

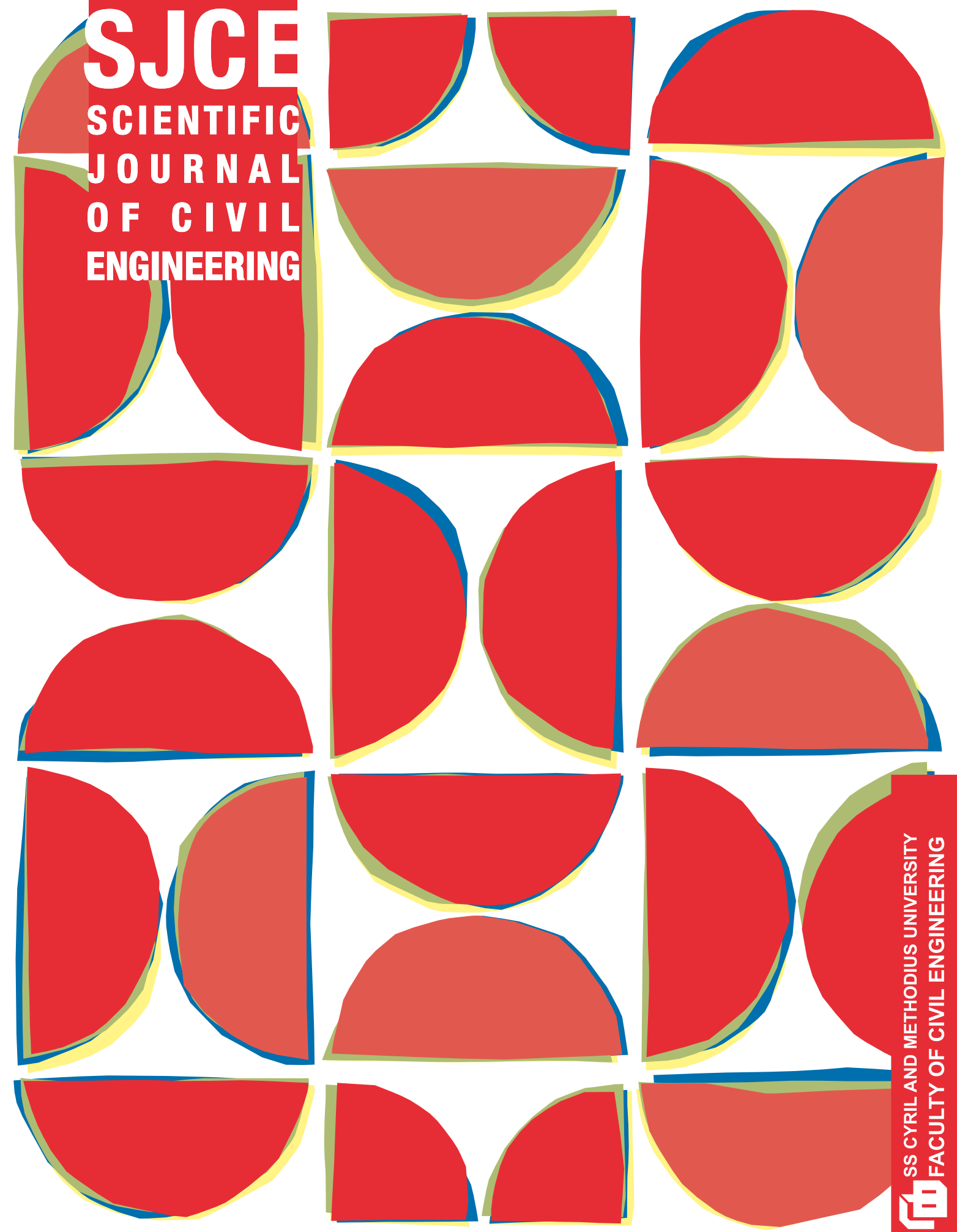
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 **SS CYRIL AND METHODIUS UNIVERSITY
FACULTY OF CIVIL ENGINEERING**

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EDITORIAL - Preface to Volume 10 Issue 1 of the Scientific Journal of Civil Engineering (SJCE)

Marijana Lazarevska EDITOR - IN - CHIEF

Dear Readers,

Scientific **J**ournal of **C**ivil **E**ngineering (SJCE) is an international, peer-reviewed journal published bi-annually since December 2012. It is an open access Journal available at the web site of the Faculty of Civil Engineering in Skopje (www.gf.ukim.edu.mk).

This Journal is committed to publish and disseminate high quality and novel scientific research work in the broad field of engineering sciences. SJCE is designed to advance technical knowledge and to foster innovative engineering solutions in the field of civil engineering, geotechnics, survey and geo-spatial engineering, environmental protection, construction management etc.

Our aim is to provide the best platform for the researchers to publish their work with transparency and integrity with the open-access model, and to provide a forum for original papers on theoretical and practical aspects of civil engineering and related sub-topics.

As an editor-in-chief of the Scientific Journal of Civil Engineering, it is my great pleasure to present you the First Issue of Volume 10, an open-subject issue that contains ten scientific-research papers that have passed the general review process of this journal.

These papers cover various advanced scientific topics. The first paper describes in detail the new technology for digital terrain and surface modelling applied for scanning of the entire territory of RNM. The second paper presents conclusions from the establishment of the national spatial data infrastructure in our country. The third paper explains the systematic approach of the tunnel risk management as a general concept that should include all the available information in order to obtain a quality tunnel designs. The assessment of the impact of bend type on flow characteristics is given in

the fifth paper. The sixth paper deals with the general principles of chemical soil treatment, whereby a special attention is paid to the application of lime as a chemical stabilizer. The seventh paper shows the results of the experimental research and analysed factors of influence on the shear strength of rock joints. The next two papers present two different views of the urban planning, one through the eyes of civil engineers who analyses the traffic load and the most acceptable traffic solution, and the other through the eyes of an architects who examine the aspects or urban plans that affect the changes of real estate values. The final paper points out the importance of Eurocodes as design principles and presents the results from the experimental investigations of RC elements exposed to long-term sustained loads of different intensity.

I sincerely hope that all papers published in this issue will encourage further researches on the fields.

I thank all the authors for contributing to this Issue and all the reviewers for providing detailed and timely evaluations of the submitted manuscripts.

Furthermore, I would like to express my sincere gratitude to all editor members for their excellent work, remarkable contribution, enthusiasm and support, especially during these tough times of COVID-19 pandemic. Let's not forget that tough times never last, tough people do.

Sincerely Yours,

Assoc. Prof. Dr. Marijana Lazarevska

July, 2021

Impressum

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AN APPROACH FOR TUNNEL RISK MANAGEMENT

Modern tunnel construction is a very complex and intense process. In this process different uncertainties and risk can occur and they should be adequately managed. This paper explains the systematic approach of the tunnel risk management as a general concept that should include all the available information and preliminary data in order to obtain a quality solution.

Keywords: Tunneling, construction uncertainties, risk management, acceptable risk, decision making

1. INTRODUCTION

The importance and value of construction projects, especially in the area of tunnels require the necessity for different approaches for assessing and dealing with risks. Therefore, there is a wide application of analyzes and methods for risk assessment, as well as their management. Globally, there is an increasing trend for the application of risk-based approaches, which idea is to increase awareness of this issue in various branches of society.

Once the risks are assessed and their intensity is determined, the management follows. This process is crucial in all design and construction issues, as it should define ways to deal with unwanted events, and it is desirable to perform it in an environment of good cooperation between stakeholders.

2. TUNNEL RISK MANAGEMENT

Tunnel risk management usually includes the following:

- Analysis of the results from the hazard and risk assessment;
- Decision making for risk treatment;
- Implementation of the proposed treatment measures;
- Monitoring.

In certain literatures the hazard and risk assesment is also stated in the risk management.

2.1 ANALYSIS OF THE ASSESSED HAZARDS AND RISKS

Once the hazards and risks have been assessed, the results obtained should be analyzed in order to suggest appropriate measures for their treatment. The analysis generally consists of classifying, ranking and comparing the assessed risks in relation to predefined parameters. Classifications or ranking systems can be defined specifically for the project itself, but most often their origin is

based on more detailed research on previous and current problems and experiences in this area (Table 1). One of the main goals of these analysis is to define the so-called acceptable (tolerable) level of risk. In relation to this level, the other levels (classes) can be determined and the necessary measures can be determined accordingly. The type of results has a great influence on the classification, more precisely whether it is a qualitative description or a quantitative value. Several organizations and agencies dealing with this problem have issued detailed classifications according to which the assessed risks can be analyzed.

Table 1. Example of risk classification and actions (measures), Eskesen et al (2004)

Risk classification	Example of actions that should be carried out for each class
Unacceptable	The risk shall be reduced at least to Unwanted regardless of the cost.
Unwanted	Risk mitigation measures shall be identified. The measures shall be implemented as long as the costs of the measures are not disproportionate with the risk reduction obtained (ALARP principle – As Low As Reasonably Practicable) .
Acceptable	The hazards shall be managed throughout the project. Consideration of risk mitigation is not required.
Negligible	No further consideration of risks or hazards is needed.

The most critical risks in society are those with the greatest consequences, and that represents human victims. Most often, these analyses first consider these risks and therefore in the literature there is a large number of data and values presented in relation to the number of victims for a certain period of time.

In the case of tunnel construction, the values for the occurrence of a risk are usually in relation to the entire period of construction. Depending on the parameters considered, the risks and hazards can also be interpreted in terms of the length of the tunnels or the number of tunnels if multiple cases are considered.

Acceptance limits for tunnels and construction in general range from 10^{-2} to 10^{-4} , often referred to as the ALARP zone or acceptable area. These values refer to the probability of occurrence of a human victim in a certain period which is usually taken as one year. Acceptance limits can also be used to analyse other critical risks, such as those with large

economic and time losses or large environmental impacts.

In our country there are no rules and guidelines that define the acceptable level of risk in tunnels. For this purpose, limits of acceptable level of risk are proposed that could be used for any type of tunnels (Figure 1).

For the probability (frequency) of occurrence of victims, the adopted limits are based on criteria and guidelines of few European countries. They are expressed through the following equations:

- Upper limit:

$$F_1 = 10^{-2} * N^{-1} \text{ for } 1 \leq N \leq 1000 \text{ victims} \quad (1)$$

- Lower limit:

$$F_2 = 10^{-4} * N^{-1} \text{ for } 1 \leq N \leq 1000 \text{ victims} \quad (2)$$

F – probability of occurrence

N – number of victims

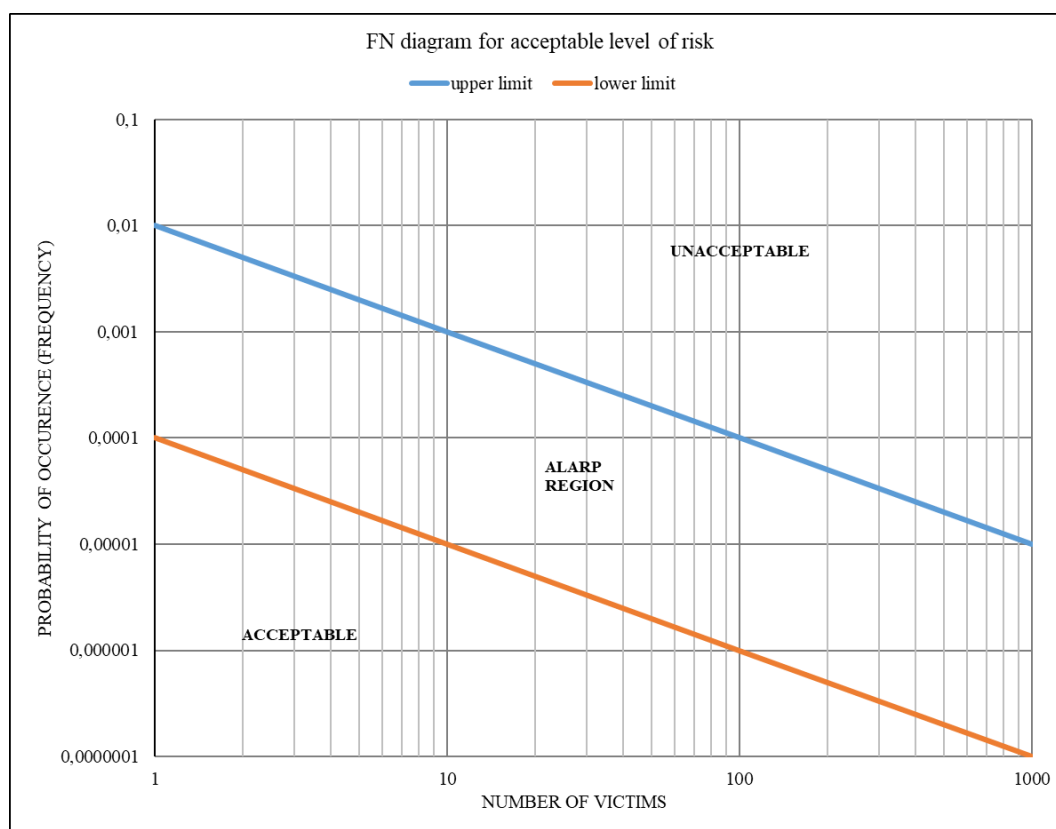


Figure 1. Proposed diagram for acceptable level of risk in relation to human victims in tunnels

The more common and frequent risks are associated with economic loss and time loss (delay). The classifications and acceptable levels for these kind of risks are usually different than the ones with human and environment consequences.

This paper presents an approach for tunnel risk management with proposed classifications and acceptable risk levels for analyzing of the assessed risk in tunnel construction.

The probability of occurrence of risks is the final value, i.e. the result of the quantitative assessment. A five-class system is proposed for ranking, which refers to the potential for risk occurrence in the entire construction period (Table 2).

Based on more detailed research, a classification is proposed that takes into account economic and time losses, which are often closely related (Table 3). The classification does not express the consequences through direct (fixed) values, but as a percentage increase of the initially defined values of the project.

Table 2. Proposed classification for the probability of occurrence of risks in tunnels

Probability of occurrence	Interval	
	Very High	> 1/2
High	1/10 - 1/2	0,1 - 0,5
Moderate	1/100 - 1/10	0,01 - 0,1
Low	1/500 - 1/100	0,002 - 0,01
Very Low	< 1/500	< 0,002

Table 3. Proposed classification for economic and time consequences in tunnels

Impact on project costs and time	
Disastrous	> 80 %
Severe	10 - 80 %
Serious	1 - 10 %
Considerable	0,1 - 1 %
Insignificant	< 0,1 %

The final classification or ranking is done using a risk matrix (table 4) which is listed in the guidelines of the ITA International Tunneling and Underground Space Association). It contains 5 columns and 5 rows that correspond to frequencies (probabilities) and

consequences. With this matrix there are 25 combinations between the frequencies and consequences and 4 possible outcomes. Based on those outcomes appropriate measures for the risk can be proposed.

Table 4. Risk matrix, Eskesen et al (2004)

	Consequence				
Frequency (probability)	Disastrous	Severe	Serious	Considerable	Insignificant
Very high	Unacceptable	Unacceptable	Unacceptable	Unwanted	Unwanted
High	Unacceptable	Unacceptable	Unwanted	Unwanted	Acceptable
Moderate	Unacceptable	Unwanted	Unwanted	Acceptable	Acceptable
Low	Unwanted	Unwanted	Acceptable	Acceptable	Negligible
Very Low	Unwanted	Acceptable	Acceptable	Negligible	Negligible

2.2 ANALYSIS OF RAILWAY TUNNELS

Using this approach for risk classification and ranking, an analysis of the assessed risk was made for railway tunnels. Four railway tunnels on the future railway line on the corridor 8 in Macedonia (section Kriva Palanka – border pass Deve Bair) were previously assessed in terms of hazards and risk (table 5). The assessment covers the three most critical hazards and risks that threaten the construction of these railway tunnels.

Using these quantitative results, a classification was made according to the risk matrix (table 4). For a serious and severe consequence and a very low and low probability of occurrence (< 0,002; 0,002 – 0,01)

the risks are classified as acceptable. This means that the hazards shall be managed throughout the project. Consideration of risk mitigation is not required.

In terms of the diagram for probability of occurrence of human victims (figure 1), the values belong to the ALARP region, which means that the measures shall be implemented as long as the costs of the measures are not disproportionate with the risk reduction obtained.

In general, the analysis and the results can help in the management process during the construction of the tunnels, which can start after a very longer period than planned.

Table 5. Results from previous quantitative risk analysis for the railway tunnels

Hazards	RISK (probability of occurrence)	
	Severe	Serious
Ground water inflow	0,0000779 (very low)	0,0007011(very low)
Excessive deformation (swelling)	0,0001990(very low)	0,0017915 (low)
Instability of the excavation face	0,0003130 (very low)	0,001252 (low)

2.3 DECISION MAKING

The treatment of unacceptable risks can be done in many ways. Risks can be avoided, reduced (mitigated) or transferred. Some risks

can be avoided by adapting to a more robust method of construction or changing the tunnel alignment. Other risks may be transferred to insurance companies. However, most of the risks must be reduced to an acceptable level.

Risk mitigation can be seen as part of quality assurance work.

The optimal methods for risk mitigation are aimed at the epistemic nature of uncertainties, which implies that risks can be reduced by obtaining additional information.

The selection of appropriate measures should be made in an environment of good cooperation between stakeholders. The following parameters usually have the largest influence on the decision making process:

- The results from the analysis of assessed hazards and risks;
- Type of project;
- The size of the project;
- Budget size;
- Design phase;
- Stakeholders and third parties;
- Possibility to implement and follow the effects of the proposed measures.

2.4 RISK MONITORING

One of the least discussed components of risk management is monitoring (figure 2). The main objectives of the monitoring are:

- Predicting future events;
- Validation of the modeled assumptions;
- Improving of the overall accuracy of the risk-related decisions;
- Better communication between the stakeholders.

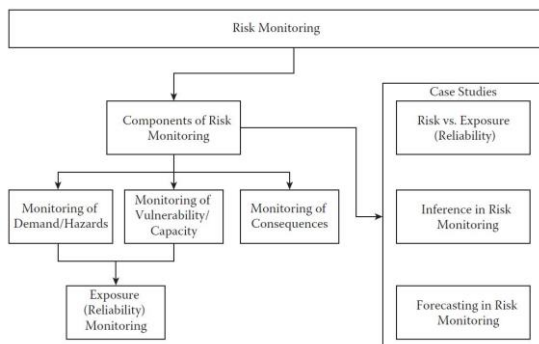


Figure 2. Risk monitoring diagram, Ettouney et al (2017)

The methods of monitoring (observation) and the location of the instruments depend on the field conditions, methods and technologies for construction and the nature of the risk events.

Risk monitoring is especially important in structures such as tunnels or bridges.

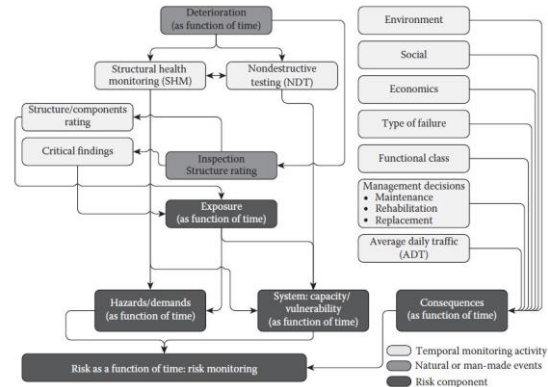


Figure 3. Risk monitoring components, Ettouney et al (2017)

3. CONCLUSIONS

Tunnel risk management is an important part in the construction phase. The success and benefits of implementing an effective risk management depend on the quality of identified risk reduction measures and the active involvement, experience and general opinion of the participants (Investor, Designers, Contractors and Supervisors). Risk management is not achieved by implementing systems and procedures individually, but through meetings where there is an understanding and appreciation of this issue.

The approach showed in this paper is based on a quantitative risk assessment which in the end gives results that can be classified or ranked. The proposed values for probabilities of occurrence and consequences may be used not only for tunneling but in other large civil engineering projects also.

The results from the railway tunnels analysis show that the three most critical risks for the projects are acceptable in terms of economic and time consequences, but in relation to human victims the risks belong in the ALARP region. This means that before (or during) the constructions of the tunnels appropriate measures should be proposed and considered.

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