Chapter 2
Risk Analysis in Impact Assessment

While there are some studies in the literature considering risk analysis in construction projects (Zavadskas et al. 2010), studies of risk analysis regarding water management constructions, especially assessment of flood protection structures (FPS), are very limited. In classical project risk-analysis techniques, risk-rating values are calculated by multiplying probability and impact values, but direct analysis of the linguistic factors involved is often neglected (Dikmen et al. 2007). This book introduces a new approach to risk assessment of activities in water management (FPS projects) using risk analysis.

Various approaches for integrating risk analysis into the EIA process have been suggested (e.g., Kwiatkowski 1998; AGIP KCO 2004; Demidova and Cherp 2005; and Catchpole and Moreno 2012). Despite its growing acceptance, no reference has been found in the present study to its use in EIA applied to FPS worldwide. The applicability of risk analysis in the Slovakian EIA system has also yet to be tested. In our opinion this country could benefit from trying out the risk-analysis method, and we understand the importance of providing examples of its application. At the same time though, the risk-analysis technique must conform to the general impact-assessment approach on which the Slovakian EIA system is abused.

This chapter describes the design adopted by this research to achieve the aims and objectives stated in the introduction. Section 2.1 discusses the methodology to be used in the study, the stages by which the methodology will be implemented, and the research design; Sect. 2.2 gives details of establishing the context of the study; Sect. 2.3 describes the risk-analysis method used in the study; and Sect. 2.4 outlines the procedure used for decision-making.

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2.1 Methodology and Research Design

2.1.1 Methodology

Floods are the most frequent natural disaster worldwide and a major natural hazard in Europe in terms of social and economic impacts. In the last 15 years, Europe has suffered over 100 major damaging floods which have caused, in total, more than 1000 casualties, affected more than 3.4 million people, about half a million of whom have been displaced, and at least € 25 billion in insured economic losses. Additionally, floods cause important environmental impacts since they seriously affect the quality of water sources and can distribute large amounts of sediments and pollutants (Papa and Torres 2012). The aim of this book is to develop a methodology for the analysis and evaluation of environmental impacts of proposed activities—flood protection structures using a risk-analysis method. The proposed methodology has been applied to one proposed flood protection structure (Zvijáková 2013). The application of developed methodology for the EIA process will produce indications for improvements, or for more effective implementation and performance of this process. The main objective of the book is to improve the course of the EIA process. More specifically, the methodology's objectives are to:

- establish the principles and methods of risk analysis in the EIA process,
- support the comparison of variants of the proposed activity on the basis of their evaluation through the concept of "risk", while strengthening the decision-making processes within the EIA process,
- increase knowledge on emerging risks and ensure their monitoring,
- create a new methodological approach applicable to the EIA process,
- enable interested parties to implement the proposed methodology consistently and effectively as part of assessment reports within the EIA process.

The authors have determined that a risk-based approach may be applied in the EIA process in Slovakia. It is assumed that this process will be applied during the scoping phases of the EIA and will include consideration of potential impacts of developments on the environment and humans.

To integrate risk analysis within EIA, it is appropriate that the criteria used within the EIA risk-based approach are consistent with the terminology and understandings used within the water-management sector.

This book provides a framework for the risk analysis component mainly of the scoping phase within the EIA process (see Fig. 2.1).

The proposed methodology consists of three stages, which includes a number of key elements and activities.

Element—the process of risk analysis according to the proposed methodology consists of four activities: creation of a set of risk factors (*A*–*Z*), determining the relative importance (weight) of the risk factors (w_i), creation of risk criteria for risk factors and determination of criterion scores (0.2–1.0).

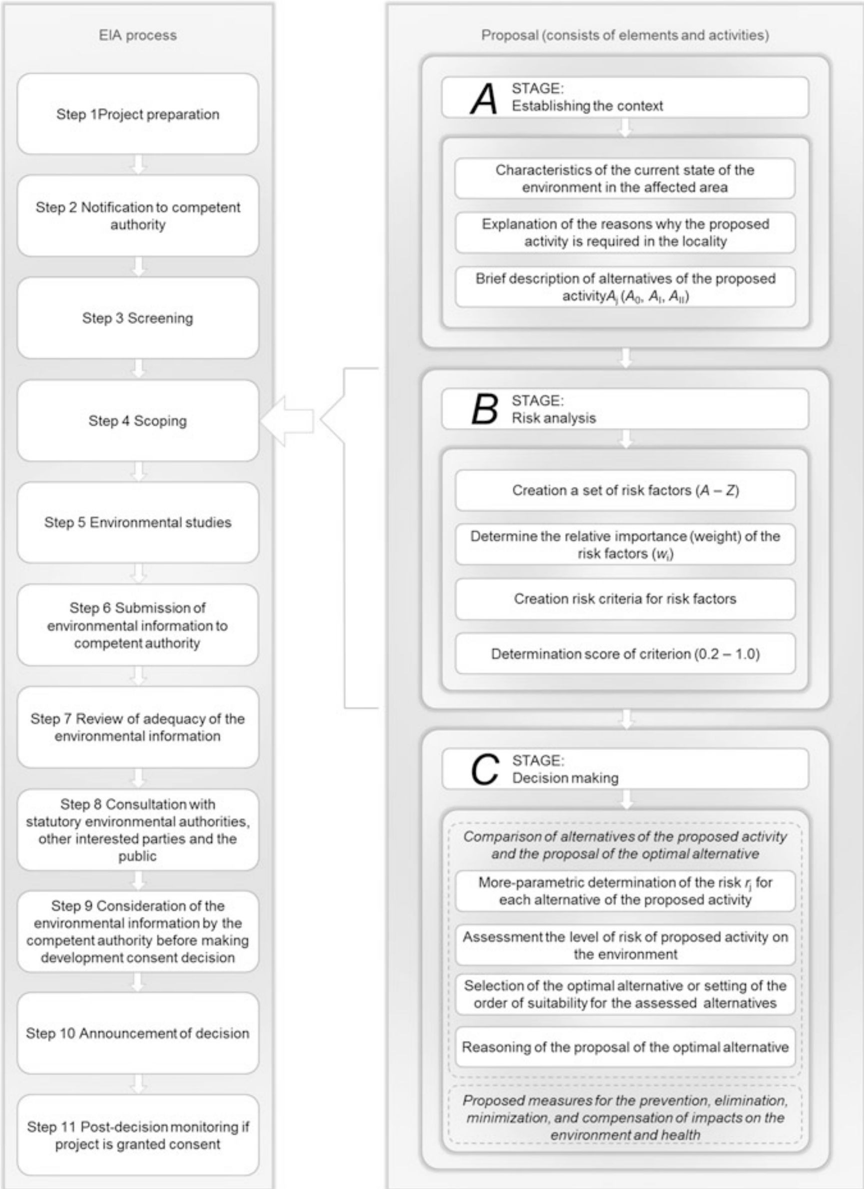


Fig. 2.1 Flow chart of the EIA process (EC 2001) and proposal methodology (Zvijáková 2013)—integration of risk analysis (RA) into the environmental impact assessment (EIA) process

Table 2.1 Proposed activity which is subject to EIA (National Council of the Slovak Republic)

Item no.	Activity, facilities and installations	Threshold values	
		Part A (compulsory assessment)	Part B (screening procedure)
7.	Flood protection objects		Without limit

2.1.2 Research Design

Environmental impact assessment of the proposed activity is a standard output within the responsibility of the proposer. Our methodical procedure introduces a quantitative approach which uses the method of risk analysis known as multi-parametric expression of risk. The role of the method is to unify the means of assessing the impacts of the proposed activity on the environment and the establishment of maximum standardized procedure for the selection of the most suitable variant of the activity and objectivization of the EIA process.

The proposed methodology of environmental impact assessment of flood protection structures is applicable for a specific type of activity.

According to Annex no. 8 to Law No. 24/2006 Coll. (National Council of the Slovak Republic 2005), flood protection structures are included in the list of proposed activities which are subject to EIA in field no 10: Water Management, whose departmental authority is the Ministry for the Environment of the Slovak Republic (see Table 2.1).

The basic principle of the methodology is to calculate the risk index, which is an estimation of the level of risk that flood protection structures may represent for the environment. Risk analysis is based on the principle that every construction, including flood-protection structures, not only by its technical character adversely affects the hydrological, morphological and geographical, ecological, archaeological/historical, and socio-economic characteristics of the area. Negative impacts can be quantified by calculating the risk index of flood-protection structures for the environment.

The following section describes the different elements and activities of impact assessment of flood protection structures which are designed to achieve the objective of risk analysis.

2.2 Establishing the Context

The primary step in the initiation of the impact assessment of the proposed activity is a comprehensive understanding of the variants of the proposed activity. It is important to know the characteristics of the current state of the environment, which

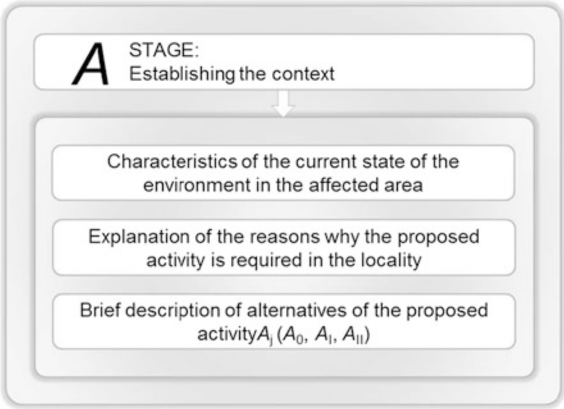


Fig. 2.2 The first stage of impacts assessment of the proposed activity and its activities

is the main task in defining the context. To complete this stage, it is necessary to perform the procedure as outlined in Fig. 2.2.

2.2.1 Characteristics of the Current State of the Environment in the Affected Area

For further steps in the procedure, it is necessary to know the current state of the environment in the area where the proposed activity is to be carried out.

The impact of the proposed activity on the environment is always limited to an area where the effects of the activity are immediately evident on site, which may be affected by visual, auditory, olfactory or other factors. Such an area is designated as the affected area.

Basic information about the present state of the environment in the affected area, according to Annex no. 9 to Slovakian Law No. 24/2006 Coll. (National Council of the Slovak Republic 2005), consists of the following:

- *"characteristics of the natural environment including protected areas [e.g., proposed protected bird areas, areas of European interest, coherent European network of protected areas (Natura 2000), national parks, protected landscape areas, protected water-management areas]";*
- *"landscape, landscape character, stability, protection, scenery";*
- *"population, its activities, infrastructure, cultural and historical values of the area";*
- *"current state of the quality of the environment including health".*

According to Annex no. 11 to Law No. 24/2006 Coll. in Slovakia, the description of the current state of the environment in the affected area consists of information regarding nineteen topics further specified in the attachment.

2.2.2 Explanation of the Reasons Why the Proposed Activity Is Required in the Locality

Another important step for the first stage of the evaluation process is the justification for the need of the proposed action, which is based on the aim of the proposed activity. It is necessary to know the reasons which have led to the planned activity and to understand its nature and the circumstances under which the activity can be performed.

2.2.3 Brief Description of Alternatives to the Proposed Activity A_j (A_0, A_I, A_{II})

The purpose of alternatives is "to find the most effective way of meeting the need and purpose of the proposal, either through enhancing the environmental benefits of the proposed activity and or through reducing or avoiding potentially significant negative impacts" (DEAT 2004).

Among the most important issues in the scoping phase of the EIA process is consideration of potential alternatives (DEAT 2002). Their significance is highlighted by Glasson et al. (1999) and by the Council of Environmental Quality (CEQ) in the United States, which describes the consideration of alternatives as the "heart" of EIA (CEQ 1978; Magness 1984). Considering alternatives is a critical aspect of the environmental-assessment process. Its purpose is to provide a framework for sound decision-making based on the principles of sustainable development (DEAT 2004).

Article 5(3d) of the EIA Directive requires the developer to include in the environmental information "*...an outline of the main alternatives studied by the developer and an indication of the main reasons for this choice, taking into account the environmental effects*".

Some EU member states have made consideration of alternatives a mandatory requirement for EIA, whilst others leave it to the developer to decide if alternatives are relevant to their project.

According to Section 22(3) of Law No. 24/2006, "*the preliminary environmental study must contain two alternatives of the proposed activity at least, as well as the zero alternative*". The zero alternative is the state that would remain if the proposed activity was not carried out.

According to Section 22(7) of Law No. 24/2006, "*the competent authority, on the request of the proponent, shall abstain from the requirement of an alternative solution of the proposed activity mainly in cases where no other locality is available or if no other technology for the proposed activity exists. If from the comments to the preliminary environmental study, submitted according to Section 23(5), the need to assess another real alternative of the proposed activity results, this fact will be taken into account in further proceedings according to this Law*".

Alternatives are substantially different manners in which the proponent can feasibly meet the project's objectives, for example by carrying out a different type of action, choosing an alternative location or adopting a different technology or design for the proposed project. Alternatives merge into mitigating measures where specific changes are made to the project design or to methods of construction or operation to avoid, reduce or mitigate environmental impacts (reduce significant adverse impacts).

DEAT (2004) presents the key criteria for identifying alternatives within projects when applying EIA to them. The various categories of alternatives that can be identified include: "activity alternatives; location alternatives; process alternatives; demand alternatives; scheduling alternatives; input alternatives; routing alternatives; site layout alternatives; scale alternatives; and design alternatives".

The "no project" (or zero) alternative must also be considered as the baseline against which the environmental impacts of the project should be considered. This may include changes from the present day situation as a result of other developments taking place in the vicinity and changes in environmental conditions of the study area.

The *Checklist on Alternatives and Mitigation* in Guidance on EIA Scoping (EC 2001) provides a useful list to consider when thinking about the different types of alternatives and mitigation which a developer should consider.

The key criteria for identifying appropriate alternatives are that they should be "practicable", "feasible", "relevant", "reasonable" and "viable". When a range of alternatives exists, it is necessary to identify which of them are applicable to the specific projects under consideration (DEAT 2004).

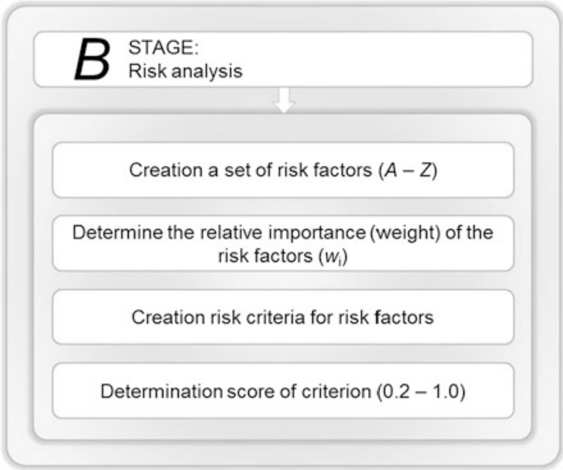
2.3 Risk Analysis

The effort to produce an empirical description of several factors simultaneously leads to multiparametric risk description (Tichý 2006). As stated in Sect. 1.2.4, this is one of the methods of risk analysis, and this book proposes an approach that uses this method. In this second phase, it is necessary to take the steps illustrated in Fig. 2.3 which is described briefly below.

2.3.1 Creation a Set of Risk Factors (A–Z)

Environmental parameters are indicators of impacts/effects of flood protection structures (Zeleňáková and Zvijáková 2012). The function of parameters is to enable relatively easily quantifiable measurement of the impact of the proposed activity on the environment. The proposed parameters are divided into five groups according to their character:

Fig. 2.3 The second stage of impact assessment of the proposed activity



- ***hydrological parameters***:

  A. maximum specific drainage;
  B. 100-year flow;
  C. designated flow;
  D. average annual rainfall;

- ***morphological and morphometric parameters***:

  E. forestation;
  F. coefficient of saturation in the basin;
  G. stream-flow character;
  H. average longitudinal-gradient flow;
  I. type of the basin;
  J. catchment area;
  K. soil type;
  L. slope of basin;

- ***ecological and historical parameters***:

  M. ecological significance of the area;
  N. vulnerability of protected species of fauna, flora and their biotopes;
  O. change to the landscape;
  P. cultural and historical importance of the territory;
  Q. vulnerability of archaeological and paleontological sites and important geological sites;

- ***territorial parameters***:

R. permanent population in the protected area;
S. coefficient of built-up area;
T. type and importance of transport;
U. infrastructure of villages;
V. production activity of the territory;
W. degree of environmental and human damage;
X. total cost of the proposed activity;

- ***technical parameters***:

Y. distance of the place of proposed-activity implementation from built-up areas;
Z. state of existing flood protection structures.

Twenty-six risk criteria have been identified and defined in this flood-mitigation-measures proposal, based on expert interviews, field studies and literature review. The proposed alphabet of parameters is used for the calculation of risk indices of the proposed construction or flood protection structure (Zeleňáková et al. 2012).

2.3.2 Determine the Relative Importance (Weight) of the Risk Factors (w_i)

In the set of parameters, not all elements of the set Pa_i have the same relative importance in relation to the particular problem under consideration. This relative significance or importance is simply referred to as a weight parameter w_i (Říha 2001). For a summary of recommended methods for determining the weights of parameters, the criteria are clearly stated for example in Říha (2001) or Křupka et al. (2012). This scale provides information about the relative social importance (impact) of individual parameters within a given set of Pa_i (*A*–*Z*).

To determine the relative importance (weight) of parameters, a survey was carried out involving twenty experts in water management and professionally qualified persons who have experience in the design and implementation of flood mitigation measures.

For the purposes of this work, a direct method of determining weights is used, based on the scoring method known as Metfessel allocation (Křupka et al. 2012). This assumes that the user is able to quantitatively evaluate the importance of the parameters relating to their impact on the environment. The user evaluates the *i*th parameter with value b_i, if it lies in the scale, e.g., b_i <0, 100>. The more important the parameter is, the higher its score is. While the scoring method requires the user to provide quantitative evaluation of indicators, it also allows for a more

Table 2.2 Determination of weight of parameters Pa_i (*A–Z*) using scoring

	$Pa_1 = A$	$Pa_2 = B$	$Pa_3 = C$	$Pa_4 = D$	$Pa_5 = E$	$Pa_6 = F$	$Pa_7 = G$
Points b_i	7	5	10	9	3	3	1
Weight w_i	0.07	0.05	0.10	0.09	0.03	0.03	0.01
	$Pa_8 = H$	$Pa_9 = I$	$PR_{10} = J$	$Pa_{11} = K$	$Pa_{12} = L$	$Pa_{13} = M$	$Pa_{14} = N$
Points b_i	3	2	1	1	3	2	2
Weight w_i	0.03	0.02	0.01	0.01	0.03	0.02	0.02
	$Pa_{15} = O$	$Pa_{16} = P$	$Pa_{17} = Q$	$Pa_{18} = R$	$Pa_{19} = S$	$Pa_{20} = T$	$Pa_{21} = U$
Points b_i	1	1	1	4	5	3	6
Weight w_i	0.01	0.01	0.01	0.04	0.05	0.03	0.06
	$Pa_{22} = V$	$Pa_{23} = W$	$Pa_{24} = X$	$Pa_{25} = Y$	$Pa_{26} = Z$		
Points b_i	4	10	4	6	9		
Weight w_i	0.04	0.10	0.04	0.06	0.09		

differentiated expression of subjective preferences than in, e.g., the ranking method. Table 2.2 lists examples of parameters evaluated by the authors according to the scoring scale <1, 10>. Calculation of weights is carried out using Eq. (2.1).

$$W_i = \frac{b_i}{\sum_{Pa=1}^{n} b_{Pa}},\ i = 1, 2, \ldots, n. \tag{2.1}$$

where: w_i weight assigned to each parameter, b_i—the number of assigned points, n—number of all considered parameters, Pa_i—parameter, i—index of the parameter, b_{Pa}—the total number of points assigned to all parameters.

The resulted weights, determined from experts` assessments, are obvious from Fig. 2.4.

Designated flow rates and state of flood protection structures are identified as the most important parameters related to the assessment of flood protection facilities.

2.3.3 Creation of Risk Criteria for Risk Factors

Each parameter (*A–Z*) then has a designated criterion for risk analysis (Table 2.3), divided into five levels. Each level of criterion has a score assigned (0.2, 0.4, 0.6, 0.8 and 1.0), which is entered into the calculation of risk indices.

These risk criteria were defined based on field studies and basic hydrological knowledge and experience as well as resources (Dub and Nemec 1969; Mosný 2002; Zvijáková 2012). Annex A for each parameter Pa_i (*A–Z*) presents the characterization of its determination.

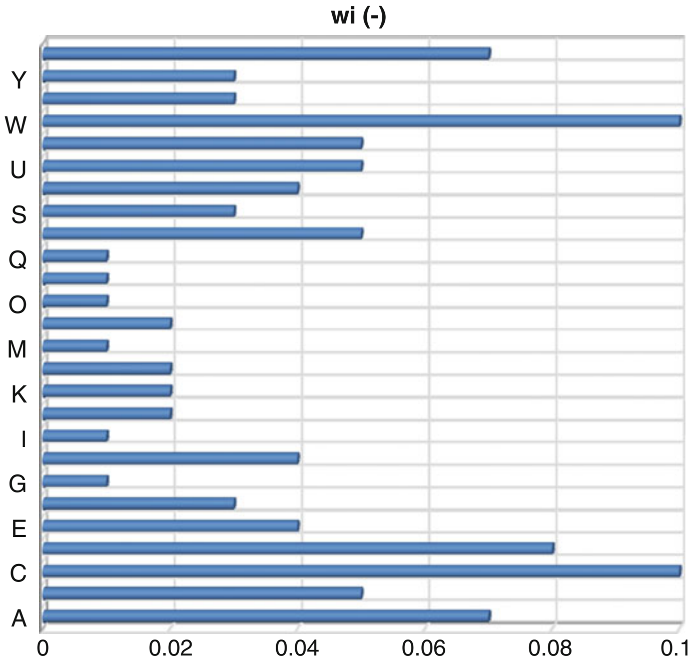


Fig. 2.4 Allocation of weights (w_i) to each parameter Pa_i (*A*–*Z*)

2.3.4 Determination Score of Criterion (0.2–1.0)

Allocation of scores for each of the proposed parameters is performed in the application of the proposed methodology for a specific proposed activity. The assessor assigns one score SPa_i (0.2, 0.4, 0.6, 0.8 and 1.0) for each parameter Pa_i (*A*–*Z*) based on Table 2.3.

2.4 Decision-Making

The aim of this step is to determine the average summation risk parameter $ASRP_j$ and average weighted summation risk parameter $AWSRP_j$ for each variant of the activity on the basis of all the allocated scores that reflect environmental impacts of the proposed activity. The risk category of the proposed activity, which determines the size of the risk that the activity poses to the environment, can be classified based on $ASRP_j$ and $AWSRP_j$. By comparing these risk parameters, it is then possible to compare the variants of the proposed construction/activity. To achieve this objective, it is necessary to make some important steps, which are shown in Fig. 2.5.

Table 2.3 Evaluation criteria of risk parameters linked with flood-protection structures

Parameter Pa_i		Score of parameter SPa_i				
		0.2	0.4	0.6	0.8	1.0
A	Maximum specific runoff q_{max} (m^3 s^{-1} km^{-2})	≤ 10	11–50	51–90	91–140	≥ 141
B	100-year discharge Q_{100} (m^3 s^{-1})	≤ 20	21–70	71–120	121–200	≥ 201
C	Design discharge Q_n (m^3 s^{-1})	$\geq Q_{100}$	$<Q_{100}$	$<Q_{50}$	$<Q_{20}$	$\leq Q_5$
D	Average annual precipitation H_z (mm)	≤ 500	501–600	601–700	701–800	>801
E	Forestation l (%)	100–80	79–60	59–40	39–20	19–0
F	Coefficient of basin saturation S (mm)	≥ 21	16–20	11–15	6–10	≤ 5
G	Character of water course (−)	Stream	Torrent	Middle torrent	Strong torrent	Very strong
H	Average longitudinal slope of the stream i_t (%)	<2	2–5	6–10	11–15	>15
I	Type of the basin (−)	–	Elongated	Transitional	Feathery	–
J	Catchment area S_p (km^2)	≤ 10	11–30	31–60	61–90	≥ 91
K	Soil type (−)	Sandy	Clay-sand, sand-clay	Loam	Clay-loam	Clay
L	Slope of the basin i_s (%)	<2	2–5	6–10	11–15	>15
M	Ecological significance of the area (−)	Very low	Low	High	Very high	Extremely high

(continued)

Table 2.3 (continued)

Parameter Pa_i		Score of parameter SPa_i				
		0.2	0.4	0.6	0.8	1.0
N	Vulnerability of protected species of fauna, flora and their biotopes (n)	0–1	2	3	4	≥ 5
O	Change of the landscape (−)	Preserved harmonic landscape, without disturbing elements (current assessment)	Impact of project on future appearance and character of landscape is not disturbing (preventive assessment)	Impact of project on landscape creates risk of negative impact (preventive assessment)	Presence of symptoms and disturbing elements in landscape (current assessment)	Degradation of landscape
P	Cultural and historical significance of the area (−)	No	Regional	National	National and sup-regional	International and national
Q	Vulnerability of archaeological and paleontological sites and important geological sites (n)	0	1	2	3	≥ 4
R	Permanently resident population in the protected area (n)	<100	101–250	251–500	501–1000	>1000
S	Coefficient of built-up area (−)	≤ 0.02	0.021–0.025	0.026–0.03	0.031–0.035	>0.035
T	Type and importance of transport (point)	≤ 1	2	3	4	≥ 5

(continued)

Table 2.3 (continued)

Parameter Pa_i		Score of parameter SPa_i				
		0.2	0.4	0.6	0.8	1.0
U	Infrastructure of the area (point)	0–1	2–3	4–5	6–7	8
V	Production activity in the area (point)	0–2	4	6	8	10
W	Degree of environmental and human damages (−)	Significant losses of property and human life are not expected	Loss of human life and environmental damage is insignificant	Loss of human life and damage to the environment is unlikely	Loss of human life and damage to the environment is likely	Significant losses of property and human life are expected
X	Total cost of the proposed activity (EUR)	0–100 000	100,001–400,000	400,001–800,000	800,001–1,200,000	>1,200,000
Y	Distance of the place of proposed activity implementation from built-up areas (km)	≥ 0.501	0.101–0.500	0.051–0.100	0.011–0.050	≤ 0.010
Z	State of flood protection objects (−)	Construction of a polder and stabilization of the stream	Regulation and stabilization of the stream in an urban zone	Ensure the regulation of runoff water and flow capacity in the stream	Maintenance of the river basin, the river bed and riparian vegetation	No technical flood protection measures are implemented

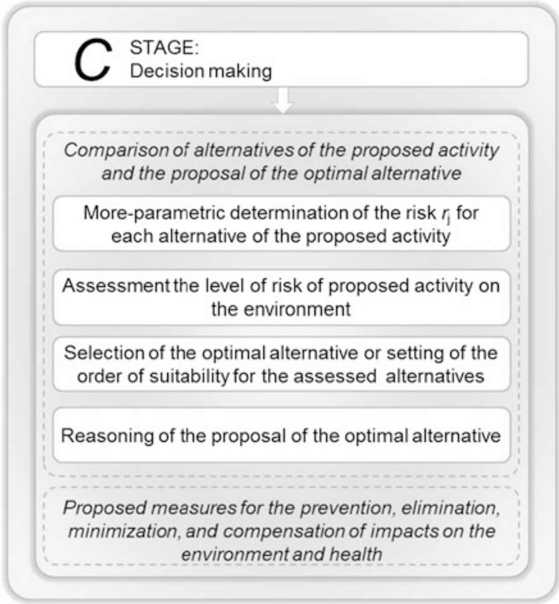


Fig. 2.5 The third stage of impact assessment of the proposed activity

2.4.1 Comparison of Alternatives of the Proposed Activity and the Proposal of the Optimal Alternative

For this step, it is necessary to perform the following four tasks.

2.4.1.1 Multiparametric Determination of the Risk r_j for Each Alternative of the Proposed Activity

The project involving construction of flood-protection structures has designated risk indices based on multiparametric risk determination as follows:

- average summation risk parameter $ASRP_j$ is calculated according to:

$$ASRP_j = \frac{\sum_{i=1}^{n} Pa_i}{n} \tag{2.2}$$

- average weighted summation risk parameter $AWSRP_j$ is calculated as follows:

$$AWSRP_j = \frac{\sum_{i=1}^{n} Pa_i w_i}{\sum_{i=1}^{n} w_i} \tag{2.3}$$

where: $ASRP_j$ is the average summation risk parameter of assessed variant (−), $AWSRP_j$ is average weighted summation risk parameter, SPa_i is assigned score (0.2, 0.4, 0.6, 0.8 or 1.0) for each assessed variant (−), n is the number of all considered parameters (−), w_i is the weight assigned to each parameter (−).

2.4.1.2 Assessing the Level of Risk of the Proposed Activity for the Environment

Both the calculated risk parameters of the activity express the level of risk that the proposed activity or assessed variant presents for the environment.

According to the numerical values $ASRP_j$ and $AWSRP_j$, which are calculated using Eqs. (2.1) and (2.2), the different variants of the proposed activity for flood protection are classified into one of the categories according to Table 2.4.

The lower the category of the proposed implementation of water-management project or flood-protection structure, the more risky the activity is for the environment, and the higher is the level of risk of the proposed activity.

2.4.1.3 Selection of the Optimal Alternative or Setting of the Order of Suitability for the Assessed Alternatives

The order of suitability of assessed alternatives of the proposed activity is determined by calculating the average summation risk parameter $ASRP_j$ and average weighted summation risk parameter $AWSRP_j$. The ranking reflects what level of risk the assessed variant represents for the environment. This means that the worst case scenario can be implemented, although that is the least suitable in terms of its possible negative effects on the environment.

2.4.1.4 Reasoning of the Proposal of the Optimal Alternative

Determination of the values of the average summation risk parameter $ASRP_j$ and average weighted summation risk parameter $AWSRP_j$ for assessing the category of the proposed activity is directly related to comparing variants of the proposed action. The optimal variant is then identified on the basis of the lowest levels of $ASRP_j$ a $AWSRP_j$. This choice is justified in terms of expected impacts on the environment.

Table 2.4 Categorization of water structures on the basis of multiparametric risk determination

$ASRP_j(-)/AWSRP_j(-)$	Category of the activity	The level of the risk of the proposed activity for the environment
0.2–0.4	IV.	Very low
0.41–0.6	III.	Low
0.61–0.8	II.	Medium
0.81–1	I.	High

2.4.2 *Proposed Measures for the Prevention, Elimination, Minimization, and Compensation of Impacts on the Environment and Health*

The task of this step is to propose measures to mitigate the adverse effects of the optimal variant of the proposed activity on the environment.

Article 5(3b) of the EIA Directive requires the developer to include in the environmental information "*…a description of the measures envisaged in order to avoid, reduce and, if possible, remedy significant adverse effects*".

According to Annex no. 11 to Law No. 24/2006 Coll., the measures can be divided into:

- territorial planning measures (e.g., need of harmonization with valid territorial planning documentation, recommendation of change and amendment of valid territorial-planning documentation etc.);
- technical measures (e.g., changes in technology, raw materials, the construction timetable, revitalisation of the area, salvage survey);
- technological measures;
- organization and operation measures;
- other measures (e.g., expected induced investments);
- statement concerning the technical and economic feasibility of the measures.

The proposal of measures to mitigate the adverse impacts of the proposed activity on the environment is an integral part of the methodology, as well as post-project analysis conducted within the EIA process.

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