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GENERAL RISK THEORY

Abstract: We all face risks of some sort, as individuals, businesses and society. We need to understand, describe, analyse, manage and communicate these risks, and the discipline of risk assessment and risk management has been developed to meet this need. This discipline is growing rapidly and there is an enormous drive and enthusiasm to implement risk assessment methods and risk management in organizations. The analysis and management of risk are not straightforward, there are many challenges. Also, whole field, with many concepts and philosophies, approaches and methods contributes to confusion and often misunderstandings between experts and society. This lecture is dedicated to general concepts and definitions in the field of risk theory.

Key words: risk, hazard, risk assessment

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1. DEFINITIONS

1.1. Hazard and risk

There is a large number of definitions of the terms "hazard" and "risk". This is a consequence of different directions from which people approach risk areas, different philosophies, as well as various experiences in this relatively young scientific field. It could be said that every area of human activity that uses methods of risk assessment and management has its own definitions, and often every author who writes about the hazard and risk area has its own definition (again, depending on the background).

These are some of the definitions of „hazard“:

- „A Hazard is a potential source of harm or adverse health effect on a person or persons.“
- „A hazard is any agent that can cause harm or damage to humans, property, or the environment.“
- „A hazard is something that can cause harm, e.g. electricity, chemicals, working up a ladder, noise, a keyboard, a bully at work, stress etc.“,

, and some of the definitions of the term "risk" that can be found in the literature:

- „Risk is the likelihood that a person may be harmed or suffers adverse health effects if exposed to a hazard.“
- „Risk is the possibility of losing something of value.“
- „A risk is the chance, high or low, that any hazard will actually cause somebody harm.“
- „In daily conversation risk is a rather common notion used interchangeably with words like chance, likelihood and probability to indicate that people are uncertain about the state of the activity, item or issue under consideration.“

It is extremely important to distinguish between the meaning of the terms "hazard" and "risk", which are often mixed or considered as terms that describe the same phenomenon, sometimes even in a serious public conversation.

Figure 1 – Difference between a „hazard“ and a „risk“

1.1.1. Concept of hazard

Hazards can be dormant or potential, with only a theoretical probability of harm. An event that is caused by interaction with a hazard is called an incident.

Hazards can be classified as different types in several ways.

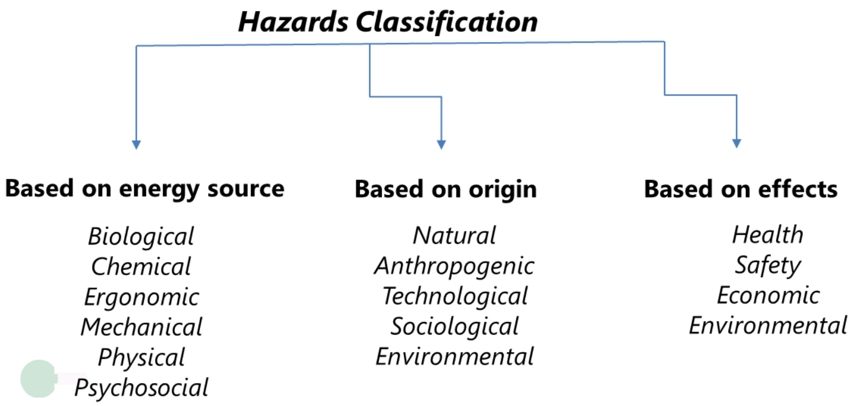

Figure 2 – Hazards classifications

The first level of protection is the possibility of physical elimination of hazard, and if this is not possible, hazard control measures are used. Hierarchy of hazard control is a system used in industry to minimize or eliminate exposure to hazards. Control methods at the top of figure 3 are potentially more effective and protective than those at the bottom. Following this hierarchy normally leads to the implementation of inherently safer systems, where the risk of illness or injury has been substantially reduced.

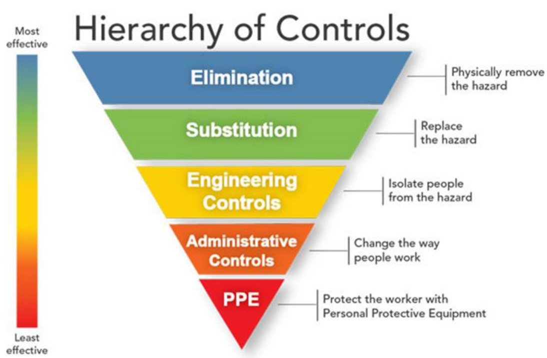

Figure 3 – Hierarchy of hazard control (NIOSH, 2015)

1.1.2. Concept of risk

Evaluation of the risk of technical systems is developing relatively late in relation to other areas (start of industrial era - 30th year). The first analyzes were about the lifetime of ball bearings in the railway (beginning of the 20th century). From that time there is a story about base principle: the strength of the chain is the same as the strength of the weakest link.

To do qualification and quantification of some risk, we need mathematical basis. Quantitative analysis involves some formal methods, like probability of event, statistics etc. and different mathematical tools and concepts.

One of the first mathematical concepts used was expected value. It is obtained by multiplying each possible outcome with the associated probability, and summing over all possible outcomes. Average value converges to the expected value when the number of experiments goes to infinity. The expected value is a key concept in risk analysis and risk management. It is common to express risk by expected values. But, in real life risk is more than calculated numbers. Risk acceptability and tolerability cannot be defined based on risk assessments alone. A balance has to be struck between different concerns, like social, cultural, economical etc. It is impossible to restrict the risk evaluation to simple comparisons between numbers. Uncertainties beyond the probabilities need to be taken into account.

Perspective risk = uncertainty is most common in business contexts. Risk refers to uncertainty of outcome, actions and events. The idea that risk equals uncertainty seems to be based on the assumption that the expected value is the point of reference and that it is known or fixed. Risk does not exist independently of the assessor, as the uncertainties are somebody's uncertainties.

Another often considered approach is risk = event. Risk is a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain (risk = event or aconsequence of an event).

1.1.3. Different approaches to risk

Two perspectives are evident in considering approaches to risk. First, discipline-based (Althaus, 2004, 2005; Aven & Kristensen, 2005), and second, model-based (Renn, 1992; af Wåhlberg, 2001; Renn & Klinke, 2002).

These four basic approaches, each originating from an independent disciplinary tradition:

- Technic
- Economic
- Cultural

- Psychrometric

In addition to basic, there are also concepts of meta-approaches, like political, socio-emotional, adaption and evolutionary.

The different approaches to risk illustrate the multifaceted nature of risk and emphasize the need to take a multidisciplinary approach to understanding and managing risk.

2. RISK ASSESSMENT

After the hazard is detected, risk assessment takes place. Risk assessment consists of an objective evaluation of risk in which assumptions and uncertainties are clearly considered and presented.

The risk assessment consists of several steps:

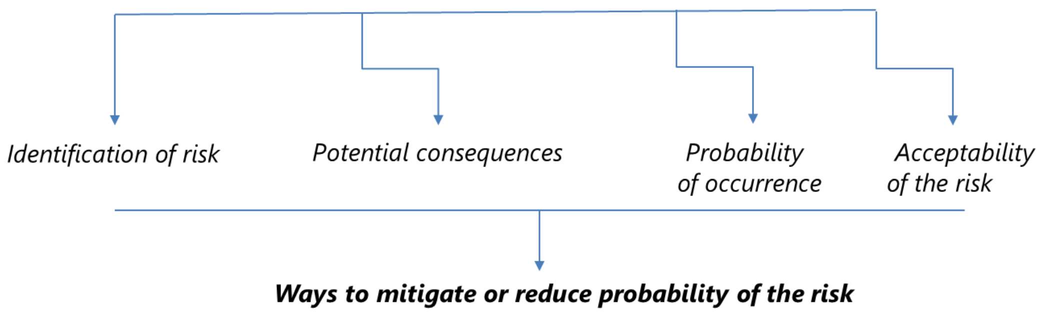

Figure 4 – Risk assessment steps

Risk identification is not always an easy and simple procedure, and is crucial for the quality of risk assessment. It is necessary to know the problem for which the risk assessment is carried out. The possible difficulties best illustrate the following simple example from everyday life:

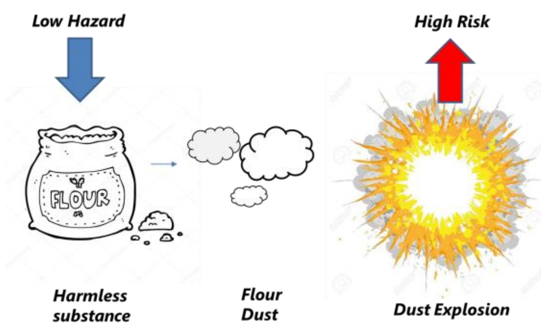

Figure 5 – Identification of hazard

Flour would not be considered from many to be a hazardous substance. Many of us using it every day. However, if the flour is raised and mixed with air in a certain proportion, it will become explosively dangerous, with possible devastating consequences if the explosion occurs. In this way, a harmless substance under certain conditions becomes a high risk substance.

All this leads to the conclusion that risk assessment is a mandated science. Neither pure science nor pure public policy, risk assessment reports are a hybrid of both. The result of the risk assessment process is a document, also termed a risk assessment, which presents risk findings and describes how they were generated.

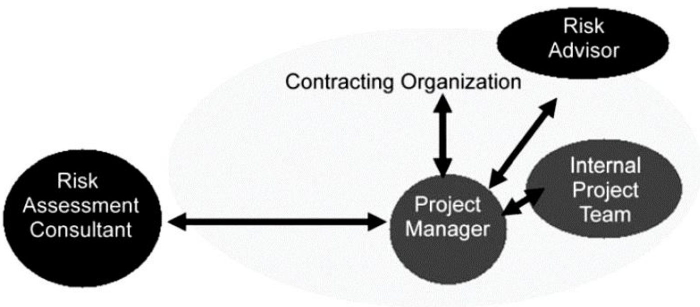

Figure67 – Structure of risk assessment project management

Although experts approach risk management processes from different aspects of human activity, the basic principles of the process itself do not usually differ. The general algorithm of the risk management process is shown in the following figure.

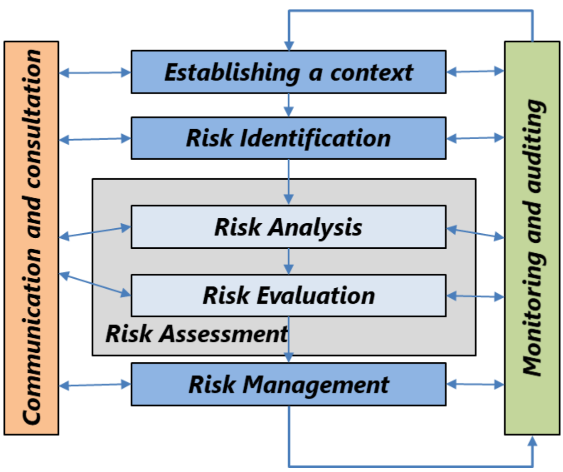

Figure 7 – Structure of risk management process

2.1. Environmental Risk assessment

Disaster risk management is a complex and multidisciplinary problem, involving the engagement of technical disciplines as well as social, economic and other expertise. As an example, we will look at the management of environmental risks as an important segment of disaster risk management.

Environmental risk assessment is an organized process used to describe and estimate the likelihood of adverse health outcomes from environmental exposures to chemicals. Steps of (environmental) risk assessment:

- hazard identification,
- dose-response assessment and categorization,
- prevention, control and reduction,
- avoiding unacceptable,
- intervent response,
- risk transfer (insurance).

At the end of the process, one question always arises: What are we managing? (or what we can manage at all?). These are probability and consequences of the realization of hazards. Disaster risk management is close related to natural hazards an dynamics of catastrophic events. Some events take place very quickly (earthquakes, explosions ...) while others last for a longer period of time and leave more time to manage. This will greatly determine the methods and possibilities for risk management.

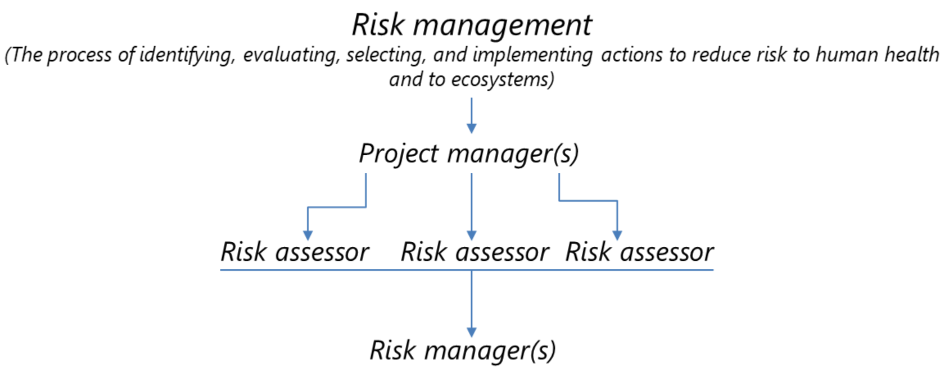

Figure 8 – Structure of project management

The goal of risk management is scientifically sound, cost-effective, integrated actions that reduce or prevent risks, while taking into account social, cultural, ethical, political, and legal considerations.

The extent to which this area is considered important in the preservation of human lives, health, property and the environment is best illustrated by the fact that the International Organization for Standardization has defined the whole field roughly through ISO 31000: Risk Management - Principles and Guidelines on Implementation.

2.2. Metodology of risk assessment and management

Today we have many methods of risk assessment and management. Most of them are of a general nature, and are applicable to the analysis of all types of risks, but there are also specially developed methods for specific conditions. These are some of the most used:

1. Preliminary (Process) Hazard Analysis (PHA),
2. Hazard and operability study (HAZOP)
3. Failure mode and effects (FMEA)
4. Human Reliability Analysis (HRA)
5. Probabilistic Safety Analysis (PSA)
6. Tasks Analysis (TA)
7. Human Error Identification (HEI)
8. Human Reliability Quantification (HRQ)
9. Job Hazard Analysis (JHA)
10. Failure mode and effects analysis (FMEA),
11. Event tree analysis (ETA),
12. Fault tree analysis (FTA),
13. Fault Modeling, Analysis of Effects and Critical Conditions
14. Consequences Modeling
15. Block Reliability Diagram
16. Comparative Analysis
17. Simulations
19. Empirical Analysis
20. Delphi methods etc.

Preliminary (Process) Hazard Analysis is a simple and fast method, through which the way of functioning of risk assessment can easily be demonstrated. The basis is the establishment of a risk matrix (Probability of occurrence x Consequences), and the categorization of the calculated risks according to this matrix.

Table 1- Preliminary (Process) Hazard Analysis risk matrix

Probability of occurrence	**Consequences**				
	Insignificant 1	Low 2	Medial 3	Significant 4	Catastrophic 5
A	H	H	E	E	E
B	M	H	H	E	E
C	L	M	H	E	E
D	L	L	M	H	E
E	L	L	M	H	H

E – Exrtreme Risk = need to act immediately
H – High Risk = need careful management
M – Significant Risk = management responsibilities must be specified
L – Low Risk = managing the usual procedures

The application of the risk assessment methodology will be presented in two short examples.

2.2.1. Example No. 1: Wild Landfills

This study has examined the environmental risk assessment associated with unregulated landfill sites in the Albert Luthuli municipality, in one South African province. The determination of the environmental risk was achieved by the use of questionnaire surveys and landfill analysis forms in selected study areas.

Figure 9 – 3 wild landfills in study area

The findings have highlighted a very high environmental risk, nearly four times and above, the threshold limits set by the authorities for all of the landfill sites examined. Several exposure pathways stemming from associated environmental impacts have also been identified for the study. The higher environmental risk determined for the problem sites is ascribed to numerous factors, including their ill-planned location, the sensitivity and vulnerability of the natural environment and adjacent rural settlements, the lack of appropriate waste pre-treatment processes prior to disposal, and most significantly, the lack of regulatory and control measures to contain the myriad of environmental problems generated.

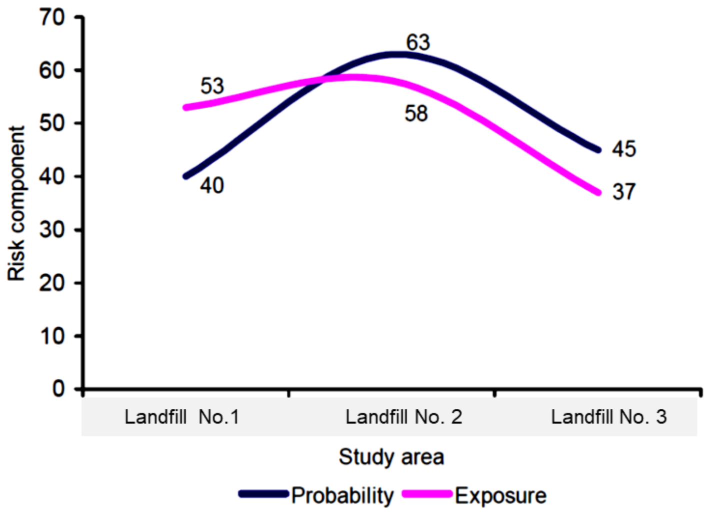

Figure 10 – Public perceptions on the probability of the various exposure pathways

Environmental risk can be estimated by multiplying the frequency of exposures by the severity of environmental impacts. This relationship or formula is illustrated as follows:

Environmental risk = Frequency of exposures x Severity of environmental impacts

The data analysed in the current study was used to determine frequencies or the number of exposures as well as the percentages characterising the severity of associated environmental impacts. The occurrences of *exposure pathways* were calculated through an examination of the number of all instances that have potential to cause environmental hazards per study area. These instances were determined by analysing the data on the completed questionnaires.

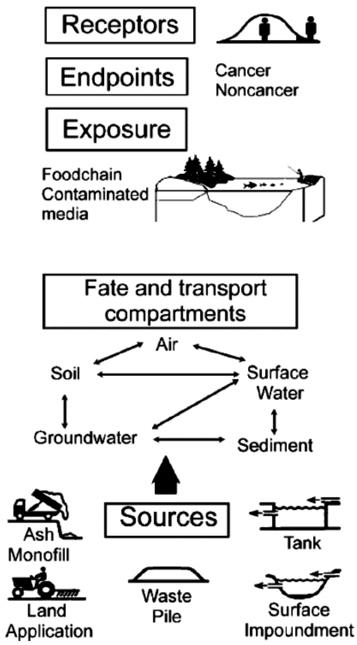

Figure 11 – Standard environmental exposure pathways

Risk probability was determined by analysing questionnaire responses which dealt with aspects such as the proximity of residential households and water bodies to landfill sites, the consumption of discarded food by reclaimers, the percentage of respondents relying on water from contaminated streams, the potential for the bio-accumulation of hazardous substances in living organisms as well as along food webs, and the frequency of personal injuries commonly associated with the problem landfill sites.

Table 2- Quantitative risk assessment

Landfill No.	Calculation	Assessment
1	40 x 53 = 2120	Extreme Risk
2	63 x 58 = 3654	Extreme Risk
3	45 x 37 = 1165	High Risk
Formula R = F x S	F = Frequency or Probability	S = Severity

In conclusion, it is recommended that several measures (including closure) should be taken in order to reduce and contain the magnitude of environmental risks involved.

2.2.2. Example No. 2: Flood Risk management

Flood risk is the product of hazard, i.e. the physical and statistical aspects of the actual flooding (e.g. return period of the flood, extent and depth of inundation, and flow velocity), and the vulnerability, i.e. the exposure of people and assets to floods and the susceptibility of the elements at risk to suffer from flood damage. (EU Floods Directive (2007).

The example presents a case study on flood hazard and flood risk assessment at the local spatial scale using geographic information systems, remote sensing, and hydraulic modelling. As for determining flood hazard in the model area, which has 3.23 km^2 (catchment of Vycoma stream, approx. 99.9 km^2, which is located in the Nitra River Basin in Slovakia), the estimation of maximum flood discharges and hydraulic modelling were important steps.

1. Determination of flood intensity

$$FI = \begin{Bmatrix} 0 \rightarrow d = 0\ \text{m} \\ d \rightarrow d > 0\ \text{m},\ v \leq 1\ \text{m/s} \\ d.v \rightarrow v > 1\ \text{m/s} \end{Bmatrix} \qquad (1)$$

Meteorological, hydrological, and hydraulic investigations to define the hazard and estimation of flood impact to define the vulnerability can be performed separately in the first place, but have to be combined for the final risk analysis.

Today, this kind of analysis required the application of different data or specialized software.

Figure 12 – Land use in the model area

2. Determination of flood hazard

Flood intensity (FI)	Hazard categories	Description
FI > 1	High	It is recommended not to allow new or extend existing buildings in which people or animals live. For existing buildings, it is necessary to implement the design of flood protection measures to ensure adequate risk mitigation or to process program of relocation of these buildings.
0.3 < FI ≤ 1	Medium	Construction is possible with restrictions which are based on a detailed assessment of the necessity of object functions in the endangered area and from the potential flood hazard of these objects. Improper is the construction of sensitive objects. It is not recommended to extend existing areas which are intended for construction.
FI ≤ 0.3	Low	Construction is possible, but the owners of the land and buildings should be warned about the potential flood hazard. For sensitive objects, it is necessary to adopt special measures e.g. in terms of crisis management.

Figure 13 – Classification of flood hazard categories (modified according to Drbal et al. 2009).

3. Determination of vulnerability and determination of flood risk

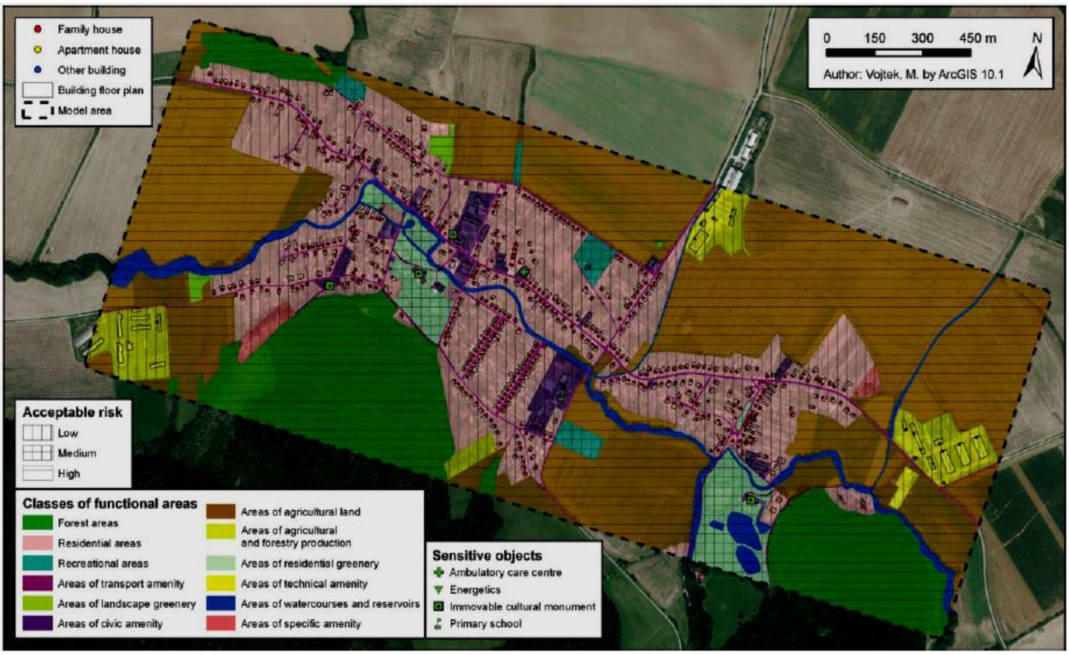

Figure 14 – Vulnerability map of the model area

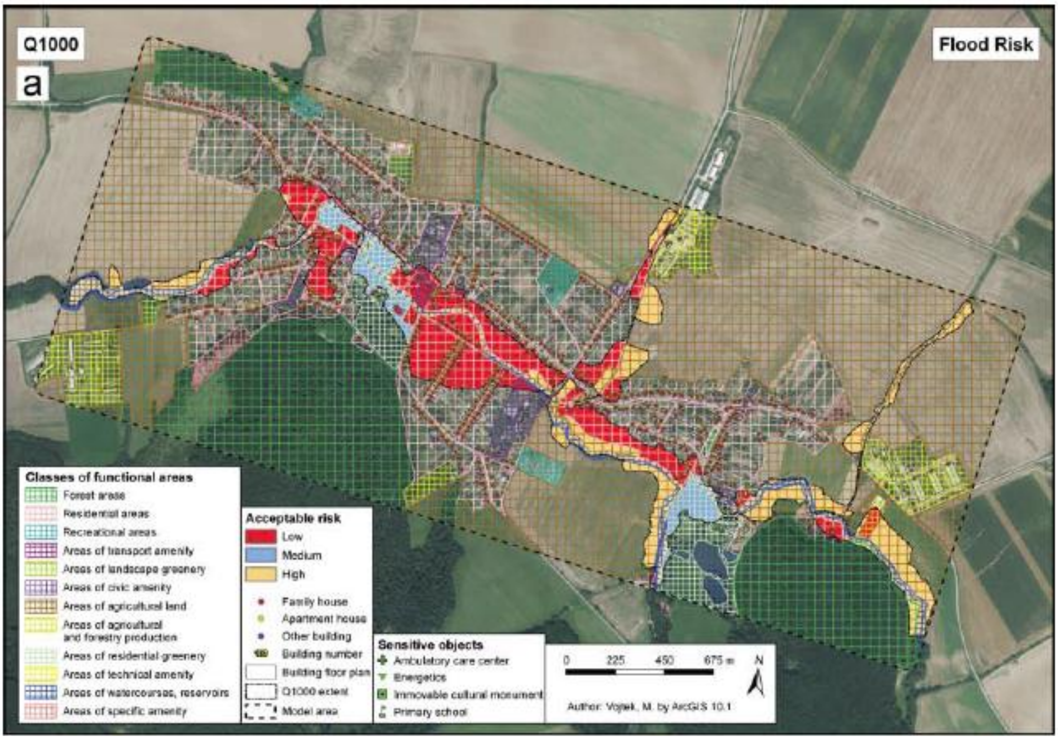

Figure 15 – Flood risk in the model area

3. CONCLUSIONS

- Acceptable Risk (safety) level - technical & „political“ decision
- Risk and Percepcion of Risk are not always in line
- What are the effects of risk management?

It is possible to find out only if we do not manage the risks - the results can be difficult to measure and prove.

- What is the price of risk management?

The best answer is another question: what is the cost of non-risk management?

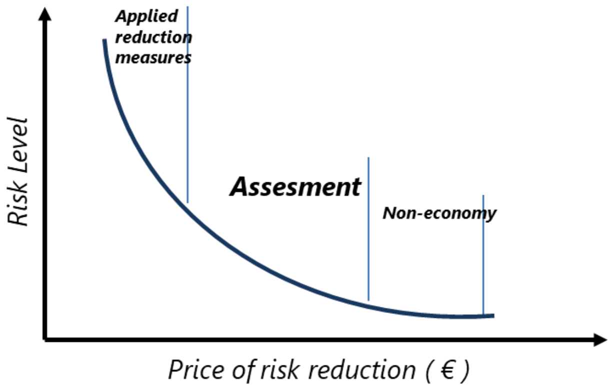

Figure 16 – Price of risk management

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REVIEW QUESTIONS?

1. Explani the difference between terms „hazard“ and „risk“?
2. How can hazards be classified?
3. What are the basic approaches to risk?
4. Explain the risk assessment process?
5. What are the most used risk assessment methods?