RAIN PROJECT

Security Sensitivity Committee Deliverable Evaluation

Deliverable Reference	**D 3.2**
Deliverable Name	**Defining critical land transport infrastructure protection methods**
Contributing Partners	**UNIZA**
Date of Submission	**December 2015**

The evaluation is:

- **The content is not related to general project management**
- **The content is not related to general outcomes as dissemination and communication**
- **The content is related to critical infrastructure vulnerability or sensitivity**
- **The content is publicly available or commonly known**
- **The content does not add new vulnerabilities, sensitivities or incidents scenarios on specific objects or transport systems**
- **The content does not add new information on vulnerabilities, sensitivities or incident scenario's in general**
- **There are no uncertainties that might lead to contact the National Security Authority**

Diagram path 1-2-3-4-5.1-5.2-9. Therefore the evaluation is Public.

Decision of Evaluation	**Public**	~~**Confidential**~~
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RAIN – Risk Analysis of Infrastructure Networks in Response to Extreme Weather

Project Reference: 608166

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

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Deliverable 3.2

Defining critical land transport infrastructure protection methods

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EXECUTIVE SUMMARY

In the processing of Deliverable 3.2 Defining critical land transport infrastructure protection methods we came out of the norm IEC 300-3-9 Risk Management which divides the processes on the identification of the risks, their evaluation (the determination of the risk level – acceptable and unacceptable) and their regulation in the preparatory and implementation phase of management of the risks.

The methods of identification of risks are described in the first part of second chapter. There are Bow tie analysis, Causes and consequences analysis, Check list, Event tree analysis, Fault tree analysis, Failure mode and effect analysis, Hazard and operability study and What if analysis. These are the methods of preparatory phase of risk management. In the second part of this chapter there are described the methods for evaluation of risk as Point method, SWOT analysis, Decision matrix and Common safety method.

In the third chapter there are described the methods in implementation phase of the risk management as the methods of network analysis (Critical path method, Program evaluation and review technique, Gantt diagram, Method of time consuming activities and Method of optimal network connecting) and the methods of protection of critical transport infrastructure.

In the individual phases we created the database of methods which might be used in the environment under the influence of extreme weather on the critical transport infrastructure.
In the searching of critical points in the systems of critical infrastructure it is necessary to follow the appropriate methods of analysis which are set up so that we achieve the expected result. The selection of methods depends on the solved problems, input data, knowledge and experience of the research team.

The fourth chapter aims to complement the deliverable by providing brief descriptions of real cases of land transport infrastructures where measures against extreme weather events have been taken. The cases include descriptions of risks identification and information merging, risks evaluation and implementation protection measures.

INTRODUCTION

The goal of Deliverable 3.2 is to define appropriate methods usable for the protection of critical infrastructure in the transport sector with the focus on rail and road transport. There are a lot of theoretical methods which are used for the sorting of transport objects, identification of dangers, analysis of risks and the preparation of sets of measures for the increase of objects. The properly set analysis is the basis of everything. Under the protection of critical infrastructure the analysis can be considered as a strategic planning tool or repression. The protection of critical infrastructure (CI) should give priority especially to the prevention activity. The prevention is generally more economically efficient than repressive intervention according to experience. The transport sector has got strong specifics. There are usually line constructions (railway lines or roads) and transport objects (railway stations, bridges and tunnels) which are technically very demanding and difficult. There are also included means of transport (vehicles or wagons) and specific control system. Additionally transport is service which has to be provided permanently. It follows the considerable complexity in the selection of objects, identification of real dangers, use of appropriate methods and techniques for the risk analysis. In general the procedure which is presented in the scheme (see the figure 1) can be used.

In the critical infrastructure protection it is essential the realisation of prevention into the analyses of vulnerability, based on scientific knowledge system reliability . In the SR there are not standardized methods of analysis (unified method is not determined for the evaluation of territorial units), therefore it is not possible to compare the results of analyses in the different areas of CI.

The specific of critical infrastructure is its extensiveness in the sectors of transport and energetics. This fact has to be taken in account in the national strategy of protection of KI, but also in the strategy of the EU. As a consequence of this extensiveness it is the fact that no EU country can allow to protect every meter of pipes, electrical wiring or each bridge or tunnel.
The procedures, methods and techniques of risk assessment are used for ensuring of the required level of safety. Then the results are subsequently used for the regulation of risks (unacceptable risks). The performed risk analyses provide the data which are needed for the risk assessment, decision support, and a selection of options for reducing risks. In the figure 1 there is a scheme of risk assessment according to the norm of IEC 300-3-9.

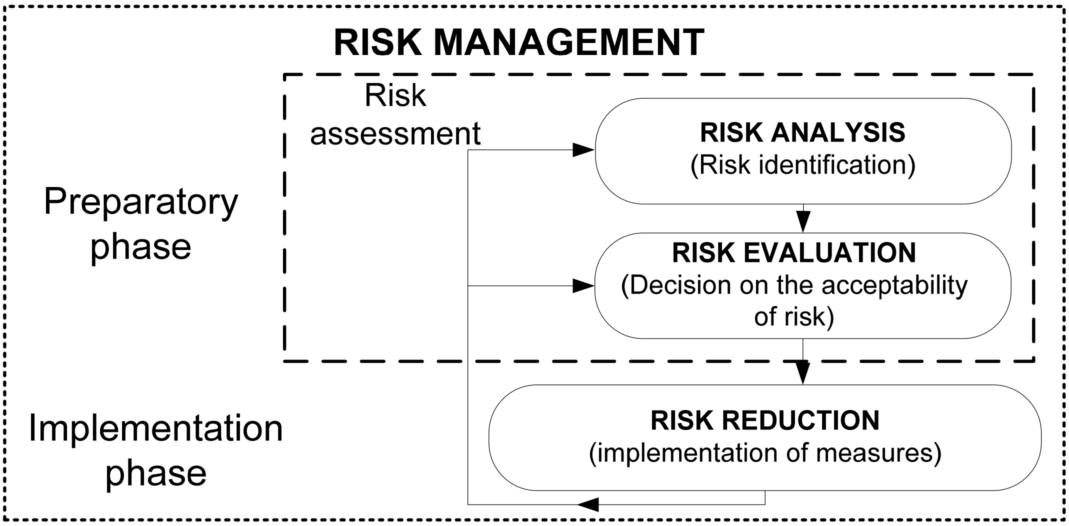

Figure 1 The structure of risk assessment and risk management according to IEC 300-3-9

The figure 1 shows that risk management can be divided into:

- risk analysis,
- risk assessment,
- risk reduction, monitoring and control.

Risk analysis

Under the critical infrastructure protection this term is often used but with the different content:

- risk analysis as the part of decision making process – setting of strategies and the ways of achieving of global and partial goals achieving,
- risk analysis of technical and technological systems – searching of causes of possible accidents or possible threats of lives and health of population,
- security risk analysis - setting of possible disruption of safety from the point of view of state, region and social system.

Risk analysis can be characterised as an instrument of comprehensive risk assessment. It draws input data which are required for risk assessment. It enables to divide risks into the risks which have to be continuously monitored and the risks which can be disregarded. The basic division of risk analysis methods is according to the way of expression of quantities with which are being worked. Two basic methods exist:

- the quantitative methods are based on a mathematical expression of risk from the frequency of occurrence of crisis events and their possible consequences.
- the qualitative methods are based on the verbal expression which can be transformed in numbers.

Risk assessment

It is the process of the determination of the size of the risk by the assessment of the possible range of damages and losses which can cause the crisis state as the result of the consequence of the risk. The determination of the importance of risk factors is possbible by two ways

- expert evaluation of risk – it is based on the appraising with the probability of occurence of the risk factor or the intensity of negative influence of a considered risk factor
- the analysis of sensitivity – it is based on the explicit presentation of the influence of risk factors on the activity of the subject and the level of safety.

Risk reduction, monitoring and control

The process of risk reduction is depended on the specific risk, the probability of origin of crisis phenomenon and its negative consequences. It is a very diverse process which realizes through the enforcement of active anti-crisis policy or the use of specific methods. In the table 1 there are presented the examples of different methods which are used for the appraising of risk elements of cirtical infrastructure in the field of transport.

The process of risk monitoring consists in keeping track of the assessed risks in the preparatory phase, monitoring residual risks by measuring environmental or performance indicators, stakeholder reactions, costs and benefits, or other indicators, and identifying new riks (normally secondary risks derived from the implementation of mitigation strategies when primary risks materialize), ensuring the execution of risk reduction plans, and evaluating their effectiveness in reducing risk.

The importane of risks change in time. The future trends of climate change may vary, affecting the probabability and severity of the identified impacts on land transport critical infrastructures, as well as new risks will develop, and anticipated risks may disappear.

So, the purpose of risk monitoring and control is to determine if:

- Risk responses have been implemented as planned.
- Risk response actions are as effective as expected, or if new responses should be developed.
- Project assumptions are still valid.
- Risk expouse has changed from its prior state, with anlysis of trends.
- A risk trigger has occurred.
- Proper policies and procedures are followed.
- Risks have occurred or arisen that were not previously identied.

The risk monitoring and control process may involve, in some cases, to re-evaluate or repeat the risk assessment process.

1. SHORTCUTS AND KEY TERMS

1.1 Used shortcuts

AS	Alarm system
BTA	Bow tie analysis
CCA	Causes and consequences analysis
CI	Critical infrastructure
CL	Check list
CPM	Critical path method
CSM	Common safety method
CTI	Critical transport infrastructure
D	Deliverable
DRAGADOS	DRAGADOS SA
EC	European Commission
ETA	Event tree analysis
FTA	Fault tree analysis
FMEA	Failure mode and effect analysis
HAZOP	Hazard and operability study
ISS	Integrated security system
MBD	Mechanical barrier devices
OM	Organizational measures
PERT	Program evaluation and review technique
PP	Physical protection
RAIN	Project - Risk Analysis of Infrastructure Networks in response to extreme weather
RIR	Railways interoperability regulation
SR	Slovak Republic
TCD	Trinity Colledge Dublin
TSI	Technical specification for interoperability
UNIZA	Zilinska univerzita v Ziline – University of Žilina
WP	Working package

1.2 Key terms

Critical infrastructure - an asset belonging to the surface transport network (road and/or rail) system or part thereof located in Member States that is essential for the maintenance of vital societal functions, transport, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact on a Member State as a result of the failure to maintain those functions. (RAIN, 2015)

Critical infrastructure - an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions. (Directive, 2008)

Critical infrastructure - elements of the TEN-T Core Transport Network such as for example, bridges, tunnels, earthworks and other structures (culverts etc.) (Project INFRARISK).

Critical infrastructure element - mainly an engineering building, public service and information system in the critical infrastructure sector whose disruption or destruction should, according to the sectoral criteria and cross-cutting criteria, have adverse effect on the performance of economic and social functions of the state, and thus on the quality of life of residents in terms of the protection of their life, health, safety, property, as well as the environment. (Act No 45, 2011)

Critical infrastructure sector - part of the critical infrastructure which includes the elements; the sector may comprise one or more critical infrastructure sub-sectors. (Act No 45, 2011)

Cross-cutting criteria - a set of criteria with threshold values that apply cross-sectionally when designating the elements of all sectors. (Act No 45, 2011)

Disaster – an accident which endangers human life and health, causes human casualties, inflicts material losses or environmental damage and exceeds the capacity of the people affected to avert the consequences with the resources of the operational services (National Program, 2015)
Disaster management – the performance of preventive, readiness, response and emergency measures for the elimination of the consequences in cases of disasters and when there are threats of disaster. Disaster management shall be implemented by the State institutions, local governments, merchants and inhabitants. (National Program, 2015)

Emergency measures for the elimination of consequences– the measures, which are performed in order to retain or restore at the minimum level the basic functions for the maintenance of public life, which are connected with the survival of inhabitants. (National Program, 2015)

Extreme weather events - weather that includes intensities that are historically seen very rarely. For example, consecutive days above 100 degrees temperature, 500-year storms, etcinvolved in response available in the relevant territory. (National Program, 2015)

Preventive measures – the measures, which are performed in order to prevent the possibility of disaster. (National Program, 2015)

Readiness measures – the measures that are performed in order to prepare for action in possible cases of disasters. (National Program, 2015)

Resilience – the ability of a system or asset to withstand or recover from the impact of a climate stressor or extreme weather event. (National Program, 2015)

Response measures–the measures which are performed in order to restrict or eliminate devastating conditions and the consequences caused by them, to prevent or reduce possible damage to persons, property and the environment. (National Program, 2015)

Risk – a measure of an asset's climate vulnerability; the threat posed by climate change to a system or asset. Risk is defined as the combination of (1) the likelihood a climate change/weather event will occur and impact the system or asset and (2) the consequence of that impact (in terms of repair costs, user costs/impacts, etc.). Higher likelihood and higher consequence events are given higher risks. (National Program, 2015)

Risk management - the identification, assessment and prioritization of activities to minimize risks. (National Program, 2015)

Sectoral criteria - a set of technical and functional criteria with threshold values which are applied in designating the elements of the same sector. (Act No 45, 2011)

Vulnerability - an assessment of a transportation asset that, when exposed to a climate stressor, might result in asset failure or damage that reduces the asset's ability to function as designed. (National Program, 2015)

2. THE METHODS IN THE PREPARATORY PHASE OF RISK MANAGEMENT

2.1 THE METHODS FOR IDENTIFICATION OF RISK IN CRITICAL INFRASTRUCTURE

It is not possible clearly determined the methods which are suitable for the search of risk or critical points in the system of critical infrastructure. Depending on the specific problem suitable and less suitable methods exist. The checklist method seems to be the most frequently used method. The combinations of several used methods are also suitable.

2.1.1 BTA - Bow tie analysis

Bow tie analysis - BTA presents a simple diagrammatic way of description from the danger to the consequence and the research of element of risk management. This analysis can be considered as a combination of logic fault tree which analyses the cause event - FTA and event tree which analyses consequences - ETA.

The analysis focuses on the barriers between the causes and risks, and the risks and consequences. The diagram is created that way that it starts with the fault conditions and a event trees. The materials come out of brainstorming. It is used for the presentation of risk which determines a bigger quantity of causes and consequences. It is used if it is not possible to use falt tree.

For instance:

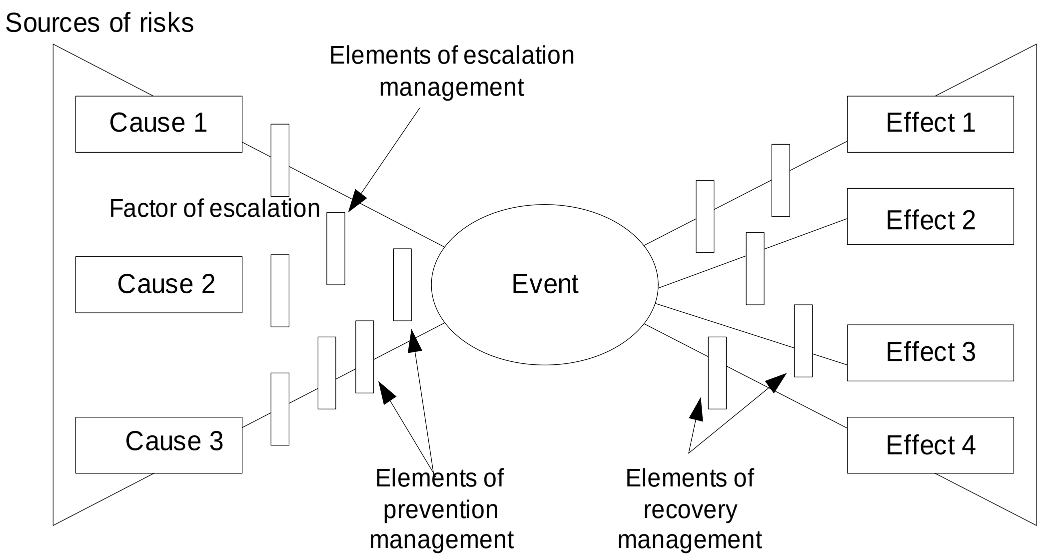

Figure 2 Bow tie analysis

2.1.2 CCA – Causes and consequences analysis

Causes and consequences analysis is the mixture of fault tree analysis and event tree analysis. Its biggest advantage is its use as a communication tool. The causes and consequences diagram shows the relations between the final states of the system failure and their basic causes. The graphic form combines fault and occurance tree into one diagram. The CCA analysis requires the knowledge of the following data and information sources such as:

- unbalanced processes which could cause the system failure,
- the security systems or emergency procedures which can influence the final state of failure,
- the potential impacts of all failures.

This analysis is the best for a small team (2 to 4 persons) with different experience. At least one member of the team has to have some experience with CCA or FTA and ETA, other members of the team have to have the experience with the project analysis or the operation of the system of the critical infrastructure implemented into the analysis. The preparation time and the costs on CCA depend on the number, complexity and the level of resolution of events implemented into the analysis (Bumba, 2003).

2.1.3 **CL - Check list**

Check list (CL) is the method that is based on the systematic control of the performance of predefined conditions and measures. The check lists of the questions are usually generated according to the list of characteristics of the system or the activities which are related to the system and the potencial impacts, the failure of system elements and the formation of the damage. Their structure can change from the simple list to the complicated form which enables to include the various relative importance of the parameter under the system.

The analysis of the check lists has the simple use and can be applied in any stage of life process. The detailed check list provides the basic for the standart evaluation of the process sourses of the risk. It can be extensive to correspond the specific situation. It should be applied conscientiously so that the problems would be revealed which require the detailed analysis. General check lists are often combined with different technique of identification of the sources of risk. The check lists often have the structure of information according to the relevant commom codes, standarts, regulations or rules. The check lists should be the living documents, and should be regurly controlled and updated.

An analyst defines the standard project and operating procedures for the creation of the check list. Then he uses them for the creation of the list of the questions based on shortages or differences. The completed check list contains the answers for these types of questions “yes”, “no”, “not applicable” or “we need more information”. The qualitative results vary on the level of the situation, but they generally lead to the decision of the type “yes”, or “no” according to the conformity with the standart procedures.
This type of analysis is a variable method. The type of evaluation can change, the technique can use for the simple evaluation, or in the case of detailed results. It is cost-saving way how to identify traditionally recognizable the risk sources.

Tab.1 Example of the check list

Check list – identification of risk sources			yes	no	other data
1	Have natural disasters been recorded in this area?	floods	X		
		fire		X	
		…			
2	Has a negative impact of meteorological phenomena been recorded on the critical infrastructure?		X		
4	Has an unacceptable impact of extraordinary events been recorded on the critical infrastructure?		X		
5	Is it the periodic occurance of extraordinary events?		X		
	…				

Tab. 2 The evaluation of check list

title	number
Summary of the total number of questions ΣC_{ot}	Y
Summary of the sum of all positive responses ΣS_{klo}	X_y
Summary of the sum of all negative responses ΣS_{zo}	X_n
Summary of the sum of all responses, other data necessary ΣS_{ndu}	0

Then, the control list is evaluated by the sum of all positive responses in %. All positive responses are calculated according to this formula:

$S_{klo} = (\sum S_{klo} / \sum C_{ot}) \,.\, 100\ \%$

Tab. 3 The summaries of risk analysis based on the control list

Positive responses in %	Evaluation of the monitoring criteria
95 and more	excellent
70-94	very good
50-69	good
20-49	bad
to 20	very bad / critical

The check list analysis uses the items or the steps of the check lists. According to them it is possible to verify the condition of operation of selected element of critical transport infrastructure. The check lists are often used for the ensuring of the compliance with the regulations and the standarts.

It is possible to analyse complicated and difficult problems and to compare them with the prepared record. It is suitable in the analysis of the causes of the problems which happened. The control records provide the list of typical uncertainties which should be taken into consideration. We can come out of the prepared records from the previous period. It is used for the identification of threats, risks and efficienty of approved measures for their management and reduction of expected consequences.

2.1.4 **ETA – Event tree analysis**

ETA is the method which monitores the the development of processes from initiating event through the construction events according two possibilities – favourable and unfavourable possibilities. This method is graphical - statistical method. The event three represents all events which can happen in the system. This method is used in the different areas for the evaluation of reliability of operation of production technology.
The accident scenarious are the result of the ETA analysis (the file of accidents or mistakes which lead to an accident). These results describe possible final state of accidents by the sequent events (successes or failures of safety systems), which happen after the initiating event. This analysis is suitable for the analysis of complex processes, which have got several levels of safety systems or processes in the case of emergency, suitable for the response on the certain initiating events. See event three in the following figure.

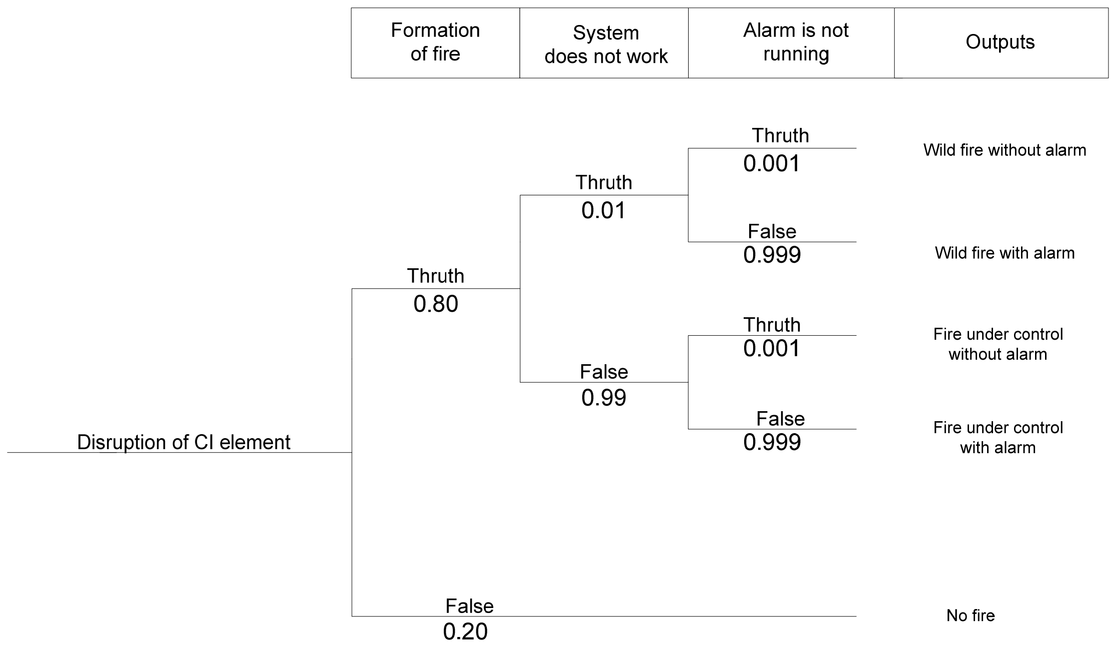

Figure 3 The event three

ETA analysis can be carried out by the individual who knows the safety system well. It prefers the team who consist of from 2 to 4 experts. These experts have experience with the assessed object. The team approach promotes the spontaneous discussion and brainstorming which leads to better model of three.

2.1.5 **FTA – Fault tree analysis**

FTA is the procedure that is based on the systematic reverse analysis of events with the using of the chain of causes which can lead to the selected top event. FTA method is graphical analytic or graphical statistical method. The fault tree presents the faults with the negotiated symbols and description. The basic goal of this analysis is to access the propability of top events with the using of analytical and and statistical methods. The process of deduction determinates various combinations of hardware, software and human mistakes which can cause occurance of a specified adverse event at the top. This method uses the logic gates of fault tree which describe the mutual relations between inputs and outputs of described events. It is used in the industrial areas in the assessing of the reliability of the production technology in the searching of the risks of the critical infrastructure. It also has the computer support.

The basic advantage of this method is the identification of combination of basic errors and human mistakes which can cause the deviation from the normal state. The analyst can focus on preventive or mitigating measures related to important, basic causes so that the probability of the origin of crisis state was decreased. FTA is designed for the analyses of comprehensive systems. It creates the logical models of the mistakes of the system. These models (Boolean logic systems like AND and OR) are about how a big system mistake can happen in the combination of the system failure and a human mistake. The analyst usually solves each logic model to create the list of mistakes which can lead to the top event. These lists of minimum critical cuts can be quantitative ordered according to the numbers and the type of mistake in each critical cut. The control of these lists shows weaknesses of the object, the operation system. The analyst can suggest the alternatives of possible safety improvements for these systems.

FTA requires:

- to understand the system operation in detail,
- to understand the drawings and procedures,
- to know the ways of failure of components and the impacts of these failures.

2.1.6 **FMEA - Failure mode and effect analysis**

FMEA is based on the analysis of ways of formation of failures and their consequences. It enables the search of the impacts and the causes based on the failures of the system. It is used for the control of the individual elements of the project proposal of the system and its operation. It represents the process model with the quantitative approach of sulutiom. It is used for the analysis of serious risks. It requires the application of computing with demanding and well targeted database.

In this analysis the table of failures of the system and their consequences on the system is created. The fault condition describes how the system fails. FMEA identifies simple ways of the fault which lead to the failure of the system. This analysis requires the following data and information:

- the list of nodes of the system,
- the knowledge of the functions and the modes of failiures,
- the knowledge of the functions of the systems and the response on the failure of the system.

This analysis can be carried out by an analytic, but these analyses should be controlled by other specialists because of the validity. The requirements for personnel may differ depending on the size and complexity of the items of the system which should be analysed.

2.1.7 HAZOP – Hazard and operability study

Hazard and operability study (HAZOP) is a general process of the identification of risks with the goal to determine possible deviations from expected or intended functionality. The system is based on the guide words. The criticality of deviations is assessed. It is a qualitative detection technique "what will have to happen not to reach targeted state". This method can be used in big continuous operations (f. e. petrochemical), it can also be used in small discontinuous processes and individual devices. It is also suitable for large organisational units and small companies. The team of experts elaborate critical assessment of operation. Each part is assessmented systematically by using of guide words. The series of guide words are used systematically that way so that the members of team could create their imagination immediately. According to it is possible to identify likely deviations from design conditions. It is also necessary to determine if the condition exists in which the deviation could occur. If this cause exists, it is necessary to explore its consequences. The typical list of the key words, their meaning and interpretation is the table 4.

The application of the key words such as **NO, NOT, MORE, LESS** shows as relatively simple, the key words usually give clear and easily understandable deviation. The remaining key words are not easily usable and they require the explanation. The following two key words **AS WELL AS, PART OF** have got qualitative character. At the same time it is assumed that the purpose is retained completely or partially. Last two mentioned key words also have the qualitative character and characterise the fact that the purpose was not achieved. The key word **REVERSE** means the negation of the original purpose, the deviation is created unequivocally. The package of key words creates the basic aid which makes easier the formulation of the deviations in the connection with the purpose. The applicability of key words is relatively wide, especially when the purpose is defined generally. In more detailed description of the purpose the usability decreases because the types of possible deviations are on the decrease.

Table 4 The key words of the HAZOP method

Key word	Meaning	Interpretation
NO, NOT	complete negation of purpose	it was not realised any part of purpose
MORE	increase	it is related to the quantity and attributes, for example the speed of floow, temperature, also to the activities (heating, reaction)
LESS	quantitative reduction	it is related to the quantity and attributes, for example the speed of floow, temperature, also to the activities (heating, reaction)
AS WELL AS	quantitative increase	all proposed purposes are achieved together with an additional activity
PART OF	quantitative increase	only some purposes are realised
REVERSE	logical contradiction	it is the most suitable for the activities as a reverse flow or chemical reaction, it can also be applied with the substances
OTHER THAN	complete replacement	No part from the original purpose was achieved, there is another activity

If the key words are applied in the connection with the time data, then **MORE and LESS** can mean longer or shorter duration or higher or lower multiplicity. If we mean the chronological order, we usually use special key words **SOONER** or **LATER.**

2.1.8 What if analysis

The analysis called What if is the type of analysis which is used for the searching of potencial impacts which may be expected in the crisis situations caused by the monitoring of crisis phenomenon. This method is based on the spontaneous discussion and the search of ideas. The group of experts ask the questions and express the considerations about possible unfavourable events in the monitoring system or the object. Experts estimate the possible critical situations and their impacts; they evaluate the effectiveness of existing measures. Then they propose the alternatives for the reduction of the identified risk. The method can include the investigation of possible deviations from the project, the construction, the modifications or operational intention. According to experience from real life the standart model is used in the application of this method which structures the problem:

- possible impacts on human lives and health,
- possible impacts on human safety,
- possible impacts on property,
- possible impacts on public interest,
- possible impacts on environment,
- possible impacts on infrastructure,
- energy supply,
- water supply,
- transport network,
- communication and information networks,
- bank and financial sector,
- food supply,
- waste disposal,
- social services,
- industry,
- agriculture,
- state administration and self administration,
- etc.

This method is useful when it is applied in a structured way in time measured from the time of origin of crisis phenomenon. The primary, secondary and other impacts can identify on the tracking system or object.

2.2 THE METHODS FOR EVALUATION OF THE RISKS

It is necessary to come out of well known risks and their consequences in the evaluation of acceptable risks of critical transport infrastructure.
This formula is the basis for most methods of evaluation of risks:

R = P x D

The propability of the existence and the formation of the risk (P) determines the estimate that an adverse event will happen by critical phenomenon in critical transport infrastructure. It is expressed by the numerical value. In the estimate of probability we come out of qualified estimate of scientists which are related to crisis phenomenon.

The consequence (D) expresses the level of importance of crisis phenomenon (injuries, damages).

The risk (R) expresses the interrelation between the probability of occurrence of crisis phenomenon and its consequence. The value of risk is determinated as the combination of frequency parameter and the consequence of crisis phenomenon. The matrix of frequency of occurance of crisis phenomenon and the matrix of categories of consequences of crisis phenomenon are set up. The final value of risk also determines the level of safety of the system:

- the first level – high risk, it recommends its gradual elimination
- the second level – adverse risk, the system is dangerous, it is recommended the risk reduction
- the third level – mild risk, the system is relatively safe, it requires higher attention.
- the fourth level – acceptable risk, the system is considered as dangerous.

2.2.1 Point method

The point method is characterised by the simplicity, understandability and broad application. The probability of the formation of the risk is usually expressed by four or five degrees (Table 5).

Table 5 The probability of the formation of the risk

probability of the formation of the risk	**numerical value**	**Frequency of formation**
very low	1	very unlikely
low	2	unlikely
medium	3	little likely
high	4	very likely
very high	5	very often

The consequences of crisis phenomenon are explained in the four basic categories (see Table 6).

Table 6 The consequences of crisis phenomenon

Consequence	**Category**	**description of the consequence**
insignificant	1	insignificant damage of the system
low important	2	lower damage of the system
critical	3	wide damage of the system
catastrophic	4	destruction of the system

The final level of the risk is possible to express the following scales.

Tab. 7 The level of the risk

Value of the risk (R = P x D)	level of the risk
20-16	High risk, the necessity to remove it progressively
15-12	adverse risk, the system is dangerous
11-4	mild risk, the system is safe and requires increased attention
3-1	acceptable risk, the system is safe

The group of experts set the value of the propability and the consequences of the crisis phenomenon under review according to their own experience and knowledge.

2.2.2 **SWOT analysis**

SWOT analysis is based on the comparison of strengths and weaknesses of the safety of the system under assessment. It also solves the opportunities for the improvement the level of safety in the comparison with the potential threats. It monitors the level of internal and external safety environment of the system under assessment. At the beginning the group of experts have to draw up the balanced list of strengths, weaknesses, opportunities and threats. Then, they assign the values to the components according to their importance. They have got 5 degree scales. The lower value it is the more important the component it is (1 – it is the highest level of importance, 5 – it is the lowest level of importance). The experts also assign the value to each factor (the probability), their total sum equals 1.

Strengths	**Importance A (1-5)**	**Value B (0-1)**	**product**	Weaknesses	**importance A (1-5)**	**value B (0-1)**	**product**
			AxB				AxB
			AxB				AxB
			AxB				AxB
			AxB				AxB
Σ	**-**	**1**		**Σ**	**-**	**1**	
Opportunities	**Value A (1-5)**	**Value B (0-1)**	**product**	**Threats**	**importance A (1-5)**	**value B (0-1)**	**product**
			AxB				AxB
			AxB				AxB
			AxB				AxB
			AxB				AxB
Σ	**-**	**1**		**Σ**	**-**	**1**	

Figure 4 The form of modified SWOT analysis

After the calculation it is possible to convert the values into the decision matrix. According to this matrix it is possible to define the solution strategy and the appropriate methods on the removal or the reduction of the most serious risks.

2.2.3 **The decision matrix**

The decision matrix can be used in the decision making about the acceptability or unacceptability of the risks. They graphically express the level of acceptability of the risks.
After the application of simple point method it is possible to convert the results of the risk evaluation into the matrix (see the figure 5).

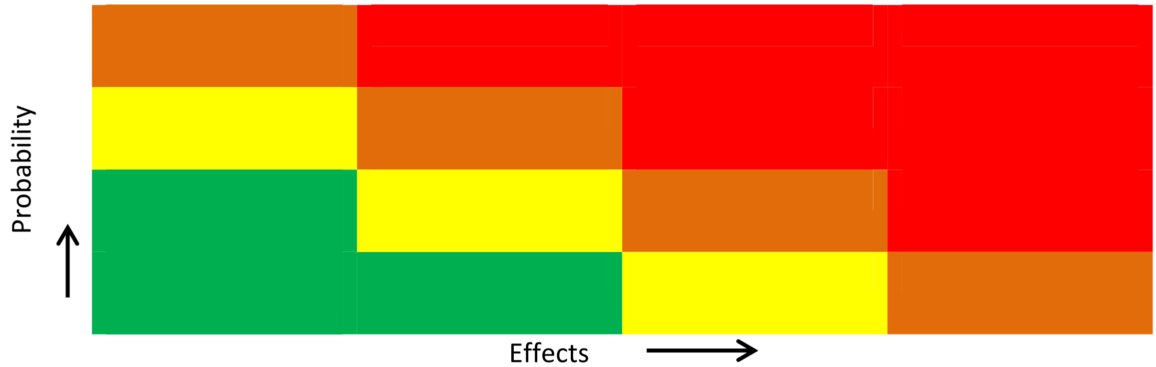

Figure 5 The decision matrix of point analysis

According to the calculated values which come from the point analysis it is possible to mark the risk value in the risk matrix and graphically explain the level of the acceptance of the examined risk.
The decision matrix is possible to create after the application of the SWOT analysis. We put strengths and weaknesses of the system on x-axis, opportunities and threats of the system are put on y-axis.

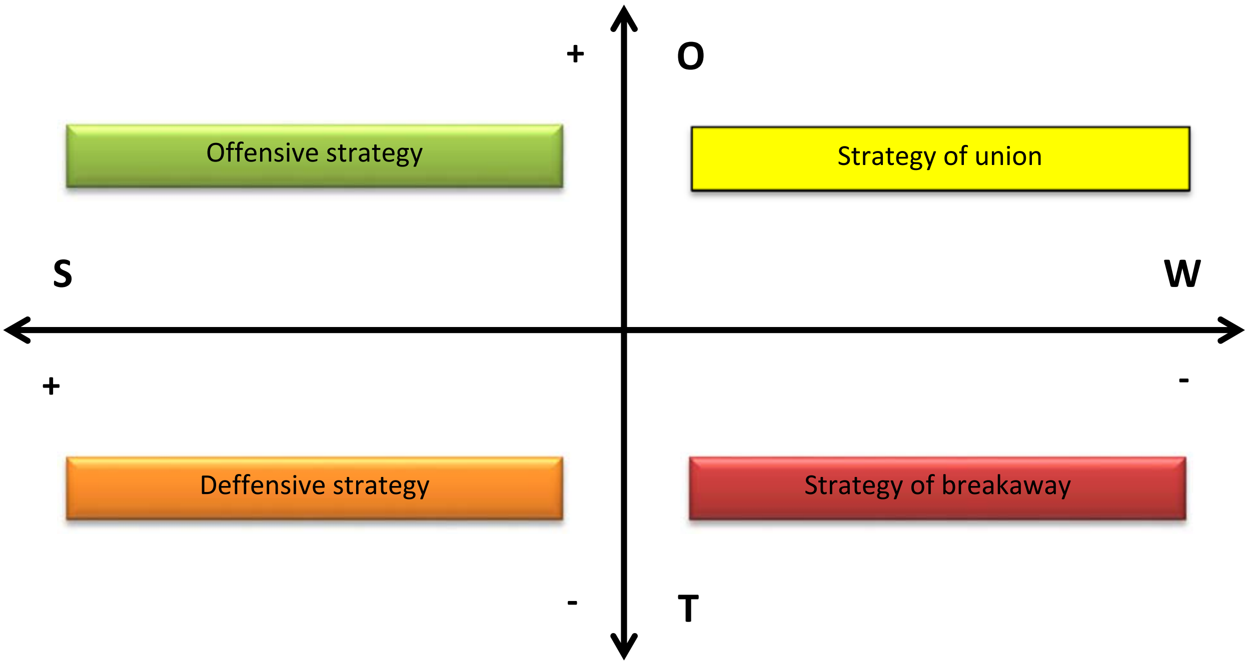

Figure 6 The decision matrix of the SWOT analysis

We put the sum of the values which come from the SWOT table on the axis. Crisis managers can take the prepared type of the strategy according to the location of the final value. The offensive strategy is the most attractive variant where strengths prevail over weaknesses.

2.2.4 **Common Safety Method**

Commission Implementing Regulation (EU) 402/2013 (the Regulation on a common safety method for risk evaluation and assessment [„the CSM RA"]) is part of a wide-ranging programme of work by the European Railway Agency (ERA) and the European Commission to bring about a more open, competitive rail market while seeking to ensure that safety levels are maintained, and, if reasonably practicable, improved. The intention of the CSM RA is to harmonise processes for risk evaluation and assessment and the evidence and documentation produced during the application of these processes. The CSM RA is a framework that describes a common mandatory European risk management process for the rail industry and does not prescribe specific tools or techniques to be used. The processes are intended to complement requirements in other legislation, for example on interoperability or safety certification, and not to duplicate them. The broad principles of how these requirements fit together are explained in the following paragraphs.

In practice, therefore, when any significant safety related change of a technical, operational or organisational nature is proposed to the mainline railway, compliance with the risk management process of the CSM RA should produce a suitable and sufficient risk assessment for that change.

The CSM RA applies when any technical, operational or organisation change is being proposed to the railway system. A person making the change (known as 'the proposer') needs to firstly consider if a change has an impact on safety. If there is no impact on safety, the risk management process in the CSM RA need not be applied and the proposer must keep a record of how it arrived at its decision. If the change has an impact on safety the proposer must decide on whether it is significant or not by using specific criteria in the CSM RA. If the change is significant the proposer must apply the risk management process. If the change is not significant, the proposer must keep a record of how it arrived at its decision.

The framework of the risk management process is based on the analysis and evaluation of hazards using one or more of the following risk acceptance principles:

- application of codes of practice,
- comparison with similar systems (reference systems),
- explicit risk estimation.

The CSM RA applies when any technical, operational or organisational change is being proposed to the railway system. A person making the change (known as 'the proposer') needs to firstly consider if a change has an impact on safety. If there is no impact on safety, the risk management process in the CSM RA need not be applied and the proposer must keep a record of how it arrived at its decision.

If the change has an impact on safety the proposer must decide on whether it is significant or not by using criteria in the CSM RA. If the change is significant the proposer must apply the risk management process. If the change is not significant, the proposer must keep a record of how it arrived at its decision. This process is summarised in Figure 7.

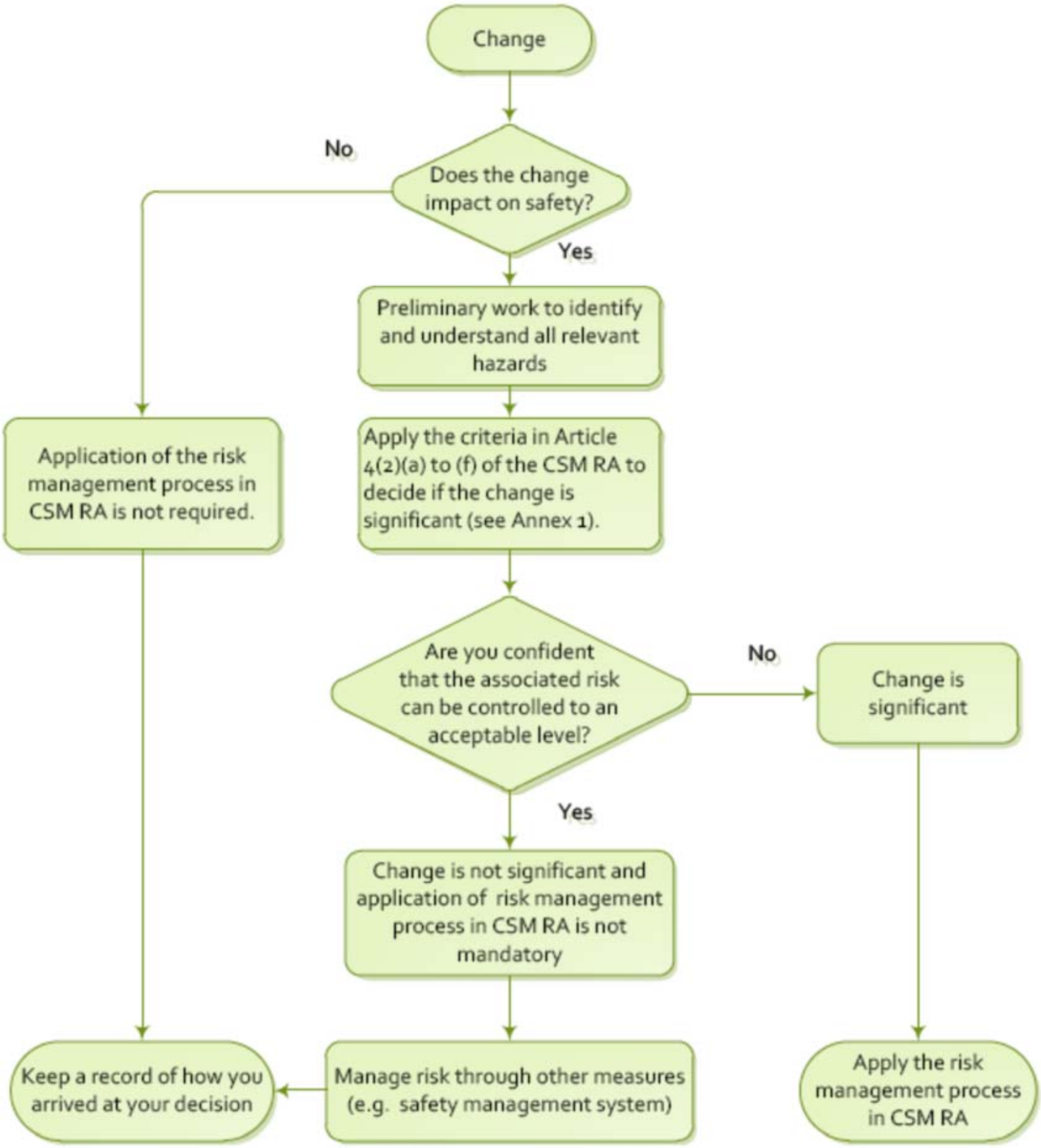

Figure 7 Applying the CSM RA for technical, operational or organisational change

In addition to structural, operational or organisational changes, application of the CSM RA may be required

- by a Technical Specification for Interoperability (TSI) when structural sub-systems falling within the scope of the Railways (Interoperability) Regulations 2011 (as amended) (RIR) are constructed or manufactured, or upgraded or renewed; or
- when placing in service a structural sub-system to ensure that it is integrated into the existing system in a safe manner.

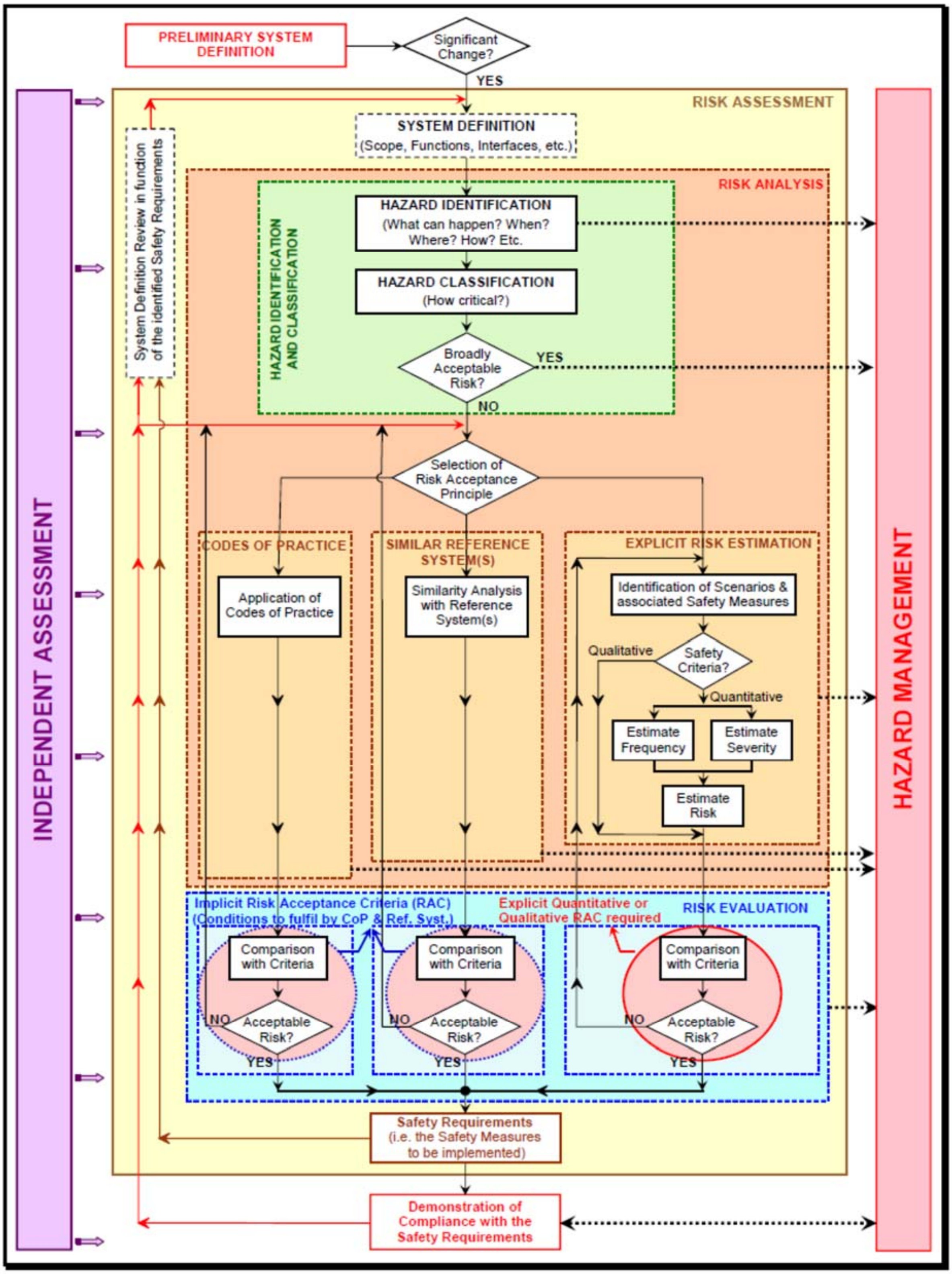

Figure 8 Risk management framework in the CSM Regulation.

The risk management process covered by the CSM can be represented within a V-Cycle that starts with the (preliminary) system definition and that finishes with the system acceptance: see Figure 9.

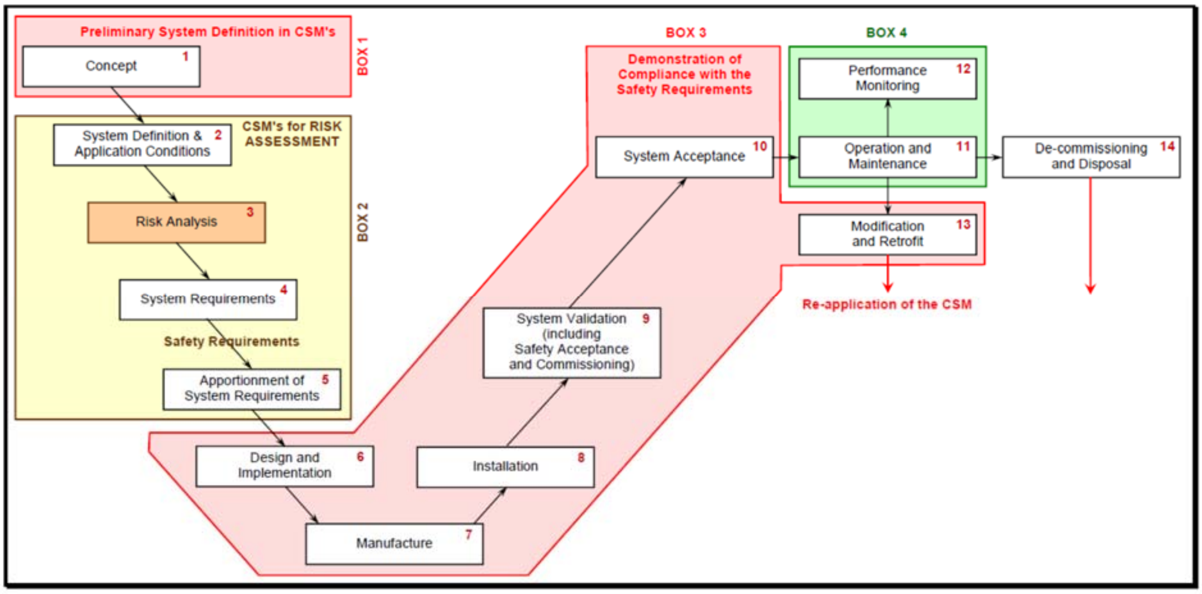

Figure 9 V-Cycle = system life-cycle.

As a criterion, risks resulting from hazards may be classified as broadly acceptable when the risk is so small that it is not reasonable to implement any additional safety measure. The expert judgement shall take into account that the contribution of all the broadly acceptable risks does not exceed a defined proportion of the overall risk.

For example, a risk associated to a hazard can be considered as broadly acceptable:
- if the risk is less than a given percentage (e.g. x%) of the Maximum Tolerable Risk for this hazard type. The value of x% could be based on best practice and experience with several risk analysis approaches, e.g. the ratio between broadly acceptable risk and intolerable risk classifications in FN-curves or in risk matrices. This can be represented as shown in Figure 10.
- or if the loss associated to the risk is so small that it is not reasonable to implement any counter safety measure.

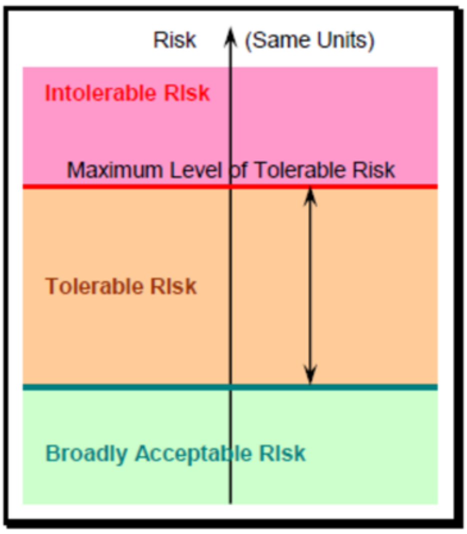

Figure 10 Broadly acceptable risks

In addition to that, if hazards with different levels of detail are identified (i.e. high level hazards on one hand, and detailed sub-hazards on the other hand), precautions need to be taken to avoid their wrong classification into hazards associated with broadly acceptable risk(s). The contribution of all hazards associated with broadly acceptable risk(s) cannot exceed a given proportion (e.g. y%) of the overall risk at the system level. This check is necessary in order to prevent that the rationale is hollowed out by subdividing the hazards into many low-level sub-hazards. Indeed, if one hazard is expressed as many different "smaller" sub-hazards, each of those can easily be classified as associated with broadly acceptable risk(s) if evaluating them independently, but associated with significant risk when evaluating them together (i.e. as one high level hazard). The value of the proportion (e.g. y%) depends on the risk acceptance criteria applicable at the system level. It can be based on and estimated from operational experience of similar reference systems.
The two checks here above (i.e. against x % and y %) enable the focus of the risk assessment on the most important hazards, as well as to ensure that any significant risk is controlled (see Figure 11).

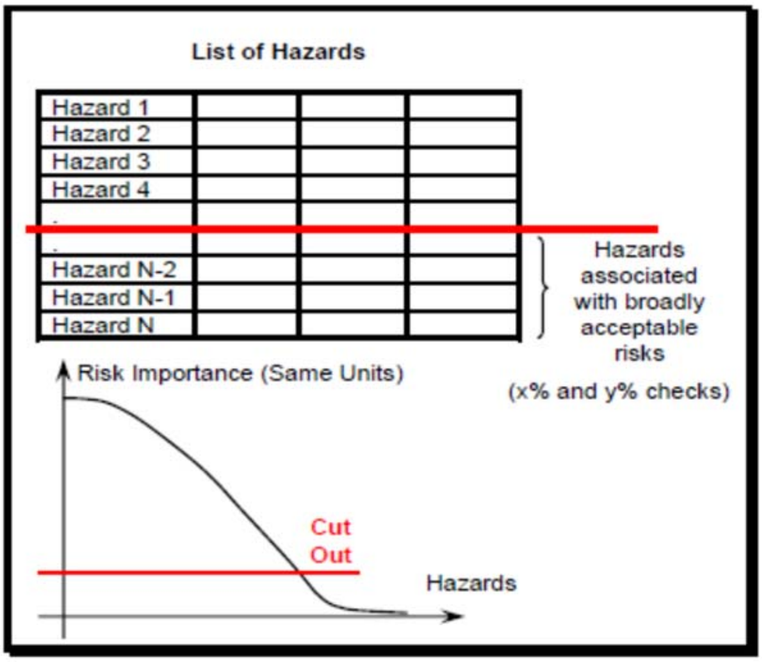

Figure 11 Filtering out of hazards associated with broadly acceptable risk

Without prejudice to the legal requirements in a Member State, the proposer is responsible to define, based on expert judgement, the values of x % and y % and to have them independently assessed by the assessment body. An example of orders of magnitude can be x = 1% and y = 10%, if this is considered acceptable by the expert judgement.
The risk management process used to assess the safety levels and compliance with safety requirements shall be documented by the proposer in such a way that all the necessary evidence showing the correct application of the risk management process is accessible to an assessment body. The assessment body shall establish its conclusion in a safety assessment report.

3. THE METHODS IN THE IMPLEMENTATION PHASE OF THE RISK MANAGEMENT

3.1 THE METHODS OF NETWORK ANALYSIS

The issues of critical transport infrastructure can be described as a network problem. Transport infrastructure consists of the elements – nodes (railway stations, intersections) and branches (the part of roads or tracks). Each element can have a significant importance for network safety. Because the topology of transport infrastructure is primarily a network problem, the use of network models is one of the ways how to solve transport protection. It is about the seeking of critical nodes by the network analysis and the application of vulnerability analysis. The goal of presented processes is the reduction or removal of risks. The network analysis has got an essential importance in the implementation phase in the field of critical infrastructure.
The network analysis constitutes the separate subset of graph theory. It is used in the areas where we evaluate complicated activities which are linked themselves or we track relations or bands in time. The deterministic methods such as CPM and its modification CPM-GE or the stochastic method such as MPM, PERT or GERT belong to the basic network analysis methods.

3.1.1 Critical Path Method and Program Evaluation and Review Technique

Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) are network-based methods which are designed to assist in the planning, scheduling and control of projects. A project is defined as a collection of interrelated activities with each activity consuming time and resources. The objectives of CPM and PERT is to advise analytic tools for scheduling the activities. First, we define the activities of the project, their precedence relationships and their time requirements. Next, the precedence relationships among the activities are modelled as a network. The third step involves specific computations for developing the time schedule. During the actual execution phase, execution of the activities may not proceed as planned in the sense that some of the activities may be expedited or delayed. When this happens, the schedule is updated to reflect the realities on the ground. This is the reason for including a feedback loop in Figure 12.

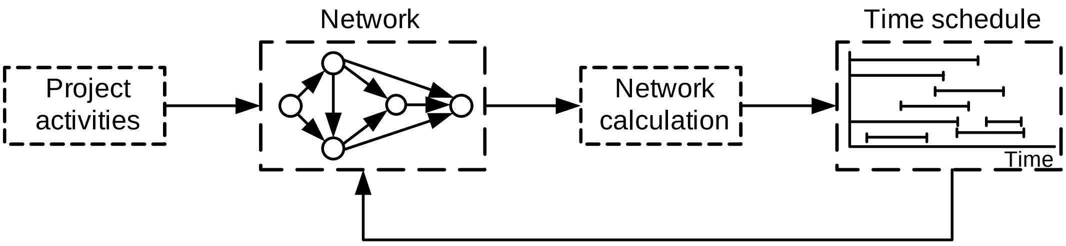

Figure 12 Phases for project planning with CPM-PERT

The two techniques CPM and PERT were developed independently. They differ in that CPM assumes deterministic activity durations and PERT assumes probabilistic durations.

This way of calculation is only used in the project management. Critical infrastructure is necessary to comprehend as a network model in which we optimise the quantity (the quantity of product, traffic intensity) that is transported in the network. The quantities which are monitored in the transport infrastructure:

- the flow in the branch,
- the capacity of the branch,
- the total flow in the net.

In the transport network we can search the shortest way. In the case that the start and the end of this way are not clearly defined they are chosen according to the problems which we want to solve by this method. We use different algorithms like Dijkstra's algorithm.
PERT differs from CPM in that it assumes probabilistic duration times based on three estimates:

1. Optimistic time, which occurs when execution goes extremely well.
2. Most likely time, which occurs when execution is done under normal conditions
3. Pessimistic time, which occurs when execution goes extremely poorly.

3.1.2 **The method of optimal network connecting**

The method of optimal network connecting is the method which may be used in the planning of supply of inhabitants affected by emergency, or in the planning of transport, communication, energetic networks. The basic goal is to find the solution which minimalizes chosen criterion function. In the crisis management the substance of the task is to find the branches (transport roads, lines) of the graph which link all its nodes (source location, warehouses) and have got the minimal
The minimal spanning tree links the nodes of a network using the smallest total length of connecting branches. A typical application occurs in the pavement of road linking towns, either directly or passing through other towns. The minimal spanning tree solution provides the most economical design of the road map.
If the solution of crisis phenomenon temporarily requires solving the supplying of inhabitants who were affected by extraordinary incident by the construction of temporary pipelines, the basic task of crisis management is to find optimal solution – optimal tree with using of modified method of network analysis.

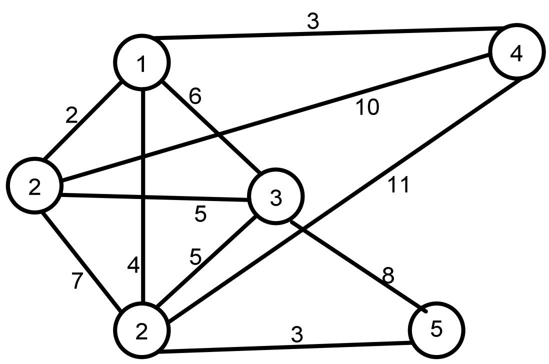

Figure 13 Diagram of possibilities of pipeline

The procedure of the solution is presented in the table.

Tab. 8 The procedure of calculation of connection

step	branch	value
1	k_{01}	2
2	k_{14}*)	3
3	k_{25}*)	3
4	k_{03} or k_{23}	5
The total consumption of the materials		17

The connection is possible to do by two ways, in the fourth step there were two alternatives of the solution.

If two or several branches have the same evaluation k_{ij} and they do not create the cycle with selected branches, any of them is put in the minimum tree. If this procedure leads to the release one of these branches in next step, then the final tree has several optimal solutions.

3.1.3 The method of time consuming activities

Time consuming activities in the process of solution of crisis phenomena is an important indicator of successful elimination their negative consequences and the minimization of loses. The upper and lower estimate (the pessimistic $\mathbf{b}_{ij}$ and optimistic $\mathbf{a}_{ij}$ duration of the activity) are determined for the determination of the duration of the activity ($\mathbf{P}_i$, $\mathbf{P}_j$). The pessimistic duration of the activity is the maximal duration of activity if we consider all possible reasons for delay (unforeseen development of crisis phenomenon) and the optimistic duration of the activity is the minimum duration of the activity in the most favourable conditions. The expected duration of the activity is calculates according to this formula:

$$\mathbf{t}_{ij} = (3\mathbf{a}_{ij}+2\mathbf{b}_{ij}) / 5$$

The presented formula follows from the probabilistic considerations. If we know the most probable estimation of activity duration, then we calculate the expected duration of the activity according to this formula:

$$\mathbf{t}_{ij} = (\mathbf{a}_{ij}+4\mathbf{m}_{ij}+\mathbf{b}_{ij}) / 6$$

After it straightens out, which presented way is better in the process of the solution of crisis phenomena, the linking of the individual activities follows into the diagram. In the application of Microsoft Office Project 2007 the four basic types of dependencies between two and more activities exist *(Dvořák, 2007).*

- ***Ending – starting*** (after the previous task finishes, the following task will start).
- ***starting – starting*** (it is the type of bond in which several tasks start in one moment).
- ***ending – ending*** (it represents the opposite type of bond to the previous type).
- ***starting – ending*** (it is atypical opposite dependence to the first step, the ending of the previous activity is initiated by starting of the following activity).

It is possible to create the graphical support based on the determination of the type of dependence of the individual activities and the acceptance of the basic rules of the formation of graphs. A crisis manager can only use this support partially; he / she can track simple technical continuities in the simple graph. He /she cannot manage the starting or ending of the individual activities without time values.

The realisation of business plans in the business environment according to these diagrams has become necessity. The use of the methods of network analysis with the software support is necessary in the decision of crisis management where it often goes about the saving of human lives, the minimizing of consequences of crisis phenomena on the environment or damages on the properties.

In the process of the solution of crisis phenomena there are the activities which do not have to be done immediately. In operating analysis we call these activities as the activities with time rserve.

The total reserve of activities R_c is the maximum number of time units which a crisis manager has for the realisation of the activities if the character of activities admits it without the extending of the duration of a whole process T^0_n. The total reserve of activities means the number of time units about which the beginning of activities may be delayed with respect to the latest possible term T^0 without the prolongation of the total duration of the process. The total reserve of activities is the difference between the term of finishing of the process and the maximum duration of the path, which passes through this activity.

Free reserve of activities R_v is the maximum allowable extension of the duration of this activity (or delay its start with respect to the earliest possible term T^0_i), which does not disturb the possibility so that all activities which come from the node P_j started in the earliest possible term T^0_j. Free reserve of the activities can be calculated according to this formula:

$$\mathbf{R_v = T^0_j - T^0_i - t_{ij}}$$

It follows that the total reserve equals free reserve in the activities which finish in the nodes and lie on the critical path.

3.1.4 Gantt diagram

In a lot of cases crisis managers meet with the problem to optimise the balancing of the need of the individual sources during the whole period of solving of crisis phenomena. It is necessary to forewarn that we need to have the different sources for the realisation of solving and decision making. There are the demands on the staff, technique, means of transport, the supplies of drinking water and food. In this part it is explained the modification of balancing of the need of one source under the solving of crisis phenomenon whereas it is not about the saving of the source. Before the solution of the problem time demands of individual activities are always known. The intensities of demands for the specific source needed for the realisation of individual activities belong to the input data. Each activity (P_i, P_j) in time (hours, days) requires the constant amounts of predetermined source (**k**). The number of activities carried out in time unit is represented by Gantt diagram. From the experience it is known that the needs of sources usually fluctuate from the beginning to the end of the solving of crisis phenomenon. The following model example documents the presented situation. In the table there are daily intensities of the demands on the source which are needed for the realisation of the individual activities.

Table. 9 The daily intensities of the demands on the source

Activity	Daily intensity of the demands on the source r^k_{ij}
$(P_0\ P_1)$	5
$(P_0\ P_2)$	3
$(P_1\ P_2)$	7
$(P_0\ P_3)$	8
$(P_2\ P_3)$	2
$(P_1\ P_4)$	10
$(P_2\ P_4)$	6
$(P_3\ P_4)$	4

The application of example into the Gant diagram increases the information value of calculations where we enter the intensities of demands on their daily realisation above the individual activities. After entering a simple sum is carried out in the individual days.

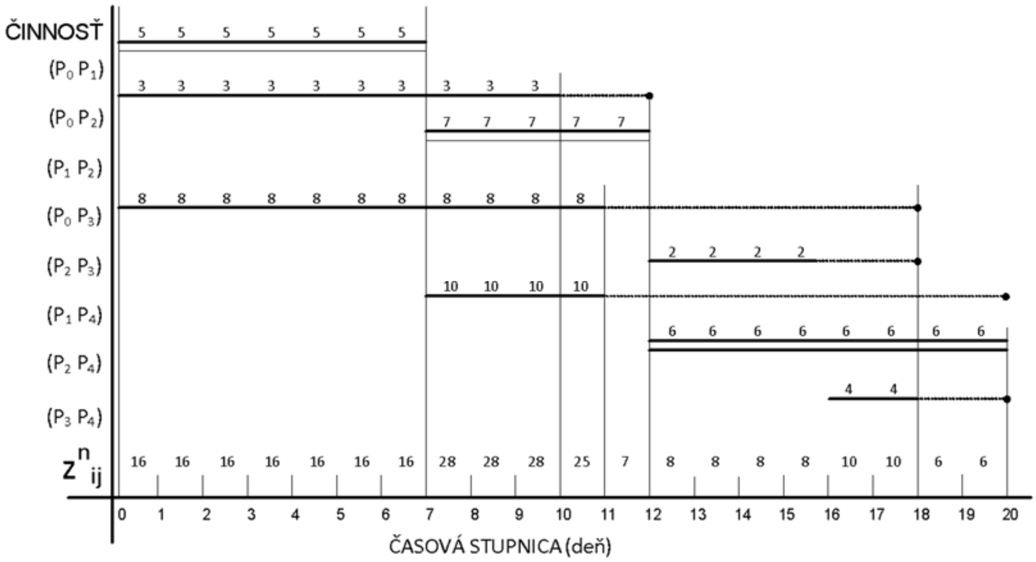

Figure 14 Gantt diagram filled about the intensity of demands on the source

In the case there are more different sources it is necessary to solve the needs individually and separately for the individual sources. In the presented example there is the fluctuation of daily needs of the source in a big interval – from 6 to 28 units. This fluctuation is a big problem in the decision making about the securing of needed sources in the process of solving of crisis phenomenon. The method which equalizes the fluctuation of the needs of the source has the following steps:

1. The first step is the construction of the Gantt diagram in its basic form that is the beginnings of line segments, which represent all activities, are plot on the term of the earliest possible start of activity. The Gantt diagram is filled about total reserves. For simple calculation the diagram is filled about the needs of source for each activity $\mathbf{r}_{ij}$.
2. The sum of the needs of the source in the individual time units $\mathbf{z}^{n}_{ij}$ is calculated. The sums are raised to the power of two $(\mathbf{z}^{n}_{ij})^2$ and the sum (**W**) of these second powers through all time units **n= 1, 2, ...d** are calculated.

$$\mathbf{z^{n}_{ij} = \sum r_{ij}}$$

$$\mathbf{Z = \sum Z^{n}_{ij}}$$

$$W = \sum (z^{n}_{ij})^2$$

3. In the Gantt diagram the smallest uncritical activity is shifted about one time unit to the term of the duration of the process. After shifting a new calculation of the value W is done. In the case that the calculated value W is higher than the original value, the shifting is not done. It is necessary to check all possible shifts which the total reserve of the corresponding activity offers

4. The previous step is repeated. In Gantt diagram we proceed all activities upwards to initial activities of the solving of crisis phenomenon.

In a lot of cases the equalisation of sources does not suffice according to the mentioned principle – without the change of input data. The circumstances make crisis managers reduce the needs of sources on the individual time units. This fact can be done by:

- the change (the prolongation) of the duration of the term of the problem,
- the change of the needs of sources on the realisation of the specific activity in the individual time units.

There will be always a time delay in the balancing of demands on the source by changing of the extension of the process. The calculated term of duration with the use of time analysis will not be met. The necessary conditions for the utilisation of this principle are:

- the maintaining of technological continuities of the individual activities which crisis phenomenon consists of,
- the maintaining of the duration of realisation of the individual activities.

The determination of the limiting level of the source per unit of time is the input condition. After the determination of this value it is recommended to use Gantt diagram in the maintaining of deadlines of the process. On this diagram we proceed from the start point that is located on the left side to the end point. In this process the individual activities are proceeded so long until the needs of the source decreases under the limited value. Regarding to the fact that the term of duration is given by the length of critical path (the sum of duration of critical activities which fulfilment follow each other without a break), the realisation of critical activities will not follow immediately. In some cases it is necessary to observe the deadline. In this case it is possible to apply two methods of solution.

- the increase of the total number of sources – in crisis management it is rarely,
- the observance of the total sums of source with the change its utilisation during the realisation of the individual activities.

For example, the activity which takes 10 time units and 3 sources are needed for the realisation, it completely requires 30 time units. If the realisation of this activity enables to deploy 30 time units another way, it is possible to achieve better equalisation of the source under the solution. In practise this way is realised by using the software support.

The presented modifications of the selected methods of operating analysis are only theoretical assumption of the mathematical inputs of the software support of crisis managers in the filling of complicated tasks of transport security. In all cases there is recommended the combination of the support of special software equipment, personal experience or the intuition of a crisis manager.

3.2 THE METHODS OF PROTECTION OF CRITICAL TRANSPORT INFRASTRUCTURE

The issue of methods, as well as adoption and realization of measures, that preventively or restrictively influence the impacts of extreme weather in conditions of crititcal transport infrastructure (CTI) elements requires individual approach. This is given by the causality of causes and consequences of extreme weather, as well as by importance and diversity of CTI elements. However, it is mainly influenced by dynamic changes of physical attributes of the environment (erosive and accumulative activities that change river relief, impact of geological activities of wind changes wind relief, human activities change anthropogenic relief, etc.).
These changes influence life of the whole society and therefore attention is being paid to them on different levels. For example, measures for removal of negative impacts of environment are in direct responsibility of government authorities. Subjects from the ranks of operators of CTI elements are usually completely or partially excluded from the process of proposal and realization, as well as scheduling of realization of these measures. Operators thus have to adopt also such methods and measures within their task to ensure operation and protection of CTI element which remove or lower other risks resulting from inaction of government and public authorities (e.g. absence of flood control measures or their lengthy realization). CTI elements are, compared with other elements of critical infrastructure, specific also by their territorial size.

Methods and measures, which are proposed in this part of the project, are directly oriented on decreasing of impacts of extreme weather and:

- are based on European and national legal framework that regulates protection of elements of critical infrastructure,
- respect real possibilities and responsibilities of operators of critical transport infrastructure (CTI),
- follow up current state of achieved level of measures that preventively influence and lower impacts of extreme weather,
- accept specifics of line and point elements of CTI.

Structure of hazards and threats that generate security risks, to which the elements of CTI are exposed, has in its core a broad spectrum and it is influenced not only by natural factors (e.g. geographical, morphological, hydrological, geological), but also by technological, technical factors, as well as by particularities of the surroundings and environment (e.g. forest vegetation, land resources). Results of extreme weather are in causal connection, as well as correlation, to environment and CTI object character. Acceptance of this premise allows us to objectively examine and evaluate impacts of extreme weather, and thus also complexly approach the proposal of measures for their prevention and mitigation.
One of the effective approaches to correction of protection of persons and property against security risks (which have an unacceptable level) is application of methods and measures within the integrated security system (hereinafter “ISS”).
Taking into account the importance of CTI element (regional, national, European), it is necessary to lower as much as possible the risk rate of the element given by potentially effecting security risks, hazards or threats especially via influence of extreme weather. It is possible to achieve an effective decrease of security risks generated by extreme weather through a complex of methods and measures that act preventively and, at the same time, protectively. The substance consists in simultaneous use of technical security elements, deployment of persons tasked with execution of physical protection,

and organizational measures. These elements constitute the ISS. Their applicability is related mainly to areal elements of CTI.

Requirement for operators to adopt methods and measures within ISS for protection of CTI or CI element in general is based on national legislation. For example, act no. 45/2011 Coll. on critical infrastructure sets a responsibility of operator of CI element for its protection from intrusion or destruction. The act sets requirements for adoption of permanent security measures for securing of element, mainly using:

1. mechanical barrier devices,
2. technical security devices,
3. security elements of the information systems,
4. organizational measures.

Protection of CTI element from effects of extreme weather has been split into following measures:

a) *preventive* (protection), which are focused on minimization of security risks connected to the threat of intrusion into, or destruction of individual facilities of the element,
b) *managerial-organizational work,* whose substance lies in planning and organizing of methodical and practical training of persons that provide protection of CTI elements and in creation of effective procedure for hazards of intrusion into, or destruction of individual CTI element facilities, focusing on elimination or lowering of presumed consequences – casualties, damage to health, property or other socially adverse impacts.

To achieve the target pursued via realization of preventive measures it is thus necessary to realize such system of protection, which integrates both passive and active barrier and security devices and services. This requirement, as already stated, is fully met by ISS.

It is possible to achieve an effective protection of CTI element from security risks initiated by extreme weather through a combination and organization of multiple subsystems of security mechanisms and security services. Through mutual coordination of these subsystems, an ISS is created. The decision about importance and priority of identified security risks related to individual CTI element is preceded by security analysis of its environment. For this analysis we recommend utilization of database of qualitative, quantitative and semi-quantitative methods.

Individual subsystems of protection are mutually related through synergic effect (Figure 15).

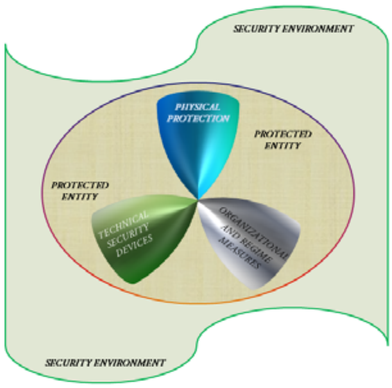

Figure 15 Integrated security system and its subsystems

Measures of the ISS for protection of CTI elements from negative effects of extreme weather consist of following subsystems:

1. technical security devices,
2. physical protection,
3. organizational measures.

1. **Subsystem of technical security devices** consists of following elements:

    a) *Mechanical barrier devices* (hereinafter "MBD") – consist of set of mechanical and technical devices, systems and components, which are, due to their construction, able to decrease or prevent the consequences of extreme weather.
    b) *Alarm systems* (hereinafter "AS") – electronic or electrical devices, whose task is, mainly, timely detection and transfer of alarm information – about the intrusion into the object – usually into the control centre (alarm registration centre).

2. **Subsystem of physical protection** (hereinafter "PP") consisting of persons tasked with execution of physical protection and internal normative acts that regulate execution of physical protection. Its task is mainly execution of security oversight and control of adherence to regime and organizational measures, acquirement and analysis of security information about intrusion into the protected object using elements of the alarm system, assessment of deviations of resulting state from security standard.

3. **Subsystem of organizational measures** (hereinafter "OM") is a sum of administrative and normative measures for securing of protected assets and values. It is characterized by system of order and regime, its maintaining and regular control.

Achievement of optimal security of the protected element of the CTI requires systematic approach and solving through application of all ISS subsystems. Mutual relations of elements and ties of individual elements of ISS subsystems in connection to its surroundings (environment) is shown on Figure 16.

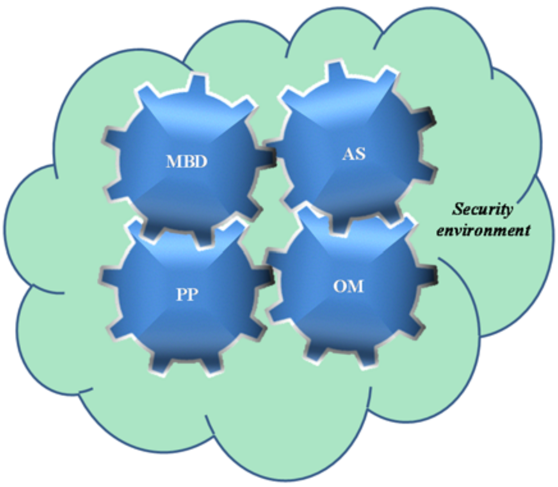

Figure 16 Integrated security system and mutual relations among the elements of its subsystems

Elements of ISS (subsystems) are utilized either individually or in mutual combination of protection methods of (Figure 17):

- *Perimetric protection* – provides security in the area around the CTI element, its perimeter, which may be delimited by natural border (e.g. watercourses) or by technical, or artificial border (fence, wall, etc.). It is a MBD designated for external use, whose basic factor is spatial separation and delimitation of internal environment of the object from external environment. These are also applied together in combination with elements of alarm system and physical protection. These act mainly in the terrain around the protected object. If the area offers the possibility, natural barriers may be used for perimetric protection, either individually or in combination with ISS elements.
- *Shell protection* – prevents violation of the outer shell and all opening fillings of the CTI element. It consists of protection of construction openings of the building (door, windows, etc.) from the effects of extreme weather.
- *Area protection* – it is understood as area delimited by internal side of outer shell (interior area protection), as well as exterior area protection, delimited by external side of outer shell of building (exterior of CTI element).
- *Asset protection* – provides protection to designated important devices and technologies inside the protected CTI element.

Figure 17 Protection zones of the protected object

Applicability of elements of abovementioned subsystems for prevention, decreasing or mitigation of consequences of extreme weather within listed protection zones is as follows:

a) *Mechanical barrier devices*:

- used during extreme wind gusts or snow storms as windbreakers, or mechanical barriers for protection from hazards caused by flying items, set into motions by extreme energy of the wind, or from snowdrifts (shell and perimetric protection),
- used during floods as flood control barriers, used for decreasing of energy or preventing or restricting of penetration of water into protected areas of CTI element (perimetric protection),
- during landslides as barrier, preventing further movement of land in direction of CTI element (perimetric protection).

Within shell protection it is advantageous to use mechanical barrier devices in opening fillings, e.g. in windows it is advantageous to use security glass, security sheets, shutters; security door with security lock mechanisms; in perimetric protection it is advantageous to use underside barriers with solid foundations or wall barriers.

b) *Alarm systems* – detection of violation of perimetric mechanical barrier devices, for example, by water, landslide or snow. Using CCTV, the existing situation caused by extreme weather, as well as its consequences (e.g. overturned fence barriers, water flow directly into the CTI protected element, and damages via wind gusts) may be analysed and assessed objectively from the control centre.

c) *Physical protection* – tasked mainly by execution of security oversight over the state of protection of the CTI element, as well as acquirement, analysis and assessment of information on situation of protected object in time of extreme weather, as well as its consequences, while simultaneously adopting appropriate technical, technological, organizational and other measures for decreasing of its consequences. It may be utilized in all protection zones.

d) *Organizational measures* – sum of procedures, methods and responsibility of specific persons for securing of protected interests and values of the CTI element in time of threat and crisis caused by negative effects of extreme weather. Measures contain not only basic principles for use and operation of CTI element in time of negative influence of security risks initiated by extreme weather, but also preventive measures focused on prevention and mitigation of their negative consequences (e.g. technological facilities, server rooms, call centres, power supply centres should be located above the ground level, these rooms should be oriented in such way they are not unnecessarily exposed to possible wind gusts, etc.).

CONCLUSION

Critical infrastructure protection means to ensure the maintaining of the continuity of business and social life of the state and the providing of response in the case of the threat or disruption of the basic conditions of life, services and systems which continuity is very important for the function of the state. The basic goals of in the field of critical infrastructure are:

- the elaboration of the analysis of vulnerability of critical infrastructure and technologies against possible extraordinary phenomena,
- to elaborate the plan on the elimination of the primary risks of critical infrastructure,
- to ensure the system of detection of natural diseases and possible attacks (their possible scenarios) on the critical infrastructure,
- to ensure the plan and the realisation of the response on the losses of functionality of critical infrastructure
- to prepare the recovery plan of critical infrastructure and other activities.

At the beginning the crisis manager has to have the database of methods by which the given tasks might be fulfilled.
In the processing of Deliverable 3.2 Defining critical land transport infrastructure protection methods we came out of the norm 31 000 Risk Management which divides the processes on the identification of the risks, their evaluation (the determination of the risk level – acceptable and unacceptable) and their regulation in the preparatory and implementation phase of management of the risks.

In the individual phases we created the database of methods which might be used in the environment under the influence of extreme weather on the critical transport infrastructure.
In the searching of critical points in the systems of critical infrastructure it is necessary to follow the appropriate methods of analysis which are set up so that we achieve the expected result. The selection of methods depends on the solved problems, input data, knowledge and experience of the research team.

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4. ATTACHEMENT 1 CASE STUDIES

4.1 INTRODUCTION

The goal of Deliverable 3.2 is to define appropriate methods usable for the protection of critical infrastructure in the transport sector with the focus on rail and road transport. This contribution aims to complement the main deliverable by providing brief descriptions of real cases of land transport infrastructures where measures against extreme weather events have been taken. The cases include descriptions of risks identification and information merging, risks evaluation and implementation protection measures.

The cases quoted represent best practices examples dealing with the preparedness and response to incidents that involve critical land transport infrastructures:

4.1.1 Brief description of the cases

The report **"Adaptation of transport to climate change in Europe: Challenges and options across transport modes and stakeholders" of the European Environment Agency (2014),** gathers some examples that search for innovative solutions across different transport modes, transport as part of broader adaptation plans, or outside traditional paths — e.g. by considering relocation, building redundancies, or changing services to accommodate current and future accessibility demands.

Some practical examples of adaptation actions for land transport critical infrastructures are quoted based on early steps like collecting the knowledge, such as the case of the **project KLIWA** — Adaptation of the ÖBB (Austrian Federal Railways) infrastructure to climate change — where existing data of disruption events since 1990 was assessed. The **xGeo** tool developed in Norway (Box 3.4 of the EEA Report, 2014) is another example of a collaborative framework platform providing a better basis for action to prevent transport disruptions in the case of natural events.

The **"Identification of flood-sensitive sections (blue spots) in the Swedish road network"** case performed by the Swedish Road Administration, consisted in developing instructions to create a homogeneous method for the inventory and analysis of serious physical dangers along a chosen road stretch. In this case, in which topographic identification was used, the results showed a total of 1,254 blue spots (flood-sensitive sections) near the TEN-T roads, varying in volume between 10 (minimum) and 2,800,870 m3 (median 687 m3) in southern Sweden.

Tools for identifying adaptation options and implementation actions are also mentioned in the **Contingency plan for Copenhagen Airport** use case**.** This plan was implemented during the cloudburst that hit Copenhagen on 2 July 2011, when the highway towards the airport that was flooded and passengers could not reach the airport.

The report also describes **Infrastructure design, construction and management,** like the **new design standards for Copenhagen Metr.** In this case**,** in order to prevent operation disruptions under the various floods that have (and will in the future) hit the city, specific designs have been developed.

Examples are the entrance upgrade above street level by small access ramps or stairs or the inclusion of access slopes and stairwells 2.42 m above current sea level.

Finally, a case related to the UK Network Rail is quoted. Network Rail is the national railway infrastructure operator for Great Britain. In 2010 NR published its first Railway Drainage Systems Manual which is considered as the first in the United Kingdom's railway system to take into account future climate change impacts in the design of railway drainage standards.

A small chapter is dedicated to briefly describe the report **Impacts of Climate Change on Transport (A focus on road and rail transport infrastructures),** from JCR Scientific and Policy Reports (2012). It is presented in combination with the case study of **U.S. DOT Gulf Coast Study, Phase 2.** (U.S. Department of Transportation. Federal Highway Administration. FHWA-HEP-14-053).
The Federal Highway Administration of the U.S.A. presented some engineering cases conducted under the Gulf Coast in Alabama. This case study focused on the vulnerability of the western abutment of US 90/98 Tensaw-Spanish River Bridge to storm surge.The JCR Reports describes that the bridge scour is the most common cause of highway bridge failure in the United States. The case study of a bridge adaptation process to scour in U.S.A. and the results of the scour protection chapter of JCR Report of 2012, are quoted here in order to show a better comprehension of the problem and its adaptation process.

Finally, The Stormwater Management and Road Tunnel (SMART) of Kuala Lumpur, is presented in the document as one of the most important adaptations to extreme events infrastructure in the world. Kuala Lumpur’s Stormwater Management and Road Tunnel (Smart) was conceived as a project under the Malaysian Federal Government to alleviate the flooding problem in the city centre. SMART is a dual purpose tunnel, incorporating a double deck motorway within the middle section of a stormwater tunnel, being the longest multi-purpose tunnel in the world.

4.2 ADAPTATION OF TRANSPORT TO CLIMATE CHANGE IN EUROPE (EEA 2014)

4.2.1 Description

Most practical examples of adaptation actions for land transport critical infrastructures can be found across Europe focussing on early steps like collecting knowledge or tailoring climate change impact information and assessments. However, there are only a few examples of implementation. The **"Adaptation of transport to climate change in Europe: Challenges and options across transport modes and stakeholders" of the European Environment Agency (2014),** gathers some of these examples that search for innovative solutions across different transport modes, considering transport as part of broader adaptation plans — e.g. by considering relocation, building redundancies, or changing services to accommodate current and future accessibility demands. Some of these examples are quoted afterwards.

The cases described below focussed on making available information accessible and filling gaps. Such as the project KLIWA — Adaptation of the ÖBB (Austrian Federal Railways) infrastructure to climate change — which assessed existing data of disruption events since 1990. In particular, warning of rockfalls and mudslides is particularly critical, so DESME (Austria) are developing a prototype system that warns, in due time, the track network controller responsible for the particular stretch of track (Alten et al., 2012).

Cooperative projects may include other areas of expertise, such as hydrology. The xGeo tool developed in Norway (Box 3.4 of the EEA Report, 2014) is a good example of a collaborative framework that serves to pull together a variety of data sources initially isolated in different fields of expertise. The result is a platform providing a better basis for action to prevent transport disruptions in the case of natural events, and empowering researchers to identify patterns that could serve to anticipate responses to future possible changes in climate.

In the field of **"Assessing risks and vulnerabilities",** simple methodologies, based on existing knowledge in other sectors such as hydrology or coastal management can be transferred to the transport sector at mínimum cost (Identification of flood-sensitive sections).

Box 3.7 of the EEA Report, 2014. Identification of flood-sensitive sections (blue spots) in the Swedish road network

Identifying and improving road sections vulnerable to flooding are of great value in terms of assessing the sensitivity to extreme weather events and climate change impacts. In 2005, the Swedish Road Administration developed instructions to create a homogeneous method for the inventory and analysis of serious physical dangers along a chosen road stretch.

The instructions contain a methodology for a comprehensive risk analysis of the road transport system with emphasis on serious physical hazards. A variety of risks are considered within this methodology, including risks associated to roads and bridges and the buildings and constructions in the surrounding area. A focus is placed on landslide and collapse risk, risk for damage on roads and bridges with high water flow, risks due to accidents with dangerous goods and risks of flooding.

In particular, **flooding risks** have been the subject of an in-depth study using different assessment methodologies. The Swedish Transport Administration (STA) uses several different methods. One of them compiled and analysed statistics for recorded nature related stops (or road closures) and mapped them in a geographic information system. Another one is based on using accidents. But the best method is the blue spot method, in which topography is used.

The results show that the number of floods increased during these years and they indicate several clusters where the road has been flooded on several occasions. The model was applied to a Swedish study area with the aim of creating an assessment of TEN-T road sections vulnerable to extreme daily precipitation in southern Sweden.

Based on topographic identification, the results showed a total of 1.254 blue spots near the TEN-T roads, varying in volume between 10 (minimum) and 2.800.870 m3 (median 687 m3).

Flooded road in southern Sweden
© Eva Liljegren, Trafikverket

Sources: Löfling, 2005; Hansson et al., 2010; Lindeberg et al., 2014; Trafikverket, 2014a and 2014b.

In the field **of "operational tools for identifying adaptation options and implementation action"**, a case in which contingency plans for extreme weather events which can be also an opportunity to establish or to strengthen interdisciplinary knowledge networks is presented:

Box 3.10 of the EEA Report, 2014. Contingency plan for Copenhagen Airport, Denmark

With a new climate change adaptation plan and a contingency plan for torrential rain, Copenhagen Airport is now in the process of adapting to future climate conditions. Copenhagen Airport is one of northern Europe's largest and most important transportation hubs. All parts of the airport infrastructure are potentially vulnerable to climate change.

Copenhagen Airport examined the climate impacts that could hit the airport, such as temperature increases and changes in precipitation or wind conditions. Different to the Copenhagen areas as such, increased rainfall and rising sea levels are not the prevailing problems for the airport itself. Under the cloudburst that hit Copenhagen on 2 July 2011, it was not the airport's own drainage pipes that collapsed. The problem was in the highway towards the airport that was under water, so passengers could not reach the airport. Thus, the airport needs to cooperate with its neighbouring municipalities to make sure that all their climate adaptation plans are coherent.

The airport's main adaptation need was to establish a contingency plan that could take effect if there is warning of extreme rain. The contingency plan — currently under development — identifies the key areas of the airport that must be adequately protected, so that operations are not disrupted for a long time. The contingency plan will also designate the stands and taxiways that will quickly be able to work when a cloudburst has peaked and those that need help in getting rid of the water. Therefore, it provides precise instructions for the responsible staff, to manage effectively sandbags, pumps and other protective response measures. The plan also includes a proposal for the purchase of flood barriers that can act as a temporary reservoir. The next step for the airport is to decide which of the recommended solutions are to be implemented and in which order.

Source: Klimatilpasning, 2014a.

In the field of **"Infrastructure design, construction and management"**, gradual climate change such as temperature and sea-level increases need to be considered:

Box 3.12 of the EEA Report, 2014. Urban transport: new design standards for Copenhagen Metro

To reduce as far as possible the risk of flooding from sea or extreme rain, Copenhagen Metro has taken this factor into account in the metro's design and construction since the design of the first line in 1993–1995. In fact, the metro has been able to continue operating under the various floods that have hit the city, including the 2011 cloudburst, which stopped rail services, but not the metro. The basis for calculation has been revised, as climate change forecasts have changed over time. For example, the upper limits of all the stairways, emergency exists and ventilation openings on the Copenhagen Metro are now 2.2 m or more above normal sea level around the city for the new lines currently under construction.

The 17 new metro stations in the Copenhagen area will also be secured against flooding. The construction company has identified how to keep water out of the tunnels in the exposed stations by projecting worst-case scenarios of water levels in the streets around the 17 new metro stations during extreme rainfall. Specific design, like augmenting the entrance above street level by small access ramps or stairs, can prevent great quantities of rain water from running down into the metro. A study on the effects of sea-level rise in Copenhagen and on options for securing the metro against the combined effects of rising sea level and flood waters due to rainfall has been prepared. All new metro stations include access slopes and stairwells 2.42 m above current sea level.

Flooding gates at different stations with direct connections to shopping malls (up) and an extra step at the entrance at Kongens Nytorv station (down)
© Metroselskabet

Source: COWI, 2009; Klimatilpasning, 2014b.

On the other hand, Network Rail, the national railway infrastructure operator for Great Britain, published its first Railway Drainage Systems Manual in 2010 (Network Rail, 2010). It is considered as the first in the United Kingdom's railway system which takes into account future climate change impacts in the design of railway drainage standards. For new and remediated railway drainage, the design life is specified as 60 years. The climate change effect will produce a 20% increase in the current design flow estimations for the event return period.

The drainage standards have been applied within Network Rail (Network Rail, 2014c):

- The new Borders rail link (Borders Railway, 2014) in Scotland will connect the city of Edinburgh with the Scottish Borders and Midlothian. The drainage for this new link has been designed according to the new standard, with appropriate scrutiny of business plan items pertaining to drainage or drainage enhancement, in order to ensure that the standard is being adopted correctly.

- All major flood sites on existing railways in Scotland have recently undergone Flood Risk Assessments to identify risk in the complete catchment area. As a result, attenuation ponds have been built in Drem and Dalmarnock and the siphon chamber capacity has been increased and an attenuation pond designed in Penmanshiel. Network Rail is currently reviewing the drainage standard as a part of a wider review of asset management processes.

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4.3 CASE STUDY: BRIDGE ABUTMENT EXPOSURE TO STORM SURGE (JCR Scientific and Policy Reports, 2012 and FHWA-HEP-14-053)

4.3.1 Description

According to Françoise Nemry, Hande Demirel in their report of: Impacts of Climate Change on Transport (A focus on road and rail transport infrastructures), from JCR Scientific and Policy Reports, 2012, river bridges represent essential components of transport network. The bridge piers (often placed in the river) – and abutment – represent a challenge for bridge engineers as they induce complex flow-structure sediment interactions. The risk associated with such complex interactions is referred to as bridge scour.

The definition of bridge scour provided by the JCR Report of 2012, is: "Bridge scour is the removal of sediment from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out scour holes, compromising the integrity of a structure". So, bridge scour is basically induced by the fact that water normally flows faster around piers and abutments making them susceptible to local scour.

According to Queensland Government (2002) and Gardiner et al (2009), bridge scour is one of the three main causes of bridge failure. It has been estimated that 60% of all bridge failures result from scour and other hydraulic related causes, being the most common cause of highway bridge failure in the United States, where 46 of 86 major bridge failures resulted from scour near piers from 1961 to 1976."

Damages on bridges, and induced bridge scour mainly occur during flood events (Bruce et al, 2000). All over Europe, bridge scour is reported as one of the most important problems for railway bridge substructures (Bell, 2004), while in US, the impact of the hurricane Katrina has been very important, including scour effect. The average flood damage per bridges has been estimated to ~1.4 million USD/bridge (Padgett et al, 2008).

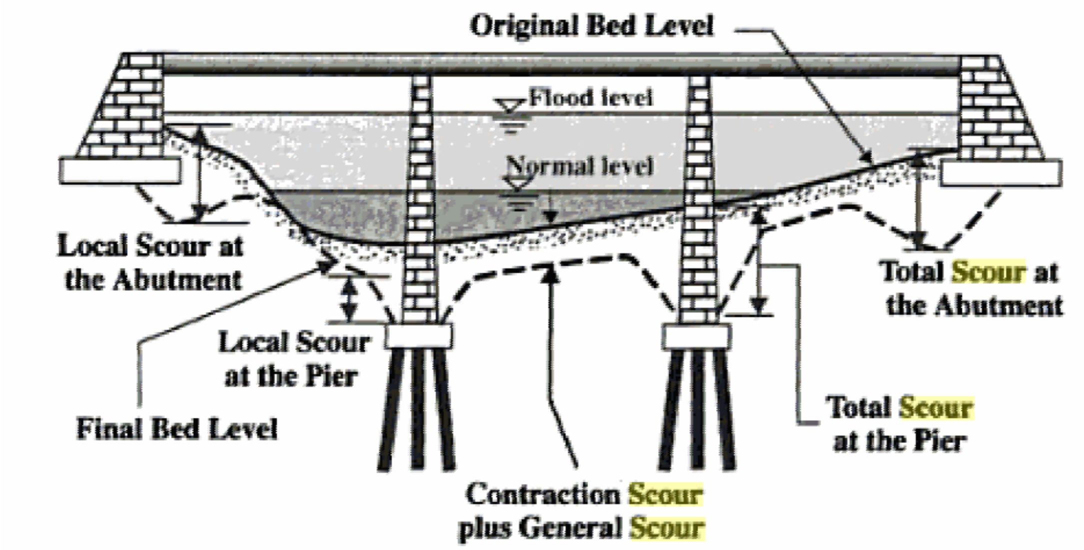


Figure 1: Types of bridge scour (from Bruce et al, 2000)

Under the future climate change, some regions in Europe will face changing precipitation regimes and altered snow melting patterns. This, in some areas will result in higher flood frequencies and or intensities. Building upon the analysis performed under the flood analysis (Feyen et al, 2012), the JCR Report of 2012 provides a first order assessment of the future vulnerability of bridges to scour as induced by changing river floods intensities.

It also performs a rough assessment of the most common measures which would be applied to prevent the risk as anticipated by 2040-2070 and by 2070-2100. These measures consist in riprap and in reinforcing the foundation with concrete.

Riprap (the most common countermeasure used to prevent scour at bridge abutments), consists in placing large blocks at the base of the bridge piers to protect the foundation footings and piers from the direct impact of water flow. They describe that, beyond water velocities of 12 and 10 km/h for sand and non-sandy material respectively, riprap measures become ineffective and foundations need to be strengthened, placing additional concrete around foundation (the second measure commented).

A schematic description of the physicals governing the mechanism can be observed in Figure 2, and a schematic representation of typical riprap configuration is presented in Figure 3.

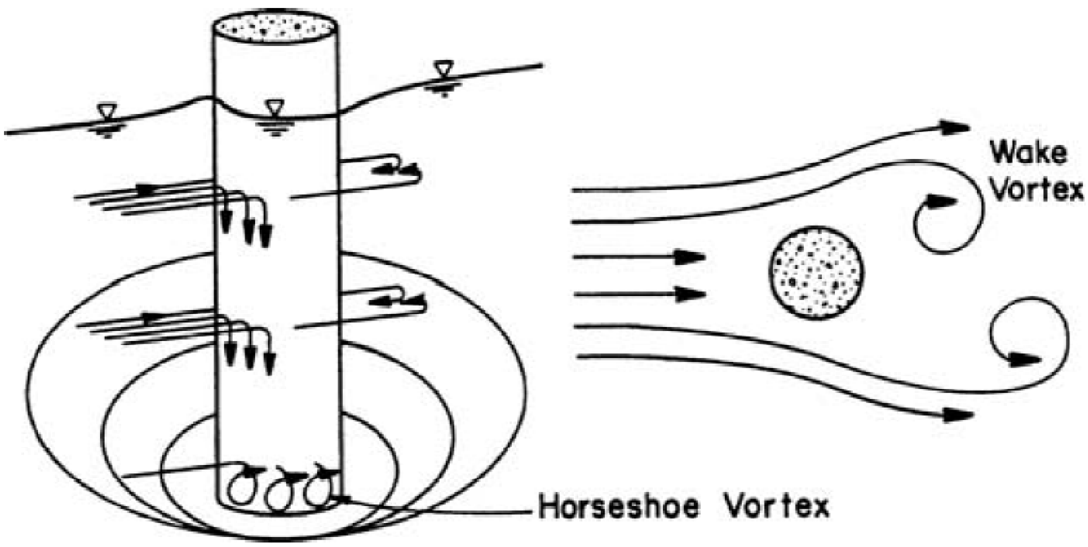


Figure 2: Schematic representation of scour at a cylindrical pier (P. F. Lagasse et. al. 2006)

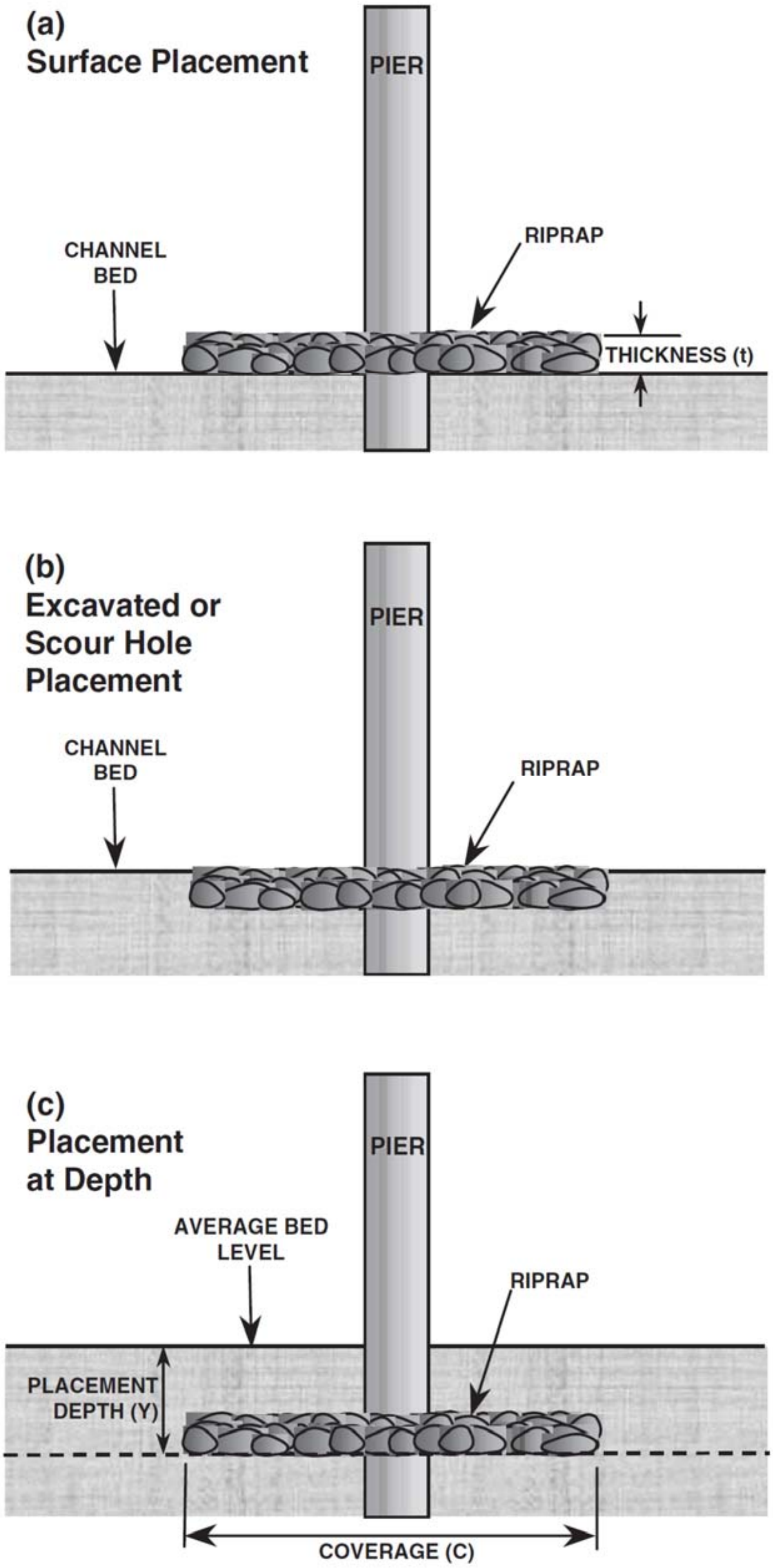


Figure 3: Typical pier riprap configurations (P. F. Lagasse et. al. 2006)

CASE STUDY: BRIDGE ABUTMENT EXPOSURE TO STORM SURGE

Ref: **U.S. DOT Gulf Coast Study, Phase 2. U.S. Department of Transportation. Federal Highway Administration. FHWA-HEP-14-053**

The Federal Highway Administration of the U.S.A. presented some engineering cases conducted under the Gulf Coast in Alabama. This case study focused on the vulnerability of the western abutment of US 90/98 Tensaw-Spanish River Bridge to storm surge.

Description of the site and facility:

This case study evaluates whether the western bridge abutment of the US 90/98 Tensaw-Spanish River Bridge, which serves as an alternative to the main I-10 crossing over Mobile Bay (Alabama) and as an access road to local commercial businesses, is vulnerable to scour during potential storm surges.

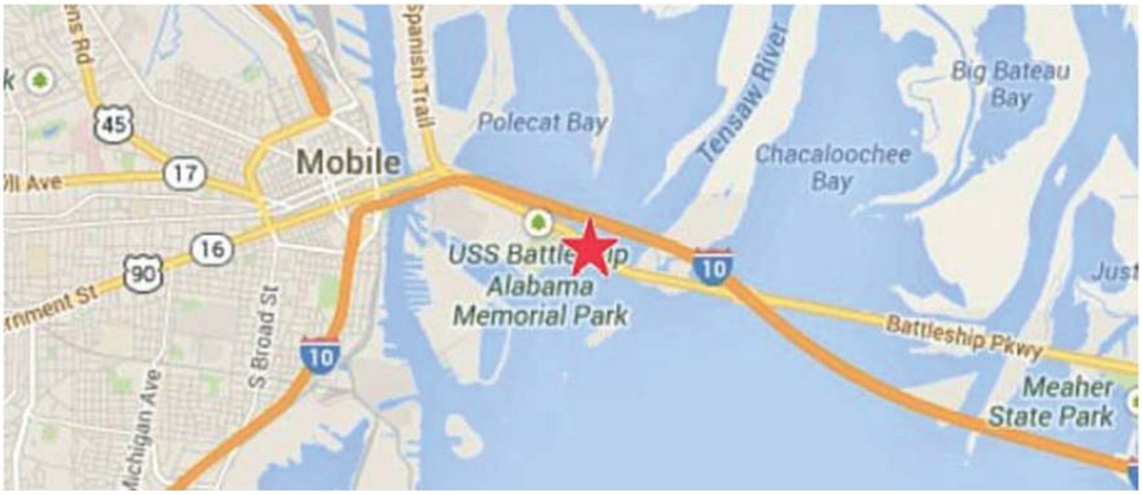
The bridge abutments are stub abutments with riprap capped earthen fill providing a spill through frontage. The abutments are armored against scour by three different protective features that work in unison:

- Willow mattress
- Timber and concrete bulkhead
- Stone riprap

The willow mattres is an interwoven series of willow branch cuttings, joined to form a contiguous semi-rigid mattress. Similar solution was placed between Cuxhaven and Otterndorf (Germany), where the Elbe River curves and the navigable water extends far from the shore. The strong currents in this area have caused continuous erosion to the shore, threatening the shore dike (http://www.eagm.eu/terrafix-and-willow-bundles-stabilise-groynes/).

Willow mattres in Cuxhaven, Germany

These features enable the abutment to be protected against surges that it might not be able to withstand on its own. The three components work together as a protective system, each contributing their own measure of protection. If one of these components does not perform as anticipated, then the entire protective system is weakened.



Location of the US 90/98 Tensaw-Spanish River Bridge within the Mobile Metropolitan Area.

Climate Stressors and Scenarios Evaluated and Impacts on the Facility

This case study focused on the combined effects of storm surge and sea level rise. To assess a range of possible storm surge impacts, this analysis considered three storm scenarios, including:

- Hurricane Katrina Base Case Scenario: This scenario represents the surge conditions that actually occurred in Mobile during Hurricane Katrina.
- Hurricane Katrina Shifted Scenario: This scenario estimates the surge levels that could have occurred if Hurricane Katrina's path was shifted east to make landfall directly in Mobile.
- Hurricane Katrina Shifted + Intensified + Sea Level Rise (SLR) Scenario: This scenario estimates the surge levels that would occur if Hurricane Katrina made landfill directly on Mobile, intensified with stronger winds, and came on top of 2.5 feet (0.8 meters) of sea level rise.

In the absence of protective features, all three of the coastal storm surge scenarios result in scour depths that exceed the constructed depth of the abutment foundation, indicating that the west abutment would be prone to failure under these storm conditions if not protected. In the more extreme storm surge scenarios, the lower cord of the bridge deck is also submerged, which lowers the predicted abutment scour but could result in damage to the approach roadway and loss of service during the surge and the immediate aftermath (due to clean-up).

Next, the effectiveness of the existing protective features in preventing scour was analysed using guidance from the FHWA HEC-23 in case of riprap solution and comparing the peak storm velocities to the estimated permissible velocities in the willow mattress case. Both solutions are believed to be stable under the storm surge scenarios.

In the case of the bulkhead, using the same analysis as for the abutment, the bulkhead depths were determined to be insufficient to protect the abutment against the peak scour conditions; however, the bulkhead is protected by the willow mattress pad and was therefore considered to be stable under storm conditions.

Overall, while the abutment itself is not designed to be stable under storm scour conditions, the protection components of riprap, bulkhead, and willow mattress pad are all stable, resulting in an abutment system that is stable under all evaluated storm events.

Identification and Evaluation of Adaptation Options

Because the overall abutment system was found to be stable under all storm scenarios, adaptation of this asset may not be necessary. However, they proposed the following adaptive design options may be considered for other abutments:

- Reconstruction of the protective bulkhead with increased depth, more sustainable material, and appropriately sized riprap coverage
- Realign flow vectors to be parallel to abutments through use of guidebanks or other measures
- Armor the bridge opening with riprap, a concrete revetment, or bulkhead/retaining walls
- Widen, lengthen, or shift the bridge
- Control drainage from the embankment and roadway to minimize erosion

Aerial Image of the US 90/98 Tensaw-Spanish River Bridge

And provided also some factors that will influence the selection of adaptation measures:

- Redundancy: Abutment failures can take a long time to repair, resulting in road closure or reduced capacity. Adaptive measures therefore may take a higher priority on important roadways for which there is not an alternate route.
- Constructability: Retrofits to bridge foundations could result in the temporary closure of a structure. Scour countermeasure work can present constructability issues due to limited clearance under the bridge.
- Durability and maintenance: The durability and maintenance of scour countermeasures, especially in light of expected surge, is a key criterion in the design of such measures.
- Environmental issues: The use of scour countermeasures or construction activities could have negative impacts on the environment, including changes to the shoreline/streambank composition.
- Aesthetics and recreational use: The use of a context sensitive treatment that does not limit the usage of the shoreline or create an eyesore, should be considered.

Example of typical timber bulkhead protection at a highway bridge abutment

Potential Course of Action

The conclusion of no adaptation measures recommended at this time should be re-evaluated if updated climate projections project more severe surge conditions at the facility.

They recommended that the abutments should be monitored and undergo periodic inspections (including inspections after significant storm events) to assess the condition of each protection element and recommend any needed repairs.

Rooting future scenarios in the experience of a single historical weather event, and then altering characteristics to reflect possible future permutations, has the benefit of providing very relatable results to local stakeholders, especially if a severe storm event occurred recently.

COMING BACK TO THE JCR REPORT (2012)

Ref.: **Impacts of Climate Change on Transport (A focus on road and rail transport infrastructures), from JCR Scientific and Policy Reports, 2012.**

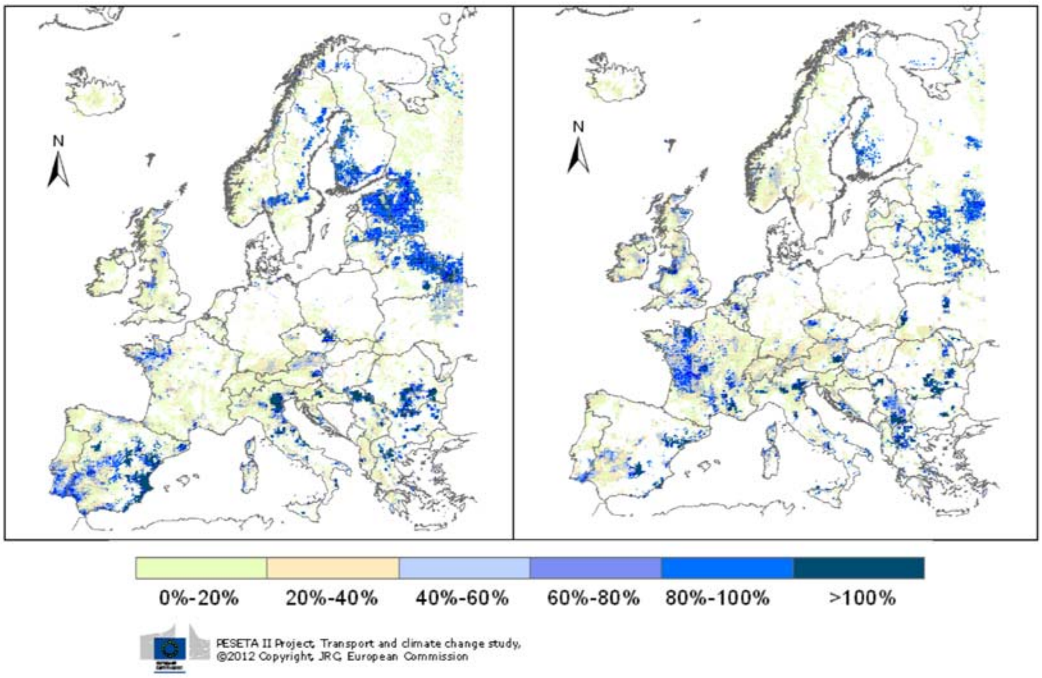
The applied method in the JCR Report (2012) is to a large extent based on a study conducted by the US Environmental Protection Agency (EPA) to analyse the vulnerability of bridges to increased floods in US as a result of climate change (Wright et al, 2012).

Among others methodologies and calculations, they developed a spatial analysis to infer the existence and location of river bridges. The rough analyse consists in spatially overlaying the main water bodies, lakes, rivers, etc with EU-wide main railways and roads.

Also, inferred bridges were indirectly characterized in terms of river bed soil type by overlaying the geo-referenced European Soil Database (ESDB) available for 1 km x 1 km raster data sets.

Based on that spatial analysis, a total of 54,674 bridges were identified, of which 10,239 rail bridges and 44,435 road bridges.

The next Figure provides a map to illustrate the level of vulnerability for bridge scour in the different zones in Europe for the periods 2040-2070 and 2070-2100. It represents the percentage of increase in 100-yr-return peak river flow. In total, ~20% of bridges are estimated to be at risk over one of the two periods. This percentage changes from one country to the other and the risks are estimated to be highest in Austria (60%), Portugal (50%), Spain (42%) and Italy (39%) (JCR Report, 2012).



Vulnerability of bridges to scour (percentage of increase in 100-yr-return peak flow by 2041-2070 and 2071-2100, respectively)

Based on this present study, the future cost for bridge protection against scour risk is estimated to about 0.38 and 0.54 billion €/yr, composed of costs for road bridges (80%) and rail bridges (20%). In the case of road bridges, this corresponds to 1.5% to 2% of current maintenance costs.

Bridges are designed for long life spans (>100 years) and their maintenance and repairing activities have to be planned long time in advance. Future climate-related risk should be included in corresponding prior cost-benefit studies.

4.3.2 References

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4.4 SMART TUNNEL

4.4.1 Description

The Royal Academy of Engineering, in its report "Engineering the Future" of February 2011, describes the importance of the dual use infrastructures, in a text courtesy of Mott MacDonald: the Smart Tunnel of Kuala Lumpur.

The Stormwater Management and Road Tunnel (SMART) is a unique solution to Kuala Lumpur's (KL) long-term traffic and stormwater management process. Conceived as a flood relief tunnel to divert the 1 in 100yr flood away from the KL city centre it was considered that the 11.8m internal diameter tunnel could be utilised in periods of low rain fall as a highway tunnel to alleviate the congested highway infrastructure.

The overall scheme consists of 9.7km of bored tunnel with the central 3km having a twin deck road within. Complex water control gate structures are located at either end of the highway tunnel section to protect motorists. The 11.8m internal diameter tunnel required the specification of a tunnel boring machine which was one of the world's largest in diameter. A procurement strategy was developed and contract documents produced in order to allow the contractor to purchase two 13.2m external diameter machines. Two ventilation shafts are sited in the heart of Kuala Lumpur. These facilities are located in the Limestone rock, with the largest excavation being 180m in length, 20m wide and 28m deep. These shafts also serve as the launch sites for the Tunnel Boring Machines.

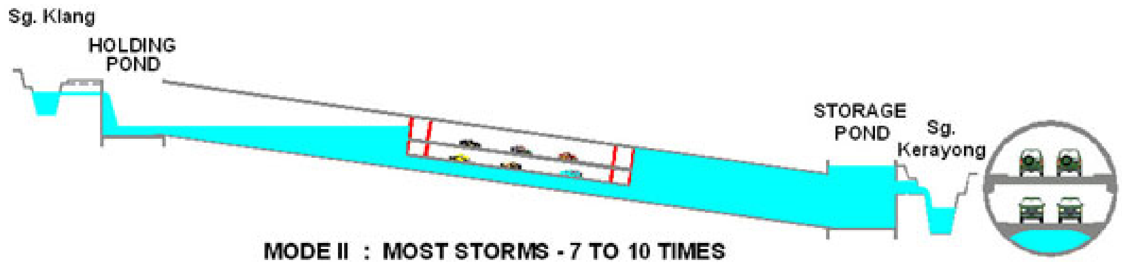
Three-mode operation: The SMART system works on a three-mode principle based on the level of flood discharge.

Mode 1:

Motorway tunnel operates as usual when there is no storm and excess floodwater

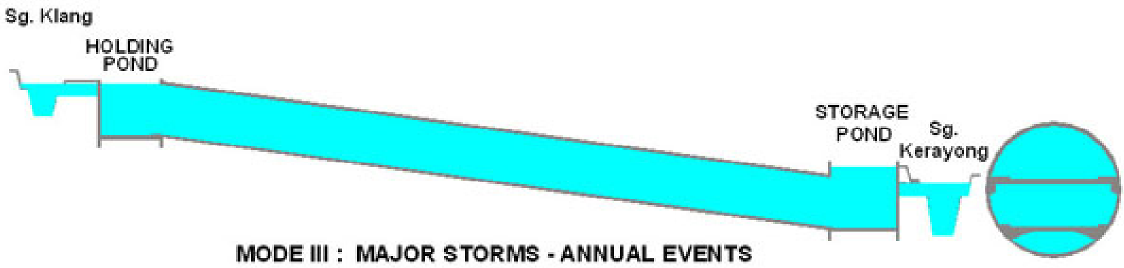
Mode 2:

In the event of a moderate storm, the SMART system will be activated and excess rainwater will be diverted through the stormwater bypass tunnel, in the lower channel of the motorway tunnel. The motorway tunnel is open to motorists



Mode 3:

During severe storm or heavy inundation, the monitoring stations will issue an alert of the need to close the motorway tunnel from motorists. Sufficient time will be allocated to allow the last vehicle to exit the motorway safely before the automated water-tight gates are opened to allow floodwater to pass through to the storage pond and subsequently to Sungai Kerayong. The motorway tunnel will be re-opened to traffic within 48 hours after closure



(Images and mode description: http://www.gamuda.com.my/smart.html)

The exceptional nature of this innovative project required particular solutions in order to design out the complex conflicts between operation as a water tunnel and as a modern highway. The project was opened to traffic in May 2007, and the flood relief function has already been utilised on a number of occasions.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(Images: http://www.amusingplanet.com/2013/05/smart-tunnel-in-kuala-lumpur-storm.html and

4.4.2 References

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