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Risk assessment on environmental impact in Xizang Road Tunnel

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ABSTRACT: Nowadays, with the increase in the demands for environmental protection, the assessment of construction on the environmental impact has become a new topic. Based on the Risk Management Software (TRM 1.0) which is developed by Tongji University, the authors investigate the surrounding environment condition and construction process, calculate the probability of hazard risks and its loss, and provide the ranks of hazard risks and the corresponding treatment on risks. It may give some advice and suggestions on underground construction.

1 INTRODUCTION

Because of its unique unseen character, isolation from nature and complexity, the construction of underground works is more difficult than the process of general buildings. In the age of high demands of environmental protection, the environmental impact caused by underground works construction is attracting increasing attention. The paper is for the risk assessment on environmental impact caused by the construction of Shanghai Xizang South Road Tunnel from the point view of risk. The authors make quantitative analysis on the impact of construction on surrounding buildings, the impact on surrounding roads and the impact on surrounding pipelines. At last, the ranks of hazard risks are provides as well as the risk reduction measures. It may give some advice and suggestions on underground construction.

2 PROJECT PROFILE

Xizang South Road Tunnel is a planning river-crossing tunnel in Shanghai Expo. The main line of the tunnel is from the intersection of Puxi Xizang South Road and Zhongshan South Road to the intersection of Pudong Binzhou Road and Yunlian Road, including the intersection of Binzhou Road and Pudong South Road. The total project is 2673 meters long. Figure 1 shows the road tunnel plan.

The tunnel is advanced by Slurry Balance Shield machine of 11.36-meter diameter. Project consists

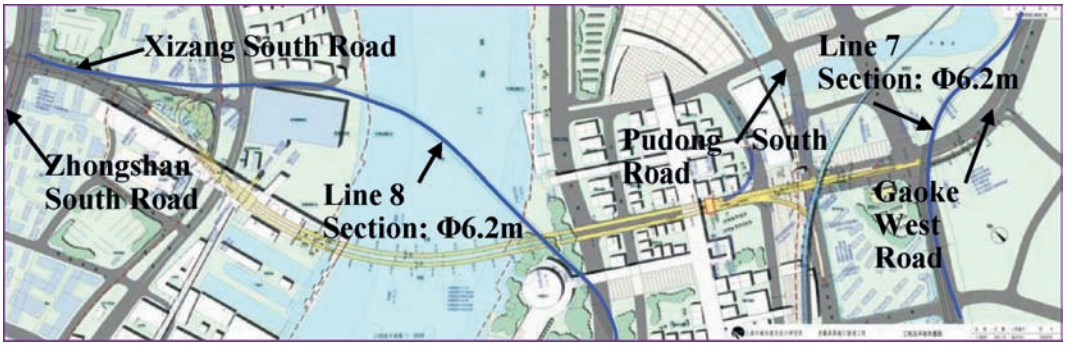

Figure 1. Xizang south road tunnel plan.

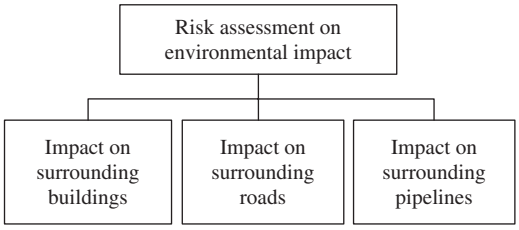

Figure 2. Risk identification map of environmental impact.

of the approach of Puxi, Puxi rectangular tunnel (including wells), the circular tunnel, Pudong rectangular tunnel (including wells) and Pudong approach. Along the setting location, there are great population, many buildings, complex pipelines and complex traffic systems. Also, the tunnel will up-cross Line 7 and down-cross Line 8, both of which are components of Shanghai Railway Transit System. Moreover, the tunnel will intersect with magnetic train line which will be constructed soon. In the later part, the authors will assess the risk of environmental impact caused by construction, including impact on surrounding buildings, on surrounding roads and on surrounding pipelines. It is shown in Figure 2.

3 RISK ASSESSMENT ON ENVIRONMENTAL IMPACT

3.1 *Risk assessment process*

Risk assessment is usually divided into three steps (Guo, 1986 & Chen, 2004):

1 Risk identification: Analyze all potential risk factors which may influence the environment during the construction process, and then classify, collating those parameters affecting greatly.
2 Risk analysis: Calculate the probability and consequence of risk factors.
3 Risk evaluation: According to some certain criteria, evaluate the risk factors.

Where, risk evaluation is to use Experts Investigation Method (EIM) and Confidence Index Method (CIM), to analyze the probability and consequence of risk factors, and to gain the ranks of risks. EIM is a kind of gathering information method. We send investigation forms concerning with the risk factors in engineering to experts, professors, senior consulters and so on. The CIM is just an index to show their confidence when doing the judgment. The data can be put into the database of TRM 1.0, which is developed by Tongji University (Huang, et al 2006b). The detailed data-input procedure can refer to the reference Huang, et al 2006b. Table 1 shows part of the risk investigation form.

In this paper, the applied risk evaluation criteria is "Guidelines for Tunnelling Risk Management" enacted by the International Tunnel Association in 2002 and "Guidelines of Risk Management for Metro Tunnelling and Underground Engineering Works" enacted by Tongji University (International Tunnel Association, 2002 & Huang, et al 2006a). They are shown in Tables 2, 3, 4 and 5.

3.2 *Risk assessment on environmental impact on surrounding buildings*

3.2.1 *Risk identification*

The possible risk hazards of surrounding buildings caused by construction can be illustrated in Figure 3 (Yao, et al 2006).

Table 1. Risk investigation form (part of it).

Environmental assessment		Occurrence probability		Loss	
Risk hazard	Risk-inducing factor	Probability rank	Confidence index	Loss rank	Confidence index

Table 2. Risk occurrence probability ranks.

Ranks	A	B	C	D	E
Occurrence probability	Impossible $P < 0.01\%$	Seldom $0.01\% \le P < 0.1\%$	Occasional $0.1\% \le P < 1\%$	Possible $1\% \le P < 10\%$	Frequent $P \ge 10\%$

Table 3. Loss ranks of risk hazards*.

Ranks	1	2	3	4	5
Details	Ignored	Considered	Serious	Very serious	Disastrous

*Here, the criterion on rank of loss differs from country to country. In China, the loss is disastrous when 5 lives lost.

3.2.2 *Risk analysis*

The overall sinking of buildings is caused by the even settlement of ground. Uneven settlement can induce the tilting and cracking of buildings. During the construction process, many factors can cause ground settlement (Yao & Huang, 2007). For example, the seepage of shield and pit, pit collapse, the improper earth pressure of shield and support damage. Such factors may also be the cause of building damage. If this happens, it will cause great social influence and economic loss.

The passing buildings of the tunnel can be shown in Table 6, Appendix 1 & 2, respectively.

We may see, the buildings are very dense, therefore the risk is high. It is very easy to tilt or crack for the buildings during the construction.

3.2.3 *Risk evaluation*

By sending out investigation forms, and using the TRM 1.0, the authors get the risk ranks of these risk hazards. The results are shown in Table 7, from which we may see building's crack is more risky and is highly probable to happen.

Table 4. Risk evaluation matrix.

		Loss				
Risk		1. Ignored	2. Considered	3. Serious	4. Very serious	5. Disastrous
Occurrence probability	A: $P < 0.01\%$	1A	2A	3A	4A	5A
	B: $0.01\% \leq P < 0.1\%$	1B	2B	3B	4B	5B
	C: $0.1\% \leq P < 1\%$	1C	2C	3C	4C	5C
	D: $1\% \leq P < 10\%$	1D	2D	3D	4D	5D
	E: $P \geq 10\%$	1E	2E	3E	4E	5E

Table 5. Risk acceptance criteria.

Ranks	Risk	Acceptance criteria	Measures
I	1A,2A,1B,1C	Ignored	No need for management and supervision
II	3A,2B,3B,2C,1D,1E	Allowable	Call for attention, need regular management and supervision
III	4A,5A,4B,3C,2D,2E	Accepted	Call for great attention, need prevention, and monitoring measures
IV	5B,4C,5C,3D,4D,3E	Unaccepted	Need the decision of policy-maker, need controlling measures
V	5D,4E,5E	Cannot be accepted	Immediately stop, need alternative plans

Table 6. Surrounding buildings in Puxi and Pudong District.

District		Buildings
Puxi district	Manufacturing bureau	6 buildings with 5 ~ 6 floors, 2 buildings with 4 floors, 2 buildings with 1 floor, 2 buildings with 3 floors, 1 building with 10 floors, 1 building with 7 floors
	Xizang south road	Many buildings with 3 ~ 7 floors, 2 buildings with 15 floors, 1 building with 12 floors, 1 building with 10 floors, several buildings with 1 floor, 1 building with 19 floors, 1 building with 28 floors (reserved for Shanghai Expo)
	South station road	1 building with 16 floors, 1 building with 5 floors, 2 buildings with 6 floors, 1 building with 7 floors
	Jiangnan shipyard	Three-floor defense project, 1 building with 6 floors, distribution substation with 5 floors, 3 docks
Pudong district	Shanghai hangbiao factory	Floating pier, floodwall, 3 steel pipe piles, several buildings with 3 ~ 6 floors
	Nanchuan factory	Plant with 1 ~ 3 floors, 1 building with 4 floors, 2 buildings with 6 floors
	Shangnan road	Several buildings with 1 ~ 3 floors, 1 building with 15 floors, 1 building with 13 floors, a library with 4 floor
	Pudong south road-Yaohua road	Several buildings with high floors, buildings with 6 floors
	Binzhou road	10 buildings with 4 ~ 6 floors

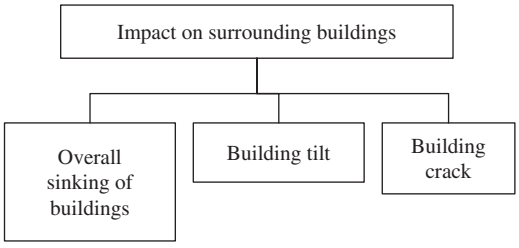

Figure 3. Risk identification of impact on surrounding buildings.

Table 7. Risk assessment of impact on surrounding buildings.

No.	Risk hazard	Probability	Loss	Ranks
1	Overall sinking of buildings	B	2	II
2	Building tilt	B	3	II
3	Building crack	C	3	III

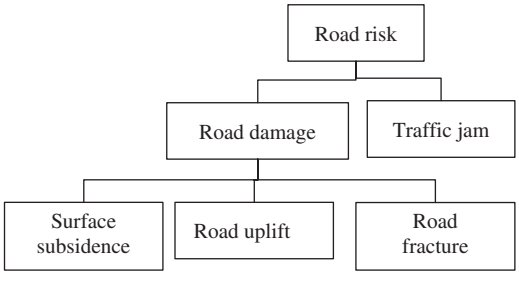

Figure 4. Risk identification of impact on surrounding roads.

3.3 *Risk assessment on environmental impact on surrounding roads*

3.3.1 *Risk identification*

The possible risk hazards of surrounding roads caused by construction can be illustrated in Figure 4.

3.3.2 *Risk analysis*

The traffic situation along the works is extremely complex. The tunnel is the link between Puxi and Pudong district, along with Nanpu Bridge, Lupu Bridge and Da-pu road tunnel. Once the road is damaged, causing traffic jam, the consequences will be serious.

There are many roads along, but because of the limit of the pages, the figure of roads is omitted. The analysis is just the same as above.

3.3.3 *Risk evaluation*

By sending out investigation forms, and using the TRM 1.0, the authors get the risk ranks of these risk hazards.

Table 8. Risk assessment of impact on surrounding roads.

No.	Risk hazard		Probability	Loss	Rank
1	Road damage	Surface subsidence	C	2	II
		Road uplift	C	2	II
		Road fracture	C	3	III
2	Traffic jam		D	2	III

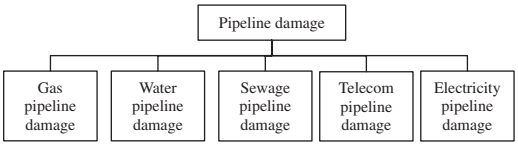

Figure 5. Risk identification of impact on surrounding pipelines.

Table 9. Risk assessment of impact on surrounding pipelines.

No.	Risk hazard	Probability	Loss	Rank
1	Gas pipeline damage	B	3	II
2	Water pipeline damage	B	4	III
3	Sewage pipeline damage	C	2	II
4	Telecom pipeline damage	B	3	II
5	Electricity pipeline damage	C	3	III

The results are shown in Table 8, from which we may see traffic jam and road fracture are more risky and are highly probable to happen.

3.4 *Risk assessment on environmental impact on surrounding pipelines*

3.4.1 *Risk identification*

The possible risk hazards of surrounding pipes caused by construction can be illustrated in Figure 5.

3.4.2 *Risk analysis*

There are many pipelines along, but because of the limit of the pages, the figure of pipelines is omitted. The analysis is just the same as above.

3.4.3 *Risk evaluation*

By sending out investigation forms, and using the TRM 1.0, the authors get the risk ranks of these risk hazards. The results are shown in Table 9, from which we may see water pipeline damage and electricity line damage are more risky.

Table 10. Risk assessment of environmental impact.

No.	Risk hazard	Rank
1	Impact on surrounding buildings	III
2	Impact on surrounding road	III
3	Impact on surrounding pipelines	III

3.5 *Summary*

The whole risk rank for environmental impact is III. The result is shown in Table 10. It should be paid more attention.

Road tunnel construction on surrounding buildings impact was mainly due to surface subsidence during the process, causing buildings sinking, tilting or cracking. The main treatments are:

1 Grout timely, and make sure the shield is well sealed.
2 Control the earth pressure during the digging to prevent the face instability, a surface subsidence and uplift.
3 Protect the important buildings. If it is necessary, consolidate the foundation.
4 All kinds of anti-leakage measures are needed. Pay attention to foundation strengthening process, otherwise it will most prone to landslides.
5 Focus on the steps of construction during the foundation engineering. Control every step of the excavation depth and slope, including good support and the timely installation;

The measures about road and traffic involve with following instructions.

1 Strictly control the quality of temporary road construction, to ensure road safety.
2 Control the load of vehicles travelling on the road to prevent overweight and crushing road.
3 Detailedly understand the traffic flow near the project before starting the construction. Disperse traffic flow to avoid jam.

There are many large diameter pipelines near the project, and once the pipelines are destroyed, it will not only have huge economic losses, but also resulted in a very bad social influence. Therefore we should take protective measures against dangerous pipelines.

1 Since there may be some errors occurring when planting the pipelines, which may induce incorrect position of pipelines. So before construction, positions of important pipelines must be verified.
2 Protect important pipelines by consolidating earth or isolation method.
3 Remove some load pushed on the pipelines.
4 Take informational construction. Monitor the pipelines frequently.

4 CONCLUSION

From the study and research on this project, we may get some useful conclusions:

1 The whole risk rank for Xizang South Road Tunnel's environmental impact is III. It should be paid more attention. When the tunnel is constructed, the workers may strictly control ground settlement. Information construction is recommended.
2 There are plenty of methods to evaluate risk. It needs to discuss deeply which method is adopted. In this paper, Experts Investigation Method (EIM) and Confidence Index Method (CIM) are applied, and they are applicable.
3 The risk rank of environmental impact is obtained, which may give advice on project decision, bidding and insurance.
4 Risk management is a dynamic progress. With the development of the project, the risk rank may be changed. The authors should follow the project, and realize the dynamic risk management.

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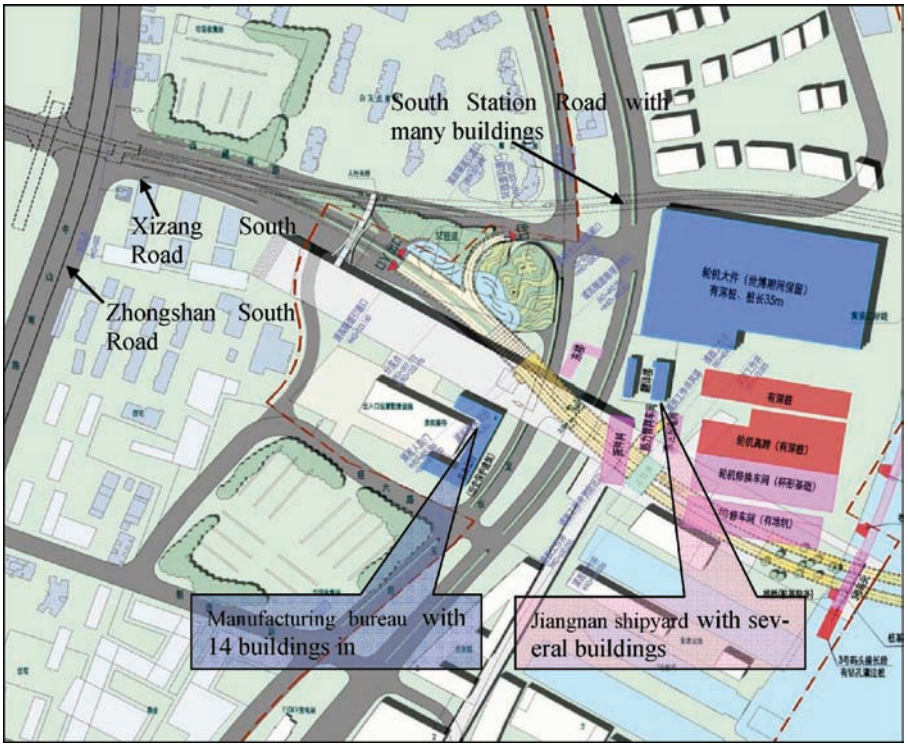
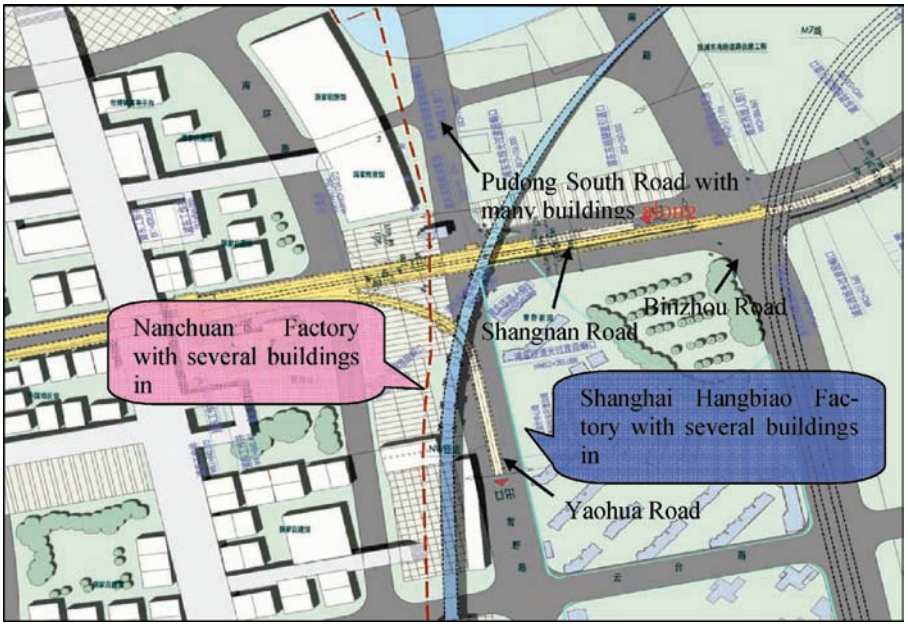


Appendix 1. Surrounding buildings in Puxi district.



Appendix 2. Surrounding buildings in Pudong district.