FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 18, Nº 3, 2020, pp. 261-286
https://doi.org/10.2298/FUACE200704019M

RISK IDENTIFICATION IN TUNNEL CONSTRUCTION PROJECT: A LITERATURE REVIEW

UDC 624.191.005.334

Opyn Devinta Mauretta Sihombing[1*], Humiras Hardi Purba[2], Aleksander Purba[3]

[1]Mercu Buana University, Faculty of Civil Engineering,
Departement of Civil Engineering, Indonesia
[2]Industrial Engineering Department, Mercu Buana University, Jakarta, Indonesia
[3]Civil Engineering Department, Lampung University, Lampung, Indonesia

Abstract. *Every construction project is always faced with the possibility of various occurrence kinds of risks. The higher the level of complexity of a project, the greater the level of risk that might happen to the project. Based on historical data from tunnel construction many problems and even failure of tunnel construction caused by various factors has been noted and it can have an impact on project delays. A risk management is expected to reduce the adverse impact of risks faced during construction work. Tunnel construction needs management handling with high risk, so it is necessary to identify risks that can minimize bad risks. A risk management is expected to reduce the adverse effects of risks faced in a construction work. It is necessary to perform risk identification to manage the risks that we will face. To successfully improve the performance of tunnel projects, we need to identify various risk factors in a project for efficient project fulfillment. The research method begins with an extensive literature review by reviewing at least 48 journal, journal papers, review articles to provide a list of the main risk factors which are also added to the expertise to achieve a list of final risk factors that contain all risks that may be encountered during road construction. This analysis involves the identification, classification of various risks involved in the construction of a tunnel construction project.*

Key words: *Risk, Tunnel Construction, Tunnel Project, Risk Identification*

Received July 4, 2020 / Accepted February 11, 2021
Corresponding author: Opyn Devinta Mauretta Sihombin
Civil Engineering of Mercu Buana University, Jakarta, Indonesia – *Student
E-mail: opyndm@gmail.com

1. INTRODUCTION

Risk identification based on failed knowledge does not change the traditional risk identification process, but it is a complement (Xue & Zhou, 2017). Traditional risk identification process is generally simplified to 4 steps: clear objectives, data collection, identification of potential risk factors, identification of project risk events, where risk factors can be divided into risk factors and risk environment (Xue & Zhou, 2017).

Tunnel safety is defined like a safety and protection of persons, property, and surround of structure, which is given by result of risk evaluation, solution reasoning in point of risks, fire-safety structure solution and solution of structure influence on environment, protection of monuments, nature and countryside (Schlosser et al., 2014). Risk management is very necessary for construction work with high level of project risk and risk. Tunnel construction is one project that has a high level of risk, Because the construction conditions are below the surface and Number of factors that must be bypassed the tunnel. The conceptual model consists of three hierarchies and three stages and thirteen factors are chosen as assessment indices. The multiple indicators are categorized as karst hydrogeological and geological engineering conditions, construction factors and feedback information for risk management. (X. Wang et al., 2019). Many risk factors affect the overall safety risk of tunnel operation. Some of them, such as driver and vehicle condition, are also difficult to quantify (B. Zhou et al., 2020). Based on the results of the risk evaluation, risks can be divided into three types: acceptable risk, acceptable risk after mitigation, and unacceptable risk (Bai et al., 2014). Human errors have recurrent patterns and typically include poor technology, slack management, and inadequate hazard handling (Wen Liu et al., 2018). Natural causes of accidents in mechanical tunnel excavation include adverse hydrogeological conditions, groundwater, heavy rainfall, soft soil layers, etc. (Wen Liu et al., 2018). Tunnel projects are inherently risky mainly because of the variability and unpredictable nature of geologic conditions (Klein & O'Carroll, 2017). Tunnel construction is a critical scope in this project because its impact greatly affects the total cost and duration of the project, so the impact of risk identification must be known and identified critically, precisely and correctly in determining the level of project risk. Risk factor identification is the foundation of risk management (H. Zhou et al., 2020). Tunneling projects find themselves involved in the situation where unexpected conditions threaten the continuation of project (Fouladgar et al., 2012). Risk is any event that can prevent / hinder the progress of a planned project, or the success of its completion.

Risks can be identified from a variety of different sources. Some risks can be identified quite clearly and can be identified before the project starts. While other risks can only be identified during the project cycle. Risks can be identified by anyone involved in the project. Some risks are inherent in the project itself, while there are risks stemming from full external influence outside the control of the project team.

2. RESEARCH METHOD

This paper is based on a literature review obtained online including various related articles from trusted sources and those related to "risk identification", "risk management", "safety risk", "tunnel projects". So we get 48 journals which are then selected and reviewed to provide comprehensive information.

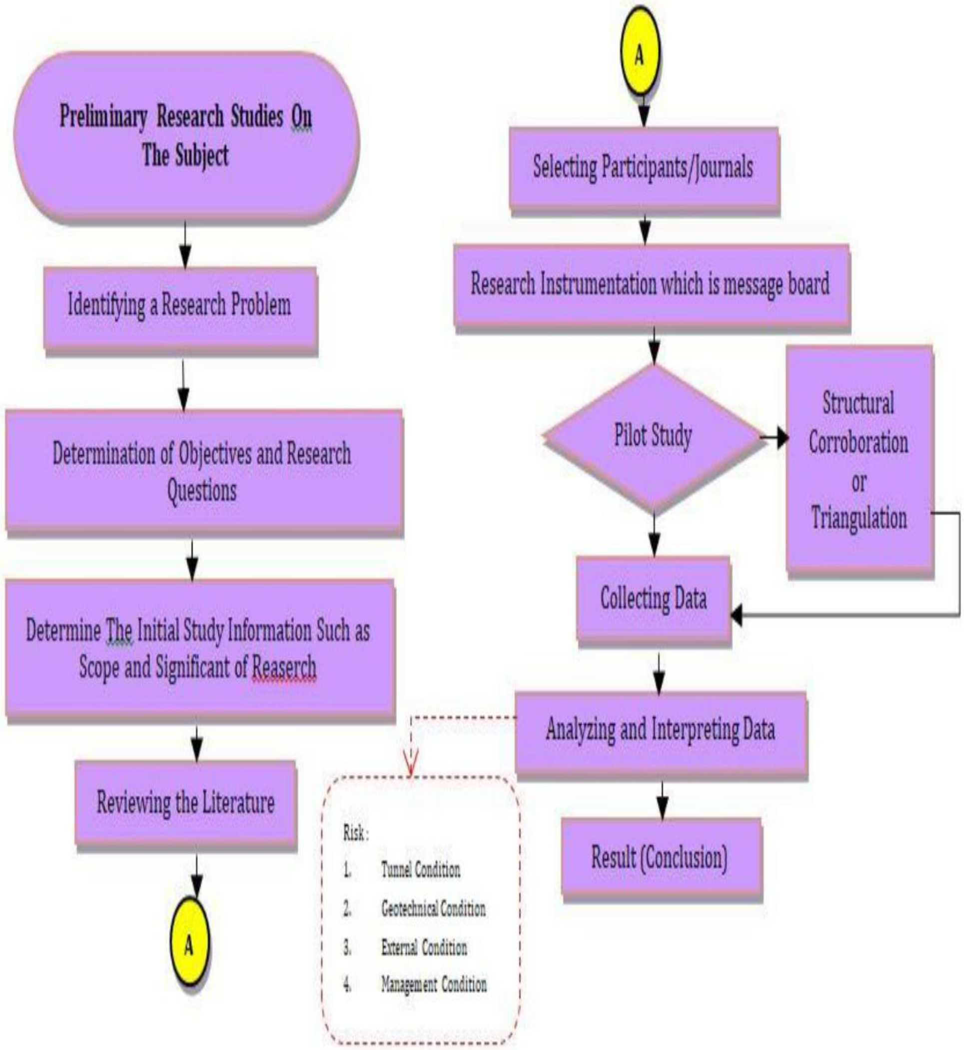

Fig. 1 Research Framework

The list of selected articles is analyzed from the aspect of risk identification in the tunnel construction project as shown in Table 1.

Table 1 Existing Literature review of Risk Identification in Tunnel in Construction Projects

No	Authors	Risk Identification				Result
		Tunnel Condition	Geotechnical Conditions	External Condition	Management Condition	
1	(F. Zhao et al., 2017)	v	v	x	x	In this study, the Bayesian method is proposed to decide the TBM type selection. The advantages and disadvantages of these three TBM (GTBM, SSTBM, DSTBM) are analyzed in detail. 80 cases which were excavated by TBM are collected to get the prior probability. In considering all the risks, the structure of the Bayesian Network model for TBM type selection is established
2	(T. Zhao et al., 2018)	v	v	x	v	This study investigated safety events of various severity levels in metro tunneling excavation. An original data set consisting of 243 event reports was compiled into a database of relevant events in metro tunneling excavation. The database was modular and fully structured, which could be further adapted and scaled to incorporate new reports and optimize analysis results.
3	(J. Zhou et al., 2017)	v	v	v	v	Risk-related regularities on defects of tunnels, obtained from past tunnel projects, is regarded as potential very helpful in risk management. A large amount of defects detection data for railway tunnels is collected in autumn every year in China. It is extremely important to discover the regularities knowledge hidden in database.

4	(H. Zhou et al., 2020)	v	v	v	x	The relationship between the quality and the risk was established using the 4M1E categories as the bridge to integrate the quality and risk measures so that risk could be better quantified by deterministic quality measures. Using D-S evidence theory and FME, the quality data were stratified and fused to avoid the subjectivity in the current expert scoring practices to assess risk.
5	(Jancarikova et al., 2017)	v	x	x	x	Conclusions from EMUT and calculation of the incident´s risk can identify the most common incidents and try to prevent them in the future. It is clear that the trend of increasing of traffic intensity as well as constantly increasing the number of incidents will continue in the upcoming years.
6	(Kembłowski et al., 2017)	v	x	x	x	The process of decision-making in public procurement of construction projects during the preparation and implementation phases ought to be supported by risk identification, assessment, and management. Typically once the risks have been assessed a decision-maker has to consider risk-management activities that minimise the risk events (mitigating factors).
7	(Qiu et al., 2020)	v	v	v	x	The generally regarded as an indicator of tunnel safety is the crack, they said it was one of the most common lining deteriorations. This study can provide a reference for the safety assessment of cracked lining tunnels in seismically active areas and help to determine the reinforcement measures and time more reasonably.

8	(Xue & Zhou, 2017)	v	v	v	v	There are two limits in this paper, on the one hand, managers need to be more rational towards failure, people pay too much attention to success, but unwilling to admit failure, fail to reverse thinking in risk identification. On the other hand, the study of failure knowledge is not perfect enough and it is difficult to quantify the issue. This paper is to put forward a method, much more quantitative work should be done for further study
9	(Andreotti & Lai, 2019)	v	v	v	v	The seismic risk of this kind of infrastructures is generally disregarded even if the post earthquake investigations have proven that tunnels are exposed to seismic risk because several degrees of seismic damage have been recorded. In this sense, a comprehensive risk analysis of mountain tunnels should include also the seismic risk.
10	(Baji et al., 2017)	v	x	v	v	The significance of this is that timely maintenance on components for identified failure modes has the potential to prevent catastrophic structural failures and hence extend the service life.
11	(Benekos & Diamantidis, 2017)	v	x	v	v	Safety measures shall be implemented also on the basis of cost-benefit and social acceptance considerations. Risk acceptance criteria need a broader appraisal and a periodic review based on the safety performance of the tunnels and on the current socio-economical situation.

12	(Borghetti et al., 2019)	v	x	v	v	These curves represent the societal risk, defined as the number of people who can be affected by a certain damage (in this case death). These curves are determined considering the number of people involved in the accident (event) and the duration of their exposure to the potential damage.
13	(Cao & Kalinski, 2017)	v	v	x	x	An assessment approach in terms of reliability indices is developed to predict the allowable design values and evaluate the ground movement by the displacement-controlled method.
14	(Chen et al., 2019)	v	x	v	v	In this paper, the isolation effect of dust masks in tunnel construction was taken into account for the first time, and the dust exposure concentration of workers was corrected by a unique formula according to the inward leakage (IL) and filtration efficiency (FE). The results showed that the isolation of masks obviously reduced the health risk, in which health risk was drastically reduced by 82% under ideal isolation effect and by 26% under actual isolation effect.
15	(Deng, 2018)	v	v	v	v	The construction of a super-long water-conveyance tunnel involves many aspects, such as geological disaster control and response, equipment operation and maintenance, construction safety, quality assurance, investment control, and environmental protection. A TBM geological prospecting system was established that could achieve real-time tracking and detection; if necessary, advanced geological drilling can verify geological situations and help to establish an emergency response plan.

16	(Dong et al., 2018)	v	v	v	v	This paper developed the KIM to visualize the safety knowledge flow in risk management. In the tunnel construction risk management, what safety knowledge was required, who owned it were highlighted by the KIM, and why was it hard to acquire was answered as the knowledge flow barriers were identified.
17	(Fabbri, 2019)	v	v	v	v	This article describes the management and allocation of risks, the procurement strategy, the adopted contractual models, contract and dispute management, and the financing model. These were some of the successful aspects that permitted the Gotthard Base Tunnel to be constructed in accordance with the agreed-upon level of quality, without exceeding the budget, and fully within the time schedule.
18	(Fu et al., 2017)	v	v	x	v	The first grade index “shield launching and arrival stage” is taken as the example to make the risk assessment in this study. There are 10 sub-indexes in shield launching and arrival stage. The expert discussion group is composed of tunnel engineering experts, technical personnel from research institutes, technical personnel from designing institutes and technical personnel from project departments.
19	(Jiang et al., 2019)	v	v	v	x	A quantitative health inspection and assessment system is proposed. Acquisition of a lining surface image with a resolution of 0.5 mm/pixel improves the precision of crack detection.

20	(Kouchami-Sardoo et al., 2019)	v	v	v	v	Bayesian Belief Networks (BBNs) provide a useful approach to address real-world problems, where available data and knowledge are disparate, limited or uncertain. The results showed that weather and management factors were the most important parameters affecting wind erosion risk.
21	(Lei et al., 2011)	v	v	v	v	Significant progress has been made for the risk management of tunnel collapse. During the advancement of excavation, a combined use of analytical (probabilistic) and numerical methods is probably the most efficient approach to check continuously the actual conditions encountered and apply the counter-measures in a timely manner, which should have a wider application in collapse risk assessment and management.
22	(Lin et al., 2020)	v	v	x	x	Water inrush disaster seriously affects the safety of karst tunnel construction. It is essential to assess the risk level of water inrush in karst tunnels accurately, and take some effective countermeasures to reduce the damage to the project.
23	(Wenli Liu et al., 2018)	v	v	v	v	The sensitivities of input variables to different output para- meters are apparently discrepant, and the crucial input variables with high GSI (e.g., X1, X3, X4, X5, X7, X8, and X9) need to be exactly controlled and managed during the tunnel operation, which helps to reduce the tunnel responses and risks. Then, decision making from the results of sensitivity analysis can help enhance the knowledge of de- signers and aid them to optimize the design or management scheme of the tunnel operation when confronting similar tunnels.

24	(Lundin & Antonsson, 2019)	v	x	x	v	In this paper a flexible approach is proposed to assist the competent authority to characterize the decision-problem with regards to the major risk aspects, making it possible in some cases during to be able to justify a decision of tunnel category with alternative approaches to a QRA. Furthermore, in addition to the framework a simple risk analysis approach based on the prescriptive Swedish requirements for road tunnels is developed and presented. With this method an appropriate tunnel category can be derived by the competent authority with less resources and competence compared to make a complete QRA.
25	(Maruvanchery et al., 2020)	v	v	x	v	The present study presents the risk assessment and evaluation of early time and cost predicting tools for large-scale underground cavern projects. Underground construction is always associated with inherent risks due to limited knowledge of existing geological conditions prevailing at the site as well as because of other uncertainties. These projects involve multiface excavation for large volume caverns. The results show that the outputs agree well with the actual construction time in Project A and can predict construction cost and time at the 95% confidence level.

26	(Ntzeremes & Kirytopoulos, 2019)	v	v	v	v	Due to the tunnels' complexity, important parameters for the safe operation of tunnel systems have significant uncertainty. These parameters include: (a) the traffic, (b) the trapped users behaviour during evacuation, (c) the response of the tunnel personnel in activating the mechanical ventilation or the traffic interruption, (d) the fire behaviour and (e) the environmental conditions.
27	(Ntzeremes et al., 2020)	v	x	v	v	With a view to enhance road network's safety, it is crucial to focus primarily on its critical infrastructures, one part of which is tunnels. Bearing in mind that trapped-users' performance can strongly determine a tunnel's level of safety, this paper proposes an evacuation simulation model for increasing the efficiency of quantitative risk assessment.
28	(Pan et al., 2019)	v	x	v	v	This research contributes to (a) the state of knowledge by integrating Bayesian networks with copula, contributing to a more robust risk assessment by accurately modeling the complex dependence structure of risk factors; (b) the state of practice by providing guidelines of the whole-life-cycle safety control for complex systems under uncertainty and randomness, which not only prevent structural failure in advance but also control risk after accident occurrence.

29	(Providakis et al., 2019)	v	v	x	v	Ground settlements caused by tunnelling excavations are particularly important in urban areas, with greater relevance in soft soils. Estimating the settlement risk to adjacent buildings is an important consideration for tunnel planning, design and construction. An example case study of such a system is provided to illustrate the methodology, and thereby demonstrates both that adjustments to the location (alignment) of the tunnel can have a major impact on the risk of settlement-related damage.
30	(Cerić et al., 2011)	v	x	x	v	Risk identification follows project phases. For each identified risk in a particular phase it is necessary to determine risk probability and risk impact, and calculate the corresponding risk exposure.
31	(W. Wang & Fang, 2017)	v	x	v	v	At the meantime, the risk management is the key to the success of the project. This paper is based on questionnaire survey to identify the risk factors of utility tunnel project in PPP mode, and uses SPSS 19 to test the reliability of the questionnaire.
32	(Z. Z. Wang & Chen, 2017)	v	v	v	v	Metro construction is typically a highly complicated project associated with various potential risks. Safety risk analysis and management of metro construction have attracted broad attention because of their close relationship to public safety.

33	(F. Wang et al., 2019)	v	v	v	v	Knowledge capture and reuse are critical in the risk management of tunneling works. This study applies non-parametric BNs, which only require the elicitation of the marginal distribution corresponding to each node and correlation coefficient associated with each edge, to develop a knowledge-based expert system for tunneling risk analysis.
34	(Xiong et al., 2018)	v	v	v	v	Because it is difficult to determine adverse geological conditions along a tunnel in the early stages of construction, 3D geological modeling often lacks sufficient borehole or section data.
35	(Xu et al., 2015)	v	v	v	v	This paper proposes a fuzzy analytic network process to evaluate the risk for Beijing subway tunnel construction using NATM. Firstly, the risk breakdown structure (RBS)–work breakdown structure (WBS) was introduced for risk identification and 5 major risk factors of the construction projects were identified. The risk control system was shown to be effective and ensure the success of tunnel excavation.
36	(Y. Zhang et al., 2019)	v	v	v	v	This paper, with the aim of predicting, monitoring, and diagnosing risk factors for tunnel-induced damage, provides a new framework that integrates the advantages of rough set (RS), cloud model (CM), and Bayesian network (BN). This research contributes to (a) the state of knowledge by providing a novel risk analysis approach that is capable of handling fuzziness, uncertainty, and dynamics in factor characterization; and (b) the state of the practice by providing insights into a better understanding of how to predict, control, and diagnose risks under given observations.

37	(X. P. . Zhou et al., 2017)	v	v	v	v	To account for the perspectives of all parties involved in mechanical tunneling projects, we consulted previous literature and engineering practices to compile a questionnaire, and data were collected from the survey to distill information for the variables of interest.
38	(Fortunato et al., 2012)	v	v	v	v	This finding served as the impetus for the present study, which aimed to identify and evaluate the safety and health risks associated with the design elements and construction management practices implemented to achieve LEED certification.
39	(S. Zhang et al., 2019)	v	v	v	v	Many potential and uncertain safety risk factors must be identified during these types of projects. Therefore, a model is proposed to conduct safety risk identification and improve decision quality
40	(Yu et al., 2017)	v	v	v	v	A probabilistic risk analysis method of diversion tunnel construction simulation is proposed. It enables comprehensive and effective risk analysis of tunnel construction by considering both ordinary risk factors and risk events, which facilitates accurate estimation of construction schedule and effective development of schedule plan.
41	(Hu & Huang, 2014)	v	v	v	v	The purpose of two documents is to indicate to owners what is recommended industry best-practice for risk management and present guideline or code to designers as to the preparation of a comprehensive tunnel risk management system in China.

42	(Pennington & Richards, 2011)	v	v	v	v	Tunnels represent some of the most demanding civil engineering projects due to the inherent uncertainty of the ground and the requirement to accurately predict ground behavior in advance of construction, and related risk consequences in construction.
43	(Fouladgar et al., 2012)	v	v	v	v	The main purpose of this paper is to propose a risk evaluation approach of the problems that might be encountered during tunneling operation.
44	(Klein & O'Carroll, 2017)	v	v	v	v	This is mainly due to the inherent uncertainty involved with geologic conditions and our limited ability to accurately predict geotechnical conditions in advance of construction.
45	(Bai et al., 2014)	v	v	v	v	Application of the proposed multiphase risk-management method is illustrated with a case study, which shows that the most appropriate and economical risk-management method can be achieved and the established objectives of construction quality and timeline can also be ensured;
46	(Teetes et al., 2017)	v	v	v	v	The concept of risk management is based upon prioritizing uncertainty based on the likelihood of risks to occur and the severity of the consequences of those risks. A qualitative risk assessment and analysis focuses on raising the awareness of all concerned to the major risks involved in the design and construction and providing a structured basis for actions to mitigate these risks.

47	(X. P. . Zhou et al., 2017)	v	v	v	v	The 15 risk factors faced by the PPP pattern in the underground comprehensive utility tunnel project are distributed at five levels, and there is a progressive relationship between the various levels of factors. The high-risk factors are affected by the low-level factors.
48	(Wen Liu et al., 2018)	v	v	v	v	The results enlightened on the understanding of the interactions and causal relationships between risk factors in mechanical tunneling, and provided a guideline for improving safety management.

Remarks: v=discussed x=not discussed

Based on the analysis of the contents of the 48 journals in the above table, it was found that the aspect of risk in tunnel construction that has the highest percentage is project risk.

Table 2 The recapitulation of selected journals analyzed

Tunnel Condition							
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
Soil Geotechnical Condition							
1	2	3	4	7	8	9	13
15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38
39	40	41	42	43	44	45	46
47	48						
External Condition							
3	4	7	8	9	10	11	12
14	15	16	17	19	20	21	23
26	27	28	31	32	33	34	35
36	37	38	39	40	41	42	43
44	45	46	47	48			
Management Condition							
2	3	8	9	10	11	12	14
15	16	17	18	20	21	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48

Remarks:
[orange box] = Risk Identification [light yellow box] = Research Journals

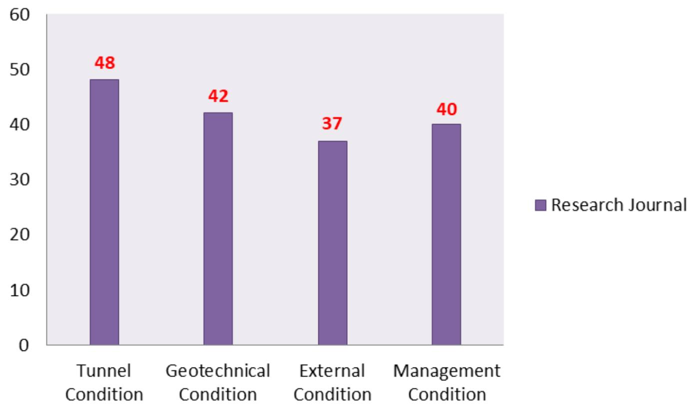

Fig 2. List of Journal's Risk Conditions

3. Result and Discussion

3.1. Tunnel Condition Risk

Generally when mechanized excavation is selected as the construction method, the most important problem is related to selection of the most appropriate TBM and its performance prediction in each geotechnical conditions (F. Zhao et al., 2017). It must be emphasized that there are numerous risk factors in metro tunneling excavation, and it is impossible or unnecessary to exhaustively analyze every risk factor(T. Zhao et al., 2018). Hence, in this research, risk factors were screened and consolidated, such that (1) easily identifiable and manageable risks were excluded (e.g., product quality issues, grout concentration, location of discharge, etc.), (2) risk factors with low probability and no catastrophic consequences were dismissed (e.g., sudden outage of water or electricity, suspended engineering, etc.), and (3) risk factors with different causes but similar consequences were combined (e.g., working face instability was considered as one single risk factor regardless of whether the root cause was sand, soil geology, or confined water) (T. Zhao et al., 2018). Tunnels with different structures may suffer different defects, because they have their own characteristics with various types of materials, geologies, environments, etc. Different defects lead to different potential failures(J. Zhou et al., 2017). Tunnel management and maintenance should pay attention to these kinds of tunnel structures(J. Zhou et al., 2017). The current practices in risk assessment and management have three limitations that have become the major barriers to their adoption in managing the risks in undersea tunneling projects (H. Zhou et al., 2020).

Modern tunneling construction typically uses a tunnel boring machine (TBM), which is a shield machine that can achieve a high-level of mechanized construction to improve productivity and enhance safety (H. Zhou et al., 2020). The tunnels are specific engineering structures, which are constructed in order to shorten transport routes and improve road safety (Jancarikova et al., 2017). Previous studies mostly analyzed concrete tunnel lining in linear elasticity (Qiu et al., 2020). Through monitoring the internal force such as axial force and bending moment of structures, the possible location of cracks and the failure state of linings can be determined (Qiu et al., 2020). The risk identification of shield tunnel construction based on failure knowledge is a complement and perfection to the existing risk identification methods (Xue & Zhou, 2017). Managers need to increase the weight of known risk factors identified from the failure project, and incorporate the unknown risk factors into the system of the existing risk factors (Xue & Zhou, 2017). The explosion-proof lamp as the change tool for the blade is an unknown risk factors (Xue & Zhou, 2017).

Although tunnels are usually less vulnerable than above-ground structures, the seismic risk may actually be greater since a minor damage may still result in great losses (Andreotti & Lai, 2019). In particular, as discussed more in detail in the first case study presented hereinafter, tunnels are part of a wider network and even a small damage to a single component (e.g. waterproofing system) may compromise the serviceability of the whole network (Andreotti & Lai, 2019). The tunnel is an essential infrastructure that plays a pivotal role in transportation network, economy, prosperity, social well-being, quality of life and the health of its population (Baji et al., 2017). From the tunnel system that can cause a variety of potential deficiencies such as seepage, cracking, delamination, drainage, convergence and settlement of the layer structure can cause catastrophic failures and economic losses (Baji et al., 2017). Most collapses of tunnel structures in the world are related to tunnel deterioration with catastrophic consequences (Baji et al., 2017). The accident of tunnel case cannot be easily identified. There are several factors influencing the accident rate in a road tunnel such as traffic volume, tunnel configuration, gradient, driver education, dimensions and alignment, lighting conditions, etc (Benekos & Diamantidis, 2017). Identification of the possible dangers connected with the tunnel system (Borghetti et al., 2019). Safety in tunnels can be improved through actions concerning infrastructures, equipment and management procedures (Borghetti et al., 2019). The identification and evaluation of these provisions requires an analysis that can make the costs and benefits of each action emerge, so that a choice (decision) can be made on the effectiveness, priority and sequence of actuation of these safety measures (Borghetti et al., 2019).

In the study, the risk factors include: (i) soil shear strength; (ii) the ground water table; (iii) concrete lining segment strength; and (iv) pile bearing capacity (Cao & Kalinski, 2017). This paper presents a risk analysis of shield tunneling construction based on the computational results from three-dimensional simulation of two metro system projects in China (Cao & Kalinski, 2017). With a quantitative approach for evaluating risk factors in shield tunneling construction is investigated with the concern of ground movement (Cao & Kalinski, 2017). Risk factors influence the safety of shield tunneling construction at each stage (Cao & Kalinski, 2017). In this paper, a health risk assessment model in the field of public environmental health was employed to quantitatively assess the occu- pational exposure of tunnel construction workers (Chen et al., 2019).

Tunnel safety is defined like a safety and protection of persons, property, and surround of structure, which is given by result of risk evaluation, solution reasoning in point of risks, fire-safety structure solution and solution of structure influence on environment, protection of monuments, nature and countryside (Schlosser et al., 2014). The main differences between urban road and highway tunnels lie in the characteristics of limited plane wiring , diversified cross section, high standard of fire and ventilation design, high requirement of tunnel entrance landscape , and high utilization rate (B. Zhou et al., 2020).

The principal risks (or hazards) to the safety in tunneling can be identified as follows (Lei et al., 2011): (1) Unforeseen or unexpected ground conditions; (2) Variable and mixed face conditions (fine sand layer); (3) Ground loss/collapse at the face, causing inundation and/or large settlements; (4) Man-made obstructions or hazards to tunneling, including utility services and unexploded bomb; (5) Human errors. Three factors of tunnel structure may disturb the surrounding excavation environment, such as the cover-span ratio (C1), covering depth (C2), and tunnel diameter (C3) (Y. Zhang et al., 2019).

3.2. Geotechnical Condition Risk

Human errors have recurrent patterns and typically include poor technology, slack management, and inadequate hazard handling. Natural causes of accidents in mechanical tunnel excavation include adverse hydrogeological conditions, groundwater, heavy rainfall, soft soil layers, etc (Wen Liu et al., 2018). With regard to mechanical tunnel excavation, it was found that only 10% of the accidents could be completely attributed to natural causes, whereas 30% of accidents resulted purely from human errors and 60% of accidents occurred because of the combination of human mistakes and natural mishap (Wen Liu et al., 2018). In fact, challenging geological conditions ranked only as the second biggest risk factor in the analysis, although geological conditions have been traditionally considered the topmost source of accidents in metro tunneling excavation (T. Zhao et al., 2018). Due to it is not conductive to our studies, the geological classification method based on the firmness and density of the rocks and soils is applied into this study (J. Zhou et al., 2017). As the shield machine drills through the underground space, the high water pressure, complex geological conditions, and pore water trapped in unstable rocks can cause water seepage and gushing that can result in devastating accidents on a large scale (H. Zhou et al., 2020). As such, in setting the range for the blade speed measure of the driving parameters of the shield machine risk factor, the difference between the actual speed and the control speed, which is determined based on the geological environment and site conditions rather than the actual speed, is used to incorporate the cross-category influences of the risk factors (H. Zhou et al., 2020). The design data and geological investigation indicate that the ground formation which the tunnels pass through is mudstone mixed with sandstone, and the upper stratum to the surface is silt and silty clay with a thickness of about 0–3 m (Qiu et al., 2020). Due to the specificity of hydrogeological conditions as well as the selection and operation of shield machine in the construction of shield tunnel, the risk identification of shield tunnel must be combined with the construction process, this is called the dynamic process of risk identification (Xue & Zhou, 2017). Even when the seismic action is not a critical issue (e.g. tunnels located in zones of low seismic activity), the design of mountain tunnels is generally associated with a high level of risks due to a whole series of uncertainties involved (e.g. complex geological environments, limited data, difficult topographical conditions, sophisticated construction technology) (Andreotti & Lai, 2019). There are risk factors in the construction of protective tunnels by investigating the mechanism of ground movement and developing an index system for stability with respect to land settlement, including spatial conditions of the nearest infrastructure and geotechnical conditions at the construction site (Cao & Kalinski, 2017). The geotechnical challenge is to understand the ground movement mechanism around the tunnel associated with the disturbance of in-situ soil in the longitudinal direction and the reconsolidation with varied pore pressure in the transverse distribution (Cao & Kalinski, 2017). The most commonly encountered geotechnical risks for tunnels are (Pennington & Richards, 2011): (1) Excessive or unexpected groundwater inflow, (2) Unstable ground or unanticipated ground behavior, (3) Limited response capability due to confined working environment, (4) Poor judgment or error in design, (5) Incompatible selection of means and methods, (6) Poor on-site management and communication, (7) Control.

3.3. External Condition Risk

Due to lack of sufficient data, this study has just considered the potential risks of defects resulted from tunnel structures (J. Zhou et al., 2017). However, other factors caused by environment, management, operation, disaster and so on should also be taken into consideration (J. Zhou et al., 2017). This paper highlighted the important effect of the longitudinal cracks in the permanent lining on the seismic capacity of tunnels by a modified deformation-based pseudostatic analysis (Qiu et al., 2020). This analysis employed a reconstructed damaged plasticity constitutive model of reinforced concrete to simulate the propagation of lining cracks (Qiu et al., 2020). The risk factors that caused the failure of the project which are reverse identified by FCTA approach (Xue & Zhou, 2017). According to the analysis above, the improper use of explosion-proof lamp as the change tool for the blade is the risk factor, the harmful methane gas and the shortage of security intention, together led to the occurrence of the explosion (Xue & Zhou, 2017). The seismic risk of this kind of infrastructures is generally disregarded even if the post-earthquake investigations have proven that tunnels are exposed to seismic risk because several degrees of seismic damage have been recorded (Andreotti & Lai, 2019). Implementation of the proposed maintenance strategy to a case study tunnel confirms the applicability of the strategy in maintenance of tunnel structures (Baji et al., 2017). In assessing risk the uncertainties of the influencing parameters is of major importance and should be dealt with (Benekos & Diamantidis, 2017). Risk in itself cannot be accepted unless compared with the benefit it brings (Borghetti et al., 2019). Risk acceptance is a very complex matter that has been studied evenby sociologists and psychologists, because it involves aspects tied to perception, level of instruction, social status and religion (Borghetti et al., 2019). These curves represent the societal risk, defined as the number of people who can be affected by a certain damage (in this case death) (Borghetti et al., 2019). These curves are determined considering the number of people involved in the accident (event) and the duration of their exposure to the potential damage (Borghetti et al., 2019).

Remarkable achievements have been made in TBM tunneling in many projects; however, the risk of frequent accidents cannot be eradicated, for the following reasons (Deng, 2018): (1) **Lack of perception.** A TBM lacks scientific methods and effective means to quickly perceive information about the surrounding rocks and the operating conditions of its equipment and key components; therefore, feedback between the rock and the machine is delayed, (2) **Lack of decision-making.** Due to a lack of tunneling evaluation and of effective means to make intelligent decisions, practical tasks mainly rely on human experience rather than on scientific bases. This shortcoming may result in low efficiency and resource waste, and may furthermore lead to serious incidents such as collapse and machine blockages, (3) **Lack of a platform.** Due to the lack of a necessary platform for information exchange and analysis, massive information on TBM tunneling is not saved and analyzed effectively. It is also urgently necessary to develop the use of information technology, the Internet of Things, big data and intelligent algorithms, and other key technologies in TBM construction projects, in order to achieve innovative breakthroughs in platform establishment.

3.4. Management Condition Risk

Many inherently risky industries improve their safety management by learning from near-miss incidents (T. Zhao et al., 2018). The construction industry is starting to manage incidents that can result in work accidents and improve safety, and several studies have been carried out to introduce systems to manage incidents that can result in work accidents during construction (T. Zhao et al., 2018). Risk management has become one of the most important tasks in construction management (Xue & Zhou, 2017). The most important purpose of risk management is to reduce the probability of risk occurrence and mitigate the impact of risk, therefore, most of the existing literatures focus on risk control, and the risk response measures from the perspective of the owners, contractors and subcontractors (Xue & Zhou, 2017). Traditionally, risks have been managed indirectly through the engineering decisions taken during the design and construction phases (Andreotti & Lai, 2019). This way of doing translates into a non- objective evaluation of the risks and a nonscientific risk management (Andreotti & Lai, 2019). On the other hand, the systematic risk assessment and management techniques can be used to control the risk level within an acceptable range (Andreotti & Lai, 2019). The significance of this is that timely maintenance on components for identified failure modes has the potential to prevent catastrophic structural failures and hence extend the service life (Baji et al., 2017). It can be concluded that the proposed framework can help tunnel operators and asset managers develop a risk cost optimised maintenance strategy for tunnels under their management (Baji et al., 2017). From this perspective, risk analysis can be seen as a useful instrument for supporting decisions when evaluating the safety of the tunnel system, identifying those infrastructure, equipment and management procedures which guarantee greater benefits in terms of expected risk reduction and at the same cost (Borghetti et al., 2019). Safety in tunnels can be improved through actions concerning infrastructures, equipment and management procedures (Borghetti et al., 2019). Considering, for example, the societal risk associated with a road tunnel, mitigation through the introduction of measures (related to infrastructure, equipment and management procedures) must be compared with the possible expected advantages (benefits), for example the reduction in travel time, road accidents, atmospheric and noise pollution (Borghetti et al., 2019). Technical personnel safety management is a known risk factor, but it is not implemented in place, it is necessary to increase their weight in the assessment of risk factors (Xue & Zhou, 2017).

Construction management: According to the project reports, it was not likely to have sufficient time for design and technical review (Lei et al., 2011). Strong and urgent social demand for the release of traffic congestion urged decision makers to hurry, which in turns engineers and construction workers involved in the project urged to hurry (Lei et al., 2011). The over-demand and insufficient time affected normal civil engineering process considerably (Lei et al., 2011). These situations were unfavorable in performing safe construction (Lei et al., 2011).

3.5. Result

Table 3 Mapping research journals based on risk factor

Factor	Research Journal
Tunnel Condition Risk	
Cover-span ratio	36
Covering depth	36 41 42 43 44 45 46 47 48
Tunnel diameter	1 2 3 4 15 36
Geological Condition Risk	
Soil quality	36 41 42 43 44 45 46 47 48
Friction angle	1 2 3 4 17 36
Compression modulus	36
Soil cohesion	20 36
Poisson ratio	36
Soil Density	20 36 41 42 43 44 45 46 47 48
Factor	Research Journal
External Condition Risk	
Relative stiffness	36
Bridge intact conditions	36 41 42 43 44 45 46 47 48
Structure configuration	36 41 42 43 44 45 46 47 48
Current condition	1 2 3 4 15 20 36 41 42 43
Tunnel diameter	20 44 45 46 47 48
Friction angle	36
Management Condition Risk	
Rate of soil loss	36
Construction method	36 39
Management level	36 39

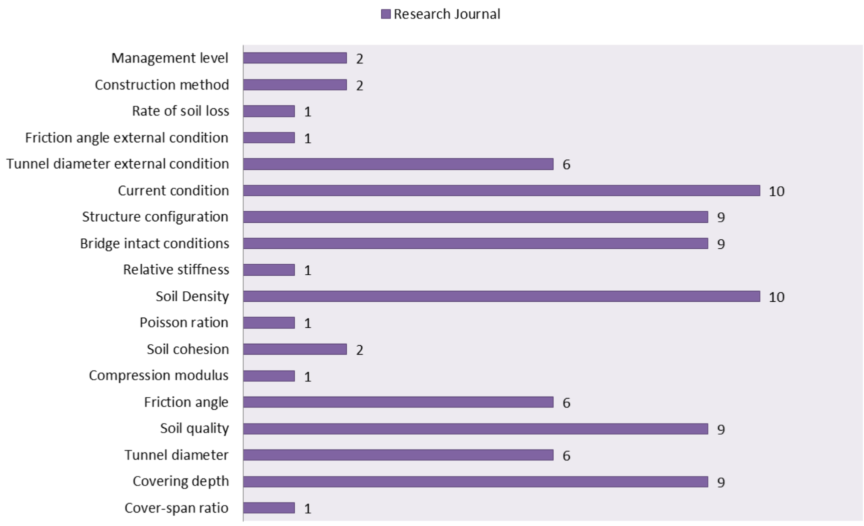

Fig 6. Bar charts of Factors Risk Conditions

Based on a compilation of available literature, a list of risks is compiled along with the boundary criteria based on the factor of influence on potential hazards as shown in Figure 7.

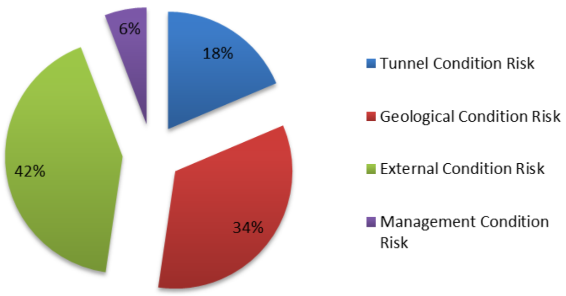

Fig 7. Risk Criteria Factor of Influence on Potential Hazards]

4. Conclusion

Every construction project is always faced with the possibility of various occurrence kinds of risks. The higher the level of complexity of a project, the greater the level of risk that might happen to the project. Risk Identification process includes activities that identify potential risks that might occur in a project. In general the risks that must be considered in road tunnel planning consists of: Unstable slopes or rocks falling on road alignments and tunnel portal, Problems with construction through fault zones, low rock mass strength, lack of stability and compression conditions, Potential environmental effects, such as deterioration and vibration, Changes in the face of natural water, water entering into excavation work, Rock cavity, Earthquake load, Tunnel length, Number of parallel tunnels and number of lanes, Tunnel cross section geometry, Vertical and horizontal alignment, Structure type, Directional or two-way traffic, Traffic volume of each tunnel (including distribution time), Risk of congestion (daily or seasonal), Access time for emergency services, Number and percent of heavy transport vehicles, The amount and percent of types of traffic that transport dangerous goods, Characteristics of access roads, Tunnel entry points and exits, Lane width, Speed of plan, Geographical and meteorological environments, Special characteristics, for example the location of the tunnel is under water or under buildings.

References

1. Andreotti, G., & Lai, C. G. (2019). Use of fragility curves to assess the seismic vulnerability in the risk analysis of mountain tunnels. *Tunnelling and Underground Space Technology*, *91*(June 2018), 103008. https://doi.org/10.1016/j.tust.2019.103008
2. Bai, Y., Dai, Z., & Zhu, W. (2014). Multiphase risk-management method and its application in tunnel engineering. *Natural Hazards Review*, *15*(2), 140–149. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000124
3. Baji, H., Li, C. Q., Scicluna, S., & Dauth, J. (2017). Risk-cost optimised maintenance strategy for tunnel structures. *Tunnelling and Underground Space Technology*, *69*(November 2016), 72–84. https://doi.org/10.1016/j.tust.2017.06.008

4. Benekos, I., & Diamantidis, D. (2017). On risk assessment and risk acceptance of dangerous goods transportation through road tunnels in Greece. *Safety Science*, *91*, 1–10. https://doi.org/10.1016/j.ssci.2016.07.013
5. Borghetti, F., Cerean, P., Derudi, M., & Frassoldati, A. (2019). *Road Tunnels: An Analytical Model for Risk Analysis*. https://doi.org/10.1007/978-3-030-00569-6
6. Cao, L., & Kalinski, M. (2017). Risk Analysis of Subway Shield Tunneling. *Geotechnical Special Publication*, *GSP 285*, 309–319. https://doi.org/10.1061/9780784480724.029
7. Cerić, A., Marčić, D., & Ivandić, K. (2011). A risk-assessment methodology in tunnelling. *Tehnicki Vjesnik*, *18*(4), 529–536.
8. Chen, X., Guo, C., Song, J., Wang, X., & Cheng, J. (2019). Occupational health risk assessment based on actual dust exposure in a tunnel construction adopting roadheader in Chongqing, China. *Building and Environment*, *165*(August), 106415. https://doi.org/10.1016/j.buildenv.2019.106415
9. Deng, M. (2018). Challenges and Thoughts on Risk Management and Control for the Group Construction of a Super-Long Tunnel by TBM. *Engineering*, *4*(1), 112–122. https://doi.org/10.1016/j.eng.2017.07.001
10. Dong, C., Wang, F., Li, H., Ding, L., & Luo, H. (2018). Knowledge dynamics-integrated map as a blueprint for system development: Applications to safety risk management in Wuhan metro project. *Automation in Construction*, *93*(October 2017), 112–122. https://doi.org/10.1016/j.autcon.2018.05.014
11. Fabbri, D. (2019). Risk, Contract Management, and Financing of the Gotthard Base Tunnel in Switzerland. *Engineering*, *5*(3), 379–383. https://doi.org/10.1016/j.eng.2019.04.001
12. Fortunato, B. R., Hallowell, M. R., Behm, M., & Dewlaney, K. (2012). Identification of safety risks for high-performance sustainable construction projects. *Journal of Construction Engineering and Management*, *138*(4), 499–508. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000446
13. Fouladgar, M. M., Yazdani-Chamzini, A., & Zavadskas, E. K. (2012). Risk evaluation of tunneling projects. *Archives of Civil and Mechanical Engineering*, *12*(1), 1–12. https://doi.org/10.1016/j.acme.2012.03.008
14. Fu, H., Huang, Z., & Zhang, J. (2017). Risk Comprehensive Assessment of Shield Tunnel Construction Based on Cloud Theory. *Geotechnical Special Publication*, *GSP 285*, 334–345. https://doi.org/10.1061/9780784480724.031
15. Hu, Q., & Huang, H. (2014). The State of the Art of Risk Management Standards on Tunnels and Underground Works in China. *Vulnerability, Uncertainty, and Risk: Quantification, Mitigation, and Management - Proceedings of the 2nd International Conference on Vulnerability and Risk Analysis and Management, ICVRAM 2014 and the 6th International Symposium on Uncertainty Modeling A*, 419–426. https://doi.org/10.1061/9780784413609.043
16. Jancarikova, E., Mikolaj, J., & Danišovič, P. (2017). Risk and Incidents Assessment in Slovak Road Tunnels. *Procedia Engineering*, *192*, 376–380. https://doi.org/10.1016/j.proeng.2017.06.065
17. Jiang, Y., Zhang, X., & Taniguchi, T. (2019). Quantitative condition inspection and assessment of tunnel lining. *Automation in Construction*, *102*(February), 258–269. https://doi.org/10.1016/j.autcon.2019.03.001
18. Kembłowski, M. W., Grzyl, B., Kristowski, A., & Siemaszko, A. (2017). Risk Modelling with Bayesian Networks - Case Study: Construction of Tunnel under the Dead Vistula River in Gdansk. *Procedia Engineering*, *196*(June), 585–591. https://doi.org/10.1016/j.proeng.2017.08.046
19. Klein, S., & O'Carroll, J. (2017). *Geotechnical Risk Assessments for Tunneling/Underground Projects*. 350–359.
20. Kouchami-Sardoo, I., Shirani, H., Esfandiarpour-Boroujeni, I., & Bashari, H. (2019). Application of a Bayesian belief network model for assessing the risk of wind erosion: A test with data from wind tunnel experiments. *Aeolian Research*, *41*(December 2018), 100543. https://doi.org/10.1016/j.aeolia.2019.100543
21. Lei, Y., Zeng, X., & Huang, F. (2011). Risk analysis and management for the collapses of tunnel. *Advanced Materials Research*, *168–170*, 2518–2523. https://doi.org/10.4028/www.scientific.net/AMR.168-170.2518
22. Lin, C., Zhang, M., Zhou, Z., Li, L., Shi, S., Chen, Y., & Dai, W. (2020). A new quantitative method for risk assessment of water inrush in karst tunnels based on variable weight function and improved cloud model. *Tunnelling and Underground Space Technology*, *95*(October 2019), 103136. https://doi.org/10.1016/j.tust.2019.103136
23. Liu, Wen, Zhao, T., Zhou, W., & Tang, J. (2018). Safety risk factors of metro tunnel construction in China: An integrated study with EFA and SEM. *Safety Science*, *105*(August 2017), 98–113. https://doi.org/10.1016/j.ssci.2018.01.009
24. Liu, Wenli, Wu, X., Zhang, L., Wang, Y., & Teng, J. (2018). Sensitivity analysis of structural health risk in operational tunnels. *Automation in Construction*, *94*(June), 135–153. https://doi.org/10.1016/j.autcon.2018.06.008
25. Lundin, J., & Antonsson, L. (2019). Road tunnel restrictions – Guidance and methods for categorizing road tunnels according to dangerous goods regulations (ADR). *Safety Science*, *116*(August 2018), 170–182. https://doi.org/10.1016/j.ssci.2019.03.004

26. Maruvanchery, V., Zhe, S., & Robert, T. L. K. (2020). Early construction cost and time risk assessment and evaluation of large-scale underground cavern construction projects in Singapore. *Underground Space (China)*, *5*(1), 53–70. https://doi.org/10.1016/j.undsp.2018.10.002
27. Ntzeremes, P., & Kirytopoulos, K. (2019). Evaluating the role of risk assessment for road tunnel fire safety: A comparative review within the EU. *Journal of Traffic and Transportation Engineering (English Edition)*, *6*(3), 282–296. https://doi.org/10.1016/j.jtte.2018.10.008
28. Ntzeremes, P., Kirytopoulos, K., & Filiou, G. (2020). Quantitative Risk Assessment of Road Tunnel Fire Safety: Improved Evacuation Simulation Model. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, *6*(1), 1–11. https://doi.org/10.1061/AJRUA6.0001029
29. Pan, Y., Ou, S., Zhang, L., Zhang, W., Wu, X., & Li, H. (2019). Modeling risks in dependent systems: A Copula-Bayesian approach. *Reliability Engineering and System Safety*, *188*(March), 416–431. https://doi.org/10.1016/j.ress.2019.03.048
30. Pennington, T. W., & Richards, D. P. (2011). Understanding uncertainty: Assessment and management of geotechnical risk in tunnel construction. *Geotechnical Special Publication*, *224 GSP*, 552–559. https://doi.org/10.1061/41183(418)54
31. Providakis, S., Rogers, C. D. F., & Chapman, D. N. (2019). Predictions of settlement risk induced by tunnelling using BIM and 3D visualization tools. *Tunnelling and Underground Space Technology*, *92*(July), 103049. https://doi.org/10.1016/j.tust.2019.103049
32. Qiu, W., Li, B., Gong, L., Qi, X., Deng, Z., Huang, G., & Hu, H. (2020). Seismic capacity assessment of cracked lining tunnel based on the pseudo-static method. *Tunnelling and Underground Space Technology*, *97*(December 2019), 103281. https://doi.org/10.1016/j.tust.2020.103281
33. Schlosser, F., Rázga, M., & Danišovič, P. (2014). Risk analysis in road tunnels. *Procedia Engineering*, *91*(TFoCE), 469–474. https://doi.org/10.1016/j.proeng.2014.12.028
34. Teetes, G., Koziol, M., & Perez, N. (2017). Risk Management on Water Infrastructure Tunnel Projects-DC Clean Rivers Project Case History. *Geotechnical Special Publication*, *GSP 285*, 388–398. https://doi.org/10.1061/9780784480724.035
35. Wang, F., Li, H., Dong, C., & Ding, L. (2019). Knowledge representation using non-parametric Bayesian networks for tunneling risk analysis. *Reliability Engineering and System Safety*, *191*(December 2018). https://doi.org/10.1016/j.ress.2019.106529
36. Wang, W., & Fang, J. (2017). Study on the Risk Evaluation Model of Utility Tunnel Project under a PPP Mode. *ICCREM 2017: Prefabricated Buildings, Industrialized Construction, and Public-Private Partnerships - Proceedings of the International Conference on Construction and Real Estate Management 2017*, 371–381. https://doi.org/10.1061/9780784481059.039
37. Wang, X., Li, S., Xu, Z., Li, X., Lin, P., & Lin, C. (2019). An interval risk assessment method and management of water inflow and inrush in course of karst tunnel excavation. *Tunnelling and Underground Space Technology*, *92*(April), 103033. https://doi.org/10.1016/j.tust.2019.103033
38. Wang, Z. Z., & Chen, C. (2017). Fuzzy comprehensive Bayesian network-based safety risk assessment for metro construction projects. *Tunnelling and Underground Space Technology*, *70*(August), 330–342. https://doi.org/10.1016/j.tust.2017.09.012
39. Xiong, Z., Guo, J., Xia, Y., Lu, H., Wang, M., & Shi, S. (2018). A 3D Multi-scale geology modeling method for tunnel engineering risk assessment. *Tunnelling and Underground Space Technology*, *73*(October 2016), 71–81. https://doi.org/10.1016/j.tust.2017.12.003
40. Xu, W., Liu, B., Ren, C. F., Han, Y., & Xin. (2015). *Risk Management for Beijing Subway Tunnel Construction Using the New Austrian Tunneling Method: A Case Study*. 289–298. http://www.asce-ictd.org/
41. Xue, M., & Zhou, H. (2017). *Risk Identification of Shield Tunnel Construction Based on Failure Knowledge*. *2015*, 337–344.
42. Yu, J., Zhong, D., Ren, B., Tong, D., & Hong, K. (2017). Probabilistic Risk Analysis of Diversion Tunnel Construction Simulation. *Computer-Aided Civil and Infrastructure Engineering*, *32*(9), 748–771. https://doi.org/10.1111/mice.12276
43. Zhang, S., Shang, C., Wang, C., Song, R., & Wang, X. (2019). Real-Time Safety Risk Identification Model during Metro Construction Adjacent to Buildings. *Journal of Construction Engineering and Management*, *145*(6). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001657
44. Zhang, Y., Zhang, L., & Wu, X. (2019). Hybrid BN Approach to Analyzing Risk in Tunnel-Induced Bridge Damage. *Journal of Performance of Constructed Facilities*, *33*(5), 1–14. https://doi.org/10.1061/(ASCE)CF.1943-5509.0001310
45. Zhao, F., Xue, Y., Li, Y., & Zhao, H. (2017). A Risk Assessment System for Hard Rock TBM Selection Based on Bayesian Belief Networks (BBN). *Geotechnical Special Publication*, *2*(GSP 285), 454–467. https://doi.org/10.1061/9780784480724.041

46. Zhao, T., Liu, W., Zhang, L., & Zhou, W. (2018). Cluster Analysis of Risk Factors from Near-Miss and Accident Reports in Tunneling Excavation. *Journal of Construction Engineering and Management, 144*(6). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001493
47. Zhou, B., Wang, C., Liu, F., & Wang, E. (2020). Whole Risk Assessment System and Management System of Urban Road Tunnel Operation Stage. *Journal of Highway and Transportation Research and Development (English Edition)*, *14*(1), 94–101. https://doi.org/10.1061/jhtrcq.0000721
48. Zhou, H., Zhao, Y., Shen, Q., Yang, L., & Cai, H. (2020). Risk assessment and management via multi-source information fusion for undersea tunnel construction. *Automation in Construction*, *111*(December 2019), 103050. https://doi.org/10.1016/j.autcon.2019.103050
49. Zhou, J., Xu, W., Guo, X., & Liu, X. (2017). A hierarchical network modeling method for railway tunnels safety assessment. *Physica A: Statistical Mechanics and Its Applications*, *467*, 226–239. https://doi.org/10.1016/j.physa.2016.10.026
50. Zhou, X. P. ., Pan, H., & Shen, Y. (2017). *China's Underground Comprehensive Utility Tunnel Project of PPP Mode Risk Identification*. *2013*, 337–344.

IDENTIFIKACIJA RIZIKA U PROJEKTIMA IZGRADNJE TUNELA: PREGLED LITERATURE

Svaki građevinski projekt uvek je suočen s mogućnošću raznih vrsta rizika. Što je nivo složenosti projekta veći, to je veći nivo rizika projekta. Na osnovu istorijskih podataka izgradnje tunela zabeleženi su mnogi problemi, pa čak i neuspesi u izgradnji tunela uzrokovani raznim faktorima koji imaju uticaj na kašnjenje projekata. Očekuje se da će upravljanje rizicima smanjiti negativni uticaj rizika na građevinske radove. Kod izgradnje tunela potrebno je upravljanj visokim rizikom, pa je neophodno identifikovati rizike koji mogu minimizovati loše rizike. Očekuje se da će upravljanje rizikom smanjiti negativne efekte rizika sa kojima se suočavaju građevinari, i potrebno je sprovesti identifikaciju rizika kako bismo upravljali rizicima s kojima ćemo se suočiti. Da bismo uspešno poboljšali izvođenje projekata tunela, moramo identifikovati različite faktore rizika u projektu radi efikasnog ostvarenja projekata. Metoda istraživanja započinje opsežnim pregledom literature i pregledom najmanje 48 časopisa u preglednim člancima kako bi se pružila lista glavnih faktora rizika koji se takođe dodaju ekspertizi kako bi se postigla lista konačnih faktora rizika koji sadrže sve rizike koji se mogu susresti tokom izgradnje puta. Ova analiza uključuje identifikaciju, klasifikaciju različitih rizika koji su uključeni u izgradnju projekta izgradnje tunela.

Ključne reči: *rizik, izgradnja tunela, projekt tunela, identifikacija rizika*