, coping or adaptive mechanisms as categories to systematize societal response capacities to deal with adverse environmental conditions (Birkmann, 2013).

Susceptibility and sensitivity are describing similar aspects but the researchers recommend using the term susceptibility as a more appropriate for vulnerability assessment in the context of natural hazards. They argue that the term “sensitivity” is more neutral and can mean positive as well as negative movement. The term “susceptibility” can better express the deficiencies which indicate the likelihood to suffer the harm and loss due to adverse event.

Institute for Environment and Human Security of the United Nations University incorporates among the core factors except susceptibility and coping capacities also exposure (Renaud,2013).

In IPCC concept the exposure is considered as own factor next to vulnerability. It is defined as the presence of people, livelihoods, environmental services and resources, infrastructure, economic, social, or cultural assets in places that could be adversely affected. Vulnerability is briefly defined as the propensity or predisposition to be adversely affected (IPCC, 2012).

The latest vulnerability concepts include various factors of vulnerability and their mutual relations i.e. linkages among exposure, susceptibility and adaptative capacities.

Based on the above mentioned vulnerability can be defined as a function of three elements:

- exposure to extreme weather events,
- susceptibility to change,
- capacity to adapt to that change.

Systems that are highly exposed, susceptible and less able to adapt are vulnerable (see Fig. 2) (Allen Consulting Group, 2005).

Exposure is the presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected (IPCC, 2012).

Susceptibility (called also sensitivity or fragility) characterizes the predisposition and likelihood to suffer harm when a hazard strikes a community or a system is exposed. Susceptibility is revealed within physical, social, environmental, cultural and institutional dimensions. Even if a community or system is exposed to hazard, this does not necessarily mean that it is high susceptible, since susceptibility is primarily associated with the conditions of the community or the system exposed. Susceptibility generally includes deficits and problematic conditions of people unable to defence themselves due to their poverty or the lack of the risks awareness (Birkmann, 2013).

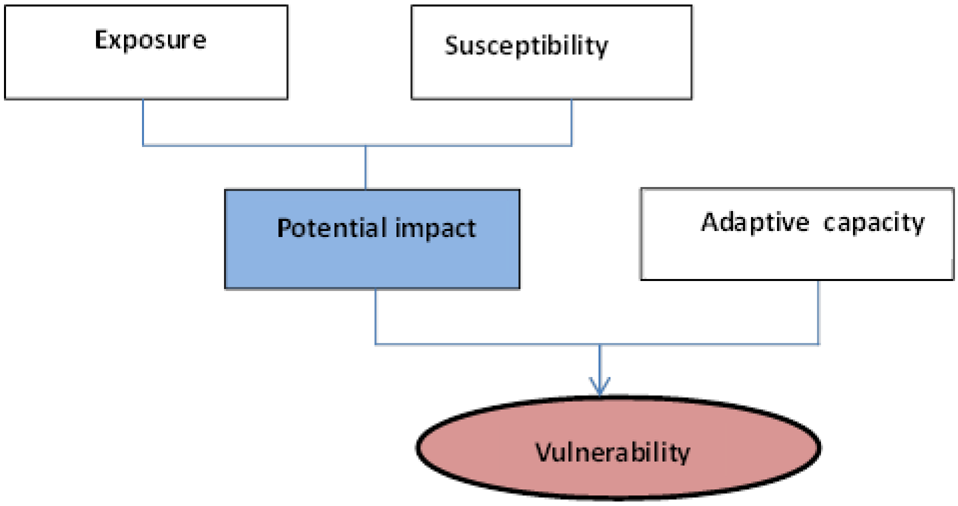


Figure 2. Vulnerability and its core factors (Adapted from Allen Consulting Group, 2005)

Adaptation reflects the ability of a system to change in a way that makes it better equipped to deal with external influences (Allen Consulting Group, 2005).

Adaptive capacity is the combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities (IPCC, 2012).

Early consideration of the all core factors of vulnerability provide a better chance for a timely and effective preparedness and risk reduction in case of the extreme crisis events.

4.4 Key dimensions of vulnerability

In general key dimensions of vulnerability usually encompass social, economic and environmental dimensions. Each of these dimensions has a number of subcategories, which map out the major elements of interest (Byrtusova, 2015).

Within the wp3 of the RAIN project the attention is concentrated especially on the social and economic categories.

The social dimension of vulnerability includes aspects such as justice, social differentiation, societal organization, individual strength, poverty, social marginalization, powerlessness, demography, social networks, education, health and well-being, gender, culture, migration, risk perception, etc. The influence of institutions and rule systems that might make people more susceptible to suffer harm and loss due to extreme weather impacts play also very important role in social vulnerability (Birkmann, 2013).

Vulnerability is often determined by the specific conditions and development processes in the respective country, region and on the respective extreme event focus. For example, disaster Indian Ocean tsunami (2004) in Indonesia and Sri Lanka revealed that young, elderly and female persons were the most vulnerable demographic groups. During the heat wave in 2003 in Europe the most vulnerable group were the elderly people due to their health conditions, social isolation, family composition and mobility which are social determinants of vulnerability (IPCC, 2012). Other characteristics of social vulnerability that influence susceptibility and exposure to extreme events and that are identified in literature include social isolation of the elderly, governance aspect, socio-economic class and caste, gender, age (both elderly and children), race and ethnicity, housing tenure (renter, owner), differential access to financial resources in post disaster processes, etc. (Byrtusova, 2015). It is needed to say that the universal checklist of vulnerable group does not exist especially due to diversity and dynamics of the living conditions and extreme weather events, too. It must be developed at national or local level.

Cannon et al. (2003) argue that social vulnerability is the complex set of characteristics that include a person's:

- Initial well-being (nutritional status, physical and mental health),
- Livelihood and resilience (assets and capitals, income and qualifications),
- Self-protection (capability and willingness to build a safe home, use a safe site),
- Social protection (preparedness and mitigation measures),
- Social and political networks and institutions (social capital, institutional environment and the like).

Economic dimension of vulnerability can be understood as the susceptibility of an economic system (public and private sectors) to potential disaster damage and loss (Mechler et al., 2010)

Birkmann (2013) defines e two basic approaches to economic vulnerability:

1. Economic vulnerability related to the specific occupational and livelihood patters and economic assets of households at risk.

2. Economic vulnerability related to the susceptibility of an economic system or the inability of a system to deal with a specific magnitude of damage or economic loss.

The first group can be understood as assessment of economic vulnerability at a microscale while the second group assesses economic vulnerability by focusing on macroeconomic issues, e.g. economic effects of an extreme events on the gross domestic product (GDP), consumption and the fiscal position (Mechler et al., 2010).

Economic vulnerabilities at macroeconomic level can be analysed e.g. by CATSIM model or the Disaster Deficit Index (Cardona et al, 2009).

The CATSIM model was designed by IIASA researchers to help policymakers, particularly in developing countries, devise public financing strategies to be implemented in both the pre- and post-disaster context. National data can be input into CATSIM allowing policy advisers to pose "what if" questions. The model will then show the best combination of financial strategies to suit current national circumstances (IIASA, 2014).

The Disaster Deficit Index (DDI) measures the economic loss that a particular country could suffer when a catastrophic event takes place, and the implications in terms of resources needed to address the situation. Construction of the DDI requires undertaking a forecast based on historical and scientific evidence, as well as measuring the value of infrastructure and other goods and services that are likely to be affected. The DDI is calculated as ratio of the demand for contingent resources to cover the losses, caused by the maximum considered event to the public sector's economic resilience, that is, the availability of internal and external funds for restoring affected inventories. A DDI greater than 1.0 reflects the country's inability to cope with extreme disasters even by going into as much debt as possible. The greater the DDI, the greater the financial gap between losses and the country's ability to face them (Cardona et al., 2009).

The environmental dimension of vulnerability deals with the fragility of ecological and biophysical systems and their different functions under a hazardous condition, to suffer damage and deterioration (Birkmann et al., 2014). It is important to remind that the environmental degradation, including deforestation, desertification, pollution, and climate change increases the vulnerability of communities. The IPCC report (2001) indicates that climate changes can generate more extreme weather patterns in many parts of the world. They include e.g. higher rainfall intensities or longer periods without rain which result in floods and droughts of higher magnitude and frequency.

4.5 Resilience

Resilience describes the capacities of societies, communities and individuals or a social-ecological system to deal with adverse consequences and the impacts of hazard events (Birkmann, 2013). Building resilience is considered to be a key strategy that allows societies, communities, individuals and social-ecological systems to transform in order to be able to live with changing environmental and socio-economic conditions. Resilience theory emphasizes that stressors and crises provide opportunity for change and innovation and are seen as important triggers for renewal and learning.

The concept of resilience originated from ecology and psychology. The concepts have been continuously enhanced into other application areas. While the original resilience concepts in ecology focused primarily on the survival of populations in times of shocks and perturbations, the newer concepts of social-ecological resilience also deals with institutions that regulate social-ecological system and decision-making questions.

Like vulnerability, multiple definitions of resilience exist within the literature, with no broadly accepted single definition (Klein et al., 2003). In the research domain of the global environmental change community, resilience in socio-ecological systems is defined as a system's capacity to absorb disturbance and re-organize into a fully functioning system. It includes not only a system's capacity to return to the state that existed before the disturbance, but also to advance the state through learning and adaptation (Cutter et al., 2008).

Resilience of critical infrastructures is rather new and has been intensified especially due to increasing dependency of societies on critical infrastructures services and also in terms of disasters such as Fukushima disaster. According to Bruneau et al. (2003) critical infrastructures would be resilient if they were characterized by systems that are:

- robust,
- redundant,
- resourceful,
- capable of rapid response.

In this regard, assessment of the resilience of infrastructure can deal with four interrelated dimensions that include:

- technical,
- organizational,
- social,
- economic issues.

They influence the robustness, capability of rapid response and functioning of critical infrastructure.

Many scientific contributions still remain abstract in terms of the question what resilience actually means for disaster risk and adaptation research (Cutter et al., 2008).

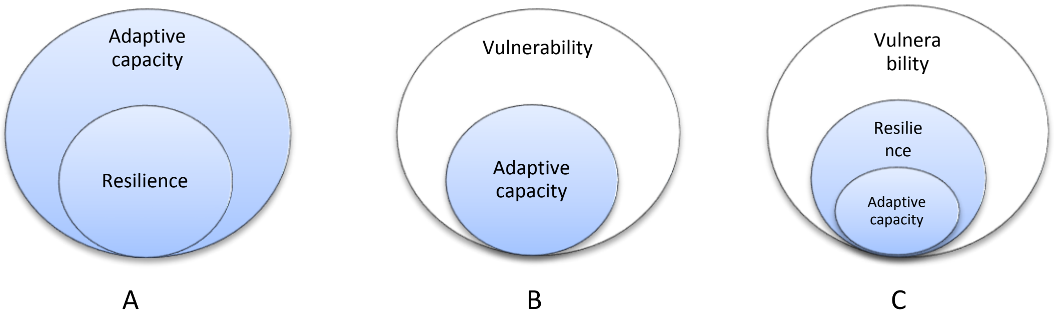


Figure 3. Conceptual linkages between vulnerability, resilience and adaptive capacity (Cutter et al., 2008)

From the literature review follows that the relationship between vulnerability, adaptive capacity and resilience is still not well articulated, too. According some researchers, resilience is an integral part of adaptive capacity (Fig. 3a) (Adger, 2006). Other concepts view adaptive capacity as a main component of vulnerability (Fig. 3b) (Burton et al., 2002) or as nested concepts within overall vulnerability structure (Fig. 3c) (Gallopin, 2006).

Despite a wide range of discussions concerning the relationship between vulnerability, adaptive capacity and resilience in the recent literature, a clear understanding is still rare. To date, there is no unified framework for understanding the relationships of vulnerability, resilience, and adaptive capacity due to the diversified academic traditions. But none concept should be overstressed alone from the others and an integral understanding of them is required. A sustainable adaptation strategy to the unavoidable disasters or changes should not be focused only on reducing the vulnerability of a societal–ecological system, but also to foster its resilience and adaptive capacity to future uncertainties and potential risks. (Yongdeng, L. et al, 2014).

In our approach for measuring societal vulnerability we understand resilience as integral part of adaptive capacity. Adaptive capacity belongs to the core factors of vulnerability (see Section 4.3 Core factors of vulnerability).

4.6 Approaches to risk and vulnerability assessment

In last years an increasing number of initiatives have been launched to measure risks and vulnerability. Although the level of use of hazard-risk-vulnerability assessment models by emergency managers from across the world is not well documented, the literature clearly defines a number of models that appear to be prominent among emergency managers and can serve as an incentive to develop own approach (a RAIN vulnerability index).

The key models are as follows (Kuban, MacKenzie-Carey, 2001):

- **EPC** (Evaluation of Peacetime Disaster Hazard) model consists of seven steps comprising updating of hazards, collection of relevant historical data, consideration of risk factors changes and external to community, expression of vulnerability and assigning the priorities for each hazard.
- **FEMA** model assess four criteria: history, vulnerability, maximum degree of threat and probability of occurrence over a period of a year, which are then given a rating.
- **APELL** (Awareness and Preparedness for Emergencies at Local Level) model, primarily aimed at reducing technological accidents and improving emergency preparedness
- **SMUG** (Seriousness, Manageability, Urgency, and Growth Hazard Priority System) model that assesses each hazard according to five factors: seriousness, manageability, urgency, risk and growth.
- **NOAA** (National Oceanic and Atmospheric Administration) model that encourages the use of GIS consists of eight steps. Each of the steps focuses on a separate component of the community and makes an analysis of available data of those elements that are considered “critical”.
- **UNDRO** (United Nations Disaster Relief Organization) model, limited to natural hazards and pollution from damage to industrial plants.
- **HIRV** (Hazard Impact Risk Vulnerability) model is designed for local communities or regional governments, and is based upon local knowledge supplemented by experts. It includes hazard identification, risk analysis, vulnerability analysis, impact analysis and risks management.
- **CVCA** (Community-wide Vulnerability and Capacity Assessment) model focuses on the population of a community. There are three main questions: who are the community’s “most vulnerable”; where do they generally reside; and, what is their capacity to respond or recover? The model consists of 18 steps.

5. Development of an approach to measure societal vulnerability

Extreme weather events reflect in the transport sector immediately, intensively and with massive negative consequences: they lead to the increase of freight transport time, prolongation of traveling and the rise of accident probability. High and low temperatures, intensive storms and snow calamities, which gain on severity due to climate change, cause serious complications for almost all means of transport. Table 1 presents the extreme weather impacts on road and rail transport infrastructure.

Table 1 Extreme weather impacts on transport infrastructure

Means of transport	**Weather extremes**	**Impacts**
Road	Storms, floods, heavy rain, snow, glare ice, fog, heavy snow, wind, etc.	Road communication closures, detours, disruption of road surface, disruption of road infrastructure, decrease of safety and traffic flow, traffic congestion, higher requirements for winter maintanance, probability of road carpet damage, higer requirements for road carpet quality
Rail	Storms, floods, frequent snow, wind, frost	Traffic break, traffic closure, disruption of infrastructure, higher requirements for winter maintanance, damage of rails and rail switches

Except for the direct above mentioned extreme weather impacts on transport infrastructure, there are also consequential negative societal and economic impacts in population which are caused by the disfunctionality of transport infrastructure. Among the most serious impacts on population are:

- unavailability of ambulance and rescue services which causes higher damage of health and loss of lives of a population,
- unavailability of essential food and goods,
- problems with providing massive evacuation,
- insufficient security of population and public order,
- transport inaccessibility of employer, i.e. longer way to work place.

Societal and economic consequences are different according to geographical location and they also depend on whether they are analysed in city or country residencies. City residencies have unique characteristics which make the inhabitants and their properties together with public property especially vulnerable to the negative impacts of extreme weather events. Among the factors which make cities more vulnerable is high concentration of inhabitants and their property or the urban heat island effect. Many cities are located and conceived in such way that the impacts, such as floods, heat waves, droughts or storms, can cause them big economic and societal problems as a consequence of transport infrastructure disruption or electric energy outage, e.g. shortage of water and food.

Extreme weather events and their impacts on CI can lead to the deepening of societal problems, including poverty and low life standard, in city as well as country residencies. Negative demographic and societal-economic trends can increase vulnerability in the future. Negative impacts will reflect most significantly on the most vulnerable part of population. In our conditions, it concerns old people, people living alone, children, people with low income and those suffering from disability.

5.1 Multilevel approach to societal vulnerability measuring

Within the RAIN project, for societal vulnerability measuring, we have applied conceptual framework that is widely used in research community (see Fig. 2). Societal vulnerability is composed of various dimensions (see Fig.1) and is affected by vast number of factors. These dimensions and factors are so different that it is not possible to use them for direct Societal Vulnerability measurement. On the other hand, these dimensions and factors have some characteristics and aspects in common, hence, it is possible to assort them into groups. This way we can gradually define the overall level of societal vulnerability. Therefore, we suggest the use of multilevel approach for the measurement of societal vulnerability (Fig. 4 and also Fig. 6) which, by gradual defining of concrete levels, will lead to the determination of overall Societal Vulnerability. It is based on the similar approach to the problem of vulnerability related to the climate change within the project ESPON CLIMATE (see ESPON CLIMATE project in Greiving et al., 2011).

We propose to define the level of Societal Vulnerability by the use of **Vulnerability Index - VI.**

The method was formed by gradual splitting (division) of Societal Vulnerability into lower levels (downwards):

- Vulnerability Core Factors (3 factors).
- Vulnerability Societal Categories (9 categories).
- Vulnerability Indicators (31 indicators).

Vulnerability Index is formed by three Vulnerability Core Factors (1) Exposure - E, (2) Susceptibility - S, and (3) Adaptive Capacity - AC, while Exposure and Susceptibility together create Potential Impact – PI (based on: Birkmann 2013, Renaud 2013, Füssel & Klein, 2006, IPCC, 2012, Allen Consulting Group, 2005). Each of these three factors is formed by different Societal Categories in our case by three Categories. Societal Categories are formed by several Vulnerability Indicators.

Each **Vulnerability Core Factor (CF)** stands for one component of vulnerability which describes the factual state in target region. According to the assessment of factual state, it is possible to subsequently determine the level of vulnerability in given region. Into consideration are taken those components of society which can be in danger (Exposure), components which are more sensitive to extreme weather (Susceptibility), as well as capacities (Adaptive Capacity) which assessed region is in disposal of in order to manage the impacts of extreme weather events.

For each Vulnerability Core Factor it was necessary to define categories (Cutter et al. 2011) in our case **Societal Categories (SC)**. Societal Categories stand for those parts of society which form the main interest/centre of our research. They could be seen also as different dimensions of Vulnerability Core Factors (dimensions were used in ESPON CLIMATE, 2013/2014) but they are more specific in order to address topic of this deliverable D3.4. In our research they concern mainly transport critical infrastructure and society, hence, performing the functions of transport infrastructure operation for society. They create the content of each Core Factor and they present a group of relevant indicators.

Individual Societal Categories are formed by **Vulnerability Indicators (I)**.These Indicators describe concrete specific characteristics of each society which are significant considering their vulnerability to extreme weather impacts.

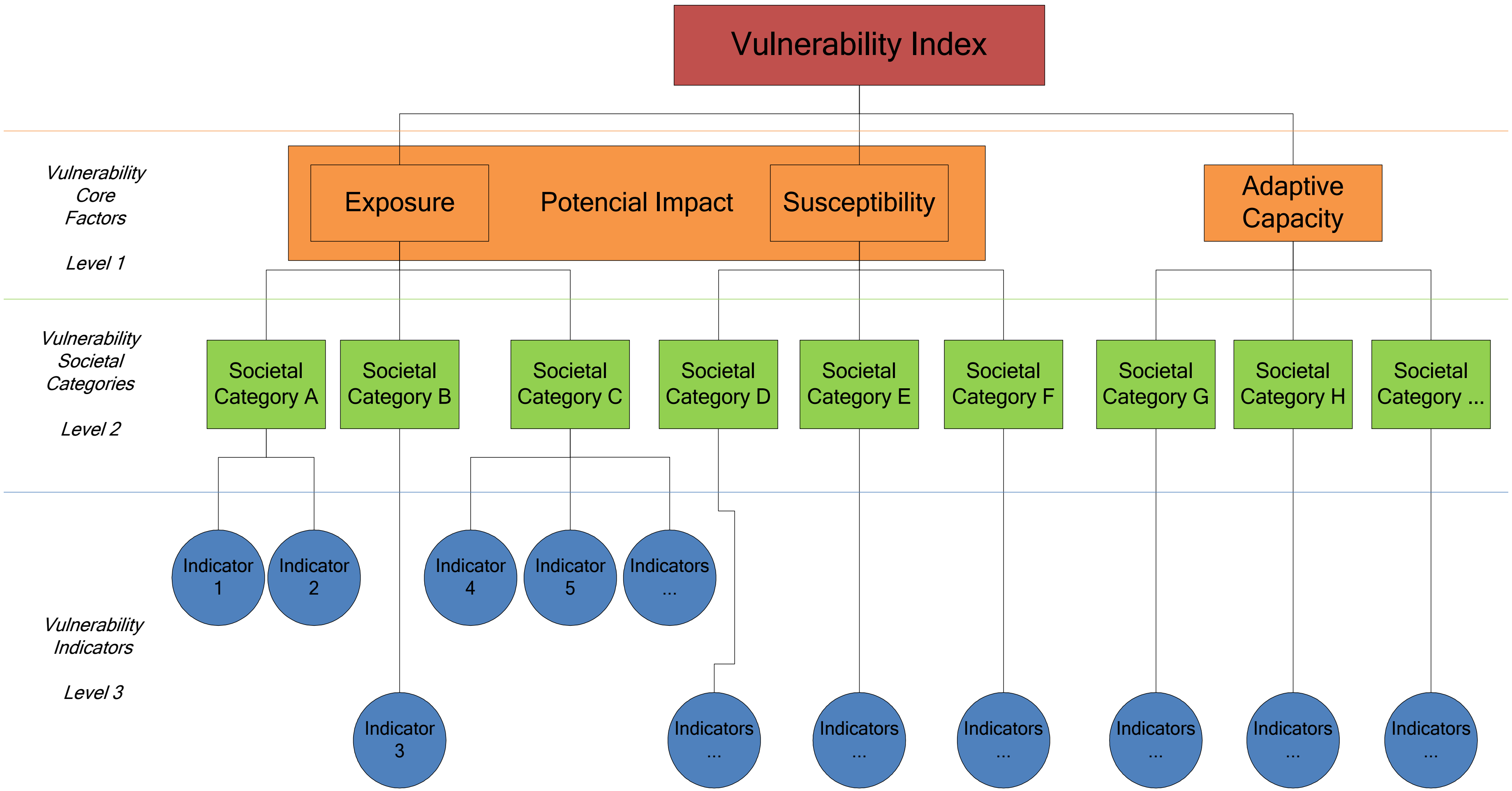
Vulnerability Index (VI) is calculated by retrospective assessment of the above mentioned levels (upwards). By the assessment of Vulnerability Indicators and the integration of Vulnerability Societal Categories and henceforth, within Vulnerability Core Factors, we will get the resulting value of VI. Vulnerability Index represents value from 1 to 5. Increasing values indicate increasing vulnerability. VI values interpretation is given in Table 2. The index and related interpretations should serve for evaluation of current state in specific region as well as for decision making purposes. In description of VI values, some recommendations for vulnerability reduction in terms of crisis planning, risk management and preparedness enhancing are provided. With increasing values of VI, the time pressure for immediate reaction (vulnerability reduction) as well as the necessity of a higher level of resources and personnel capacities to cope with extreme weather events is rising. If the given approach is applied on more sectors simultaneously, it is possible to compare them and it allows the identification of more vulnerable areas. Detailed VI calculation method is in Fig.6. The responsible authorities should manage their reaction based on their current possibilities and with cooperation with crisis management representatives. They should apply some specific measures (hard or soft, or combination) based on particular hazard which should be addressed (e.g. different measures could be applied for floods or landslides).

RAIN – Risk Analysis of Infrastructure Networks in Response to Extreme Weather

Project Reference: 608166

FP7-SEC-2013-1 Impact of extreme weather on critical infrastructure

Project Duration: 1 May 2014 – 30 April 2017



Date: 30/01/2017

Dissemination level: PU

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Figure 4. Multilevel approach to the Vulnerability Index identification

Table 2 Vulnerablity Index values

VI value	Description
<1;1,8>	The level of societal vulnerability is minimal. Indicators of societal vulnerability indicate that the examined region (area) is vulnerable minimally in comparison with the average vulnerability in the country. It can be said that the examined region shows a negligible rate of possible impacts caused by specific extreme weather event. Preparedness in terms of material resources and personnel capacities is at high level. In the long-term planning tasks aimed at maintaining the preparedness level of the society and monitoring the risk factors changes that could increase the vulnerability level should be included.
(1,8;2,6>	The level of societal vulnerability is low. Indicators of societal vulnerability indicate that the examined region (area) is less vulnerable in comparison with the average vulnerability in the country. It can be said that the examined region shows an acceptable rate of possible impacts caused by specific extreme weather event. Preparedness in terms of material resources and personnel capacities is at sufficient level. In the long-term planning tasks aimed at reducing the risk factors that could endanger the examined regiojn and maintaining a required level of capacities for solving possible crisis events should be included.
(2,6;3,4>	The level of societal vulnerability is medium. Indicators of societal vulnerability indicate that the vulnerability of examined region (area) is comparable with the average vulnerability in the country. It can be said that the examined region shows a moderate rate of possible impacts caused by specific extreme weather event. Preparedness in terms of material resources and personnel capacities is at tolerable level but in case of large-scale disasters can be unsufficient. Within the crisis planning, in the medium–term aspect, tasks aimed at reducing the societal vulnerability level and increasing the level of preparedness for coping with extreme weather events should be included.
(3,4;4,2>	The level of societal vulnerability is high. The society contains several parts which are very sensitive to extreme weather event. Transport network and society are poorly prepared to cope with potential extreme events and very sensitive towards the impacts of that event almost in every aspects. Transport network can be so disturbed that it is not possible to provide essential services for society. It is necessary to adopt measures to reduce the society susceptibility and to ensure a higher level of resources and personnel capacities to cope with extreme weather event.
(4,2;5>	The level of societal vulnerability is very high. Transport network and society contain many critical parts which make them more vulnerable. Also, the transport network and society are minimally prepared to cope with respective crisis event and they are also very sensitive towards the effects of the crisis event almost in every respect. Transport networks can be so disturbed that it is not possible to provide essential services for society. It is necessary to make measures to reduce vulnerability as soon as possible because in case of crisis event extensive impacts on society can start up.

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Societal Vulnerability is so complicated to define in regard to society and transport that it was necessary to consider many factors and relations which affect this vulnerability. We have found out that Vulnerability Factors are so different contentwise that it was not possible to find a unifying unit to express the vulnerability level (e.g. determination through money or other). Therefore, we suggest the use of **point assessment** for each Vulnerability Indicator. Thereby, the unity of determination of each indicator will be ensured and will enable further operation.

Each Indicator is given a value from 1 to 5 in accordance to the assessment table which is part of the description of every indicator (more about the identification and selection of indicators is below in part 5.2.). Indicators have been given also **weight (w_1)** apart from the given value because the relevance of indicators does not need to be the same or the evaluators in given country can assess the weight of relevance according to their preferences. Weights are given to indicators separately within each Societal Category according to the principle that indicator weights must have the value of 1 within one Societal Category. Indicator weights have been determined by comitted problem solvers based on expert assumptions using Deplhi-based assessment (used also in ESPON CLIMATE project, 2013/2014).

To set the resulting value of Vulnerability Index, it was necessary to assess the weight of all Core Factors, Societal Categories as well as of all indicators **(w_{SC}, w_{CF}).** These weights (together with given values) were gradually counted into the resulting value of VI (Fig. 5) and also, they were defined according to expert assumptions of the comitted problem solvers. There is a principle for these weights which sets the sum of Exposure weight **(w_E)** and Susceptibility weight **(w_S)** to the value of 1. Similarly, the sum of Potential Impact weight **(w_{PI})** and Adaptive capacity weight **(w_{AC})** results in the value of 1.

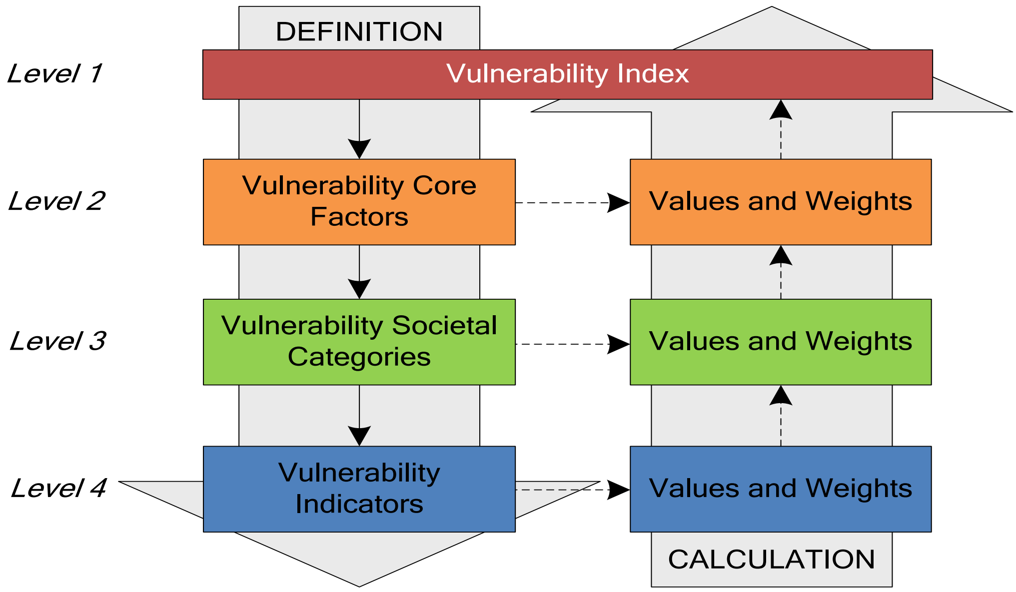

Figure 5. Multilevel definition (downwards) and calculation (upwards) of Vulnerability Index

By summing the values of Vulnerability Indicators and considering indicator weights, values of Vulnerability Societal Category were calculated according to the relation (1):

$$SC_x = \sum_{i=1}^{n} w_{I_i} I_i \quad (1)$$

SC= Societal Category
x = designation of Societal Categories
n = total number of indicators within Societal Category
w_{Ii}=weight of Indicators
I_i = value of Indicators

Similarly, values of Societal Categories were added to the value of Core factor. As in the case of other indicators, even all Societal Categories needed their weight **(w_{SC})** to be assessed. Aggregated value of Core Factor is calculated according to the relation (2):

$$CF_y = \sum_{j=1}^{m} w_{SC_j} SC_j \quad (2)$$

CF = Core Factor
y = designation of Core Factors
m = total number of Societal Categories within Core Factor
w_{SCj}= weight of Societal Category
SC_j = value of Societal Category

Resulting value of VI is obtained in a similar way as it was done in previous steps. The final calculation of VI is preceded by one extra step which lies in the calculation of Potencial Impact **(PI)**. Potential Impact represents possible level of impacts on society after considering all aspects which can be in danger (Exposure) and after considering all societal groups which are more sensitive to extreme weather impacts (Susceptibility). The weights of Exposure and Susceptibility (**w_E, w_S)** are counted as well. Potential Impact is calculated according to the relation (3):

$$PI = w_E E + w_S S \quad (3)$$

PI =Potential Impact
E= Exposure
S = Susceptibility
w_E = weight of Exposure
w_S = weight of Susceptibility

Resulting value for VI is the sum of PI weight value and weight value of Adaptive Capacity (4):

$$\boldsymbol{VI} = w_{PI} PI + w_{AC} AC \quad (4)$$

VI = vulnerability index
AC = Adaptive Capacity
w_{PI}=weight of PI
w_{AC}=weight of Adaptive Capacity

As it was mentioned in the theoretical part, vulnerability is dependent on **specific hazard.** Hence, target region can be more vulnerable to a certain kind of threat but much more resistant, i.e. less vulnerable to another kind of threat. We incline to this idea and therefore, it is necessary to evaluate vulnerability for each threat or danger separately. Threats which are taken into consideration are the same as in milestone M2.1. Defitions and Thresholds.

There could be significant differences between vulnerabilities of the same area to the same hazard with different intensity, e.g. windstorm with speed of 70km/hour or 140km/hour; flood with probability of occurrence 1 in 10 years, and flood with probability of occurrence 1 in 1000 years.

To address intensity of hazard within vulnerability analysis, it is important to identify the indicators which can vary based on the hazard intensity. In core factor “Exposure” there is only description of current state in the area and it does not depend on the intensity of hazard. The similar conditions are in core factor “Adaptive capacity”. The only core factor where intensity of hazard could be addressed is “Susceptibility”. Within “Susceptibility” there are three societal categories. “Social susceptibility” cannot change by changing hazard intensity. It is similar for “Transport Services Susceptibility”.

“Infrastructure susceptibility” takes into consideration spatial distribution of the hazard which can differ based on hazard intensity, e.g. if the flood intensity is low then the flood area size is low, too (and vice versa). Therefore, the intensity of the hazard should be addressed in this part of vulnerability within relevant indicators which are identified in 5.2.2.

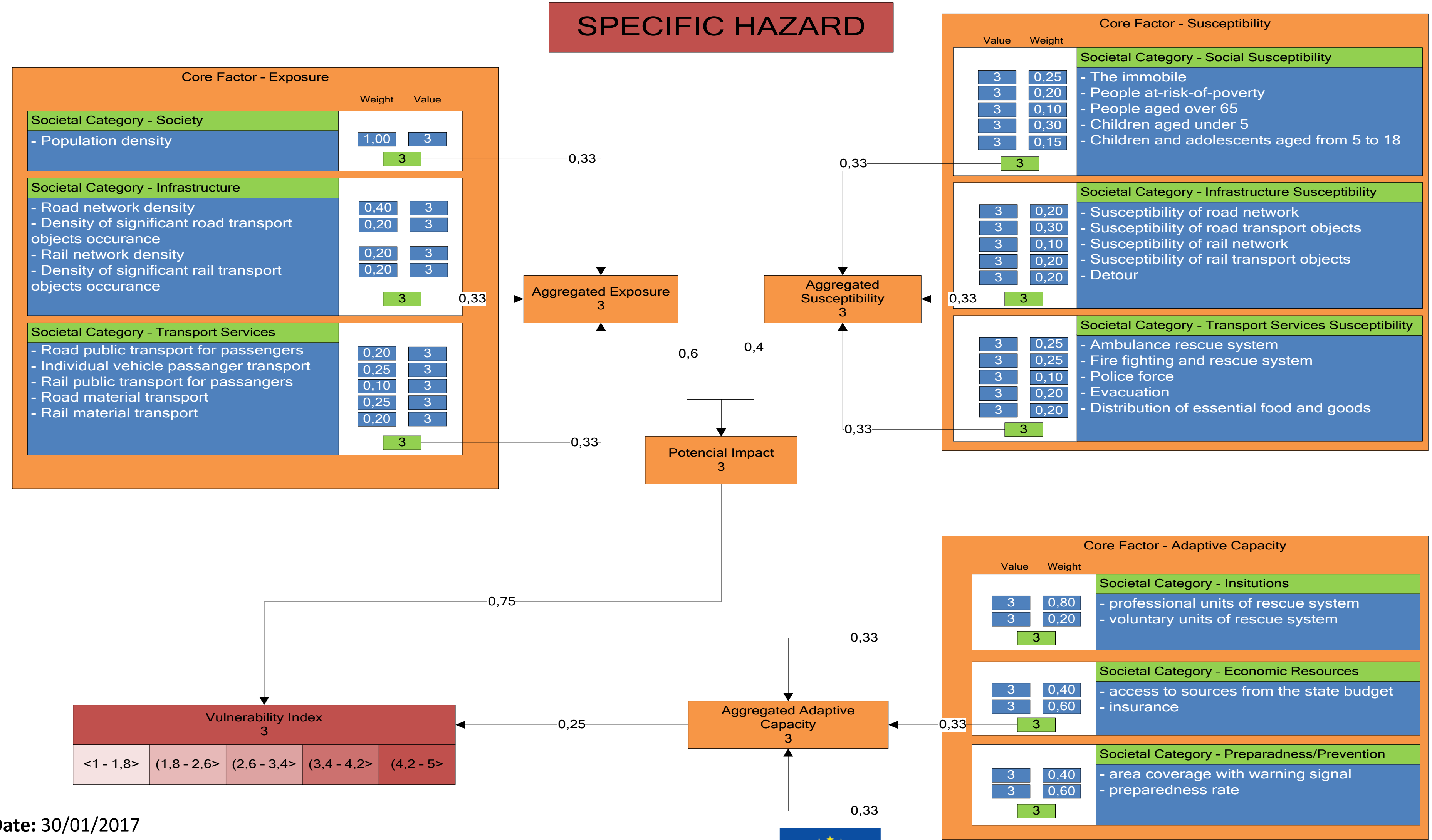

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Figure 6. Detailed depiction of approach for the determination of Societal Vulnerability

5.2 Identification and selection of indicators for measuring societal vulnerability to impacts of extreme weather events on critical land transport infrastructure

Identification and selection of indicators for measuring societal vulnerability to impacts of extreme weather events on critical land transport infrastructure is based on the definition of vulnerability as a function of exposure to extreme weather events, susceptibility to change caused extreme weather events and capacity to adapt to that change.

Indicators have been selected with regard to their:

- relevance and usefulness,
- measurability, i.e. they are available, adequately documented and regularly monitored.

By the determination of individual indicators, it is crucial to consider the specifications of given affected region or country according to the socio-economic development context as well as the cultural and institutional aspects of daily life and also, to consider respective statistical data available.

Indicators are assorted into three basic groups (related to the Core Factors) and subgroups (related to Societal Categories)

1. **Vulnerability Indicators related to Exposure**
2. **Vulnerability Indicators related to Susceptibility**
3. **Vulnerability Indicators related to Adaptive Capacities**

The indicators were selected based on the previous projects (ESPON CLIMATE, 2013/2014; ATEAM), investigations and related articles (Burton & Khazai, 2012; Cardona, 2009; Cutter, 2003, Inter-American Development Bank, 2010; CIA Factbook, 2014; Isoard et al., 2008; Schneiderbauer et al., 2011; Adger et al., 2005; Smit & Wandel, 2006).

They were also discussed with subject matter experts in workshop (April 5, 2016) focusing on the development of an methodology for societal vulnerability measuring due to failure of critial land transport infrastructure elements. Experts were from the Dutch USAR-team (Urban Search and Rescue), Dutch police academy, and United Kingdom Network Rail asset management, expert involved in EC and UN-assessments and other researchers.

5.2.1 Exposure

Our approach is considering the suggestion according to Fig. 2 and mainly defintion of IPCC (2012) where EXPOSURE is part of vulnerability and is defined as the presence of people, road and rail transport infrastructure and transport services in places that could be adversely affected. It is a different view as e.g. in the project ESPON CLIMATE. In ESPON CLIMATE project the exposure contain stimuli and trigger effects of climate changes and extreme weather events.

Considering the definition of IPCC (2012) and domain of this deliverable the assessment of societal vulnerability in part EXPOSURE, includes these societal categories (Society, Infrastructure, and Transport Services) and these concrete indicators:

SOCIETY:

1. population density,

INFRASTRUCTURE:

2. road network density,
3. density of significant road transport objects occurrence,
4. rail network density,
5. density of significant rail transport objects occurrence,

TRANSPORT SERVICES:

6. road public transport for passengers,
7. individual vehicle passanger transport,
8. rail public transport for passangers,
9. road material transport,
10. rail material transport.

The importance of the various indicators and groups of indicators for the overall exposure is distinguished through assigning weights based on the assessment of the evaluator (can be determined on the subject matter experts estimates).

SOCIETY

This subgroup or societal gategory stands for the societal part of exposure. It consists of only one indicator which represents population living in target region.

1. **Population density – I_1**

Indicator "population density" (adapted from Burton & Khazai, 2012, in CIA Factbook) covers the number of people per km^2 living in target region because this population forms the society which can be exposed to negative extreme weather events and hence, they are the direct or indirect users of transport infrastructure. Number of inhabitants increases societal vulnerability because more people can be affected and then it is more complicated to provide help if necessary. Burton, G. Ch., Khazai, B. 2012CIA Factbook

This indicator is calculated as the percentage share of population density in target region ($I_{1.1}$) and population density in given country ($I_{1.2}$).

$$I_1 = I_{1.1} / I_{1.2} * 100$$

where: $I_{1.1}$ = number of inhabitants in target region/target region area [km^2]

$I_{1.2}$ = number of inhabitants in given country/given country area [km^2]

Values for population density are calculated according to available statistical data. Indicator compares population density in target region with population density in given country. If the calculated indicator value equals to 100%, it means equality between population density in target region and population density in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 3). Indicator is divided into 5 intervals. The higher population density in target region is in comparison with population density in given country, the higher resulting value is given to the indicator and vice versa, in case population density in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 3.

Table 3 Population density

Indicator - Population density		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of population density in target region and in given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of population density in target region and in given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of population density in target region and in given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of population density in target region and in given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of population density in target region and in given country is 160% and more	<160 and more)	5

INFRASTRUCTURE

Transport infrastructure/network (adapted from Burton & Khazai, 2012, in Geodata Portal CIA) allows the execution of transport and transit processes. This network is opened and exposed to direct impacts of weather conditions. Tranport network consists of linear parts (given in km) and transport objects (given in number of objects) and therefore specific indicators for linear parts of the land transport network as well as for land transport objects were identified.

2. **Road network density– I_2**

Indicator "road network density" stands for road network (its linear parts) in target region which can be exposed to extreme weather events. Road network represents the key infrastructure for every region because it provides all necessary functions of society. Its functionality is the base for balanced functioning of society and for its development.

This indicator is calculated as the percentage share of road network density in target region ($I_{2.1}$) and road network density in given country ($I_{2.2}$) (all calculated per 1000 inhabitants).

$$I_2 = I_{2.1} / I_{2.2} * 100$$

where: $I_{2.1}$ = length of road network in target region [km]/1000 inhabitants

$I_{2.2}$ = length of road network in given country [km]/1000 inhabitants

Values for road network density are calculated according to available statistical data. This way of expressing the road network density provides clearer population data for target region and thereby, allows us to compare specific regions of interest. Indicator compares road network density in target region with road network density in given country. If the calculated indicator value equals to 100%, it means equality between road network density in target region and road network density in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 4). Indicator is divided into 5 intervals. The higher road network density in target region is in comparison with road network density in given country, the higher resulting value is given to the indicator and vice versa, in case road network density in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 4.

Table 4 Road network density

Indicator - Road network density		
Description	**Calculated value of indicator [%]**	**Goven value**
Percentage share of road network density in target region and in given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of road network density in target region and in given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of road network density in target region and in given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of road network density in target region and in given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of road network density in target region and in given country is 160% and more	<160 and more)	5

3. Density of significant road transport objects occurrence – I_3

Indicator "density of significant road transport objects occurrence" represents the amount of significant transport objects on road network in target region. In accordance with D3.1, the elements to be studied as potential elements of the critical infrastructure in the subsectors of the road and rail transport are terminals of intermodal transport, motorway junctions, bus and railway stations, bridges and tunnels (both road and railway). Their disruption or destruction would have a serious impact on the whole economy, but mainly on the transport of people and material. Significant transport objects in road transport include bus stations, motorway junctions, road tunnels and bridges over 5 meters. Bridges shorter than 5 meters, so called road locks, are relative fast to rebuild and therefore, not taken into account.

This indicator is calculated as the percentage share of density of significant road transport objects occurrence in target region ($I_{3.1}$) and density of significant road transport objects occurrence in given country ($I_{3.2}$).

$I_3 = I_{3.1} / I_{3.2} * 100$

where: $I_{3.1}$ = number of significant road transport objects in target region/ length of road network in target region [km]

$I_{3.2}$ = number of significant road transport objects in given country/ length of road network in given country [km]

Values for the density of significant road transport objects occurrence are calculated according to available statistical data. Indicator compares density of significant road transport objects occurrence in target region with density of significant road transport objects occurrence in given country. If the calculated indicator value equals to 100%, it means equality between density of significant road transport objects occurrence in target region and in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 5). Indicator is divided into 5 intervals. The higher density of significant road transport objects occurrence in target region is in comparison with density of significant road transport objects occurrence in given country, the higher resulting value is given to the indicator and vice versa, in case density of significant road transport objects occurrence in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 5.

Table 5 Density of significant road transport objects occurrence

Indicator – Density of significant road transport objects occurrence		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of density of significant road transport objects occurrence in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of density of significant road transport objects occurrence in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of density of significant road transport objects occurrence in target region and given country is in interval from 80% to 120%	<80 –100 – 120)	3
Percentage share of density of significant road transport objects occurrence in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of density of significant road transport objects occurrence in target region and given country is 160% and more	<160 and more)	5

4. Rail transport density – I_4

Indicator "rail transport density" covers the rail network (its linear part) in target region which can be exposed to the impacts of extreme weather events. Rail network represents an essential infrastructure for every region because it provides all necessary functions of society. Its functionality is the base for balanced functioning of society and for its development. In comparison with road transport, rail transport is not so dense and flexible, however, on the other hand, it provides material and commodity transport of vast amount.

This indicator is calculated as the percentage share of rail network density in target region ($I_{4.1}$) and rail network density in given country ($I_{4.2}$) (all calculated pre 1000 inhabitants).

$$\mathbf{I_4 = I_{4.1} / I_{4.2} * 100}$$

where: $I_{4.1}$ = length of rail network in target region [km]/1000 inhabitants

$I_{4.2}$ = length of rail network in given country [km]/1000 inhabitants

Values for rail network density are calculated according to available statistical data. This way of defining the rail network density provides clearer population data for target region and thereby, allows us to compare specific regions of interest. Indicator compares rail network density in target region with rail network density in given country. If the calculated indicator value equals to 100%, it means equality between rail network density in target region and rail network density in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 6). Indicator is divided into 5 intervals. The higher rail network density in target region is in comparison with rail network density in given country, the higher resulting value is given to the indicator and vice versa, in case rail network density in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 6.

Table 6 Rail network density

Indicator – rail network density		
Description	**Calculated value of indicator[%]**	**Given value**
Percentage share of rail network density in target region and in given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of rail network density in target region and in given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of rail network density in target region and in given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of rail network density in target region and in given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of rail network density in target region and in given country is 160% or more	<160 and more)	5

5. Density of significant rail transport objects occurrence – I_5

Indicator "density of significant road transport objects occurrence" stands for the amount of significant transport objects on rail nework in target region. In accordance with D3.1, the elements to be studied as potential elements of the critical infrastructure in the subsectors of the road and rail transport are terminals of intermodal transport, motorway junctions, bus and railway stations, bridges and tunnels (both road and railway). Their disruption or destruction would have a serious impact on the whole economy, but mainly on the transport of people and material. Significant rail transport objects include terminals of intermodal transport, railway stations and all railway bridges and tunnels.

This indicator is calculated as the percentage share of density of significant rail transport objects occurrence in target region ($I_{5.1}$) and density of significant rail transport objects occurrence in given country ($I_{5.2}$).

$I_5 = I_{5.1} / I_{5.2} *100$

where: $I_{5.1}$ = number of significant rail transport objects in target region/ length of rail network in target region [km]

$I_{5.2}$ = number of significant rail transport objects in given country/ length of rail network in given country [km]

Values for the density of significant rail transport objects occurrence are calculated according to available statistical data. Indicator compares density of significant rail transport objects occurrence in target region with density of significant rail transport objects occurrence in given country. If the calculated indicator value equals to 100%, it means equality between density of significant rail transport objects occurrence in target region and in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 7). Indicator is divided into 5 intervals. The higher density of significant rail transport objects occurrence in target region is in comparison with density of significant rail transport objects occurrence in given country, the higher resulting value is given to the indicator and vice versa, in case density of significant rail transport objects occurrence in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 7.

Table 7 Density of significant rail transport objects occurrence

Indicator – Density of significant rail transport objects occurrence		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of density of significant rail transport objects occurrence in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of density of significant rail transport objects occurrence in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of density of significant rail transport objects occurrence in target region and given country is in interval from 80% to 120%	<80 –100 – 120)	3
Percentage share of density of significant rail transport objects occurrence in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of density of significant rail transport objects occurrence in target region and given country is 160% and more	<160 and more)	5

TRANSPORT SERVICES

Transport, as a sector of material production, satisfies the vast need of personal and physical relocation. In accordance to the main focus of project RAIN in research on vulnerability, we will be considering only road and rail transport. Indicators of availability of important services are also used in Burton & Khazai (2012).

With regard to the determination of vulnerability indicators, in road transport we will differentiate:

- public transport, which serves wide public, is available under conditions known to the public and includes city public transportation and suburban city transportation,
- individual auto transportation,
- freight transportation of goods and commodities.

With regard to the determination of vulnerability indicators, in rail transport we will differentiate

- freight transportation of goods and commodities,
- passenger transportation.

6. Road public passenger transportation– I_6

Indicator "road public passenger transportation" represents the value which we obtain by the rate of road public trasportation index in target region ($I_{6.1}$) and road public transportation in given country ($I_{6.2}$).

$$I_6 = I_{6.1}/I_{6.2} * 100\ [\%]$$

where: $I_{6.1}$ = average number of transported persons by road public transport per 24 hours in target region/number of inhabitants in target region

$I_{6.2}$ = average number of transported persons by road public transport per 24 hours in given country/number of inhabitants in given country

Values concerning road public passenger transportation are calculated according to available statistical data. Indicator compares the transportation of passengers by road public transport in target region with the transportation of passengers by road public transport in given country. Calculated indicator value which equals to 100% means that the index for passenger transportation by road public transport in target region is equal to the index for given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 8). Indicator is devided into 5 intervals. The higher index rate of passenger transportation by road public transport in target region is in comparison with the index rate of passenger transportation by road public transport in given country, the higher resulting value is given to the indicator and vice versa, in case the index rate of passenger transportation by road public transport in target region is lower (given values can be seen in Table 8).

Table 8 Road public passenger transportation

Indicator – Road public passenger transportation		
Description	**Claculated value of indicator [%]**	**Given value**
Percentage rate of indices for road public passenger transportation in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage rate of indices for road public passenger transportation in target region and given country is in interval from 40% to 80%	<40 –80)	2
Percentage rate of indices for road public passenger transportation in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage rate of indices for road public passenger transportation in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage rate of indices for road public passenger transportation in target region and given country is 160% and more	<160 and more)	5

For better understanding of the I_6 indicator calculation, we feature a concrete example for the Slovak republic. Assuming that the region affected by extreme weather events is the city of Žilina, in 2013, 10,630,000 persons were transported by road public transport, which means 29,000 persons/24 hours. Number of inhabitants of Žilina is 84,000.

$I_{6.1}$= 29 000/84000= 0,35

According to statistical data of SR (STATdat, 2015) in 2013, 639 446 000 persons were transported by road public transport, which is approximately 751 907 persons/24 hours. Population of Slovakia is 5,414,000 persons.

$I_{6.2}$=1 751 907/5 414 000 = 0,32

I_6= $I_{6.1}$/$I_{6.2}$ *100 = 0,35/0,32*100= **109%**

Thereby, indicator "**r**oad public passenger transportation" has been given value 3 according to Table 8.

7. individual auto transportation – I_7

Indicator "individual auto transportation" stands for thr value (in %) which we obtain from the rate of index of individual auto transportation in target region ($I_{7.1}$) and index of individual auto transportation in given country ($I_{7.2}$).

$I_7=I_{7.1}/I_{7.2}*100$ [%]

where: $I_{7.1}$ = average number of transported persons by individual auto transportation per 24 hours in target region/number of inhabitants in target region

$I_{7.2}$ = average number of transported persons by individual auto transport per 24 hours in given country/number of inhabitants in given country

Values concerning individual auto transport are calculated according to available statistical data. Indicator compares the transportation of persons by individual auto transport in target region with the transportation of persons by individual auto transport port in given country. Calculated indicator value which equals to 100% means that the index for individual auto transport in target region is equal to the index for given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 9). Indicator is devided into 5 intervals. The higher index rate of individual auto transport in target region is in comparison with the index rate of individual auto transport in given country, the higher resulting value is given to the indicator and vice versa, in case the index rate of individual auto transport in target region is lower (given values can be seen in Table 9).

Table 9 Individual auto transport

Indicator – Individual auto transport		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of indices individual auto transport in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage rate of indices individual auto transport in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage rate of indices individual auto transport in target region and given country is in interval from 80% to 120%	<80 –100 – 120)	3
Percentage rate of indices individual auto transport in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage rate of indices individual auto transport in target region and given country is 160% and more	<160 and more)	5

8. Rail public passenger transportation – I_8

Indicator "rail public passenger transportation" represents the value which we obtain by the rate of road public trasportation index in target region ($I_{8.1}$) and road public transportation in given country ($I_{8.2}$).

$I_8=I_{8.1}/I_{8.2}*100$ [%]

where: $I_{8.1}$ = average number of transported persons by rail public transport per 24 hours in target region/number of inhabitants in target region

$I_{8.2}$ = average number of transported persons by rail public transport per 24 hours in given country/number of inhabitants in given country

Values concerning rail public passenger transportation are calculated according to available statistical data. Indicator compares the transportation of passengers by rail public transport in target region with the transportation of passengers by rail public transport in given country. Calculated indicator value which equals to 100% means that the index for passenger transportation by rail public transport in target region is equal to the index for given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 10). Indicator is devided into 5 intervals. The higher index rate of passenger transportation by rail public transport in target region is in comparison with the index rate of passenger transportation by rail public transport in given country, the higher resulting value is given to the indicator and vice versa, in case the index rate of passenger transportation by rail public transport in target region is lower (given values can be seen in Table 10).

Table 10 Rail public passenger transportation

Indicator – Rail public passenger transportation		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of indices for rail public passenger transportation in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage rate of indices for rail public passenger transportation in target region and given country is in interval from 40% to 80%	<40 –80)	2
Percentage rate of indices for rail public passenger transportation in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage rate of indices for rail public passenger transportation in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage rate of indices for rail public passenger transportation in target region and given country is 160% and more	<160 and more)	5

9. Road cargo transportation of goods – I_9

Indicator "road cargo transportation" represents the value which we obtain from the rate of road cargo transportation index in target region ($I_{9.1}$) and road cargo transportation in given country ($I_{9.2}$).

$I_9=I_{9.1}/I_{9.2}*100$ [%]

where: $I_{9.1}$ = average amount of transported goods by road cargo trasnportation per 24 hours in target region/number of inhabitants in target region

$I_{9.2}$ = average amount of transported goods by road cargo trasnportation per 24 hours in given country/number of inhabitants in given country

Values concerning road freight transportation are calculated according to available statistical data. Indicator compares the transportation of goods by road freight transport in target region with the transportation of goods by road freight transport in given country. Calculated indicator value which equals to 100% means that the index for road freight transportation in target region is equal to the index for given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 11). Indicator is devided into 5 intervals. The higher index rate of road freight transportation in target region is in comparison with the index rate of road freight transportation in given country, the higher resulting value is given to the indicator and vice versa, in case the index rate of road freight transportation in target region is lower (given values can be seen in Table 11).

Table 11 Road freight transportation

Indicator – Road freight transportation		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of indices for road freight transportation in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage rate of indices for road freight transportation in target region and given country is in interval from 40% to 80%	<40 –80)	2
Percentage rate of indices for road cargo transportation of goods in target region and given country is in interval from 80% to 120%	<80 –100 –120)	3
Percentage rate of indices for road freight transportation in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage rate of indices for road freight transportation in target region and given country is in 160% and more	<160 and more)	5

10. Rail freight transportation– I_{10}

Indicator "road freight transportation" represents the value which we obtain from the rate of road freight transportation index in target region ($I_{10.1}$) and road freight transportation in given country ($I_{10.2}$).

$I_{10}=I_{10.1}/I_{10.2}*100$ [%]

where: $I_{10.1}$ = average amount of transported goods by rail freight trasnportation per 24 hours in target region/number of inhabitants in target region

$I_{10.2}$ = average amount of transported goods by rail freight trasnportation per 24 hours in given country/number of inhabitants in given country

Values concerning rail freight transportation are calculated according to available statistical data. Indicator compares the transportation of goods by rail freight transport in target region with the transportation of goods by rail freight transport in given country. Calculated indicator value which equals to 100% means that the index for rail freight transportation in target region is equal to the index for given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 12). Indicator is devided into 5 intervals. The higher index rate of rail freight transportation in target region is in comparison with the index rate of rail freight transportation in given country, the higher resulting value is given to the indicator and vice versa, in case the index rate of rail freight transportation in target region is lower (given values can be seen in Table 12).

Table 12 Rail freight transportation

Indicator – Rail freight transportation		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of indices for rail freight transportation in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage rate of indices for rail freight transportation in target region and given country is in interval from 40% to 80%	<40 –80)	2
Percentage rate of indices for rail freight transportation in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage rate of indices for rail freight transportation in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage rate of indices for rail freight transportation in target region and given country is 160% and more	<160 and more)	5

5.2.2 Susceptibility

Our approach is considering the suggestion according to Fig. 2 where susceptibility is a part of vulnerability and is characterizes as the predisposition and likelihood to suffer harm when a hazard strikes a community or a system is exposed (Birkmann, 2013).

Considering the assessment of societal vulnerability in part SENSITIVITY, following societal categories (Social Susceptibility, Infratructure Susceptibility, and Transport Services Susceptibility) including these concrete indicators are going to be the main subject of assessment:

SOCIETAL SUSCEPTIBILITY:

6. the immobile,
7. people at-risk-of-poverty,
8. people aged over 65,
9. children aged under 5,
10. children and adolescents aged from 5 to 18,

INFRUSTRUCTURE SUSCEPTIBILITY:

11. susceptibility of road network,
12. susceptibility of road transport objects,
13. susceptibility of rail network,

14. susceptibility of rail transport objects,
15. detour,

SUSCEPTIBILITY OF TRANSPORT SERVICES:

16. ambulance rescue system,
17. fire fighting and rescue system,
18. police force,
19. evacuation,
20. distribution of essential food and goods.

As can be seen above the core factor SUSCEPTIBILITY represent susceptible part of all exposed components mentioned in part of EXPOSURE.

The importance of the various indicators and groups of indicators for the overall susceptibility is distinguished through assigning weights based on the assessment of the evaluator (can be determined on the basis of expert estimates).

SOCIETAL SUSCEPTIBILITY

Societal susceptibility represents all societal groups of population which are, for various reasons, more sensitive (vulnerable) to negative impacts of extreme weather conditions. Population is devided into several groups according to the ability to react and deal with the impacts of extreme weather conditions. Each of these groups covers certain percentage of common population, regarding common population as employable adults in the age from 18 to 65. Age aspect is considered also by Cutter et al. (2003), Birkmann (2013), Burton & Khazai (2012).

The problem of inhabitants being counted into different groups multiple times (e.g. a person over 65 can be also immobile) has been taken into consideration and solved by gradual counting of inhabitants into groups according to importance/measure (as well as according to order). At first, immobile people are considered, then people at-risk-of-poverty and the remaining groups are differentiated enough, hence, impossible to combine.

11. **The immobile – I_{11}**

The "immobile" indicator stands for the part of population in target region which is immobile - which includes people with temporarily or permanently limited ability to move freely. This part of population is more sensitive to the impacts of extreme weather events because in case of emergency, they are dependent on the help of others and these inhabitants are not able to take care of themselves and deal with negative external impacts. This group of people increases the societal sensitivity level because of the need to be taken care of. Similar indicator is used by Cannon et al. (2003).

This indicator is calculated as the percentage share of immobility rate in target region ($I_{11.1}$) and the immobility rate in given country ($I_{11.2}$).

$$I_{11} = I_{11.1} / I_{11.2} * 100$$

where: $I_{11.1}$ = number of the immobile in target region/number of inhabitants in target region

$I_{11.2}$ = number of the immobile in given country/number of inhabitants in given country

The values of immobility rate are calculated according to available statistical data. Indicator compares the number of the immobile in the target region population with number of the immobile in the entire population of the given country. Resulting indicator value which equals to 100% means the immobility rate equality in target region and given country. This indicator limit is considered as medium limit which serves for the creation of percentual intervals (see Table 13). Indicator is devided into 5 intervals. The higher immobility rate there is in target region compared with the given country, the higher resulting value is given to the indicator and vice versa, in case the immobility rate in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 13.

Table 13 The immobile

Indicator - The immobile		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of immobility rate in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of immobility rate in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of immobility rate in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of immobility rate in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of immobility rate in target region and given country is 160% and more	<160 and more)	5

Even though the immobile can be counted into different age and income category, the care which needs to be taken of them is the same, therefore inhabitants are counted into this group at first in order to avoid multiple additions into one of the above mentioned groups.

12. People at-risk-of-poverty – I_{12}

The indicator "people at-risk-of-poverty" stands for the part of population in target region which is on the line of poverty, i.e. their income is under the level which is considered as minimum in the given country. Lack of financial sources and other disposable reserves make this group much more vulnerable to extreme weather impacts and other aftermath problems with transport because they are unable to deal with potencial consequences or keep their living standard in case they are fully affected (they are not capable of residence renewal, food supply or new societal integration, etc.). It should be said that a lot of similar indicators within literature that are related to the poverty and unemployment of the people are defined, see e.g. Burton and Khazai (2012), Cutter et al. (2008), Inter-American Development Bank, 2010).

This indicator is calculated as the percentage share of people at-risk-of-poverty rate in target region ($I_{12.1}$) and people at-risk-of-poverty rate in given country ($I_{12.2}$).

$$\mathbf{I_{12} = I_{12.1} / I_{12.2} * 100}$$

where: $I_{12.1}$ = number of people at-risk-of-poverty in target region/number of inhabitants in target region

$I_{12.2}$ = number of people at-risk-of-poverty in given country/number of inhabitants in given country

The values of at-risk-of-poverty rate are calculated according to available statistical data. Indicator compares the number of people at-risk-of-poverty among inhabitants of the target region with number of people at-risk-of-poverty in the entire population of the given country. Resulting indicator value which equals to 100% means equality in the rate of at-risk-of-poverty in target region and given country. This indicator limit is considered as medium limit which serves for the creation of percentual intervals (see Table 14). Indicator is devided into 5 intervals. The higher at-risk-of-poverty rate there is in target region compared with the given country, the higher resulting value is given to the indicator and vice versa, in case at-risk-of-poverty rate in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 14.

Table 14 People at-risk-of-poverty

Indicator - People at-risk-of-poverty		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of at-risk-of-poverty rate in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of at-risk-of-poverty rate in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of at-risk-of-poverty rate in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of at-risk-of-poverty rate in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of at-risk-of-poverty rate in target region and given country is 16 0% or more	<160 and more)	5

People at-risk-of-poverty can be put into different age categories, therefore they are counted into this group right after the indicator for the immobile regardless of their age. Other inhabitants are subsequently put into age groups in order to avoid their multiple additions.

At-risk-of-poverty rate for individual states is calculated in relation to their national poverty tresholds, meaning 60 per cent of national median equivalised disposable income (according to EU SILC 2014). In Slovakia, the value is 4086 EUR per year, which means 341 EUR per month in a single adult household. In 2014, 12.6% of inhabitants (660,000 people) were at poverty risk. Highest poverty risk has been detected in case of unemployed people and at significant risk are also incomplete households with three or more children.

13. People aged over 65 – I_{13}

Indicator "people aged over 65" stands for the part of population in target region which is over 65 years old. This group of population is more sensitive to the impacts of extreme weather events because most frequently, their physical abilities (stamina, mobility, endurance, perception, ability to react, speed, etc.) do not allow them to carry out some critical activities (movement, problem solving, evaluation of situation, etc.) effectively and sufficiently enough to overcome health damage, life or property damage.

In some cases not even the mental condition of these inhabitants is on such level which would allow them to adequately react to risks that are caused by the impact of extreme weather events and hence, avoid the negative impacts on their lives.

This indicator is calculated as the percentage share of people aged over 65 rate in target region ($I_{13.1}$) and the rate of people aged over 65 in given country ($I_{13.2}$).

$$\mathbf{I_{13}= I_{13.1}/ I_{13.2} *100}$$

where: $I_{13.1}$ = number of people aged over 65 in target region/number of inhabitants in target region

$I_{13.2}$ = number of people aged over 65 in given country/number of inhabitants in given country

The values for the rate of people aged over 65 are calculated according to available statistical data. Indicator compares the number of people aged over 65 in the target region with number of people aged over 65 in the entire population of the given country. Resulting indicator value which equals to 100% means equality in the rate of people-aged-over-65 in target region and given country. This indicator limit is considered as medium limit which serves for the creation of percentual intervals (see Table 15). Indicator is devided into 5 intervals. The higher rate of people aged over 65 there is in target region compared with the given country, the higher resulting value is given to the indicator and vice versa, in case the people-aged-over-65 rate in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 15.

Table 15 People aged over 65

Indicator – People aged over 65		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of people-aged-over-65 rate in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of people-aged-over-65 rate in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of people-aged-over-65 rate in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of people-aged-over-65 rate in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of people-aged-over-65 rate in target region and given country is 160% and more	<160 and more)	5

14. Children aged under 5 – I_{14}

Indicator "children aged under 5" stands for the part of population in target region which is under 5 years of age. This group of population is more sensitive to the impacts of extreme weather events because their physical abilities (stamina, mobility, speed, etc.) and mental maturity (perception, danger awareness, experience, independence, etc.) do not allow them to carry out some critical activities (movement, problem solving, evaluation of situation, etc.) independently in order to avoid health or life damage. Basically, parents take care of them but in case of separation, they become very fragile and sensitive to the influence of critical events.

This indicator is calculated as the percentage share of children aged under 5 rate in target region ($I_{14.1}$) and rate of children aged under 5 in given country ($I_{14.2}$).

$$\mathbf{I_{14}= I_{14.1}/ I_{14.2} *100}$$

where: $I_{14.1}$ = number of children aged under 5 in target region/number of ihabitants in target region

$I_{14.2}$ = number of children aged under 5 in given country/number of inhabitants in given country

The values for the rate of children aged under 5 are calculated according to available statistical data. Indicator compares the number of children aged under 5 in the target region with number of children aged under 5 in the entire population of the given country. Resulting indicator value which equals to 100% means equality in the rate of children-aged-under-5 in target region and given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 16). Indicator is devided into 5 intervals. The higher rate of children aged under 5 there is in target region compared with the given country, the higher resulting value is given to the indicator and vice versa, in case the children-aged-under-5 rate in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 16.

Table 16 Children aged under 5

Indicator – Children aged under 5		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of children-aged-under-5 rate in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of children-aged-under-5 rate in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of children-aged-under-5 rate in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of children-aged-under-5 rate in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of children-aged-under-5 rate in target region and given country is over 160% and more	<160 and more)	5

15. Children and adolescents aged from 5 to 18 – I_{15}

Indicator "children and adolescents aged from 5 to 18" covers the part on population in target region which is of age from 5 to 18. This group of population is more sensitive to the impacts of extreme weather events because, in comparison with common population (adults from 18 to 65) their physical conditions (stamina, mobility, speed, etc.) and mental maturity (perception, danger awareness, intelligence, independence, etc.) are not on such level to react adequately to risks in a way common population would and receive required measures.

This indicator is calculated as the percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region ($I_{15.1}$) and children-and-adolescents-aged-from-5-to-18 rate in given country ($I_{15.2}$).

$$I_{15} = I_{15.1} / I_{15.2} * 100$$

where: $I_{15.1}$ = number of children and adolescents aged from 5 to 18 in target region/number of inhabitants in target region

$I_{15.2}$ = number of children and adolescents aged from 5 to 18 in given country/number of inhabitants in given country

The values for the rate of children and adolescents aged from 5 to 18 are calculated according to available statistical data. Indicator compares the number of children and adolescents aged from 5 to 18 in the target region with number of children and adolescents aged from 5 to 18 in the entire population of the given country. Resulting indicator value which equals to 100% means equality in the rate of children and adolescents aged from 5 to 18 in target region and given country. This indicator limit is considered as medium limit which serves for the creation of percentual intervals (see Table 17). Indicator is devided into 5 intervals. The higher rate of children and adolescents aged from 5 to 18 there is in target region compared with the given country, the higher resulting value is given to the indicator and vice versa, in case the children-and-adolescents-aged-from-5-to-18 rate in target region is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 17.

Table 17 Children and adolescents aged from 5 to 18

Indicator – Children and adolescents aged from 5 to 18		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region and given country is in interval from 80% to 120%	<80 – 100 –120)	3
Percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of children-and-adolescents-aged-from-5-to-18 rate in target region and given country is 160% and more	<160 and more)	5

INFRASTRUCTURE SUSCEPTIBILITY

Infrastructure susceptibility is perceived as increased vulnerability of transport infrastructure parts or objects to extreme weather events due to increased danger of impacts or bad technical-constructional conditions of transport constructions. This societal category and specific indicators are defined based on the variables for measuring disaster resilience adapted from Cutter (2011) in Burton and Khazai (2012).

The reason for categorization of infrastructure susceptibility into several indicators is to emphasize their different significance for the overall susceptibility rate and hence, the overall vulnerability rate. Thanks to this categorisation, the evaluator is given space for considering the differences in significance of the means of transport in target region (road and rail transport) and differences in concrete groups of transport elements, especially from their operational and constructional aspects, their renewal requirements or uniqueness in target region.

The importance of all indicators has been determined according to the significance of means of transport, the reconstruction and renewal requirements of concrete elements or the importance of detour availability.

16. Road network susceptibility – I_{16}

Indicator for "road network susceptibility" stands for the line parts of road transport infrastructure in target region which are more vulnerable to extreme weather impacts. These parts are more sensitive because they are located in the hazard prone areas. These are individual roads or their parts, which are located:

- close to a river (in danger of underwashing or overflowing),
- in a flood region – considering also coastal flooding (some parts in danger of flooding according to flood maps),
- below slopes (in danger of soil and rock sliding on the road),
- in forest regions (in danger of tree fall, danger of forest fires),
- areas liable to extreme winds,
- highland mountain zones (snowfall risk).

Linear infarstructure parts could be added to these more sensitive parts as well since they can be in bad technical state and hence, they can be more vulnerable to constructional damage caused by extreme weather. Differentiation would be possible also according to the classes/categories of road infrastructure because roads of higher classes are constructionally more resistant.

This indicator is calculated as the percentage share of road network length in hazard prone areas located in target region ($I_{16.1}$) and overall road network length in target region ($I_{16.2}$).

$$\mathbf{I_{16}= I_{16.1}/ I_{16.2} *100}$$

where: $I_{16.1}$ = road network lenght near a river [km] + road network length in flood region [km] + road network length below slopes [km] + road network length in forests regions [km] + road network length in areas liable to extreme winds + road network length in bad technical state [km] (only relevant areas for specific hazard should be taken into consideration)

$I_{16.2}$ = overal road network length in target region [km]

Data about road network length and its more sensitive parts are obtained from available statistical sources. Calculated percentage of the indicator is assorted into one of the five created intervals (see Table 18.) The higher more-sensitive-road-network rate is in target region, the higher resulting value is given to the indicator and vice versa, in case of lower rate of more sensitive road network in target region (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 18.

Table 18 Road network susceptibility

Indicator – Road network susceptibility		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of more sensitive road network parts in overall road network length in target region is from 0% to 20%	<0 – 20)	1
Percentage share of more sensitive road network parts in overall road network length in target region is from 20% to 40%	<20 – 40)	2
Percentage share of more sensitive road network parts in overall road network length in target region is from 40% to 60%	<40 – 60)	3
Percentage share of more sensitive road network parts in	<60 – 80)	4

overall road network length in target region is from 60% to 80%		
Percentage share of more sensitive road network parts in overall road network length in target region is from 80% to 100%	<80 – 100>	5

17. Susceptibility of road transport objects – I_{17}

Indicator "susceptibility of road transport objects" covers all objects in road transport infrastructure in target region which are more vulnerable to the impacts of extreme weather events. These objects are more sensitive because they are located in the hazard prone areas. They are, for example, bridges (higher than 5 metres), tunnels, bus stops, motorway junctions, etc. which are located:

- close to a river (in danger of underwashing or overflowing),
- in a flood region – considering also coastal flooding (some parts in danger of flooding according to flood maps),
- below slopes (in danger of soil and rock sliding on the road),
- in forest regions (in danger of tree fall, danger of forest fires),
- areas liable to extreme winds,
- highland mountain zones (snowfall risk).

To these more sensitive transport objects belong also objects which are in bead technical state and hence are more vulnerable to constructional damage caused by extreme weather events.

This indicator is calculated as the percentage share of the number of significant transport objects in hazard prone areas located in target region ($I_{17.1}$) and the number of all significant road objects in target region ($I_{17.2}$).

$$I_{17} = I_{17.1} / I_{17.2} * 100$$

where: $I_{17.1}$ = number of road objects near a river + number of road objects in a flood region + number of road objects below the slope + number of road objects in a forest region + number of road objects in areas liable to extreme winds + number of road objects in bad technical state (only relevant areas for specific hazard should be taken into consideration)

$I_{17.2}$ = number of significant road objects in target region

Data about the number of significant road objects and their occurrence in hazard prone areas are obtained from available statistical sources. Calculated percentage value of the indicator is assorted into one of the five created intervals (see Table 19.) The higher rate of more sensitive road objects is in target region, the higher resulting value is given to the indicator and vice versa, in case of lower rate of more sensitive road objects in target region (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 19.

Table 19 Susceptibility of road transport objects

Indicator – Susceptibility of road transport objects		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of more sensitive road obejcts in overall number of significant road objects in target region is from 0% to 20%	<0 – 20)	1
Percentage share of more sensitive road obejcts in overall number of significant road objects in target region is from 20% to 40%	<20 – 40)	2
Percentage share of more sensitive road obejcts in overall number of significant road objects in target region is from 40% to 60%	<40 – 60)	3
Percentage share of more sensitive road obejcts in overall number of significant road objects in target region is from 60% to 80%	<60 – 80)	4
Percentage share of more sensitive road obejcts in overall number of significant road objects in target region is from 80% to 100%	<80 – 100>	5

18. Susceptibility of rail network – I_{18}

Indicator "susceptibility of rail network" stands for linear parts of rail transport infrastructure in target region which are more vulnerable to the impacts of extreme weather events. These parts are more sensitive because they are located in hazard prone areas. These are the rail roads which are located:

- close to a river (in danger of underwashing or overflowing),
- in a flood region – considering also coastal flooding (some parts in danger of flooding according to flood maps),
- below slopes (in danger of soil and rock sliding on the rail network),
- in forest regions (in danger of tree fall, danger of forest fires),
- areas liable to extreme winds,
- highland mountain zones (snowfall risk).

These more sensitive parts include also rail roads or their parts which are in bad technical state and hence, are more vulnerable to constructional damage caused by extreme weather events.

This indicator is calculated as the percentage share of rail network length in hazard prone areas located in target region ($I_{18.1}$) and overall rail network length in target region ($I_{18.2}$).

$$I_{18} = I_{18.1} / I_{18.2} * 100$$

where: $I_{18.1}$ = rail network lenght near a river [km] + rail network length in flood region [km] + rail network length below slopes [km] + rail network length in forests regions [km] + rail network length in areas liable to extreme winds + rail network length in bad technical state [km] (only relevant areas for specific hazard should be taken into consideration)

$I_{18.2}$ = overal rail network length in target region [km]

Data about rail network length and its more sensitive parts are obtained from available statistical sources. Calculated percentage of the indicator is assorted into one of the five created intervals (see Table 20.) The higher more-sensitive-rail-network rate is in target region, the higher resulting value is given to the indicator and vice versa, in case of lower rate of more sensitive rail network in target region (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 20.

Table 20 Susceptibility of rail transport

Indicator – Susceptibility of rail transport		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of more sensitive rail network parts in overall rail network length in target region is from 0% to 20%	<0 – 20)	1
Percentage share of more sensitive rail network parts in overall rail network length in target region is from 20% to 40%	<20 – 40)	2
Percentage share of more sensitive rail network parts in overall rail network length in target region is from 40% to 60%	<40 – 60)	3
Percentage share of more sensitive rail network parts in overall rail network length in target region is from 60% to 80%	<60 – 80)	4
Percentage share of more sensitive rail network parts in overall rail network length in target region is from 80% to 100%	<80 – 100>	5

19. Susceptibility of rail transport objects – I_{19}

Indicator "susceptibility of rail transport objects" covers all objects in rail transport infrastructure in target region which are more vulnerable to the impacts of extreme weather events. These objects are more sensitive because they are located in the hazard prone areas. They are, for example, bridges, tunnels, train stations, intermodal transport station, etc. which are located:

- close to a river (in danger of underwashing or overflowing),
- in a flood region – considering also coastal flooding (some parts in danger of flooding according to flood maps),
- below slopes (in danger of soil and rock sliding on the rail network),
- in forest regions (in danger of tree fall, danger of forest fires),
- areas liable to extreme winds,
- highland maoutain zones (snowfall risk).

These more sensitive rail transport objects include also objects which are in bad technical state and hence are more vulnerable to constructional damage caused by extreme weather events.

This indicator is calculated as the percentage share of the number of significant rail objects in hazard prone areas located in target region ($I_{19.1}$) and the number of all significant rail objects in target region ($I_{19.2}$) (see indicator I_5).

$I_{19} = I_{19.1} / I_{19.2} * 100$

where: $I_{19.1}$ = number of rail objects near a river + number of rail objects in a flood region + number of rail objects below the slope + number of rail objects in a forest region + number of rail objects in areas liable to extreme winds + number of rail objects in bad technical state (only relevant areas for specific hazard should be taken into consideration)

$I_{19.2}$ = number of significant rail objects in target region

Data about the number of significant rail objects and their occurrence in hazard prone areas are obtained from available statistical sources. Calculated percentage of the indicator is assorted into one of the five created intervals (see Table 21.) The higher share of more sensitive rail objects is in target region, the higher resulting value is given to the indicator and vice versa, in case of lower share of more sensitive rail objects in target region (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 21.

Table 21 Susceptibility of rail transport objects

Indicator – Susceptibility of rail transport objects		
Description	**Caluculated value of indicator [%]**	**Given value**
Percentage share of more sensitive rail objects in overal number of significant rail objects in target region is from 0% to 20%	<0 – 20)	1
Percentage share of more sensitive rail objects in overal number of significant rail objects in target region is from 20% to 40%	<20 – 40)	2
Percentage share of more sensitive rail objects in overal number of significant rail objects in target region is from 40% to 60%	<40 – 60)	3
Percentage share of more sensitive rail objects in overal number of significant rail objects in target region is from 60% to 80%	<60 – 80)	4
Percentage share of more sensitive rail objects in overal number of significant rail objects in target region is from 80% to 100%	<80 – 100>	5

20. Detour (detour availability) – I_{20}

Indicator "detour (detour availability)" stands for possible replacement of the common road access to target region. The shortest detour is considered (if detour exists). Only one access road disruption is taken into consideration, which is the one requiring the longest detour from all possibilities. For example, if there are four access roads to the target region, only the disruption of the most sensitive one is taken into consideration, which requires the longest detour and hence, in some measures indicates infrastructure sensitivity with the need for a detour. It is mainly due to the vast variability of the number of access roads to target region which is derived from the area of examined target region. Consideration of only one access road disruption gives the possibility to compare given target regions by the use of this indicator.

Given indicator is defined only for road transport and the detour road will be counted only in case of road communications because the substitution for rail transport is basically solved by road transport.

This indicator is calculated as the rate of length of the shortest possible detour ($I_{20.1}$) and lenght of the shorest possible road ($I_{20.2}$).

$\mathbf{I_{20}= I_{20.1}/ I_{20.2}}$

where: $I_{20.1}$ = length of the shortest possible detour [km]

$I_{20.2}$ = lenght of the shorest possible road [km]

Data about the lengths of common roads and detours can be obtained from available map and transport sources. Resulting rate expresses how many times longer the detour is in comparison with the common road. Basically, detour is always longer than a common road and therefore, the resulting rate is always higher, eventually equals to 1. In case there is only one access road to the target region, indicator is given the highest value. Calculated indicator value is assorted into one of five created intervals (see Table 22). The higher this rate is, the higher value is givent o the indicator (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 22.

Table 22 Detour (detour availability)

Indicator – Detour (detour availability)		
Description	**Calculated value of indicator**	**Given value**
Shortest possible detour is 1 or 2 times longer than shortest common road	<1 – 2)	1
Shortest possible detour is 2 or 3 times longer than shortest common road	<2 – 3)	2
Shortest possible detour is 3 or 4 times longer than shortest common road	<3 – 4)	3
Shortest possible detour is 4 or 5 times longer than shortest common road	<4 – 5)	4
Shortest possible detour is 5 and more times and longer than shortest common road	<5 and more)	5

SUSCEPTIBILITY OF TRANSPORT SERVICES

Susceptibility of transport services includes that part of transport services which is sensitive to transport infrastructure disruption when considering the importance of solving an emergency situation, because these services provide health care for citizens, their protection, evacuation from affected regions and their supply throughout the time of extreme weather events. This societal category and specific indicators are defined based on the variables for measuring disaster resilience adapted from Cutter (2011) in Burton and Khazai (2012) where fire, police, and emergency relief structures are considered as important vulnerability indicators.

21. Ambulance rescue system (ARS) – I_{21}

Indicator "ambulance rescue system" stands for the performance of ambulance rescue units in target region. There is a justified assumption that this performance (number of ambulance journeys) will be as high or higher in course of emergency caused by extreme weather events. ARS provides immediate health care or pre-hospitalised urgent health care for patients whose life or health is in danger. Execution of these services will be significantly more complicated in case of transport infrastructure disruption since it is carried out mainly by ARS vehicles. From this point of view, this service is sensitive to the functionality of transport infrastructure. This indicator is calculated as the percentage share of average number of ARS journeys in target region per 24 hours ($I_{21.1}$) and average number of ARS journeys in given country per 24 hours ($I_{21.2}$) and all that counted per 1000 inhabitants.

$$I_{21} = I_{21.1} / I_{21.2} * 100$$

where: $I_{21.1}$ = average number of ARS journeys in target region over 1 year/365/1000 inhabitants
$I_{21.2}$ = average number of ARS journeys in given country over 1 year/365/1000 inhabitants

Values for the number of annual ARS journeys are obtained from available statistical data. Indicator compares the number of ARS journeys in target region with the number of ARS journeys in given country, due to better comparability counted per 1000 inhabitants. If the calculated value of indicator equals to 100%, it means the equality in numbers of journeys in target region and given country. This indicator limit is determined as the medium limit and serves as the base for interval creation (see Table 23). Indicator is devided into 5 intervals. If the average number of ARS journeys in target region is higher than the average in given country, indicator is given respectively higher value and vice versa, in case the average number of ARS journeys in target region is lower (given values from 1 to 5). Exact limits of indicator intervals and of given values can be seen in Table 23.

Table 23 Ambulance rescue system

Indicator - Ambulance rescue system		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of number of ARS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of number of ARS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of number of ARS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of number of ARS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of number of ARS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval 160% and more	<160 and more)	5

22. Fire fighting and rescue system (FFRS) – I_{22}

Indicator "fire fighting and rescue system" stands for the preformance of fire fighting and rescue system units in target region. There is a justified assumption that this performance (number of journeys) will be as high or higher in course of emergency caused by extreme weather events. FFRS provides protection against fire, rescue actions in case of accidents, natural disasters and other situations, protection of health, property and environment. Execution of these services will be significantly more complicated in case of transport infrastructure disruption since it is carried out mainly by emergency vehicles. From this point of view, this service is sensitive to the functionality of transport infrastructure. This indicator is calculated as the percentage share of average number of FFRS journeys in target region per 24 hours ($I_{22.1}$) and average number of FFRS journeys in given country per 24 hours ($I_{22.2}$) and all that counted per 1000 inhabitants.

$$I_{22} = I_{22.1} / I_{22.2} * 100$$

where: $I_{22.1}$ = average number of FFRS journeys in target region per 1 year/365/1000 inhabitants
$I_{22.2}$ = average number of FFRS journeys in given country per 1 year/365/1000 inhabitants

Values for the number of annual FFRS journeys are obtained from available statistical data. Indicator compares the number of FFRS journeys in target region with the number of FFRS journeys in given country, due to better comparability counted over 1000 inhabitants. If the calculated value of indicator equals to 100%, it means the equality in numbers of journeys in target region and given country. This indicator limit is determined as the medium limit and serves as the base for interval creation (see Table 24). Indicator is devided into 5 intervals. If the average number of FFRS journeys in target region is higher than the average in given country, indicator is given respectively higher value and vice versa, in case the average number of FFRS journeys in target region is lower (given values from 1 to 5). Exact limits of indicator intervals and of given values can be seen in Table 24.

Table 24 Fire fighting and rescue system

Indicator - Fire fighting and rescue system		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of number of FFRS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of number of FFRS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of number of FFRS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of number of FFRS journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of number of FFRS journeys over 1000 inhabitants over 24 hours in target region and given country is 160% and more	<160 and more)	5

23. Police force (PF) – I_{23}

Indicator "police force" represents the performance of PF in target region. There is possible to assume that this performance (number of journeys) will be approximately the same or higher in course of emergency caused by extreme weather events. PF fulfills tasks to keep order in the country, to keep citizens safe, protect lives, etc. Execution of these services will be significantly more complicated in case of transport infrastructure disruption since it is carried out mainly by police vehicles (troop units are excluded). From this point of view, this service is sensitive to the functionality of transport infrastructure. This indicator is calculated as the percentage share of average number of PF journeys in target region per 24 hours ($I_{23.1}$) and average number of PF journeys in given country per 24 hours ($I_{23.2}$) and all that counted per 1000 inhabitants.

$$I_{23}= I_{23.1}/ I_{23.2} *100$$

where: $I_{23.1}$ = average number of PF journeys in target region per 1 year/365/1000 inhabitants
$I_{23.2}$ = average number of PF journeys in given country per 1 year/365/1000 inhabitants

Values for the number of annual PF journeys are obtained from available statistical data. Indicator compares the number of PF journeys in target region with the number of PF journeys in given country, due to better comparability counted per 1000 inhabitants. If the calculated value of indicator equals to 100%, it means the equality in numbers of journeys in target region and given country. This indicator limit is determined as the medium limit and serves as the base for interval creation (see Table 25). Indicator is devided into 5 intervals. If the average number of PF journeys in target region is higher than the average in given country, indicator is given respectively higher value and vice versa, in case the average number of PF journeys in target region is lower (given values from 1 to 5). Exact limits of indicator intervals and of given values can be seen in Table 25.

Table 25 Police force

Indicator - Police force		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of number of PF journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 0% to 40%	<0 – 40)	1
Percentage share of number of PF journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 40% to 80%	<40 – 80)	2
Percentage share of number of PF journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 80% to 120%	<80 – 100 - 120)	3
Percentage share of number of PF journeys over 1000 inhabitants over 24 hours in target region and given country is in interval from 120% to 160%	<120 – 160)	4
Percentage share of number of PF journeys over 1000 inhabitants over 24 hours in target region and given country is 160% or more	<160 and more)	5

24. Evacuation – I_{24}

Indicator "evacuation" stands for that part of population in need of evacuation in case of concrete danger. This pat of population is more sensitive because it relies on spontaneous or controled evacuation caused by specific extreme weather events. If transport infrastructure happens to be disrupted at the same time, the whole evacuation process will become much more complicated and therefore, sensitivity level of transport services and hence, societal vulnerability as such, increases in the target region. On the other hand, during evacuation the demand for certain transport sections is higher which makes evacuation even more difficult, especially in case of danger with minimum time limit needed for their activation (e.g. flash floods).

This indicator is calculated as percentage rate of number of inhabitants in target region in need of evacuation ($I_{24.1}$) and number of all inhabitants in target region ($I_{24.2}$).

$$\mathbf{I_{24}= I_{24.1}/ I_{24.2} *100}$$

where: $I_{24.1}$ = number of inhabitants in target region in need of evacuation

$I_{24.2}$ = number of all inhabitants in target region

Data about the number of inhabitants in need of evacuation can be obtained from flood maps, historical documents about the need of evacuation (if they are available or if considered danger had occured in past) and/or expert assumptions. Calculated percentage value of indicator is assorted into one of five given intervals (see Table 26). The higher percentage of population needs to be evacuated in target region, the higher resulting value is given to the indicator (given values from 1 to 5). Exact limits of indicator intervals and of given values can be seen in Table 26.

Table 26 Evacuation

Indicator – Evacuation		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of population in target region in need of evacuation is from 0% to 20%	<0 – 20)	1
Percentage rate of population in target region in need of evacuation is from 20% to 40%	<20 – 40)	2
Percentage rate of population in target region in need of evacuation is from 40% to 60%	<40 – 60)	3
Percentage rate of population in target region in need of evacuation is from 60% to 80%	<60 – 80)	4
Percentage rate of population in target region in need of evacuation is from 80% to 100%	<80 – 100>	5

25. Distribution of essential food and goods – I_{25}

Indicator "distribution of essential food and goods" represents the need of supplies of life-essential food and goods, e.g. drinking water, food, medicaments, fuel, for population in target region after a disaster. That part of population which is reliant on the supplies of these commodities is the more sensitive part of population and increases its overal vulnerability.

This indicator is calculated as percentage rate of number of inhabitants in target region in need of supplies of essential food and goods ($I_{25.1}$) and number of all inhabitants in target region ($I_{25.2}$).

$$\mathbf{I_{25} = I_{25.1} / I_{25.2} * 100}$$

where: $I_{25.1}$ = number of inhabitants in target region in need of supplies of essential food and goods

$I_{25.2}$ = number of all inhabitants in target region ($I_{25.2}$).

Data about the number of inhabitants in need of supplies of essential food and goods can be obtained from flood maps, historical documents about the need of supplies (if they are available or if considered danger had already occured in past) and/or expert assumptions. Calculated percentage of indicator is assorted into one of five created intervals (see Table 27). The higher percentage of population needs to be supplied in target region, the higher resulting value is given to the indicator (given values from 1 to 5). Exact limits of indicator intervals and of given values can be seen in Table 27.

Table 27 Distribution of essential food and goods

Indicator - Distribution of essential food and goods		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of population in target region in need of supplies is from 0% to 20%	<0 – 20)	1
Percentage rate of population in target region in need of supplies is from 20% to 40%	<20 – 40)	2
Percentage rate of population in target region in need of supplies is from 40% to 60%	<40 – 60)	3
Percentage rate of population in target region in need of supplies is from 60% to 80%	<60 – 80)	4
Percentage rate of population in target region in need of supplies is from 80% to 100%	<80 – 100>	5

5.2.4 Adaptive capacity

Our approach is considering the suggestion according to Fig. 2 where adaptive capacity is part of vulnerability and is defined as the combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities (Allen Consulting Group, 2005, IPCC, 2012) and is often determined by a local set of resources and conditions that constrain or facilitate the ability of the system to successfully adapt to changes in climate (Adger, Arnell & Tompkins 2005, Smit & Wandel 2006). This adaptive capacity can be in the wider sence considered as resilience of the community (society) to impacts of an extreme weather event (Cutter et al., 2008) beceause resilience can be similarly expressed as potential to resist, adapt, mitigate, learn, recover from an extreme weather event impacts, see Figure 3 (Birkmann, 2013, Bruneau et al. 2003).

This study, along the lines of previous research of the ESPON CLIMATE (ESPON CLIMATE, 2013/2014) and ATEAM (Schröter et al., 2004) considers ADAPTIVE CAPACITY to reflect aspects as awareness and preparedness of society, ability to cope with impacts and possibility of institution to act. Therefore, the following socetial categories (Rescue services, Economic sources, Preparedness/Prevention) including following concrete indicators were defined and assessed:

RESCUE SERVICES:

26. professional units of rescue system
27. voluntary units of rescue system

ECONOMIC SOURCES:

28. access to sources from the state budget
29. insurance

PREPAREDNESS/PREVENTION:

30. area coverage with warning signal
31. preparedness rate

By some authors (Burton, 2011) are several of these above mentioned indicators (variables) used also for quantifying of a social resilience value. It follows that adaptive capacity and resilience of society have several attributes in common and this way it is posibble to address resilience of the society to the extreme weather event within the societal vulnerability assessment.

The importance of the various indicators and groups of indicators for the overall adaptive capacity is distinguished through assigning weights based on the assessment of the evaluator (can be determined on the basis of expert estimates). ORT application can be also used for this purpose.

RESCUE SERVICES

Capacities for the management of extreme weather conditions mainly consist of all rescue services which are available in target region or local area. Adger, Arnell & Tompkins (2005) and Smit & Wandel (2006) has determined adaptive capacity as local set of resources. Among them are professional units as well as voluntary units of integrated rescue system. As a matter of course, the state can provide the affected region also with facilities and services outside the target area, but basically, it can distribute the same amount for all regions. Considering this, target regions will differentiate according to the number of rescue services available immediately.

Rescue services represent capacity of the local governance to deal with risks or extreme weather events a therefore can be seen as part of institutional dimension of vulnerability as it is defined in e.g. Adger (2000) or Fund for Peace (2011).

26. Professional units of rescue system – I_{26}

Indicator "professional units of rescue system" stands for professional forces and facilities of RS (RS_{PRO}), which are available in target region. RS_{PRO} provides all essential services for population. RS_{PRO} include professional firefighters, medical assistence units, police units, etc.

This indicator is calculated as the percentage share of RS_{PRO} rate in target region ($I_{26.1}$) and RS_{PRO} rate in given country ($I_{26.2}$) (all calculated per 1 000 inhibitants).

$$I_{26} = I_{26.1} / I_{26.2} * 100$$

where: $I_{26.1}$ = number of RS_{PRO} in target region/ number of inhabitants in target region*1000

$I_{26.2}$ = number of RS_{PRO} in given country/number of inhabitants in given country*1000

Values of RS_{PRO} numbers are obtained from available statistical data. Indicator compares number of RS_{PRO} per 1000 inhabitants in target region with number of RS_{PRO} per 1000 inhabitants in given country. If the calculated value of indicator equals to 100%, it shows the equality of numbers of RS_{PRO} in target region and in given country. This indicator limit is considered as medium limit which serves for the creation of percentage intervals (see Table 28). Indicator is divided into 5 intervals. The higher number of in target region is in comparison with the number of RS_{PRO} in given country, the lower resulting value is given to the indicator and vice versa, in case the number of RS_{PRO} in target region is lower (since adaptive capacity is supposed to lower the rate of vulnerability, assessment of particular indicators is solved in the opposite way; given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 28.

Table 28 Professional units of rescue system

Indicator – Professional units of RS		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of RS_{PRO} in target region and given country is in interval from 0% to 40%	<0 – 40)	5
Percentage share of RS_{PRO} in target region and given country is in interval from 40% to 80%	<40 – 80)	4
Percentage share of RS_{PRO} in target region and given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of RS_{PRO} in target region and given country is in interval from 120% to 160%	<120 – 160)	2
Percentage share of RS_{PRO} in target region and given country is 160% and more	<160 and more)	1

27. Voluntary units of rescue system (RS_{VOL}) - I_{27}

Indicator "voluntary units of rescue system" stands for voluntary forces and facilities of RS (RS_{VOL}), which are available in target region. RS_{VOL} also provides essential services for target region. RS_{VOL} include mainly volunteer firefighters and units of another volunteer organisations.

This indicator is calculated as the percentage share of RS_{VOL} rate in target region ($I_{27.1}$) and RS_{VOL} rate in given country ($I_{27.2}$) (all calculated per 1 000 inhibitants).

$$I_{27} = I_{27.1} / I_{27.2} * 100$$

where: $I_{27.1}$ = number of RS_{VOL} in target region/ number of inhabitants in target region*1000

$I_{27.2}$ = number of RS_{VOL} in given country/number of inhabitants in given country*1000

Values of RS_{VOL} numbers are obtained from available statistical data. Indicator compares number of RS_{VOL} per 1000 inhabitants in target region with number of RS_{VOL} per 1000 inhabitants in given country. If the calculated value of indicator equals to 100%, it shows the equality of numbers of RS_{VOL} in target region and in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 29). Indicator is divided into 5 intervals. The higher number of RS_{VOL} in target region is in comparison with the number of RS_{VOL} in given country, the lower resulting value is given to the indicator and vice versa, in case the number of RS_{VOL} in target region is lower (since adaptive capacity is supposed to lower the rate of vulnerability, assessment of particular indicators is solved in the opposite way; given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 29.

Table 29 Voluntary units of rescue system

Indicator – Voluntary units of rescue system		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of RS_{VOL} in target region and given country is in interval from 0% to 40%	<0 – 40)	5
Percentage share of RS_{VOL} in target region and given country is in interval from 40% to 80%	<40 – 80)	4
Percentage share of RS_{VOL} in target region and given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage share of RS_{VOL} in target region and given country is in interval from 120% to 160%	<120 – 160)	2
Percentage share of RS_{VOL} in target region and given country is 160% and more	<160 and more)	1

ECONOMIC SOURCES

The program of Inter-American Development Bank (2010) which is dealing with indicators of disaster risk and risk management has developted several indicators which are related also to the societal vulnerability and adaptive capacity and therefore some of them were used also in following part of work. Similar indicators are considered also in Burton & Khazai (2012).

28. Access to sources from the state budget – I_{28}

Indicator “access to sources from the state budget“ is presented as the rate of financial sources which the state allocates to regions affected by emergency consequences. Each state finances different scale of consequences (used also by Inter-American Development Bank, 2010).

I_{28} = percentage rate of the measure of financing the emergency consequences [%]

The measures of financing the consequences from state budget can be obtained from available data concerning the past and state politicy of financing such consequences. Percentage value of indicator is assorted into 5 created intervals (see Table 30). The higher the measure of financing is, the lower value is given to the indicator and vice versa, in case the measure of financing is lower (given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 30.

Table 30 Access to sources from the state budget

Indicator – Access to sources from the state budget		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage share of financing the consequences is from 0% to 20%	<0 – 20)	5
Percentage share of financing the consequences is from 20% to 40%	<20 – 40)	4
Percentage share of financing the consequences is from 40% to 60%	<40 – 60)	3
Percentage share of financing the consequences is from 60% to 80%	<60 – 80)	2
Percentage share of financing the consequences is from 80% to 100%	<80 – 100>	1

29. Insurance – I_{29}

Indicator "insurance" (Inter-American Development Bank, 2010; Burton & Khazai (2012)) stands for the amount of insured households in target region.

This indicator is calculated as the percentage share of home insurance rate against specific hazard in target region ($I_{29.1}$) and home insurance rate against specific hazard in given country ($I_{29.2}$).

$I_{29} = I_{29.1} / I_{29.2} * 100$

where: $I_{29.1}$ = number of insured households in target region / number of households in target region

$I_{29.2}$ = number of insured households in given country/ number of households in given country

Values of home insurance numbers are obtained from available statistical data. Indicator compares the rates of home insurance rate in target region and in given country. If the calculated value of indicator equals to 100%, it shows the equality of the rates of home insurance rate in target region and in given country. This indicator limit is considered a medium limit which serves for the creation of percentage intervals (see Table 31). Indicator is divided into 5 intervals. The higher rate of insured households in target region is in comparison with the rate of insured households in given country, the lower resulting value is given to the indicator and vice versa, in case the rate of insured households in target region is lower (since adaptive capacity is supposed to lower the rate of vulnerability, assessment of particular indicators is solved in the opposite way; given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 31.

Table 31 Insurance

Indicator – Insurance		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of home insurance in target region and given country is in interval from 0% to 40%	<0 – 40)	5
Percentage rate of home insurance in target region and given country is in interval from 40% to 80%	<40 – 80)	4
Percentage rate of home insurance in target region and given country is in interval from 80% to 120%	<80 – 100 – 120)	3
Percentage rate of home insurance in target region and given country is in interval from 120% to 160%	<120 – 160)	2
Percentage rate of home insurance in target region and given country is 160% or more	<160 and more)	1

PREPAREDNESS/PREVENTION

30. Area coverage with warning signal– I_{30}

Indicator "area coverage with warning signal" stands for that part of target region which is covered with warning signal.

This indicator is calculated as the rate of target region area which is covered with warning signal ($I_{30.1}$) and overall area of target region ($I_{30.2}$).

$$I_{30} = I_{30.1} / I_{30.2} * 100$$

where: $I_{30.1}$ = target region area which is covered with warning signal [km^2]

$I_{30.2}$ = area of target region [km^2]

Data about the area coverage with warning signal can be obtained from available statistical data. Percentage value of indicator is assorted into one of five created intervals (see Table 32). The bigger the area covered with warning signal is, the lower resulting value is given to the indicator and vice versa, in case the region area covered with warning signal is smaller (since adaptive capacity is supposed to lower the rate of vulnerability, assessment of particular indicators is solved in the opposite way; given values from 1 to 5). Exact interval limits of an indicator and given values can be seen in Table 32.

Table 32 Area coverage with warning signal

Indicator – Area coverage with warning signal		
Description	**Calculated value of indicator [%]**	**Given value**
Percentage rate of target region area covered with warning signal is from 0% to 20%	<0 – 20)	5
Percentage rate of target region area covered with warning signal is from 20% to 40%	<20 – 40)	4
Percentage rate of target region area covered with warning signal is from 40% to 60%	<40 – 60)	3
Percentage rate of target region area covered with warning signal is from 60% to 80%	<60 – 80)	2
Percentage rate of target region area covered with warning signal is from 80% to 100%	<80 – 100>	1

31. Preparedness rate – I_{31}

Indicator "preparedness rate" covers the estimated rate of preparedness of population and responsible organs to solve potential emergency caused by extreme weather events. This indicator is also used by e.g. Cannon et al. (2003) and in more detailed way can be found in Burton & Khazai (2012).

The assessment of preparedness rate will be based on expert analysis of critical state plans, plans for societal recovery after a disaster, for existence and condition of protection buildings, preventive activities in given region, etc. (Table 33).

Table 33 Preparedness rate

Indicator – Preparedness rate	
Description	**Given value**
Preparedness rate of population and responsible organs to manage the impacts of extreme weather events is on a very high level	1
Preparedness rate of population and responsible organs to manage the impacts of extreme weather events is on a high level	2
Preparedness rate of population and responsible organs to manage the impacts of extreme weather events is on an adequate level	3
Preparedness rate of population and responsible organs to manage the impacts of extreme weather events is on a satisfactory level	4
Preparedness rate of population and responsible organs to manage the impacts of extreme weather events is on a very low level	5

6. Conclusion

Understanding and assessing multifaceted nature of societal vulnerability is a great challenge since the social, economic and environmental conditions of people as well as the hazards that affect them are still changing. In recent years, an increasing number of initiatives have been launched to measure vulnerability with a set of indicators and indices. We can find them in the literature especially in the form of case studies. They include quantitative and qualitative approaches and are an important basis for further enhancing and disaster-risk reduction before a disaster occurs.

One of the most important tasks for developing tools focused on vulnerability measuring is interconnection of the theory and practical experience. Vulnerability is important to be understood as a process with defined measures and instruments that allow assessing the past, current and potential vulnerable groups and the areas at risk.

Measuring vulnerability requires different approaches in dependence on the hazard in question and the socio-economic development context and cultural and institutional aspects of daily life. The research should be oriented on how to improve and adjust existing indicator approaches for specific purposes and different scales.

Basic, relatively low - cost and highly effective tool for minimizing the social and economic impacts associated with extreme weather is education and providing objective information to all levels of the process and for all stakeholders. It can be achieved e.g. through:

- continual increasing of risk awareness aimed on the target groups (children, elders, disabled, etc.),
- more effective preparation of responsible authorities for all phases of the disaster cycle,
- incorporating subject of vulnerability into a typological disaster plans,
- allocating necessary resources within regions to address potential negative impacts of disaster,
- ensuring evacuation compliance,
- contributing to successful long-term recovery,
- etc.

In order to provide needful and appropriate information to local and national decision makers more transparency and more information about the most vulnerable areas and groups are needed. The more we will concentrate on the research how to improve and adjust existing indicators approaches for specific events and purposes the better results concerning the risk and vulnerability reduction we can expect.

Indicators are based on temporal and spatial distribution because they compare different area (the majority of the indicators) with the average in the selected country. The conditions can change over time and over the space (in country as well as in individual areas). It is important to update evaluation of indicators to address identified changes. Reevaluating is also important in terms of getting feedback – if adopted measures from previous period were effective or not. In other words, if the vulnerability was reduced.

7 Objective Ranking Tool

7.1 Introduction

One of the remarks made during the midterm review by the Commision (autumn 2015) was the strong wish to pay attention to the use of a Delphi-panel[1]. As was stated by the reviewers in their review report (point 7): *"The potential innovation lies with the development of a unified framework for evaluating critical infrastructure, identifying natural hazards and assessing risks, in order to make effective decisions on the mitigation of the negative impact of extreme weather events to society. Although there is significant work in the field, few practical results are currently available. This project has the potential to result to some practical tools and methods that will form the desired unified framework."*

Also, remarks were made by the reviewers in point 5d of their report: *"Also, experts judgments have been utilized through the Objective Ranking Tool (ORT), interviews and participation in the workshop. However, the Delphi studies conducted should involve more experts, stakeholders and users and more importantly experts outside of the project consortium."*
In addition, during the midterm meeting, it was stated by the project officer based on advises from the reviewers, to look for possibilities to enlarge the scope of Task 3.3 to resilience as well.

Based on these remarks it was decided in January 2016 by the coordinator of the RAIN-project to look for possibilities to include in the scope of Task 3.3 the approach of a Delphi-panel and the development of a dedicated Objective Ranking Tool application focusing on vulnerability and resilience.

This paragraph describes the process which was followed after January 2016, the principles of the Objective Ranking Tool application, the development of criteria for vulnerability and resilience, the outcome of the analyses for some fictive municipalities and two real life cases, the experiences and conclusion. The previous work done by UNIZA on vulnerability as it is described in the previous chapters was included in the approach. The work was executed by RAIN-partners PSJ and ISIG with contributions from UNIZA, TU Delft and Hellenberg.

After decision making by the coordinator of the RAIN-project to enlarge Task 3.3 a Delphi-panel was raised to discuss the approach in a workshop (Delft, April 2016), the development of criteria and the AHP-process (September 2016), the interviews with the real-life case municipalities (November 2016). After this was finalized the Deliverable D3.4 was extended and an internal review have been organized (November 2016).

7.2 Objective Ranking Tool

Theory

The principles behind the contrast model, on which the similarity judgment (SJ) methodology is developed, may well be used to prioritize or compare objects. Through the use of Delphi panels (expert judgment panels) and the use of Analytic Hierarchy Processing (AHP) a reliable identification of characteristics is possible and proper weight percentages to these characteristics can be provided.

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[1] See paragraph 7.2.2 for a brief explanation

This paragraph s meant to give an introduction of the scientific principles behind the Objective Ranking Tool.

The Objective Ranking Tool (ORT) is based on three scientific principles: Similarity Judgment, Analytic Hierarchy Processing and the use of a Delphi-panel. ORT is developed by Peter Prak, owner of the Dutch small and medium-sized enterprise as a dedicated application that can be used in any form of decision support, decision making and prioritization of alternatives. ORT provides a unified process and structured support tool. The principle of “equality” (hereinafter referred to as similarity) supposes that people make judgments and reviews about “phenomena” by comparing the agreement and differences between these objects. Similarity Judgment is developed within cognitive psychology for one-to-one comparisons, and has applications in many areas. This principle, developed by Tversky (1977), has been used to prioritize objects within the National Alert System in the Netherlands for the most vulnerable locations related to terrorism.

Tversky (1977) concluded that the equivalence of two phenomena is determined by the analysis of commonalities as well as by the unique characteristics of both phenomena separately. Based on this insight, Tversky developed a mathematical model $S_{ij} = f_{ij}/[f_{i;j} + a(f_{i;\,not\,j}) + b(f_{not\,i;j})]$ in which (i) features in the reference object but not in the study object, $f_{i;\,not\,j}$, (ii) features in the study object, but not in the reference object, $f_{not\,i;j}$, (iii) common features, $f_{i;j}$, (iv) the constant ‘a’ and ‘b’ add up to ‘1’.

The principles behind the contrast model, on which the Similarity Judgment methodology is developed, may well be used to prioritize phenomena, objects or alternatives. Through the use of Delphi panels (expert judgment panels) and the use of Analytic Hierarchy Processing (AHP) a reliable identification of features is possible and weight percentages to these characteristics can be provided.

ORT facilitates larger numbers of simultaneous judgments between different objects. ORT applies a reference object that meets all the features, and compares alternatives with this reference. Features should be developed by a Delphi-panel, a dedicated group of experts, representing the subjects of interests that covers the question to be answered. By assigning to all features a weighting factor with AHP, the application calculates the degree of similarity to the reference.

All objects are assessed to the developed features. A feature can be TRUE or FALSE. Applying a value between TRUE and FALSE is possible within ORT. Features are then divided into substitutive or additive. When using many features, it is not desirable to apply a correction factor within the contrast model. Setting a limit on the outcome of the ORT analysis, a number between 0 and 1 is not appropriate. The ORT analysis is about the relative ordering between objects. Whether a sector designates a prime location depends also on other factors. The outcome of the ORT analysis can be used to prioritize the deployment of available capacities. With the results of the ORT analysis it is possible to agree on an ordering of objects within and between sectors. This similarity is expressed as a number between 0 and 1. The closer to 1, the higher the equivalence is with the reference object. The highest scoring alternative meets the requirements as set with the developed features the best.

Within ORT some amendments are made within the formula and the use of the 1-1 comparison principle. 1) A reference is introduced, which fulfils all the developed criteria; 2) an unlimited number of objects can be judged to this reference; 3) the introduction of relative weights to the identified features by the use of Analytic Hierarchy Processing; 4) the use of a Delphi-panel for the development of features and the scoring process; 5) within the ORT-applications additional functionalities are implemented such as the use of different criteria sets and analyses possibilities.

Process

Using a structured group of experts in the form of a Delphi panel is needed in order to achieve more accurate results. This has benefits for both the determination of the characteristics, determining the weighting factors as well as in assessing whether an item meets the characteristics. A Delphi panel with a number between five and 10 people each with own expertise is suggested.

For the determination of weighting factors, the AHP is proposed. Pairwise comparisons are carried out in a structured way in which a preference is given for one of the characteristics. A value of 1 indicates an equivalence (no preference), a value of 9 gives an extreme inequality (high preference for one of the characteristics). Reliable results are obtained with up to seven comparable characteristics. Within ORT, this means an adaptation to three levels (criteria, sub-criteria, sub-sub criteria) of seven characteristics that, in theory, can lead to 343 (7.3) features to be assessed.

The combination of a Delphi panel and the use of AHP is a one-time investment to develop features, give these features a weight and assess the developed features.

Within ORT, a differentiation is possible for assessing whether an object conforms to the described characteristics. The contrast model checks the unique and common features of objects. The ORT assigns a score of 0 when an object to be compared does not hold the characteristic (FALSE) or 1 if the object to be compared does possess the characteristic (TRUE). This is called a substitutive feature. When reviewing some characteristics, such binary assessment is not always possible. These characteristics may be partly true or false and, are qualified as additive characteristics. For these additive characteristics, a linear point scale is proposed with an ascending value of 0.1. With this addition, a more refined result is achieved.

The constant a and b in the formula add up to 1. With this constant, a correction factor is suggested that one characteristic is weighed more heavily in relation to the other characteristic. The reliable determination of this constant can be achieved through a process of AHP. In a Delphi panel discussion on the value of this constant, the reason for the distinction are ask. Arguments are used as complementary characteristics. It is therefore more valuable to invest in an investigation of these additional features than to determine the value of a and b.

The results of the ORT process indicate a ranking in the extent to which objects have a certain degree of equivalence. The ranking of objects facilitates the decision-making process.

Construction

To execute an ORT-analyses a step by step approach should be followed:
Step 1: management

- Define the question that should be answered. i.e., which part of the road network is more vulnerable to the risks of natural hazards
- Define the needed fields of interests and experts that should be part of the Delphi-panel
- Define the participants of the Delphi-panel
- Decide on a scoring process based on commitment of all participants, or accept outliers

Step 2: Delphi-panel

- Analyses of the question in term of areas of interest, stakeholders and scientific views
- Analyses of the criteria to involve in the judgment process, and set criteria
- Define different criteria sets if needed (i.e., vulnerability of landslides might give different criteria and weights than flooding or the opinion of the outlier)

- Set weights to the criteria based on Analytic Hierarchy Processing

Step 3: management
- Define the objects to score (i.e., those lines of the road network to take into consideration)
- Define the expertise with local knowledge that can score the objects to the criteria

Step 4: scoring team
- Score objects according to the developed criteria
- Discuss results based on the ORT-application
- Analyse and discuss the most contributing criteria to the outcome
- Suggest interventions and actions in terms of quick wins

Step 5: management
- Accept results
- Define actions
- Decide on the frequency of analyses

After each step, it is recommended to discuss questions:
- Are we satisfied with the input and output?
- Are there strange outcomes that should be explained?
- Does the outcome give confidence?

Nowadays the ORT-application is a dedicated web-based-tool and will be extended with additional features in the future. The web-based data can be exported by .csv-files.

Advantages and limitations

The main advantages of ORT are that the application:

- Is a combination of three proven scientific techniques: similarity judgment, Analytic Hierarchy Processing and Delphi-panel;
- Includes all relevant stakeholders, their interests and the translation to criteria. The process which is needed to define the criteria, the common scoring process will lead to a better acceptance of the outcomes;
- Is easy to adapt or to repeat if new information will be available;
- Involving relevant stakeholders will lead to a better acceptance of the outcome because they have been part of the analyses and scoring process;
- Sensitivity analyses are possible within the application in which i.e. the views of outliers can be shown quit easily.

The main limitations are that the ORT application:

- The criteria to score can be either quantitative or qualitative. If there is data available these can be used in the scoring process. If no data will be available, the scoring team should agree based on consensus of the qualitative judgment;
- The execution of the defined steps will take some time.
- There might be unexpected or undesirable results for one or more stakeholders which can lead to discussions of the acceptance of these results.

- Consist of the main basic functions. It delivers the main goal and will be extended with more functionalities in the future;
- Is developed in the Dutch language.

7.3 Development of a dedicated ORT application on vulnerability and resilience

Delphi-panel

April 4, 2016, a Delphi-panel was organized in Delft to discuss the approach for the development of this ORT-application. Participants of this Delphi-panel were selected based on previous scientific work within this subject (TNO), practical experience (member USAR-team, teacher at Police Academy and member of the Union Civil Protection Mechanism) and a participant from the InfraRisk-project with relevant experience. Also, members of the consortium with dedicated background and experiences were involved (UNIZA, ISIG, HELLENBERG, PSJ, TU DELFT). It was tried to involve more participants outside the Netherlands but due to the lack of compensation for traveling costs and expenses no other organisations could be interested to participate.

The aim of the application was discussed. It was concluded that a relative comparison of the level of preparation for different municipalities within a specific region could be of added value to prioritize the improvements and to divide budgets. The second remark made was that there were many attempts to develop an index on vulnerability or resilience and that this had been very complicated. To develop a scientific approach within a short timeframe was seen as unrealistic.

Within the workshop it had been made clear that the development of such an ORT-application was meant to make a proof of concept based on criteria that were already available. The outcome of the work of UNIZA in this task will be included, even as previous work from ISIG in this field.

Criteria, selection of variables

The selection of variables for the evaluation of vulnerability and resilience stems from the further development of the research work conducted by ISIG within the ECOSTRESS project (www.ecostress.eu, DG ECHO 2013-2015) for the definition of SeAT (Self-Assessment Tool, available online at http://www.ecostress.eu/social-vulnerability-self-assessment-tool/)

The self-assessment grid from SeAT was divided in 2 parts:

1. An internal component, identifying the SENSITIVITY (i.e. of a given local community to potential stress;
2. An external component, identifying the ADAPTIVE CAPACITY (i.e. dynamic variables) that the local community can develop to cope with and respond to the impacts of a stress.

For the development of RAIN ORT, the variables selected for SeAT (some of which started from a more quantitative approach based on statistical data – for the part concerning sensitivity- as most commonly found in relevant literature) where the starting point. Those have then been further selected and rephrased so to better meet ORT specificities.

The tables below[2] summarise the variables selected for ECOSTRESS SeAT both for Sensitivity (that in RAIN ORT were conveyed under the umbrella of 'Vulnerability assessment', as context data, less likely to be changed in short periods of time) and Adaptive capacity ('Resilience' in RAIN ORT; by understanding resilience as the capacity of a community to cope with and recover from a natural hazard).

The tables 34-41 summarises all variables and the references in literature from which the relevance of each one was extrapolated.

A: Vulnerability

Social dimension

Table 34 - Selected variables for the social (internal) dimension

Variable	Relevance in Literature	ORT
% of the population that is a minority	*(Burton 2012, p.100)*	*Not applied – the variable implies, in the traditional vulnerability assessment, that a higher number of citizens belonging to minorities within a community could represent a further element of vulnerability. This is due to the fact that mitigation and emergency communication tools might not always be shaped in a format and language accessible to minority groups (especially groups of recent residency in the area). In order to better capture this aspect (which is more related to effectiveness of communication addressed to specific target groups), other variables were inserted in the "Resilience" section (related to knowledge among citizens on risk-reducing behaviours and Implementation of targeted stakeholders risk communication tools). In fact, it is not the presence or absence of minorities that per se represents an element of more or less vulnerability, but the capacity of that community to provide adequate tools for all (also new residents) to be aware and prepared in case of emergency is a key factor for enhancing resilience.*
% of the population (25-64) with at least a high school diploma	*(Burton 2012, p.100)*	*"Level of education"*
Number of vehicles per 1000 inhabitants	*(Burton 2012, p.100)*	*The number of vehicles defines traditionally the expression of the possibility for citizens to evacuate in case of emergency. Since RAIN project focuses more specifically on transport infrastructures and mode shift alternatives, this variable has been taken out and instead "Transport possibilities" was dedicated a new dimension in the "Resilience" section of the ORT. This new dimension was considered as*

[2] Source: revision and integration by Chiara Bianchizza (ISIG) on the work done by Del Bianco, Bianchizza (2015) for ECOSTRESS D.D.3 Vulnerability Self-Assessment Tool Report

Variable	Relevance in Literature	ORT
		composed by 4 variables: namely a) Mode shift possibilities; b) (adequacy of means/routes for) Distribution of food and goods (in case of emergency); c) Existence of public evacuation mechanisms; d) Redundancy for bus and road for passengers, freight and animals
% of the population that is elderly (75 years or above)	*(Burton 2012, p.101); (Holand et al. 2011, p. 8)*	*"Density of citizens without the ability of self-protection" (older age being traditionally used as an indicator of higher vulnerability as less capacity to enact protective or defensive behavior)*
% of the population 6 years or younger	*(Holand et al. 2011, p. 8)*	
Incidence of population living in condition of crowding	*(Burton, 2012)*	*"Density of citizens"*
Population density	*(Eidsvig et al. 2011); (Cardona 2005)*	*"Density of citizens"*
Percentage of elderly living alone	*(Baum et al 2008); (ENSURE 2009); (Tapsell 2005)*	*"Density of citizens without the ability of self-protection"*
Per capita expenditure for assistance and social services	*(Burton, 2012)*	*Turned into "use of social welfare funds" and "availability of social welfare funds"*
Incidence of families in potential lack of assistance	*(Baum et al 2008)*	*Households in potential economic difficulty (turned into a variable of the Economic dimension)*
Incidence of centres and settlements	*(Burton 2012, p. 79)*	*This indicates how much of the area is urbanised (the more urbanisation often is related to higher vulnerability). Yet this was aspect was included in the variables looking at concentration of industries and density of population/buildings in the area. This specific variable was thus not considered.*
Number of hospital beds per 1,000 inhabitants	*(Burton 2012, p. 113)*	
Number of active NGOs per 1,000 inhabitants	*(Burton 2012, p.101); (Holand et al. 2011, p. 8)*	*"Availability of active NGOs"*

Economic dimension

Table 35 - Selected variables for the economic (internal) dimension

Variable	References in literature	ORT
Per capita income (average income)	*(Burton 2012, p. 102); (Holand et al. 2011, p. 8); (Baum et al, 2008)*	*"Average income"*
Incidence of housing in property	*(Burton 2012, p. 102)*	*"Incidence of housing in property"*
Employment rate	*(Burton 2012, p. 102)*	*"Unemployment rate" (to avoid duplication of variable in the positive and in the negative)*
Unemployment rate	*(Holand et al. 2011, p. 8)*	
% female labour force participation	*(Burton 2012, p. 102)*	*"Incidence of women with an occupation outside the household"*
Index of households with potential economic difficulty	*(Cardona 2005)*	*"Households in potential economic difficulty"*
Incidence of employed in the agricultural sector	*(Burton 2012, p. 102); (Holand et al. 2011, p. 8)*	*Not applied as not relevant if context specific is not included (not for this piloting phase)*
Incidence of employed in the industrial sector	*(Burton 2012, p. 103); (Holand et al. 2011, p. 8)*	*Turned into "Active industries in the area"– the more industries, the richer the area: the richer the area, the less vulnerable.*

Variable	References in literature	ORT
Incidence of employed in low-skill service sector	*(Holand et al. 2011, p. 8); (ENSURE 2009); (Tapsell 2005)*	*Not applied as very context specific and not suitable for a more general pilot*
Number of active enterprises per 1,000 inhabitants	*(Burton 2012)*	*Turned into "Active industries in the area"– the more inustries, the richer the area: the richer the area, the less vulnerable. Also, a new variable was added, namely "Economic investments in the area" for the evaluation of the vitality of the economy in the area.*

Infrastructural dimension

Table 36 - Selected variables for the infrastructural (internal) dimension

Variable	Relevance in literature	ORT
Schools (primary and secondary education) per 10 km^2	*(Burton 2012, p. 107)*	*The variable in this case was to cover the density in a certain area of buildings where people with less ability of self-protection are concentrated. Thus, this resulted in 3 variables: a) "concentration of schools in the area"; b) concentration of hospitals in the area"; c) concentration of elderly homes in the area. Also, to cover also other types of infrastructures hosting people without the ability of self-protection, that might be specific to certain areas (kindergartens; precarious settlements; etc.), the variable "Density of citizens without the ability of self-protection" was inserted*
Density of building (n. of houses per Km^2)	*(Burton 2012)*	*Density of citizens (rather than buildings).*

Institutional dimension

Table 37 - Selected variables for the institutional (internal) dimension

Variable	Relevance in literature	ORT
% electorate voting in municipal election	*(Holand et al. 2011, p. 8); (ENSURE 2009); (Tapsell 2005)*	*The identification of variables assessing the vitality of citizens' participation into public life lead to a more detailed description of other variables, such as "Availability of active NGOs" (for "Vulnerability") and "volunteers' involvement in preparedness" for "Resilience").*
Municipal spending capacity	*(Holand et al. 2011, p. 8)*	*Turned into "use of social welfare funds" and "availability of social welfare funds" in the "Social"*

Variable	Relevance in literature	ORT
		dimension.
Funds allocated for major hydrogeological emergencies (2009-2012) - in EUR	*(Eidsvig et al, 2011)*	*Very specific to the ECOSTRESS project (in relation to floorings) thus not deemed as relevant here*
Amounts allocated within the Program Agreements from 2010 - in EUR	*(Eidsvig et al, 2011)*	*Very specific to the ECOSTRESS project (rather at EU level more than local) thus not deemed as relevant here*

B: Resilience

Social dimension

Table 38 - Selected variables for the social (external) dimension

Variable	Relevance in literature	ORT
Soft mitigation strategies in place	*Kuhlicke and Steinfuhrer, 2010 (Knowledge and Procedural capacities i.e. the capacity to elicit the implementation of such knowledge of structures, frameworks, governance schemes towards enhancing resilience)*	*"Education, training and exercises in place"* *"Auditing of education, training and exercises"*
Soft mitigation strategies brokered to wider public	*Bollin and Hidajat, 2006 (Role of public awareness programmes in reducing vulnerability)*	*"Knowledge among citizens about temporary measures to reduce impact"*
Soft mitigation strategies brokered to stakeholders	*Cutter and Boruff et al, 2003; Tapsell et all, 2010 (Availability of Information –on hazards, protective action decision options - and knowledge - understanding of warning sources and mitigation, preparedness and response actions- for stakeholders as means of vulnerability reduction)*	*"Mitigation strategies brokered to stakeholders"*
Volunteers/CSO involvement in mitigation strategies	*Bollin and Hidajat, 2006 (Role of public participation in mitigation as means for reducing vulnerability)*	*"Volunteers involvement in preparedness and execution"*
Implementation of targeted risk communication tools for locals	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if risk communication is available, it is important to evaluate the capacity to effectively communicate to different targets)*	*"Implementation of targeted stakeholders risk communication tools"*
Implementation of targeted risk communication tools for tourists	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if risk communication is available, it is important to evaluate the capacity to effectively communicate to different targets)*	
Level of risk awareness among the population	*Fielding et al, 2002 (no experience of flooding increases vulnerability)*	*"Level of risk awareness among citizens"*
Level of knowledge on risk-reducing behaviours among the population	*Cutter, Boruff et al, 2003 (Knowledge (i.e. more informed/prepared citizens for what concerns warning sources and mitigation, preparedness and response actions); Kuhlicke and Steinfuhrer, 2010 (knowledge*	*"Level of knowledge on risk-reducing behaviours among citizens"*

	capacity)	
Reactivity of CP volunteers' association networks in emergency	*Kuhlicke and Steinfuhrer, 2010 (network capacity: possession and exploitation of social capital, i.e. to mobilise networks and resources*	*"Volunteers involvement in preparedness and execution"*
Level of participation of the population in local policy making	*Kuhlicke and Steinfuhrer, 2010, p. 20 ("Motivational capacities: the building of a sense of responsibility for one's own actions but also for those of other actors")*	*Not inserted in this version of ORT but after the pilot maybe its addition has to be considered (as to have more elements to evaluate the vitality of citizens' engagement in public life and potentially also in risk self-protection and community risk awareness)*
Capacity of local CSOs to mobilise population	*Kuhlicke and Steinfuhrer, 2010, p. 20 ("Motivational capacities: the building of a sense of responsibility for one's own actions but also for those of other actors" and procedural capacities, in this sense capacity to actually elicit action)*	*Not inserted in this version of ORT but after the pilot maybe its addition has to be considered (as to have more elements to evaluate the vitality of citizens' engagement in public life and potentially also in risk self-protection and community risk awareness)*

Economic dimension

Table 39 - Selected variables for the economic (external) dimension

Variable	Relevance in literature	ORT
Existence of specific funds allocated for mitigation by Regional/national authorities	*Kuhlicke and Steinfuhrer, 2010 (Economic capacities)*	*"Existence of specific funds allocated for mitigation by Regional/national authorities"*
Existence of specific funds allocated for post emergency recovery by Regional/national authorities	*Kuhlicke and Steinfuhrer, 2010 (Economic capacities)*	*"Existence of specific funds allocated for post emergency recovery by Regional/national authorities"*
Capacity to access existing exogenous resources	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if resources exist, it is import to evaluate the capacity to effectively assess them)*	*"Capacity of authorities to access existing exogenous resources"*
Existence of PPPs for economic sustainability of mitigation/prevention strategies	*Kuhlicke and Steinfuhrer, 2010 (Economic as well as network and procedural capacities)*	*"Existence of PPPs for economic sustainability of mitigation strategies "* *A further variable considered was also "Protocols for business continuity in place", as part of "Preparation".*
Propensity of in-kind resources allocation from civil society	*Kuhlicke and Steinfuhrer, 2010 (network and procedural capacities)*	*Rather than looking at propensity of population to mobilise in-kind resources (more difficult to assess for a local manager) reference to private recovery schemes was inserted with the variable "Insurance possibilities" (as insurances would be subscribed by individuals).*

Infrastructural dimension

Table 40 - Selected variables for the infrastructural (external) dimension

Variable	Relevance in literature	ORT
Planning of ad hoc mitigation activities	*Kuhlicke and Steinfuhrer, 2010 (knowledge and institutional capacities)*	*In more detail, on one specific aspect suggested by stakeholders during Delphi panel sessions: "Cultural heritage adequately protected" (in "Preparation")*
Implementation of ad hoc mitigation activities	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if resources exist, it is import to evaluate the capacity to effectively assess them)*	*"Implementation of ad hoc mitigation activities"*
Identification of infrastructural assets needing upgrading as means of mitigation/prevention	*Kuhlicke and Steinfuhrer, 2010 (knowledge capacity: on hazard and risk)*	*"Identification of infrastructural assets needing upgrading as means of mitigation/prevention"*

Institutional dimension

Table 41 - Selected variables for the institutional (external) dimension

Variable	Relevance in literature	ORT
Policy making capacity to upgrade identified infrastructural assets	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if resources exist, it is important to evaluate the capacity to effectively assess them)*	*"Policy making capacity to upgrade identified (infrastructural) assets"*
Level of awareness of the degree of dependence of the local economy on natural coastal assets	*Kuhlicke and Steinfuhrer, 2010 (knowledge capacity: on potential impact of hazard on local system)*	*"Level of awareness of the degree of dependence of the local economy on natural assets (susceptible to the impact of extreme weather events)"*
Existence of civic engagement mechanism in local governance settings	*Renn, 2008 (Consideration of principles of fair governance - legitimacy, equity, responsiveness, accountability)*	*Not inserted in this version of ORT but after the pilot maybe its addition has to be considered (as to have more elements to evaluate the possibilities for citizens to actively engage)*
Existence of updated Emergency plan	*Compliance with law as first indicator of preparedness*	*"Existence of updated emergency and evacuation planning"*
Implementation of updated Emergency plans	*Kuhlicke and Steinfuhrer, 2010 (evaluation of effective procedural capacity)*	*Considering that the implementation implies that the plans take into account also new developments (in legislation, infrastructures, implementing bodies, involved actors, etc.) the variable was simplified into "Emergency and evacuation plans revised yearly"*
Existence of updated Evacuation plans	*Compliance with law as first indicator of preparedness*	*"Existence of updated emergency and evacuation planning"*

Variable	Relevance in literature	ORT
Policy making capacity to upgrade identified infrastructural assets	*Kuhlicke and Steinfuhrer, 2010 (Procedural capacities- even if resources exist, it is important to evaluate the capacity to effectively assess them)*	*"Policy making capacity to upgrade identified (infrastructural) assets"*
Level of awareness of the degree of dependence of the local economy on natural coastal assets	*Kuhlicke and Steinfuhrer, 2010 (knowledge capacity: on potential impact of hazard on local system)*	*"Level of awareness of the degree of dependence of the local economy on natural assets (susceptible to the impact of extreme weather events)"*
Existence of civic engagement mechanism in local governance settings	*Renn, 2008 (Consideration of principles of fair governance - legitimacy, equity, responsiveness, accountability)*	*Not inserted in this version of ORT but after the pilot maybe its addition has to be considered (as to have more elements to evaluate the possibilities for citizens to actively engage)*
Existence of updated Emergency plan	*Compliance with law as first indicator of preparedness*	*"Existence of updated emergency and evacuation planning"*
Implementation of updated Evacuation plans	*Kuhlicke and Steinfuhrer, 2010 (evaluation of effective procedural capacity)*	*Considering that the implementation implies that the plans take into account also new developments (in legislation, infrastructures, implementing bodies, involved actors, etc.) the variable was simplified into "Emergency and evacuation plans revised yearly"*
Level of definition of roles/competences according to relevant policies/strategies for risk management	*Matthiesen, 2005 (existence of cooperation structures within formal-institutional structures and functions, with clearly defined roles for each subject)*	*"Agreed roles and responsibilities between identified stakeholders for risk management"*
Existence of participated bodies for risk management (i.e. involving all stakeholders)	*Kuhlicke and Steinfuhrer, 2009 (effective environmental management (EM) is given by strength/competences/configuration of institutional and CSO proponents of EM); Nun, 2007 (role of management and accountability of systems and processes); Renn ("science, politics, economic actors and representatives of civil society are invited to play a role in both assessment and management")*	*"Existence of participatory bodies for risk management"*

7.4 AHP-analyses

The possible criteria which were developed by ISIG and PSJ were discussed within the RAIN-project. The final list of criteria used is given below. The next step was to determine the relative weighting percentages of the individual ranking criteria. To do so, each member of the Delphi-panel applied the principles of similarity judgment individually using an online AHP-tool (www.bpmsg.com). Finally, nine persons gave their input.

The overall relative weighting percentages of the individual ranking criteria are shown in the figures 7 and 8 below.

In these figures the three levels of criteria are shown and the consolidated result of their relative weight according to the outcome of the AHP-analyses. The fourth column gives the result for each individual subsubcriterion.

less vulnerability	0.2736	institutional	0.391	existence of social networks	0.047	0.5 %
				effectiveness of social networks	0.0902	1.0 %
				availability of first responders	0.2402	2.6 %
				experiences with past events	0.1944	2.1 %
				lessen learned implemented	0.2248	2.4 %
				availability of budget	0.2034	2.2 %
		infrastructural	0.2297	concentration of schools	0.0799	0.5 %
				concentration of hospitals	0.192	1.2 %
				concentration of elderly homes	0.1211	0.8 %
				density of citizens without ability	0.189	1.2 %
				density of citizens	0.1812	1.1 %
				proximity of critical cross points	0.2368	1.5 %
		economics	0.2057	active industries	0.2315	1.3 %
				economic investments	0.2005	1.1 %
				households in potential economic di	0.1375	0.8 %
				incidence of women with an occupati	0.095	0.5 %
				umemployment rate	0.1556	0.9 %
				incidence of housing in property	0.0722	0.4 %
				average income	0.1077	0.6 %
		social	0.1736	availability of active NGOs	0.2902	1.4 %
				use of social welfare funds	0.1859	0.9 %
				availability of social welfare fund	0.2037	1.0 %
				level of education	0.3203	1.5 %

Figure 7. Overall relative weighting percentages of the individual ranking criteria (vulnerability part)

good resilience	0.7264	institutional*	0.2253	early warning system in place for p	0.2383	3.9 %
				existence of participatory bodies f	0.076	1.2 %
				agreed roles and responsibilities b	0.1431	2.3 %
				emergency and evacuation plans revi	0.1431	2.3 %
				existence of update emergency and e	0.105	1.7 %
				level of awareness of the degree of	0.1581	2.6 %
				policy making capacity to upgrade i	0.1365	2.2 %
		infrastructural*	0.155	identification of (infrastructural)	0.2468	2.8 %
				implementation of ad hoc mitigation	0.3188	3.6 %
				availability of risk assessment inc	0.4344	4.9 %
		transport possibilities*	0.1742	mode shift possibilities	0.1466	1.9 %
				distribution of food and goods	0.2133	2.7 %
				existence of public evacuation mech	0.4538	5.7 %
				redundancy for bus and road for pas	0.1863	2.4 %
		preparation*	0.2248	cultural heritage adequately protec	0.1019	1.7 %
				preparedness protocols implemented	0.2459	4.0 %
				education training and exercises in	0.2353	3.8 %
				auditing of education training and	0.1073	1.8 %
				knowledge among citizens about temp	0.3095	5.1 %
		economics*	0.1073	insurance possibilities	0.1088	0.8 %
				protocols for business continuity i	0.1973	1.5 %
				existence of (PPP) for economic sus	0.0985	0.8 %
				existence of PPP for economic susta	0.0727	0.6 %
				capacity of authorities to access e	0.1872	1.5 %
				existence of specific funds allocat	0.1782	1.4 %
				existence of funds allocated for mi	0.1575	1.2 %
		social*	0.1133	level of knowledge on risk reducing	0.284	2.3 %
				level of risk awareness among citiz	0.2431	2.0 %
				implementation of targeted stakehol	0.1188	1.0 %
				volunteers involvement in preparedn	0.1479	1.2 %
				mitigation strategies brokered to s	0.2062	1.7 %

Figure 8. Overall relative weighting percentages of the individual ranking criteria (resilience part)

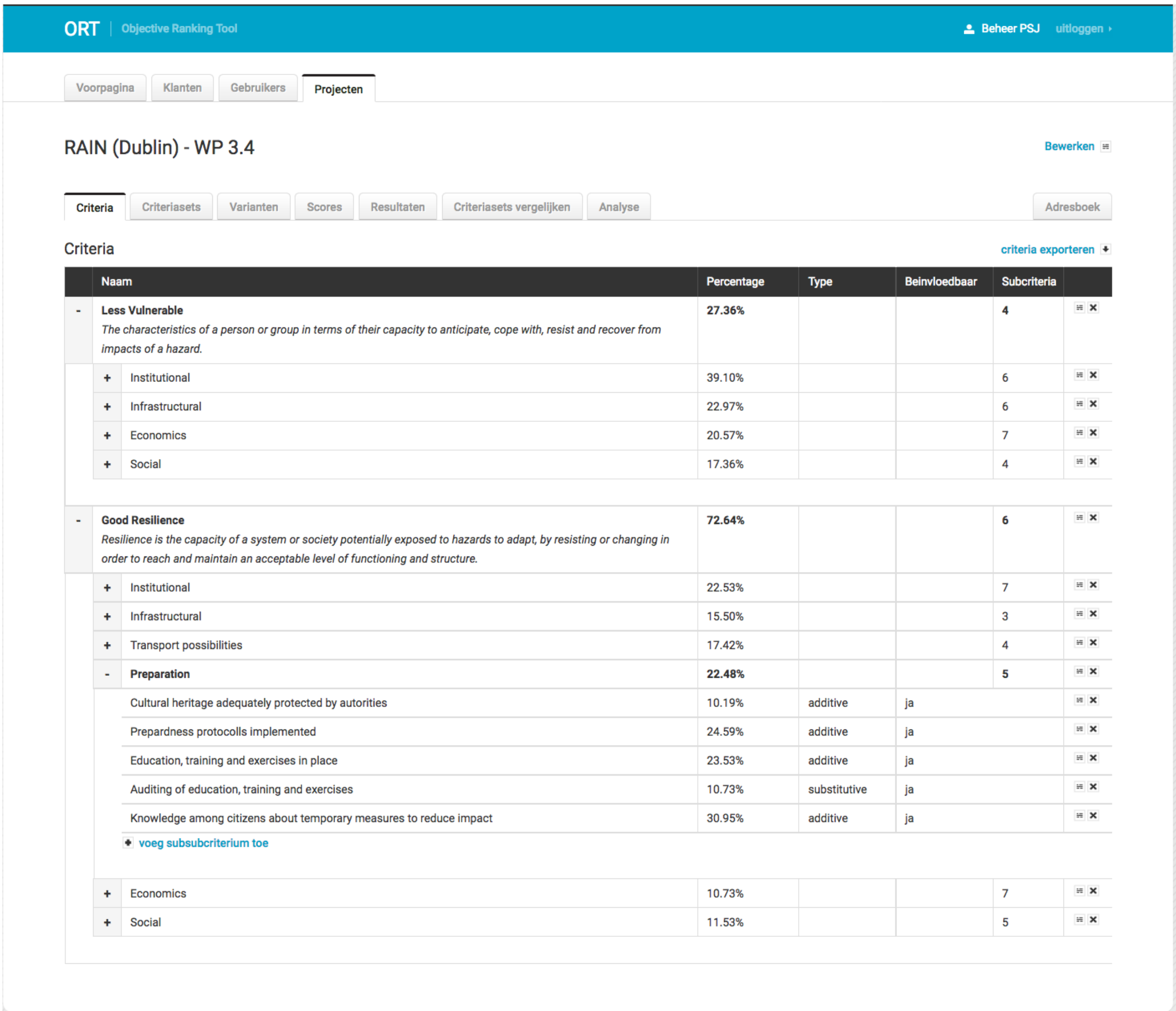
As most important criteria are examined by the Delphi-panel:

1. Existence of public evacuation mechanisms (5.7%)
2. Knowledge of citizens about temporary measures (5.1%)
3. Availability of risk assessments included natural hazards and extreme weather (4.9%)
4. Preparedness protocols implemented (4.0%)
5. Early warning system in place for people and businesses (3.9%)
6. Education, training and exercises in place (3.8%)
7. Implementation of ad hoc mitigation activities (3.6%)
8. identification of (infrastructural) assets needing upgrading as means of mitigation and prevention (2.8%)
9. Distribution of food and goods (2.7%)
10. Level of awareness of the degree of dependence of the local economy on natural hazards or extreme weather events (2.6%) and availability of first responders (2.6%

The outcome of the scoring process for these top 11 (out of 54) is 41.7%. it should be concluded that these criteria are all part of the criterion ‘good resilience’.

7.5 ORT-application

In these paragraphs screenshots are described to understand the working of the application.[3]



	Naam	Percentage	Type	Beinvloedbaar	Subcriteria
-	**Less Vulnerable** *The characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from impacts of a hazard.*	**27.36%**			**4**
+	Institutional	39.10%			6
+	Infrastructural	22.97%			6
+	Economics	20.57%			7
+	Social	17.36%			4
-	**Good Resilience** *Resilience is the capacity of a system or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.*	**72.64%**			**6**
+	Institutional	22.53%			7
+	Infrastructural	15.50%			3
+	Transport possibilities	17.42%			4
-	**Preparation**	**22.48%**			**5**
	Cultural heritage adequately protected by autorities	10.19%	additive	ja	
	Prepardness protocolls implemented	24.59%	additive	ja	
	Education, training and exercises in place	23.53%	additive	ja	
	Auditing of education, training and exercises	10.73%	substitutive	ja	
	Knowledge among citizens about temporary measures to reduce impact	30.95%	additive	ja	
	+ voeg subsubcriterium toe				
+	Economics	10.73%			7
+	Social	11.53%			5

Figure 9. Partial view showing the criteria and additional information

Figure 9 shows the first tab within the system (criteria) giving the name (NAAM) of the criteria within the ORT-application on three levels and the relative weight (percentage) is given. The type of the criterion (additive or substitutive). For each criterion, it is decided if mitigation measures for improvement can be given yes or no (beïnvloedbaar). Clicking on the '=' opens a new window to set each criterion.

The second tab, figure 10, shows criterion sets. Within the ORT-application it is possible to use subsets. For this application sub sets are given for 'vulnerability' and 'resilience' separately. The aim of these sub sets is to make more specific analyses.

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[3] The application is developed within the Dutch language; translation will be given

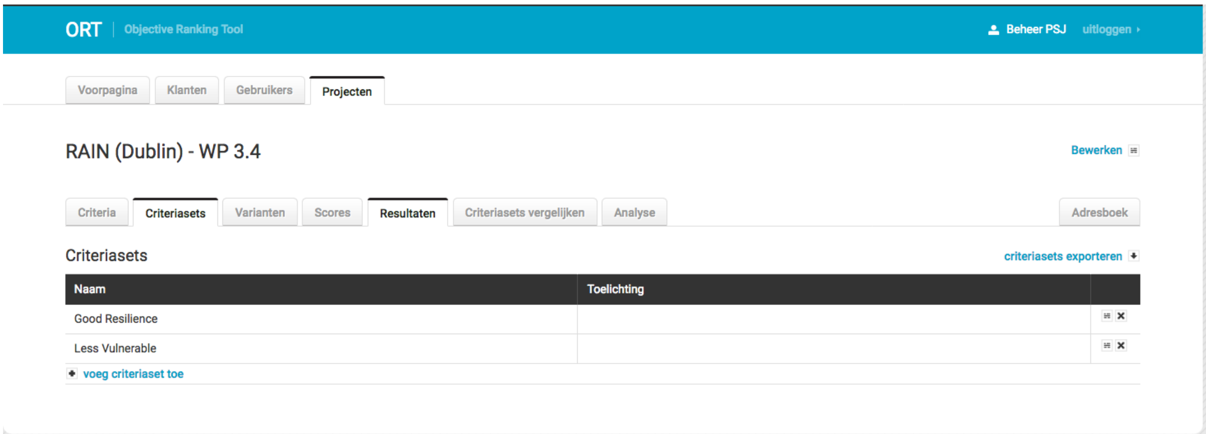

Figure 10. Criteria sets

The next tab 'alternatives' (varianten) given in figure 11 is to define for this application the different municipalities to score. For this application five fictive municipalities are used, even as two real-life cases, i.e., the city of IJsselstein in the Netherlands and the city of Gorizia in Italy. For these two municipalities interviews were held with the responsible officers for the civil protection mechanism. It should be stated that the answers reflect the present state of preparation but should not be seen as an official and accorded result. The interviews were held to proof the appropriate working of the application and the possibility to use the application as a self-assessment tool.

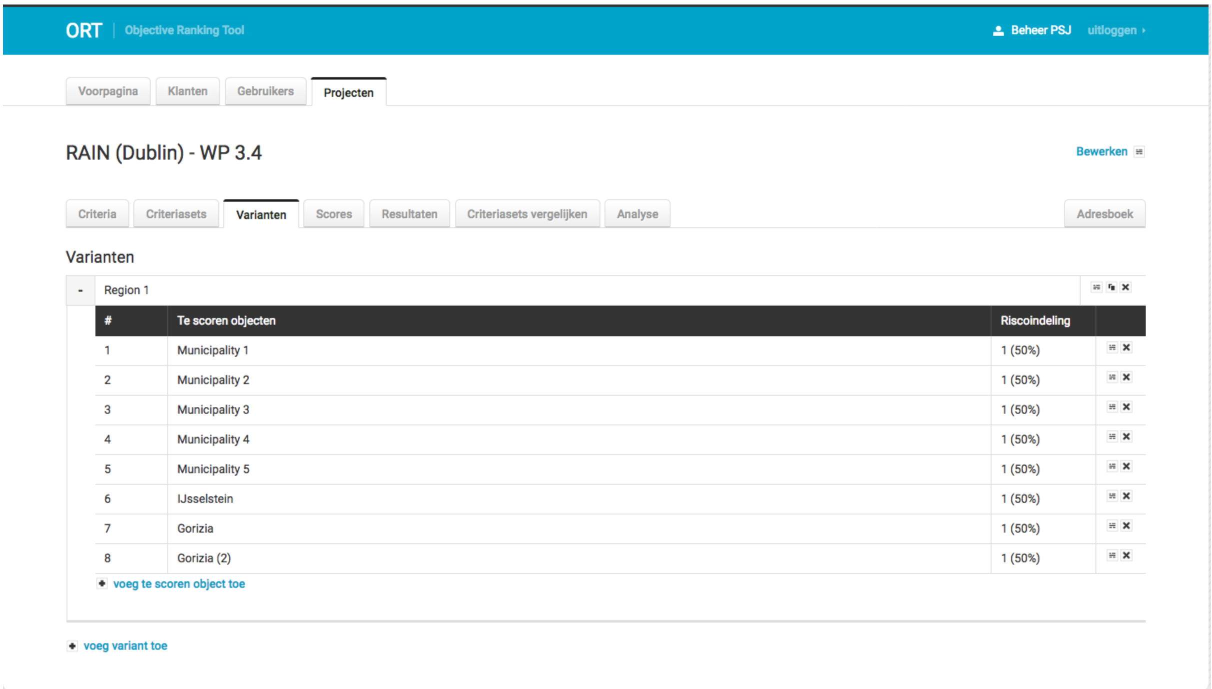

Figure 11. Alternatives taken into consideration

Figure 12 is the scoring (scores) tab. In this screenshot a combination of the identified criteria is shown even as the alternatives taken into consideration. For each identified alternative (in this application the municipalities) all criteria should be scores. Substitutive criteria should be scored either '1' (TRUE) or '0' (NOT TRUE). The additive criteria can be scored in between '0' and '1'. Table 42 will help to define the scoring:

Table 42 Scoring table

Definition	Suggested scoring
not or almost not:	0 ≥ 0,1
limited	0,2 ≤ 0,3
partially	0,4 ≤ 0,5 ≥ 0,6
almost	0,7 ≤ 0,8
full	0,9 ≥ 1,0

Based on the idea that the real-life interviews were meant to make a proof of concept it was decided for additive criteria only to use ‘0’, ‘0,5’ or ‘1’. The interviewee in Gorizia asked to see the difference for a more specific outcome. In ‘Gorizia’ only ‘0’, ‘0,5’ and ‘1’ is used; in ‘Gorizia 1’ a more precise scoring is used.
Within the application it is possible the enter notes. The cell will get a different colour. By right-mouse clicking the notes will be shown on the screen.

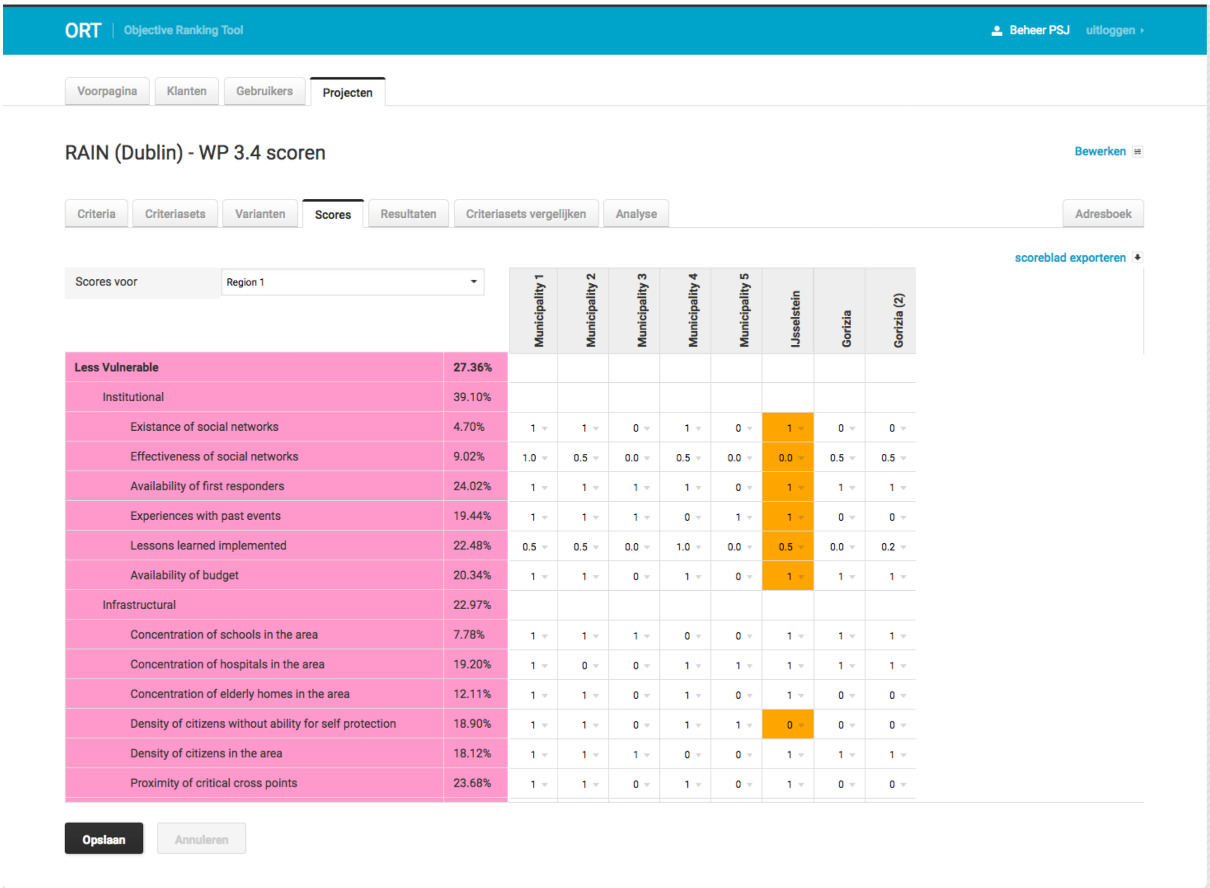

Figure 12. Scoring screen

7.6 Outcome ORT-analyses

The second part of the ORT-application presents the results and analyses.
Figure 13 is the result tab based on the formula of similarity judgment ($S_{ij} = f_{ij}/[f_{i;j} + a(f_{i;\,not\,j}) + b(f_{not\,i;j})]$) a calculation is made of the similarity. The formula is adapted due to the use of many alternatives (instead of pairwise comparison) and the use of relative weights for each criterion. Important is the use of the ‘reference’. This reference is a fictive alternative which score ‘1’ on each criterion. Based on the outcome the relative scoring can be seen. In this example IJsselstein score 0,8367 of the

maximum of 1 where fictive municipality scores 0,3777. Where IJsselstein will have insight in those criteria that will lead to improvements the preparation is already on a high level. For the fictive municipality 5 it can be concluded that major improvements will be necessary. Also, the differences in outcome between ‘Gorizia’ and ‘Gorizia 1’ can be seen. Although only some criteria are scored more precisely there already is a difference in outcome.

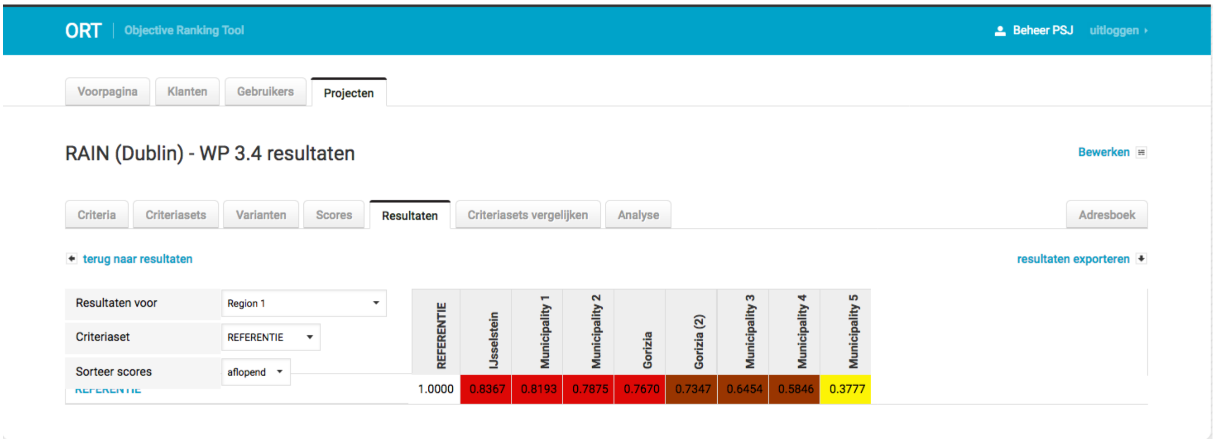

Figure 13. Results related to the reference

Figure 14 is the comparison of criteria sets (criteriasets vergelijken). In this tab, all alternatives will be compared with all defined sub sets. It will be interesting to discuss the results of ‘Municipality 4’. The overall outcome based on the reference is 0,5846. However, looking to Good Resilience the outcome is 0,4878 and for Less Vulnerable 0,7908. Based on the outcome of Good Resilience it might be expected that improvements should be made. However, in this example the evaluation on vulnerability is high. A possible conclusion might be that there is hardly no risk of natural hazards or extreme weather events so the preparation can be on a lower level.

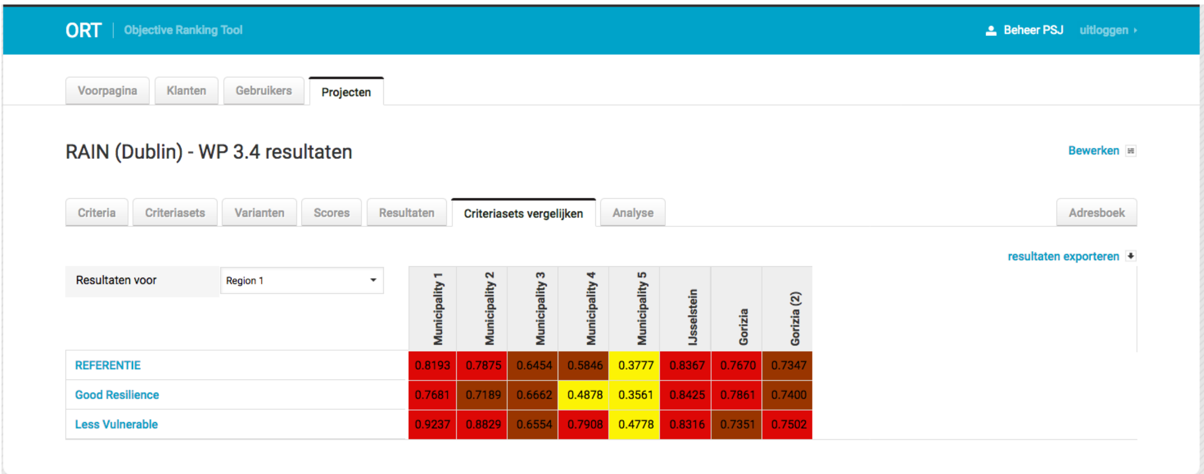

Figure 14. Results based on comparison on different criteria sets

The last tab shown in figure 15 is the analyses (analyse) tab. In this tab, several selections can be made. Which alternatives (here set to region 1), which criteria set (criteriaset), if criteria can be mitigated (beïnvloedbaar), the number of marked fields (aantal gearceerde velden), to see the highest or lowest scoring outcome (laagste scores) and to show the owner of a criterion (eigenaar) yes or no.

The screenshot shown in figure 15 gives the outcome for ‘Municipality 5’, based on the ‘reference set’, for the three lowest scoring criteria and showing the owner. This analysis might be the start of a discussion on an action plan for improvements.

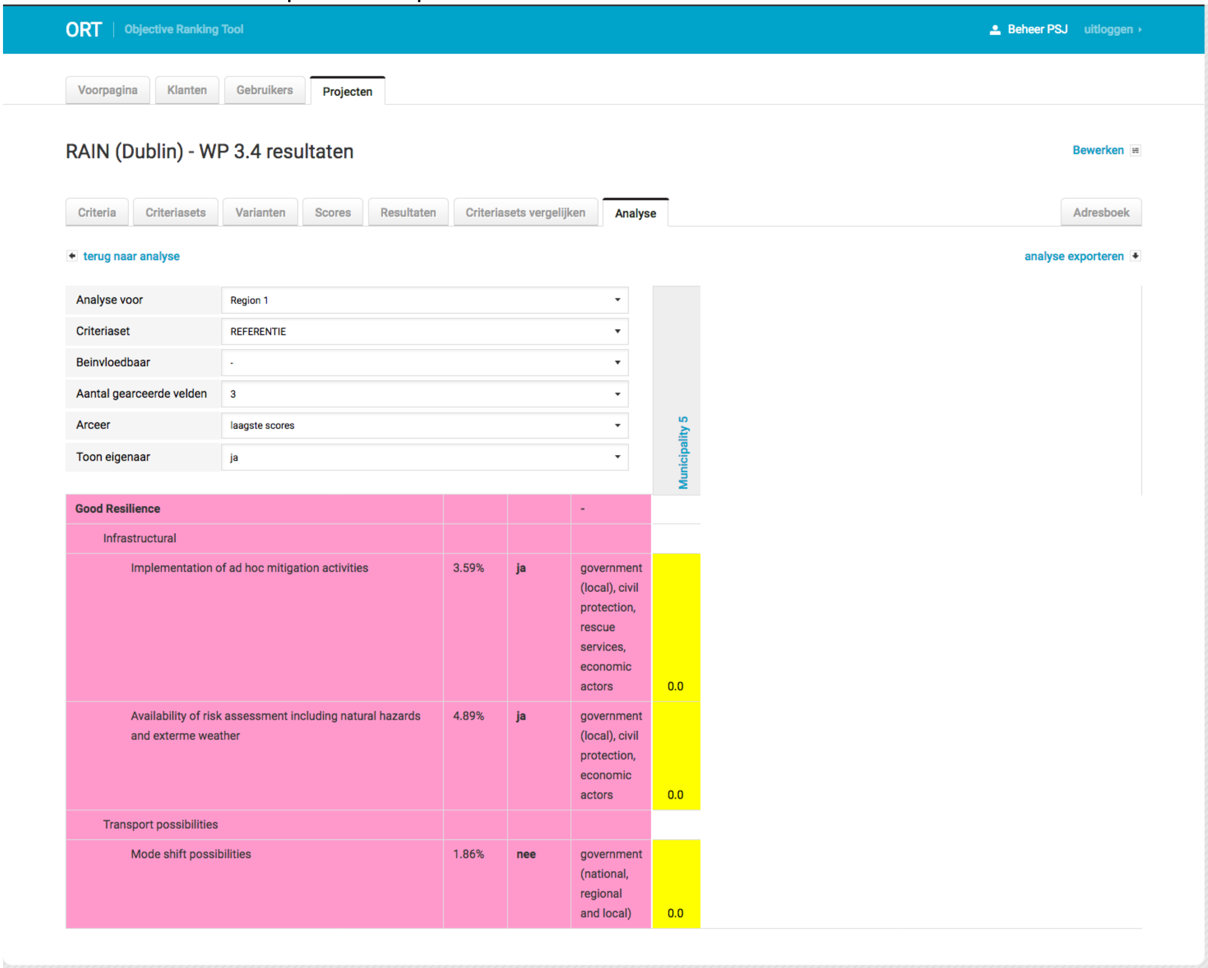

Figure 15. Analyses of results

7.7 Experiences

Based on the two real-life interviews positive comments were made. This kind of self-assessment is an easy to use method for a first evaluation of –for this purpose- the preparation on natural hazards or extreme weather events. It will be important to introduce all criteria with a clear explanation before using the ORT-tool.

Specific remarks made:

- It is difficult to score ‘in general’ without a specific event in mind -> if an evaluation is done based on the outcomes of a general risk assessment it will be wise to have the highest scoring extreme weather event in mind. It might be expected that most of the criteria for other extreme weather events will be incorporated;
- The scoring should have more ranges; -> initially it was set to ‘0’, ‘0,5’ and ‘1’ for this proof of concept. The application can work with steps from ‘0,1’ between ‘0’ and ‘1’;
- The consequences in terms of economic impact were discussed. A remark was made that in a region with less economic activity there will be not that many consequences after an extreme weather event or natural hazard. In this proof of concept approach, it was concluded that the ‘richer’ the region the more vulnerable a region would be;

- The outcome –even as it was presented as a proof of concept- could be understand and accepted.

7.8 Conclusions

The aim of the development of this specific ORT-application was to show a proof of concept to measure the preparation on vulnerability and resilience based on a more qualitative approach on social aspects characterising capacity of a community to cope with and recover from stress.

Some conclusions can be made:

- The degree of vulnerability (shaped by context factors that are by their nature more 'static') of a region or municipality to extreme weather events is the least likely to be reduced by targeted actions in the short term. Resilience (as the capacity of a community to face a stress, and rooted in its organisational capacity and flexibility to change) however is something that can be influenced by stakeholders in a shorter-term timeframe. The results of the ORT-analyses will help stakeholders to focus on institutional, economic, social and infrastructural aspects that could be improved so to enhance their resilience;
- For stakeholders on regional level it will be possible to compare the outcome between, i.e., municipalities, so decisions can be made for those geographical areas where the greatest improvements should and can be made;
- Stakeholder involvement is needed from the beginning of projects on vulnerability/resilience assessment, as their perception shapes also the way in which the community is going to organise itself to face external stress;
- The main advantage is that, having access to the ORT-application, a self-assessment can be made easily and, based on the analyses, suggestions for improvements can be discussed with stakeholders;
- The work done by UNIZA is more focused on quantitative data and focused on vulnerability. A comparison between the work done by UNIZA and this ORT-application can provide a more thorough understanding of a certain context under analysis. The two models can thus result as complementary tools,
- A guideline - step-by-step approach- should be prepared for the process how to execute an ORT-analyses. Specific attention in this guideline should be given to the analyses where to invest for improvements. Based on the outcomes of the ORT-analyses decisions should be made where investments are the most effective in terms of improvements related to the costs.

7.9 Lessons identified

- Research projects are mainly focused on the scientific part of the work to be done. However, involvement of end-users is needed to look for the possibilities of the practical implementation of this scientific work, responding to the actual needs of practitioners, citizens and operators of risk management. Results of these type of research projects will be accepted more by stakeholders if at least proof-of-concepts are developed which shows potential solution to issues identified by stakeholders as well as inclusion of their own insights within the project architecture;
- Calibrating the criteria developed for this proof-of-concept is needed to ensure a good acceptance from the point of view of end-users and stakeholders involved. Measuring the level vulnerability and resilience was part of research activities in other projects but a

standard formula is difficult to identify and largely depends on the approach adopted. For this proof-of-concept a limited literature review was done based on the available timeframe;

- Enlarging the scope of these types of proof-of-concepts with a more in depth involvement of stakeholders is needed to assure ways to interpreted results of the analyses. That will lead to a better acceptance and use of the results;
- A pilot phase should be incorporated to test the application over a longer time. Such a pilot phase will also give the possibility to prepare analyses for different extreme weather events in the same region. It might be expected that the outcome on storms will differ from heavy rainfall. Within the ORT-application it will be possible to develop some reference scorings for the different extreme weather types and their combinations. Therefor it will be possible to enlarge the support from the ORT-application itself. This might be part of future work in other projects.

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