Zeszyty Naukowe SGSP 2022, Nr 82, s. 73–97
ISSN: 0239-5223; e-ISSN: 2720-0779

DOI: 10.5604/01.3001.0015.8882

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APPROACHING CLIMATE CHANGE RISK ASSESSMENT – SOME CONSIDERATIONS

Abstract

As one of the objectives of the CASCADE project is to carry out a cost-benefit analysis to enhance resilience, in order to develop the CCRA (Climate Change Risk Assessment) methodology, the guidelines include a capacity analysis. The ability to adapt to change or to respond in the event of a disaster, as well as the ability to recover from damage within a specified timeframe, are key elements of resilience. Because changes are inevitable, the investment in these three elements is necessary. This is due to the fact that disaster scenarios are uncertain and the question arises as to how to invest in risk reduction to reach a satisfactory goal. The proposal comprised by the CCRA guidelines is to use the game theory. Actually, this proposal is a part of game theory, namely Game with Nature where Nature is not interested in benefit and probability of Nature State in future is unknown. As there are many possibilities of Nature State a probability that a correct investment decision would be made is low. To a much greater extent the decision will be wrong or almost wrong in the case of an optimised decision. The only thing the decision maker can do is randomly select investments or apply the game theory to minimise his sense of loss.

Keywords: climate change, risk assessment, disaster, security, risk management, resilience

PODEJŚCIE DO OCENY RYZYKA ZMIAN KLIMATU – KILKA ROZWAŻAŃ

Abstrakt

Ze względu na fakt, że jednym z celów projektu CASCADE jest przeprowadzenie analizy kosztów i korzyści w celu wzmocnienia odporności, w celu opracowania metodologii CCRA (Climate Change Risk Assessment) w wytycznych uwzględniono analizę zdolności. Zdolność do przystosowania się do zmian lub do reagowania w przypadku wystąpienia katastrofy, a także zdolność do odbudowy zniszczeń w określonym czasie stanowią główny element odporności. Ponieważ zmiany są nieuniknione, konieczne jest inwestowanie w te trzy elementy. Wynika to z faktu, że scenariusze katastrof są niepewne i pojawia się pytanie, jak inwestować w zmniejszenie ryzyka, aby osiągnąć zadowalający cel. Propozycja zawarta w wytycznych CCRA polega na wykorzystaniu teorii gier. W rzeczywistości propozycja ta jest częścią teorii gier, a mianowicie Gry z Naturą, w której Natura nie jest zainteresowana korzyściami, a prawdopodobieństwo wystąpienia Stanu Natury w przyszłości jest nieznane. Ponieważ istnieje wiele możliwości wystąpienia Stanu Natury, prawdopodobieństwo podjęcia prawidłowej decyzji inwestycyjnej jest niewielkie. W znacznie większym stopniu decyzja będzie nietrafiona lub prawie nietrafiona w przypadku decyzji zoptymalizowanej. Jedyne, co może zrobić decydent, to losowy wybór inwestycji lub zastosowanie teorii gier w celu zminimalizowania swojego poczucia straty.

Słowa kluczowe: zmiana klimatu, ocena ryzyka, klęska żywiołowa, bezpieczeństwo, zarządzanie ryzykiem, odporność

1. Introduction

This article is a result of the implementation of aims of the Cascade project entitled "CASCADE – Community Safety Action for Supporting Climate Adaptation and Development".

The last twenty-five years have been characterized by a dynamic growth of disaster studies. Many problems became much more comprehensible, understood and a practical implementation has been discovered. However, new challenges have emerged and as Alexander [1] points out … *disaster studies must adapt to the new reality. … ()….With climate change, globalization and human mobility, I believe we will increasingly need a redefinition of the field of disaster studies….* This statement is confirmed by statistical data. There are no doubts that extreme weather phenomena emerge not only more frequently, but they also cause more severe consequences as compared with the preindustrial period. One can conclude that these phenomena constitute a very clear manifestation of climate changes during the past several decades. The Climate Change Assessment (CCA) has become one of the most important issues in contemporary climate science. The results have been found to be rather pessimistic. They are pessimistic to such an extent that they became political issues embracing international dimensions. This may be expressed by the Sendai Framework as a successor instrument of the Hyogo Framework for Action (HFA) 2005–2015): Building the Resilience of Nations and Communities to Disasters.

The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Miyagi, Japan [26]. Taking into account the experience gained through the implementation of the Hyogo Framework for Action, and in pursuance of the expected outcome and goal, there is a need for focused action within and across sectors by States at local, national, regional and global levels in the following four priority areas:

Priority 1: Understanding disaster risk.

Priority 2: Strengthening disaster risk governance to manage disaster risk.

Priority 3: Investing in disaster risk reduction for resilience.

Priority 4: Enhancing disaster preparedness for effective response and to "Build Back Better in recovery, rehabilitation and reconstruction".

Disasters have demonstrated that the recovery, rehabilitation and reconstruction phases, which need to be prepared ahead of a disaster, lead to a critical opportunity to "Build Back Better", including through integrating disaster risk reduction into development measures, making nations and communities resilient to disasters.

The next fundamental document on which the article is based is National Climate Change Impact, vulnerability and risk assessments in Europe, 2018 [19]. This report was developed by a team of experts from the EEA and the European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation ETC/CCA [32] and provides the first systematic review of national climate change impact, vulnerability and risk (CCIV) assessments across Europe. It is based on information and reflections reported from and authorised by EEA member countries on assessments that are multi-sectoral and cover the whole country. The document reveals the results of a questionnaire related to CCIV assessment general management. CCIV assessments differ widely in their thematic and geographical scope, their assessment approach and method, the terminology applied, the involvement of stakeholders and use of obtained results for developing adaptation policies and actions. The concepts that have been elaborated in this report were adapted to concepts of these considerations and helped clarify them for the purpose of this work.

Following the authors of EEA Report, it is useful for the purpose of CASCADE Project to cite them: *(…) Twenty-two out of 30 European countries that responded to the survey in 2014 stated that they had risk or vulnerability assessments available. Most of the assessments focused more on the national level and less on the sub-national level. The sectors that attracted the greatest attention in these assessments were agriculture, water, forestry, human health and biodiversity. One of the findings of the report was that risk and vulnerability assessments are still needed at the local level. Furthermore, European countries reported the need for more information about the estimated costs of climate change impacts and of response measures*.

A direct relation of these guidelines to the Climate Change Risk assessment (CCRA) can be found in at least three projects that have been implemented by the Baltic Sea States Region countries under the framework of Policy Area Secure (Priority Area 14 in the 2009 version of the EUSBSR Action Plan). This is the EUSBSR flagship project 14.3. The approach adopted in the project was based on the EU Guidelines for Risk Assessment and Mapping Guidelines for Disaster

Management [24]. The EUSBSR 14.3 project also provided a venue for an exchange of experience and ideas with regard to risk assessment *methodology* in the national contexts [14]; Project entitled: Risk Management Capability on Gaps Identification in the BSR", the acronym being: "From Gaps to Caps".

A concept of resilience was the subject of a project entitled: "The Baltic Sea Region everyday accidents, disaster Prevention and resilience – BaltPrevResilience".

Although this Project was not directly connected with climate change risk assessment, many topic issues were taken into consideration that can be used in these guidelines. Among others such topics may be mentioned, as: improvement of data processing, cross border cooperation action or community resilience in preparedness and response phase of crisis management.

The Climate Change Risk Assessment (CCRA) guidelines may be considered an implementation of global and European strategy in the Policy Area of Security, European Directives and Guidelines and also a continuation of challenges that have revealed the BSR previous Projects results. The general review of European Policy related to Climate Change Adaptation can be found in material devised by M. Fichter [9] including an identification of hazards, while a general review of climate change risk management is in Preston's considerations [23] where some concepts of key term are explained, and the case study presenting the impact of climate change on Hungarian water management strategy can be a good example for the European countries [30].

2. Security and Risk concept

2.1 Conceptualisation of risk assessment

The terminology set used in risk management in general as in CCRA plays an important role and therefore it seems necessary to provide a brief explanation of basic definitions, terms and their meanings. It allows a better understanding of the process of climate change risk assessment. It also is conducive to simplifying, as much as practically reasonable, the description of some terms defined in different sources in various ways, however, here in CCRA guidelines they remain consistent with functioning standards.

The basic definition is the concept of security. There are numerous definitions of security (let us assume that *safety* is a synonym but considered on a "small scale"- a work place, a household or a community). In this guideline the notion of security should be understood as: a state of (or/and permanent processes which appear in) natural and /or civilizational spaces characterized by risk.

Civilizational space should be understood as an artificial environment created by human beings often comprising the natural environment to assure a safer life.

Additionally, this definition suggests that the value of risk (regardless whether quantitative or qualitative) is a parameter that best characterizes security.

Alternatively, it can be said that risk is a measure of security. Consequently, knowing the value of risk means that everything is also known about security. So, instead of analysing the security concept as a political issue given the definition of security formulated in this way, risk may be analysed similarly to engineering problems. The difference is that in risk, emphasis is placed on an assessment that can be not only qualitative but semi-quantitative or quantitative as well. Approach to risk as a measure of security seems to be better measurable than the characteristics of political situation intended as a description of security, although the qualitative description can appear in both approaches.

According to the European and ISO standards in these guidelines risk means, roughly speaking, the possibility (probability) of a hazard occurring (occurrence of critical event – CE) generating harm (losses, damages, fatalities) in a given scenario and the severity of that harm [8].

Alternatively, risk is a combination of the consequences of an event (hazard) and the associated likelihood/probability of its occurrence (ISO 31010) [24]. However, the first definition that appears to be more elaborate and far more suitable for these CCRA guidelines indicates elements that should be taken into account is the risk assessment process. Consequently, such elements can be distinguished as: hazard identification and its possibility or probability of occurrence, scenario identification and the extent of harm in the given scenario. One out of two gaps that exist in this definition is the lack of consideration connected with scenario uncertainty. Regardless of this, there is no contradiction between both definitions.

As it has been mentioned above in this definition, one more very important element of risk is concealed, namely, its psychological aspect, which is strictly related to risk perception and risk awareness. Depending on the extent to which emotional risk is perceived, it affects prevention activity in different ways and perhaps, what is even more important, it also affects the behaviour of potential victims during a tragedy. Despite the importance of this aspect of risk assessment it is not comprised by the discussion in CCRA guidelines.

As regards climate change, risk assessment has to be considered as conditional risk [10]. This is because climate change risk assessment should only answer the question as to what are consequences in the given scenario if a hazard does occur. Consequently, the question is not about what is the probability that extreme weather phenomena would occur, but on the assumption that they would emerge more frequently, which scenario might come true during and after their occurrence, along with the ensuing consequences. The only thing that is unknown is the uncertainty of the given scenario, i.e. the possibility of its occurrence in the expected form and strictly connected with its consequences. The conclusion is that a very basic step in climate change risk assessment comprises scenario analyses along with their consequences, as well as a description of the uncertainty of each scenario anticipated. Therefore, the CCRA guidelines assume that the probability that a hazard would occur equals to 1 (meaning undoubtedly). Elements to be analysed are scenarios, their consequences and uncertainty, i.e. the possibility that the whole analysed picture would become true.

The next concept that should be briefly discussed is vulnerability. Even though it seems to be clearly separated from the risk definition concept, in fact vulnerability characterizes consequences of the occurrence of a hazard. According to EU general risk assessment guide, vulnerability is *the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR, 2009).* This definition comprises a very general description of vulnerability and cannot be directly implemented in practise. This is because instead of speaking of vulnerability we tend to speak of susceptibility, which says nothing of the measure or indicators. One term is substituted by another one, which is just as ambiguous. Having this in mind for practical use an adaptation of SRA [2] definition in these guidelines has been done, namely: vulnerability means the degree to which a system is affected by the occurrence of a hazard in the given scenario.

If we look at the risk definition a conclusion can be drawn that vulnerability characterizes the severity of harm expressed by consequences, i.e. the expected losses, the number of fatalities and so on. Consequently, vulnerability is strictly related to consequences, which are connected with a given scenario.

In Risk assessment guidelines, vulnerability is associated with term *susceptibility*. Indeed, such a connection does exist. As has already been said, vulnerability is the extent of damage in the presence of a given hazard. Hazard may be characterized by its intensity or magnitude. The intensity of a hazard can be (and often is) a random variable. It may change in time and space. The value of this change influences consequences. A small change in hazard intensity can cause disproportionately severe consequences. A protected system that reacts in such a way to hazard is more susceptible than the system the reaction of which is proportional to hazard intensity change or the system that does not react at all.

As an effect, susceptibility (in this case a synonym of sensitivity) can be described as an extent of a change of consequences (reaction) of the protected system to the intensity (magnitude) of hazard change.

The selection of variables and variable values form the scenario can also serve as a basis for several other steps in the analysis of this scenario, such as discussion concerning likelihood, sensitivity analysis and uncertainty assessment [10, 27]. It is worth emphasising that such definition of susceptibility indicates at once its measures expressed by measures of consequences.

Another element of CCRA guidelines is the devising of a scenario. Generally speaking, a scenario provides a picture of a specific situation during the development of a disaster. So, scenario is a qualitative description of a situation after the occurrence of a hazard.

According to BSR methodology ("From Gaps to Caps"..., 2016) a scenario embraces four basic steps:

1) determination of the "worst credible scenario";
2) determination of the starting and ending time;
3) a choice of variables and variable values;
4) summarization of the scenario narrative.

The adaptation of these steps to guidelines requires certain comments. If only the "worst credible scenario" is taken into consideration, a decision about costs of minimising risk might prove to be too high. This is due to fact that the possibility of the occurrence of the worst scenario is much smaller than the occurrence of a "frequent" scenario with relatively fewer consequences or "medium frequency" scenario with "mean" consequences. The problem that should be solved is what scenario should be taken into account in a specific situation to make a decision on the assumption that the budget is usually limited. An attempt to provide an answer will be made in the below part of this paper in the cost-benefit analysis part. The starting point of a scenario requires the identification of "triggers". The end of a scenario should be understood as the moment when the critical event ceases to generate its consequences.

There are some difficulties in understanding the *cascade* description. According to a review of [21] we may assume that: Cascading emergencies – situations when one hazard triggers others in a cascading fashion – should be considered. For example, an earthquake that ruptured natural gas pipelines could give rise to fires and explosions that dramatically escalate the type and magnitude of events.

It is worth emphasising that the cascading (domino) effect means that a critical event triggers secondary events that tend to escalate the type and magnitude of events. The consequences of these secondary events are amplified and usually exceed the consequences of a critical event.

Having assessed the risk, a decision should be made whether to minimise or not to minimise the level of risk. Such decisions depend on available budget and on the crisis management phase. The following activities may be undertaken:

1) in the preventive phase – adaptation;
2) in the response phase – coping;
3) in the recovery phase – rebuilding and modernization.

In CCRA guidelines budget is considered as part of expenses under Value at Risk (VaR). Before making an outline of a proposal of the VaR concept in these guidelines it is worth explaining a broader meaning of resilience of the protected system as an element of CCRA guidelines. Research indicates that a direct connection exists between resilience and crisis. This is because permanent processes of changes of the surrounding natural and civilizational environment force individuals, communities, organizations, states and international institutions even on a global scale to carry out continuous processes of adaptation to new conditions.

Relations between processes of changes and adaptation do not progress in a smooth way. In many cases, changes may materialize rapidly and because of the inadequate adaptation to these changes they cause violent phenomena that affect everyday life and threaten citizens, their cultural and/or material values. This inadequacy not only causes losses, but quite often threatens their existence. As a result of an interaction of these phenomena, quite frequently emerge crisis situations. They can have personal, local, regional even global dimensions. Following Boin one should understand that a crisis situation means that something bad threatens a person, a group, an organization, a culture, a society and that something should be done urgently and in conditions of uncertainty [3].

Many authors determine resilience in different ways. For instance, according to Kwok et al. [16], following Paton and Johnson [21], resilience is described as … the adaptive capacities of a social system to recover from a natural hazard event. That is, resilience to disasters refers to abilities of individuals and groups to learn from and to adapt to be able to co-exist with natural hazards and their potential consequences. John De Boer et al. [6] has analysed the concept of resilience as one that is interconnected with the fragility concept in regard to a city indicating that these two concepts are not antonyms even though they are not mutually exclusive. Both of them are strictly related to risk. According to the authors resilient cities are those that are able to maintain and potentially improve the delivery of their core functions before, during and after exposure to shocks and stresses. This definition distinguishes three phases of crisis management, and namely: (1) preventive and preparedness (before exposure), 2) the response phase (during action aimed at minimising consequences) and 3) the recovery/rehabilitation phase (after exposure). In NIST Special Publication 1190GB-13 [13] the authors have discussed resilience gaps and prioritizing efforts to close them after critical infrastructure disruption, that is only after a disaster (recovery phase). They determine the resilience gap as a difference between the desired time to recover damages and the anticipated time depending on the hazard level. However, the glossary devised by T. Aven et al, from the Society for Risk Analysis (SRA) [2] contains some definitions of resilience and examples of their metrics/descriptions. Following these authors, resilience should be understood as: the ability of a system to reduce the initial adverse effects (absorptive capability) of a disruptive event (stressor) and the time/speed and costs at which it is able to return to an appropriate functionality/equilibrium (adaptive and restorative capability). The measure of resilience is expressed by a probability that a system can sustain its functionality in a situation of high stress or (unexpected) disturbances. In this case the authors take into account two phases: response and recovery. Having in mind what has been said above, it can be assumed for the needs of these guidelines that indeed, as was considered in cascade effect description, resilience has at least three dimensions: in the preventive phase adaptation, in the response phase coping and in the recovery phase rehabilitation.

The main issue intended to allow assessing resilience is that in each phase certain investments are required in order to minimise risk. The course of climate changes are ambiguous, moreover, in line with those scenarios it is uncertain as well. Nature seems to play with the humankind. In attempts at predicting potential scenarios and the interrelated consequences, the cascading effect experts have a rather limited number of tools at their disposal. One of these tools, very useful in these guidelines, is the so-called anticipation weather scenarios worked out for Europe on an interactive platform (European Climate Risk Typology Map) where typology of threats, measures and indicators are illustrated for each European country. The platform offers illustrated "expected weather scenarios", which means that these scenarios are based on average values of weather parameter changes. The possibility of making a mistake in risk reduction investment estimation is in this case rather high. In order to be able to decide which type of investment is less risky, the following tool is presented as a feasible proposal.

The tool is named "Game with Nature". Three scenarios should be taken into consideration by experts: "expected", "medium" and "worst scenario". Next, consequences connected with the given scenario should be taken into account including the cascading effect. Budget estimation is necessary to be able to maintain consequences within risk criteria. The money invested to minimise the consequences in a given scenario due to uncertainty of scenario are at risk and are called Value at Risk (VaR). VaR versus risk criteria should help make the least risk of losing money. Summarizing the forgoing considerations, the fundamental scheme presenting the logical chain of elements of risk assessment (Fig.1) and climate change risk management (Fig. 2) has been shown below.

Analysing this scheme, a general remark can be made. Starting from the box "risk" and ending on the box "cascading effect" [22] the analyses executed by the experts are closely connected with threats "generation". Furthermore, resilience and the following boxes are connected with activities that should be carried out to limit this "generation". Briefly, the scheme illustrates respective steps in these guidelines.

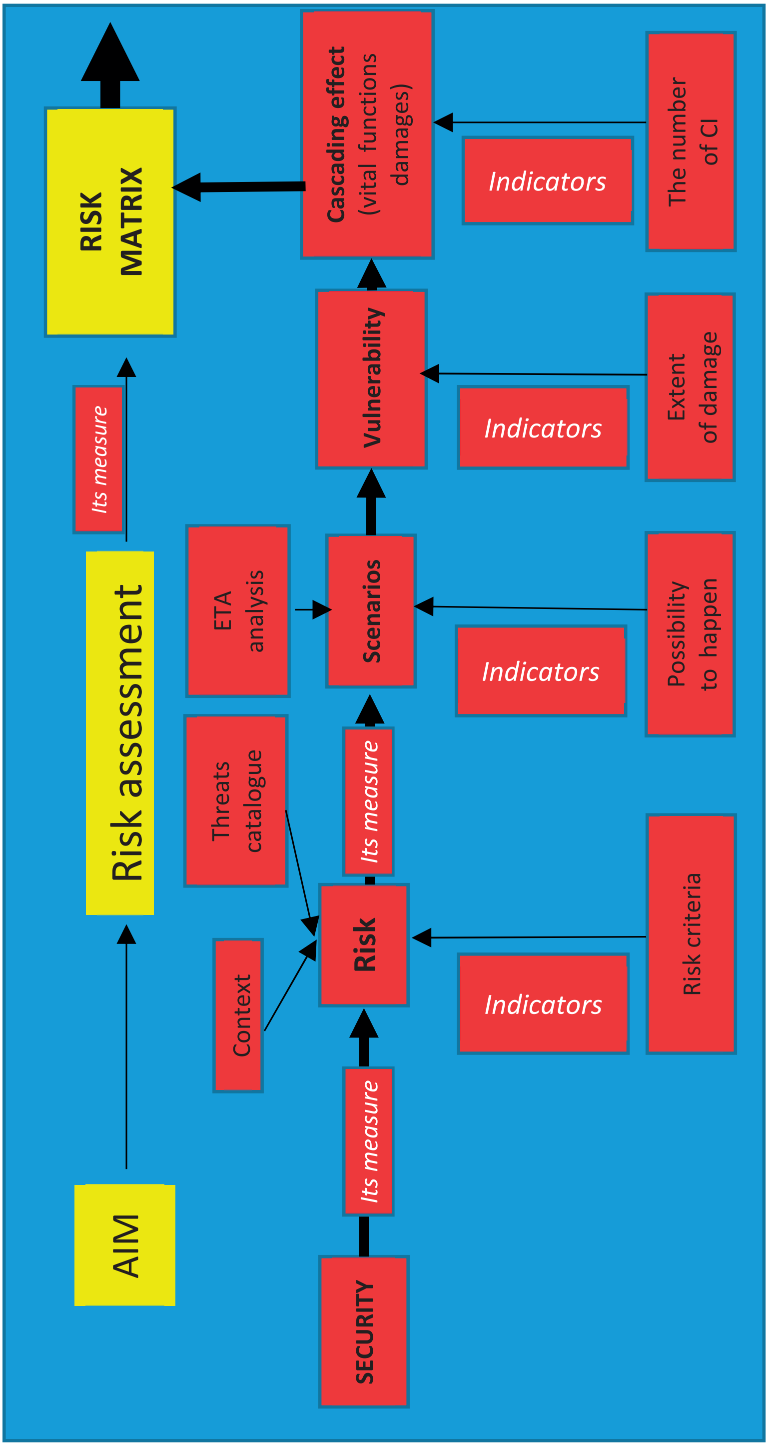

Fig. 1. Logical scheme of the climate change risk assessment methodology

Source: own study

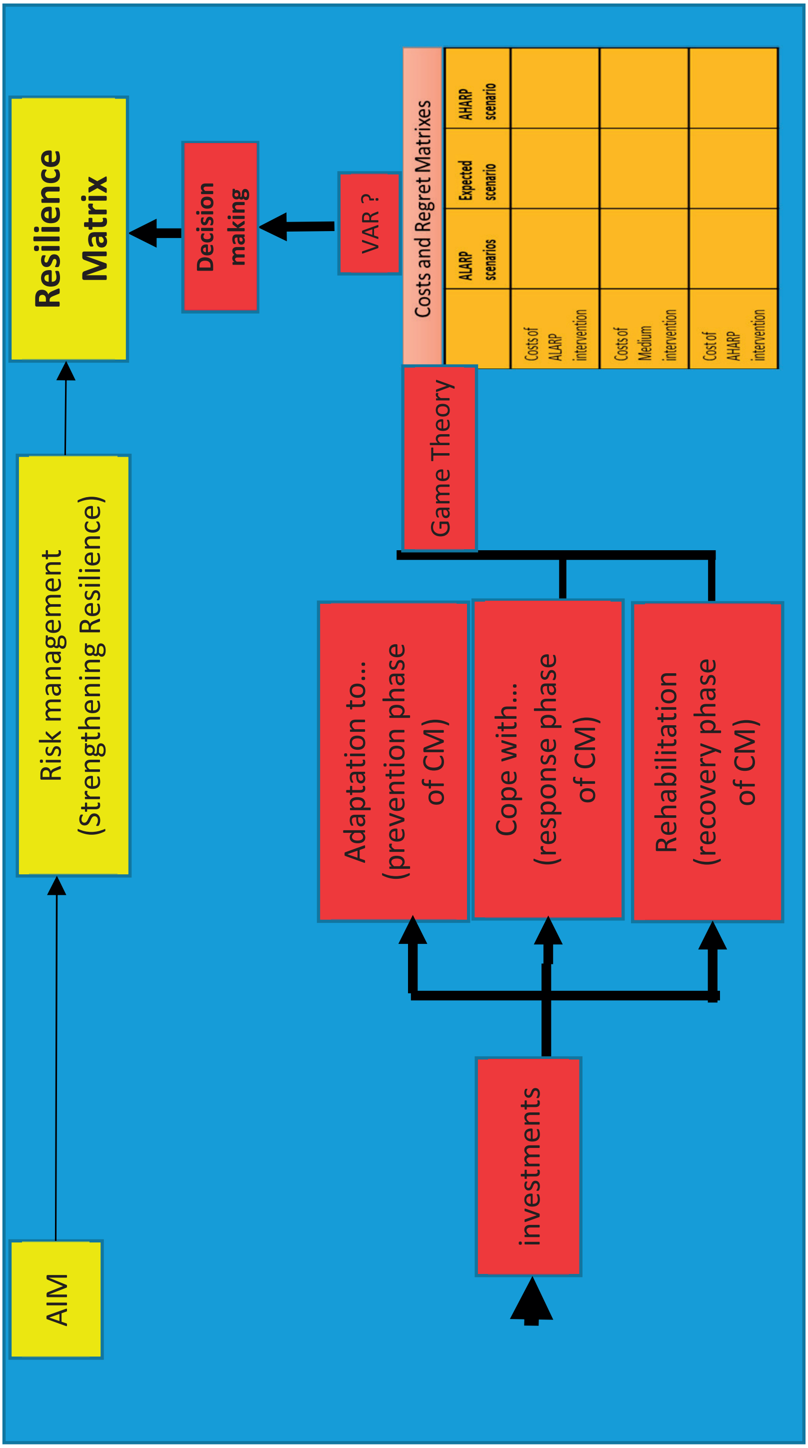

Fig. 2 Logical scheme of the climate change risk management methodology

Source: own study

2.2 Estimation of VaR

Games with nature belong to the types of games in which only one participant cares about the final result. The other participants are not interested in the final result of the game. Due to the fact that investment in risk is often uncertain, such investments are frequently referred to as blind investments or investment in dark. Costs earmarked for protection often do not bring any profit, so there is a tendency to limit them for no rational reason. This is an effect of the existing uncertainty in the devising of a scenario. In such a situation, a decision should be made to minimize losses if decision turns out to have been wrong. If losses are minimised, then the value at risk (VaR) is at a minimum level. In this guidance, the specific scenario developed under the CCRA is treated as a future possible 'state of nature' after the threat has been materialised. Below is an outline of the procedure of VaR estimation.

The presented rule [7] expresses the pessimistic strategy (missed decision) of dealing with a given scenario. It means that the rule minimises losses (minimises regret) among the maximum possible losses associated with missed decisions of individual investment decisions (actions) with respect to a given possible scenario.

According to this criterion, the losses for each of the possible scenarios should be estimated together with the costs of deciding to reduce them to an acceptable level. The estimation of the volume of investment cost losses reducing, that is reducing the risk, should be then correlated with the approved risk criteria. Next, a cost matrix can be created. Values of elements of the cost matrix comprise results of differences between the losses for the given scenario and expenses ensuing from the given decision regarding this particular scenario.

For this purpose, the starting point is to create a matrix of costs, which is defined by the following two dimensions:

- Action is understood as the magnitude of interventions that may not be of a routine nature at all, and it may be small, medium or large. These activities are beyond the costs of "normal" risk.
- State of nature – determined by the magnitude of the threat expressed by the feasibility of the scenario. In these guidelines it is assumed that three possible scenarios would be taken into account, and namely the scenario of small changes in CCR, the scenario of expected changes in CCR and the worst scenario or black swan in CCR. For each scenario (range of changes) and for each action a Cost Matrix should be developed (Table 1).

The variety of interventions means that costs vary - they will increase with an increase in the scale of scenario changes. This means that a greater scope of intervention would cost more. The reference point for further considerations is to define the scope of intervention in the context of different types of activities and their costs:

1) Do nothing (routine activities),
2) Small intervention,
3) Medium intervention,
4) Large intervention.

A given strategy of action (magnitude of intervention) is burdened by a great dose of uncertainty. This is due to the fact that we do not know what "state of nature" would occur. Therefore, the decision makers can only plan the scope of intervention. The costs should embrace the rebuilding outlays for the particular scenario.

The prepared matrix of cost will allow indicating the biggest loss in the event of a wrong decision - every decision about undertaking action (investment) should be taken into consideration, which might cause the greatest possible losses if the scenario is not implemented.

Table 1. Fulfilled matrix of cost – example

Action (magnitude of intervention)	State of nature (possible scenarios)		
	Negligible changes Small changes	Expected (average) changes	Worst scenario
Do nothing (or routine activities)	10	40	70
Small intervention	11	45	71
Medium intervention	13	38	65
Large intervention	21	37	57

Source: own study

Having Cost Matrix Creating a Regret Matrix (Table 2) enables the following:
- Finding the smallest value of costs (the lowest value of costs incurred) in the columns,
- Removing this cost value from cost values defined in each field of the cost matrix, that is subtracting this minimum value from other values in the column.

The next step is to choose from the prepared regret matrix the MAXimum value of the possible loss for the given action (maximum horizontal value). The resulting cost values for giving example are:
- Do nothing (or routine activities): 13
- Small intervention: 14
- Medium intervention: 8
- Large intervention: 11

Table 2. Regret matrix - example

Action (magnitude of intervention)	State of nature (possible scenario)		
	Small changes	Expected (average) changes	Worst scenario (black swan)
Do nothing (or routine activities)	0	3	13
Small intervention	1	8	14
Medium intervention	3	1	8
Large intervention	11	0	0

Source: own study

The meaning of these values is that if a decision made is failure, these values mean maximum losses for each activity (investment).

As in making decisions the point is to minimise losses (minimised regret) in case of failure, the MINimum value should be chosen from among the above presented four values (in this case this makes 8, and so the medium intervention should be undertaken). In practice, this means choosing the most rational decision, which if the right decision is not made (the scenario will not be implemented); this will give the relatively lowest regret (minimum losses among their maximum possible values; MINIMAX-method).

3. Process of Risk Assessment

3.1 Team gathering

Working Groups [31] are a great way to analyse a particular area or topic in a discussion process to identify risks that may not appear to be obvious to the risk identification group. The working group is usually a separate group of people working a particular area under the project carrying out risk identification. It is assumed here that members of the core risk assessing team include the authorities, decision makers and officers responsible for security on the area. Consequences of a critical event, especially consequences of the cascading effect that "doesn't know" sectoral limits, give rise to trans sectoral consequences. Then, relevant sectoral experts need to become involved in the assessing process. Risk as a possibility of occurrence of the critical event and possible consequences such an event has a subjective dimension due to uncertainty. This causes some difficulties in obtaining unique results and often discrepancies arise among assessors. To solve this problem certain expert methods may be used to manage the teamwork. They include among others: foresight, the Delphic method and the knowledge panel.

The foresight [29, 18] expert method employs the following methods:

- Explorative methods are an estimation of the current situation, describing diverse events and establishing trends that will take place in the future. These methods are based on historical data or on an estimation of causes of changes in the dynamics;
- Analytical methods are based on the numerical future illustration (this is trend extrapolation, simulations, modelling and analyses of cross impact). These methods are complementary to explorative methods;
- Experts' methods employ expert knowledge, allowing the formulation of a long-term strategy. They include the Delphic method, experts' panel, brainstorm, mindmapping, scenarios analyses, seminars and the SWOT analysis;
- Pragmatic methods identify key points of strategic activity.

Classifying methods regarding types of activity in foresight processes can presented as follows:

1) Scenario creation – strategy formulation,
2) Future extrapolation – prediction,
3) Variant future narrative – futurism.

Delphic method

This method is also called the Delphic research or the Delphic Questionnaire and is aimed at reaching opinions' agreement within the given criterion. Using this method, the assumptions are the following:

Brainstorming.

Brainstorming is a technique that is best accomplished when the approach is unstructured (the facilitator encourages random inputs from the group). Group members verbally identify risks that provide the opportunity to build on others' ideas.

Any need for consultant support should be identified on an early stage of the process. A list of involved experts from sectors possibly affected by climate changes should be established.

3.2 Context

Context in this case implies a description of the protected system. There are two main issues for performing of this task. The first is to establish what kind of data should be compiled. The second is what standards for "affected elements" should be required to apply. The second problem gives rise to the following question: what are the indicators of an affected element? The answers to all three issues can be found among others in the "Guidance for Recording and Sharing Disaster Damage and Loss Data" [12] or in the platform European Risk Typology/Map. Generally speaking, the context embraces the overall picture of a city, a community or another protected subject. In this picture the above mentioned elements should be emphasised, which can cause a critical event or which can be affected by critical

events or escalating events arising from the cascading effect. They include among others:
- geographical location;
- infrastructure characteristics;
- climate characteristics, especially the characteristics of precipitation, snowing and hailstorms, seasonal temperature, characteristics of wind speed, hurricanes;
- description of the population;
- one of the most important elements directly related to resilience are the formal and informal ties among people, their common history and traditions and the experience of coping with disasters. Characteristics of possible seasonal increasing of the number of people (tourists, clients etc.);
- due to the fact that the disaster affects the vital societal functions it is necessary to describe all processes that are important for the wellbeing of citizens and which can be disrupted by a critical event;
- cooperation with neighbours in case of critical event;
- another specific characteristic for the particular area.

Once a description of the protected system (administrative area) is available, the next step is to establish risk criteria.

3.3 Catalogue of hazards

The catalogue of hazards is a tool supporting and facilitating CC assessors in selecting the types of hazards that can occur on the protected area. First of all, this can be the European Climate Risk Typology [5]. Moreover, hazards connected with climate change are reachable in such sources, as different reports regarding National Risk Analyses [20, 17].

Generally, sources of hazards can be divided into three basic groups: natural, technological and human-caused hazards [28]. Frequently hybrid hazards can occur. The last type of hazards takes place predominantly when the cascading effect is triggered.

3.4 Risk

CCRA guidelines comprise an assumption that climate changes will come true in the future. The question, therefore, is not whether a critical event will occur, but the extent to which the climate change will increase the frequency of extreme events that would generate damage. One of the most important goals of the climate change policy should be to limit the probability of very bad consequences to an acceptably small value. The criteria of acceptability of this conditional risk should be determined (if a critical event occurs then it is sufficient to consider only the scenario). This is an important step due to their confrontation with VaR to make an investment decision at the final step of CCRA.

Regardless of what the risk concerns, these fundamental questions need to be answered. In case of CCRA the overall diagnosis is quite clear. Drivers of the climate change risk, such as wind speed, rainfalls, extreme temperatures and so on, cause critical events – described by the weather scenario. Given the fact that they are recognised due to their occurrence in the past and its prediction in the future, it can be assumed that climate changes tend to increase their intensity and frequency. Moreover, the tendency of changes is known and so it is reasonable to assume that identified threats are unavoidable. Having this in mind, the only thing that can be done to manage CCR is including this in procedures connected with the crisis management cycle, that is in the *preventive and preparedness phases* - adaptation of the protected system to future climate phenomena, in the *response phase* there is a need to be prepared to absorb possible consequences by the protected system and/or to cope with disaster limiting its consequences, and finally as the *recovery phase* to rebuild and/or repair damages and re-establish vital processes within an acceptable period of time. Additionally, it is worth emphasising that due to the cascading effect multi–risk should be taken into consideration

Therefore, a comprehensive approach should be adopted for the assessment of natural and specifically climate-related disaster risks in order to consider the entirety of aspects contributing to the increase of hazards, exposure and vulnerability in a multi-risk perspective [11].

Risk can be presented in a risk matrix. It is rather more convenient for risk assessors to estimate the risk qualitatively as: small, medium (consequences are expected) and extreme uncertainty (worst scenario including black swans). This risk classification has to be coherent with the extent of changes that describe the state of nature. In addition, instead of assigning the probability of the given scenario to the vertical axis, uncertainty should be indicated. Knowing that risk reduction decision is strictly related to VaR consequences presented in the risk matrix, the state of nature should be described in a coherent way. Below an example (coherent with scenarios) outline of the risk matrix has been shown (Table 3).

As may be seen, negligible changes can be omitted in CCRA. The same can be done in VaR calculations. For further analysis indicators in the risk matrix are used to select this box, which is a result of risk analysis for a particular scenario with given uncertainty. Consequently, it will be a subject of all "unacceptable" and "to consider" elements, which have to be included in the VaR analysis. However, it is possible to narrow uncertainty for a particular scenario. The concept of uncertainty reduction is considered in an article of Halsanes and Kaspersen [15].

The authors indicate that "(…) many of the uncertainties revealed in traditionally structured climate risk assessments are not equally relevant to specific decisions and presenting wide cascades of uncertainties can mask key decision-making parameters".

Tab. 3. Outline of Risk matrix of CCRA guidelines – example

	Consequences		
Uncertainty	Small changes (small risk)	Medium changes (expected) (medium risk)	Worst scenario (including black swan if needed) (extreme risk)
High	Acceptable	to consider	to consider
Medium	to consider	to consider	Unacceptable
Small	to consider	unacceptable	Unacceptable

Source: own study

This approach allows making the risk matrix more precise and in such a way makes prioritisation of risk to be reduced more reliable.

3.5 Creation of scenarios

Uncertainty related to risk arises from the vagueness of the scenario (and furthermore from consequences of such uncertainty). The scenario can be described in a formalized document. This kind of scenario is compiled first of all to collect data necessary for risk analysis in a single place, secondly to describe a sequence of events, especially if the cascade effect should be emphasised. The descriptive scenario enables risk assessors not only to depict the entire picture of the given situation, but also serves as a necessary tool to identify threats and to categorise the linkage between events that create the cascade effect. It also allows distinguishing between primary and secondary phenomena, i.e. between causes and their consequences in escalating dynamic development of hazards. Even though the scenario is merely imagined, the overall picture is not abstract. It should refer to the context and include parameters necessary to analyse vulnerability. Special attention should be paid to critical infrastructure.

3.6 Vulnerability as a measure of threat magnitude

Analyses of scenarios, of vulnerabilities and of cascade effects belong to the analysis of consequences. Thus, vulnerability as the element of consequence analysis is a convenient measure of threat "magnitude" in a particular scenario. The extent of damage is measurable and so it can serve as an indicator. For instance, the number of fatalities or fraction of population being affected, an extent of property damages measured by costs, the material losses direct and indirect are countable. This indicator is irreplaceable especially for economic losses caused by a disaster. The losses are simultaneously consequences and embrace[27]:

1) Property – buildings, content/equipment, vehicles products, stocks, crop;
2) Economic activity – any object representing economic activity, such as an industry;
3) Owner – individuals/business/government/non-governmental organizations and insurance companies;
4) Entity bearing the loss – individuals/business/government/nongovernmental organizations and insurance companies.

While devising a vulnerability assessment it is necessary to distinguish these groups of people and elements of the protected system that are more vulnerable than others. Obviously elder handicapped people and children belong to these groups.

4. Risk Management

Decisions related to the investment belong to risk management activity. As has already been said, its role is to lower the risk to an acceptable level according to local risk criteria and to certain VaR that can be considered as exposure to risk. Let us analyse three communities (indicated as stars) and their two precise risk matrices. In Table 4 risk matrix before investment is presented.

Table 4. Risk Matrix before investment

	Risk Matrix (before investment)				
Events Possibility (%) (per year)	Small	medium	high	Very high	extreme
100				★	Not tolerable
95	Neglected	Acceptable	ALARP		Risk ☆
90	Risk	Risk	Risk		★
85					
80					

Source: own study

Investment reduced the risk for each community. Investment in risk reduction can never reduce the risk to a zero value. Risk that remains after reduction is called residual risk. The residual risk should be confronted with process risk criteria established at the beginning of the risk assessment process.

However, it is still unclear in what way are these communities able to adapt, cope and recover from the damage after the occurrence of disasters. In other words, resilience is not indicated in these matrices.

Table 5. Risk matrix after investment

	Risk Matrix (after investment – residual risk)				
Events Possibility (%) (per year)	Small	medium	high	very high	extreme
100			★		Not tolerable
95	Neglected	ALARP			Risk
90	Risk	Risk ☆	ALARP Risk		AHARP
85	☆				
80					

Source: own study

5. Resilience

Resilience is the other side of the coin and is directly connected with vulnerability as its inverse.

As it has been mentioned beforehand, in guidelines one of the basic assumptions is that climate change drivers would occur more frequently and more intensively. This is inevitable so it impossible to stop phenomena per se. However, there are ways (methods, solutions) that can be employed to limit the risk to acceptable level. These ways constitute the resilience concept.

First of all, if we cannot stop the danger of natural phenomena, we can adopt the protected system in order to limit vulnerability (extent of consequences) to an acceptable level. Adaptation can be assigned to prevention activity and it is analogous to the preventive phase in crisis management. Nevertheless, when adaptation is not sufficient or when it is impossible to adapt the system (for instance the eco system), CE could take place and an urgent reaction is required. The basic aim of reaction (response) as the second way is to limit consequences similarly as in the adoption process. Such reaction is a synonym of response and preparedness phases in crisis management. Thirdly, the rebuilding process (recovery or rehabilitation) is analogous to recovery or modernization phase in the crisis management stage. These three pillars form resilience. The main issue of resilience building comprises ways of investing in each pillar without knowing which scenario would be implemented by nature. Even if the prediction of some climate change risk drivers' values is possible, the scenario that will "bring" these drivers still remains uncertain.

According to Salim et. al. [25] …the compilation of risk assessment and adaptation options from all sectors would be used as the basis for adaptation prioritization. For this purpose, first a multi-risk map is generated and then overlaid with the current land use map (for baseline) and the land use plan map (for future condition).

The process of prioritization should include all actors involved in the adaptation activity even if it is cross sectoral. As an example of an adaptation plan of city, a document entitled "Cambridge City Council Climate Change Adaptation Plan 2018" may be assumed as a point of reference [4]. The role of adaptation is to avoid or sufficiently reduce the possibility of occurrence of a critical event and in case of its occurrence to minimise consequences. If a critical event occurs, response activity is activated and afterwards only mitigation of its consequences is possible. It should be emphasised that during mass casualties, big scale or long lasting event the response forces (for instance, rescue and medical services) would not be able to cope with consequences of catastrophe due to the lack of resources. Moreover, these services belong to critical infrastructure and they can be affected by a critical event to a degree causing their malfunctioning as well. These conclusions clearly show that the following issue should be considered: what kind of gaps in human and technical resources exists according to the considered future scenario. Finding an answer to this question should facilitate ways of strengthening these services if needed during decision making.

Adaptation and response phases cost, but the recovery phase is the most costly one. Thus, avoiding a critical event or minimizing its consequences are priorities in resilience strategy arising from minimizing the recovery cost. The cost of recovery can be estimated by cost of direct losses. Extent of damages and time to recovery should be estimated in strict association with the given scenario and then prioritized.

After analysing three elements of resilience and after investing in selected hazards and selected elements intended to reduce the climate change, the resilience matrix can be established.

It seems that a very convenient argument for the acceptability of residual risk level is as follows: a risk is acceptable only if the protected subject (a city, a community or any local administrative level) is capable of insuring itself with its own budget. Otherwise, there is a need of support from higher level of administration or state and even on an international scale.

If risk criteria meet residual risk consequences, monitoring of risk is conducted. Otherwise, resilience should be strengthened and the possibility of adaptation to climate changes, effectiveness of coping with disaster or rehabilitation possibility should be re-considered.

The next issue, of great importance for practitioners, is that in practice acceptable risk criteria cannot be fully fulfilled due to random circumstances that occur during a hazard. For instance, during flash flood one or some fatalities can occur because this hazard has occurred while some people were present in the given place. Statistics reveal many similar random accidents related to each hazard and all kinds of consequences. As a result, it is necessary to assess the effectiveness of the protection system on an acceptable level of confidence connected with residual risk (for instance, in Poland fire units form a network that enables arriving on the scene of an incident in 15 minutes; however, this criterion is fulfilled only in 75% cases). Having values of the effectiveness of the protection system versus residual risk, a resilience matrix can be constructed (Table 6).

Table 6. Resilience Matrix

RESILIENCE MATRIX					
"EFFECTIVENESS OF INVESTMENT" (%)	Residual risk				
	Small	medium	high	very high	Extreme
100	High	resilience			
80	☆	☆	Tolerable	resilience	No resilience
60			★		Unique facilities
40	Acceptable	resilience	Too low	resilience	Extreme event (black swan)
20					

Source: own study

The resilience matrix is a facilitating tool intended to estimate the degree of withstanding climate change by the protected system. It describes residual risk related to climate changes versus the extent of possibility to absorb, react and recovery consequences. In a scale of 100% (or 1) this means that critical event consequences are on an acceptable level due to fulfilled risk criteria without any deviation ascertained. On the other hand, a scale of 0% implies the maximum (pure) consequences in the event when nothing is absorbed, no reaction during critical event occurrence, no ability of recovering damages. If resilience is on an acceptable level, it should be monitored. Otherwise, the procedure of risk assessment should start from steps leading to strengthening resilience. In other words, there is a need of considering further investment. Conclusions that can be drawn from the process of resilience establishment are that there are two ways of strengthening resilience: make lower residual risk and/or make a more effective protection system.

6. Conclusion

The CCRA guidelines have been worked out based on a classical methodology of risk assessment. However, due to certain peculiarities this classical methodology should be adapted to risk connected with climate change. Based on the EU's Guidelines for Risk Assessment and Mapping, there are five steps in such analyses:

The first is *defining values – defining societal values and likelihood based on EU guidelines*

- In case of CCRA this step includes the establishment of risk criteria, i.e. to what extent the established values can be protected. However, there is a certain difference. In CCRA we do not determine the likelihood of events threatening these values due to assumption that there is a very strong probability that climate change drivers would occur. Both methods require planning work and team gathering.

The second is *hazard identification – getting input from risk assessments implemented by national authorities and other entities*

- There are no differences at all between both methodologies in this step. Although in CCRA guidelines *others* means relevant cross-sectoral experts and there is a demand off involving them in a team of assessors owing to the cascade effect.

The third is *scenario building – prioritizing hazards and building scenarios together with experts*

- There are some differences in scenario building. Namely, in CCRA three scenarios should be developed because the magnitude and intensity of climate change drivers are not predictable (they are random) so free reasonable options of scenarios should be taken into consideration.

The fourth is *risk analysis – arranging workshops where expert judgments are made.*

- Risk analysis in classical method means:
  - determination of the probability (in qualitative analyses possibility) of hazard occurrence. In CCRA guidance this item can be omitted due to the assumption that hazard occurrence is certain:
  - determination of the consequences of hazard occurrence.

The fifth is *risk matrix – visualizing cross-border risks in the Baltic Sea region.*

- Actually, the risk matrix is used to evaluate and hierarchize the risks. The classical risk matrix is based on the probability of hazard occurrence (vertical axis) and consequences in particular scenario. Meanwhile in CCRA guidelines due to above discussed reason the risk matrix is based on uncertainties (vertical axis – analogue to probability) and scenarios (analogous to consequences, even though in this case it is the same). As an effect, the risk matrix is modified to allow its adopting to project goals. The structure of the CCRA guidelines may be used for further considerations, i.e. which risk assigned to particular scenario should be reduced.

These five steps cover the entire risk analysis method. Generally the development of the risk matrix and its hierarchization end the risk assessment process. In case of CCRA guidelines the development of a resilience matrix is the last step in risk management.

References

1. Alexander D.E., *The game changes: "Disaster Prevention and Management" after a quarter of a century*, "Disaster Prevention and Management" 2016, Vol. 25 No. 1, pp. 2–10.
2. Aven T. et al., *Society for Risk Analysis Glossary*, SRA-Glossary-FINAL.pdf, 2018.
3. Boin A., Hart P., Stern E., Sundelius B., *The Politics of Crisis Management. Public Leadership under Pressure*, Printed in the United Kingdom by Clays, St Ives plc., second edition 2017.
4. *Cambridge City Council Climate Change Adaptation Plan*, https://www.cambridge.gov.uk/media/5996/climate-change-adaptation-plan.pdf, 2018.
5. Carter J.G., Hincks S., Vlastaras V., Connelly A. and Handley J., *European Climate Risk Typology*, http://european-crt.org/index.html 2018.
6. De Boer J., Muggah R., Patel R., *Conceptualizing City Fragility and Resilience*, "Working Paper 5" October 2016, United Nations University Centre for Policy Research.
7. Dembo R., Willey S., Freeman J., *Seeing Tomorrow – Rewriting the Rules of Risk*, John Willey and Sons INC, New York 1998.
8. *EU general risk assessment methodology (Action 5 of Multi-Annual Action Plan for the surveillance of products in the EU (COM(2013)76).* Ref. Ares(2016)2656912 - 08/06/2016, European Commission.
9. Fichter M., *Adaptation to climate change, risk prevention and management in the 2014–2020 Regional Policy*, European Commission, DG Region Team leader "Sustainable Growth", Unit G1 – Competence Centre "Smart & Sustainable Growth", 2013.
10. *"From Gaps to Caps"* – Possible *Future Opportunities for Risk and Capability Assessment in the Baltic Sea Region,* ed. by: Karlsson B., Olsson A.J. and Riedel M., 2016.
11. Gallina V., Torresan S., Critto A., Sperotto A., Glade T., Marcomini A., *A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment,* "Journal of Environmental Management", 2016, 168, pp. 123-132.
12. *Guidance for Recording and Sharing Disaster Damage and Loss Data: Towards the development of operational indicators to translate the Sendai Framework into action,* "JRC Science and Policy Report" 2015.
13. *Guide Brief 13 – Resilience Gaps - Identifying and Prioritizing - Closure of Resilience Gaps*, "NIST Special Publication 1190GB-13" 2017, https://doi.org/10.6028/NIST.SP.1190GB-13.
14. *Guiding and Tailoring Risk Assessment for the Baltic Sea Region. Red Book Two*, www.14point3.eu, 2013.
15. Halsnes K., Kaspersen P.S., *Decomposing the cascade of uncertainty in risk assessments for urban flooding reflecting critical decision-making issues*, "Climatic Change" 2018, 151, pp. 491–506, https://doi.org/10.1007/s10584-018-2323-y.
16. Kwok A.H., Paton D., Becker J., Hudson-Doyle E., Johnston D., *A bottom-up to developing a neighbourhood-based resilience measurement framework*, "Disaster Prevention and Management" 2018, Vol. 27, No. 2, pp. 255-270.
17. *Manual for Risk Analysis for Civil Protection. A stress test for general hazard prevention and disaster management*, "Civil Protection Practice" 2015, Vol. 16, Germany.

18. Miles A., Keenan M., *Practical guide to Regional Foresight in the United Kingdom*, European Commission, Luxembourg 2002.
19. *National climate change vulnerability and risk assessments in Europe*, EEA Report No 1/2018, European Environment Agency, Denmark.
20. *National Risk Profile for Denmark*, Danish Emergency Management Agency, Denmark 2018.
21. Paton D., Johnston D., *Disaster Resilience: An integrated Approach*, 2nd ed., Ch.C. Thomas, Springfield 2017.
22. Pescaroli G., Alexander D., *A definition of cascading disasters and cascading effects: Going beyond the "toppling dominos" metaphor*", "Planet and Risk " 2015, Vol. 3 No 1.
23. Preston B.L., *Assessing and Managing Climate Change Risk*, Climate Change Science Institute at Oak Ridge National Laboratory, Bonn, Germany 2014.
24. *Risk Assessment and Mapping Guidelines for Disaster Management,* European Commission staff working paper, 21.12.2010 SEC (2010) 1626 final, Brussels.
25. Salim W. et. al., *Guidelines for Risk and Adaptation Assessment and for Mainstreaming into Policy*, Ministry of Environment, Jakarta 2012, p. 6.
26. *Sendai Framework for Disaster Risk Reduction 2015 -2030*, UNISDR/GE/2015 – ICLUX EN5000 1st edition, United Nations, Geneva 2015.
27. *The Baltic Sea Region Methodology For Risk And Capability Assessment – A First Approach,* edited by: Karlsson B., Olsson A. J. and Riedel M., 2017.
28. *Threat and Hazard Identification and Risk Assessment Guide. Comprehensive Preparedness Guide (CPG)*, Homeland Security, Second Edition, 2013.
29. Tilley F., Fuller T., *Foresighting methods and their role in researching small firms and sustainability*, "Futures" 2000, 32, No 2.
30. Zwęgliński T., Balatonyi L., Impact of climate change on Hungarian Water Management Strategy as a case study for other European countries, "Zeszyty Naukowe SGSP" 2021, 78, pp. 127–150.
31. www.cunnart.com, 2013.
32. http://cca.eionet.europa.eu, 2019.