Assessment of Risk Areas of a Tunnel Project based on Expert Opinion

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ABSTRACT: Based on evaluation of tunnel accidents/collapses during traffic tunnel excavation in Czech Republic and in Austria, it was found, that in Czech Republic has happened similar number of accident as in Austria in years 1990 -2010. However, amount of tunnelling in these two countries differs for approximately one order, in Austria 315 km and in Czech republic 35. Probability of the tunnel accident during construction/excavation was therefore approximately 10-times higher. Detail and complex analysis of the reasons of this state is not existing and performed expert opinion questionnaire investigation should have contribute to better understanding of risk areas and their weights/contributions to accidents during excavation. Evaluated and interpreted results as well as comparison of opinions between „domestic" and „international" experts are presented.

1 OVERVIEW OF REALIZED TUNNELS AND TUNNEL ACCIDENTS/COLLAPSES DURING CONSTRUCTION/EXCAVATION IN CZECH REPUBLIC AND AUSTRIA IN YEARS 1990 - 2010

For comparison of frequency Austria, considered as suitable country, was selected form following reasons:

- NATM (widely used conventional tunnelling method) originated and is further developed and improved in Austria
- It is, tunnel concerned, highly developed country with number of tunnel projects and high productivity and efficiency in tunnel construction
- Geographically, historically, and economically similar environment to Czech Republic, EU member country

Enclosed tables and graphs of realization of transport tunnels on road and rail net are showing big, approximately of one order, difference in number of accidents/collapses, based on tunnel lengths. Additionally, individual collapses in Austrian tunnels did have much lower impact to projects than in Czech tunnels and also there are no repetitive collapses on one project in Austria.

Tab. 1 Traffic tunnels in CZ - total 1990 – 2010

	Length (m)
Road	25 885
Rail	8 855
Total	34 740

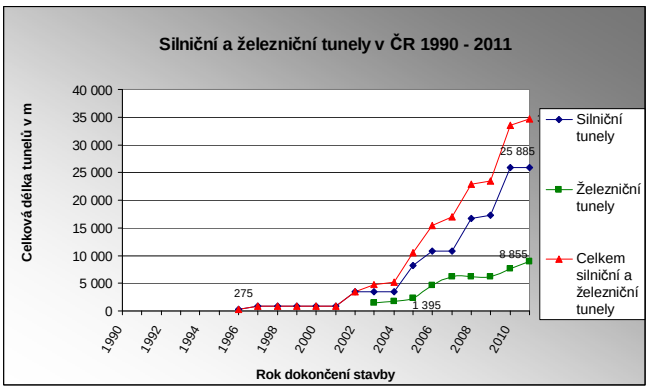


Fig.1 Transport tunels in Czech Republic

Tab. 2 Accidents/collapses during excavation of traffic tunnels in CZ 1990-2010

	Collapses (no.)	Year	Length of tunnel (m)
Hřebeč	1	1995	275
Blanka Špelc	2	2008	4 400
Blanka Mypra	1	2010	1 100
Březno	3	2003, 2005, 2006	1 500
Jablůnkov	3	2008, 2009	500
total	10		

Tab. 3 Traffic tunnel in Austria - 1990 - 2010

	Length (m)
Road	188 584
Rail	126 257
Total	314 841

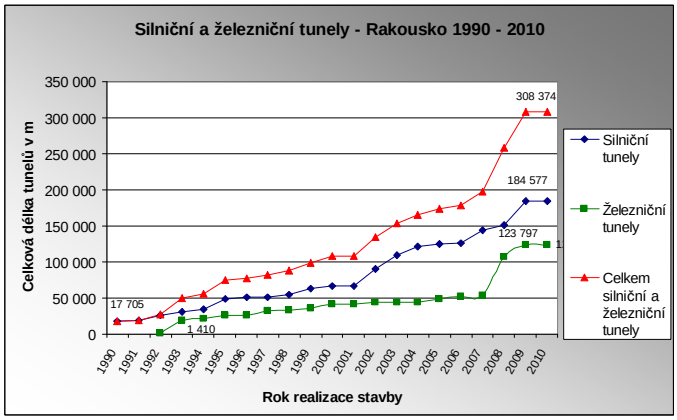


Fig.2 Transport tunnels in Austria

Tab. 4 Accidents/collapses during excavation of traffic tunnels in Austria 1990-2010

Name of the tunnel	**Purpose**	**Year of accident**
Lambach Tunnel	rail	1992
Galgenbergtunnel	rail	1994
Tunnel Radfeld-Brixlegg	rail	2001
Wienerwaldtunnel	rail	2005
Reiserberg (Perschlingkette)	rail	2007
Tunnel Vomp	rail	2005
Lainzer Tunnel	rail	2008
Tunnel Raingruben (Perschlingkette)	rail	2008-2009
Total	**8**	

Due to unique features of each tunnel project, it is difficult to compare and evaluate with statistical tools. In spite of these limitations, performed survey has predictive value. It is obvious that difference in frequency of accidents is high, even considering influence of geological and geotechnical conditions. Part of Austrian tunnel was driven in hard rock conditions with higher overburden. Having compared just tunnels with low overburden (where most of collapses happened), difference may have not been so high.

2 EXPERT OPINION SURVEY

2.1 *The questionnaire survey*

The questionnaire survey carried out between limited number of domestic and international experts determined weight of basic risk factors influencing possible origin of the tunnel collapse. Individual answers are statistically evaluated and interpreted.

Definitions:

- Accident/Collapse - unexpected and unwanted event during the tunnel excavation (before completion of the final/inner lining), which causes which causes the interruption of the excavation for more than one month

- "Domestic" expert – is of Czech or Slovak nationality

Questionnaire response:

Domestic respondents: 13 responses out of 20 addressed, i.e. **65%** response rate

International respondents: 15 responses out of 21 addressed, i.e. **71%** response rate

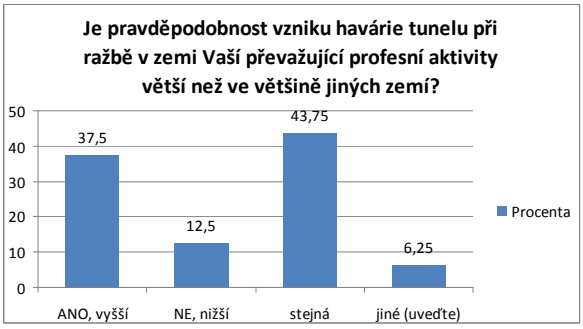
Tab. 5 Identification of respondents

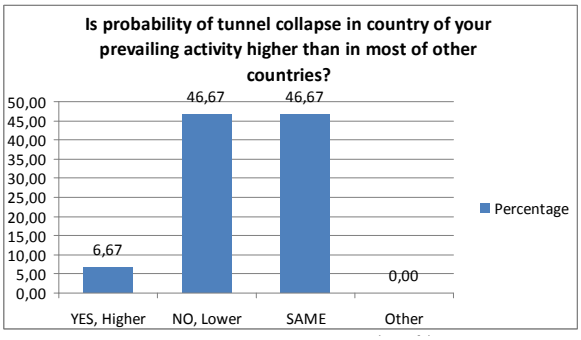
Professional Experience (length) - domestic	10-20 years ≥ 20 years	86 % 14 %
- international	10-20 years ≥ 20 years	87 % 13 %
Professional Experience (area) -domestic	Consultants/design research/education contractor client individual expert	48 % 14 % 30 % 6 % 2 %
- international	Consultants/design research/education contractor client individual expert	47 % 24 % 6 % 11 % 12 %
Nationality of international experts	Austria 9 Swiss 1 Danish 1 UK 1 Brazil 2 Canada 1	60 % 7% 7% 7% 13% 7%
International experience (out of home country) - domestic	79%	
- international	100%	
Geographic experience - domestic	≥ 75% ≥ 6%	CZ A, D, SK, UK
- international	≥ 9% ≥ 6% ≥ 3%	A D UK, US, I, TR, BR, IR
Experience with collapses - domestic	86% yes 14% no	
- international	100% yes	

Comments to respondents:
In profiles of "domestic" and "international" respondents there are no significant differences regarding professional experience, length and

structure. Prevailing are experts from consulting/design environment, at "international" experts is higher portion of representatives from research and education, and client´s sphere. At "domestic" experts, there are more representants of contractors.
"Domestic" experts are active at home (Czech) and significantly less in neighboring countries (SK, A, D) and UK.
"International" experts are mostly Austrians, but, besides Austria and Germany, they are active world-wide.
Prevailing number of Austrian experts is considered as acceptable, also because their activities are international, not limited to Austria.

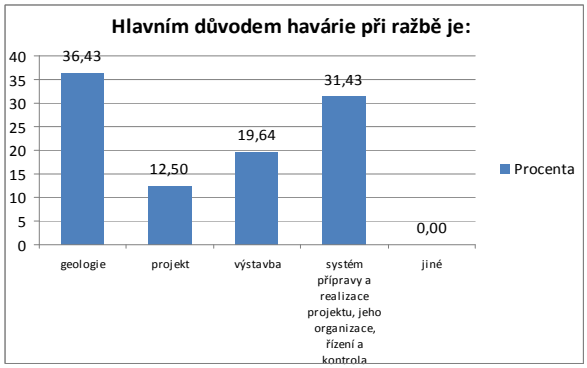
2.2 *Comparison of responses of international (English) and domestic (Czech) experts and their interpretation*

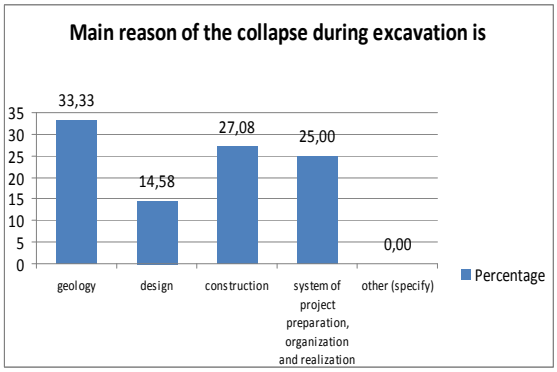




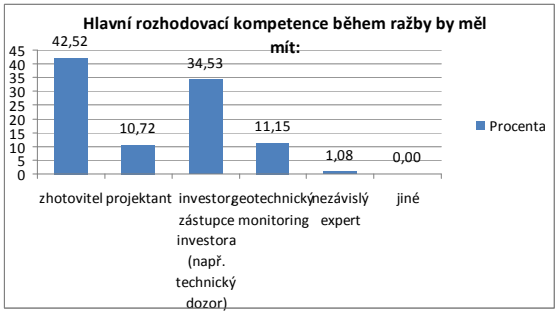
More than one third of domestic experts believe that probability of an accident during the excavation is in the Czech Republic higher than in other countries; nearly half believe that the probability is the same and one eighth believes that the probability is lower. Foreign experts consider the probability of accidents in the country of their activity lower or the same, both about 50%.

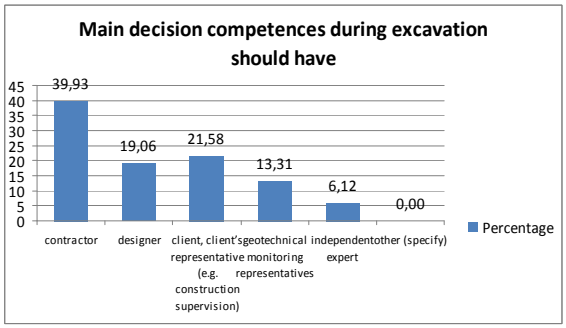
A large part of domestic experts does not fully recognize the fact demonstrated in Chapter 1 that the relative number of collapses/accidents (due to the number and length of tunnels) in the Czech Republic is significantly (about 10x) greater than, for example in Austria.





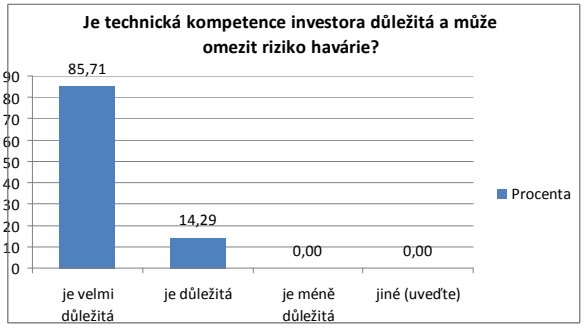
There is a fairly strong consensus among domestic and foreign experts on the causes of accidents during the excavation . Domestic experts consider besides geology as an important factor also system of project preparation and realization, foreign experts consider besides geology as an important factor also excavation performance and workmanship.

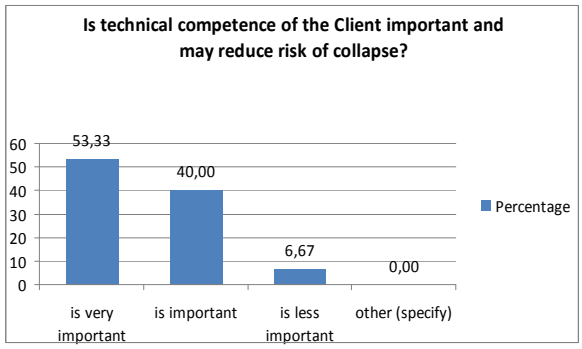




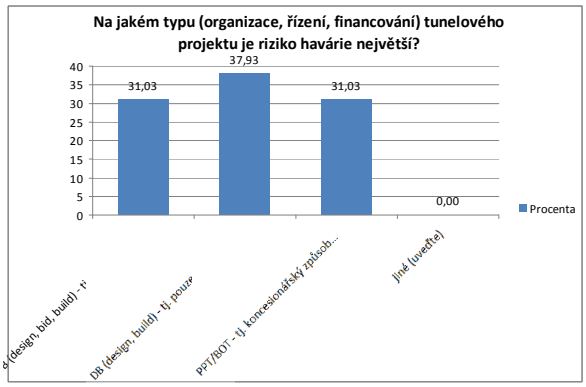
There is a consensus that the main decision-competences during the excavation should have a contractor and client and his representatives. Foreign experts give more importance also to other participants of the project, namely de-

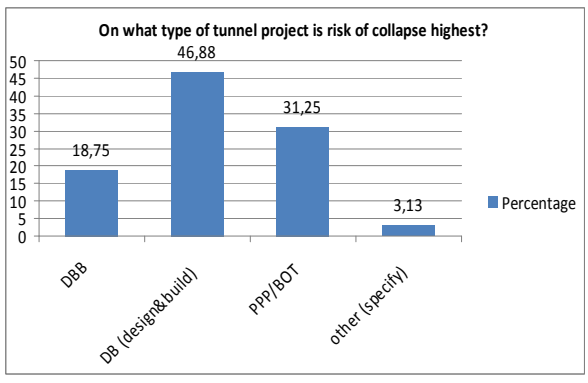
signer, geotechnical monitoring and individual experts.





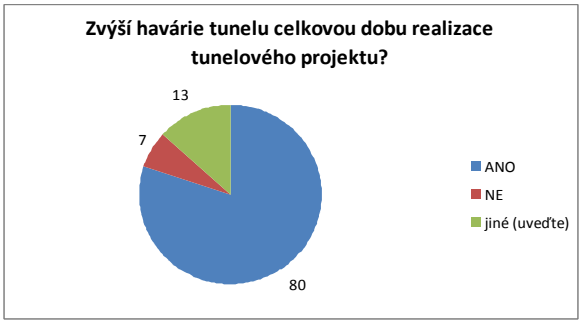
There is a consensus that the technical competence of the client is an important or very important factor influencing the risk of collapse/accident. Increased emphasis on this competence between domestic experts is probably due to the fact that the technical competences and capacity of the clients on Czech tunnel projects is often not sufficient.

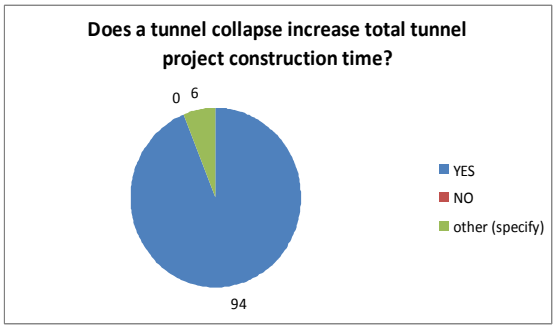




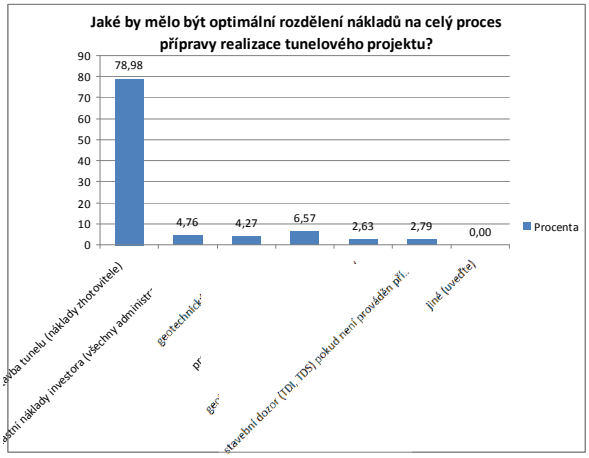
For domestic experts, the risk of accident is approximately the same for all three types of project organization type. This view may be based on the relatively small experience of domestic experts with other types of project assignments.

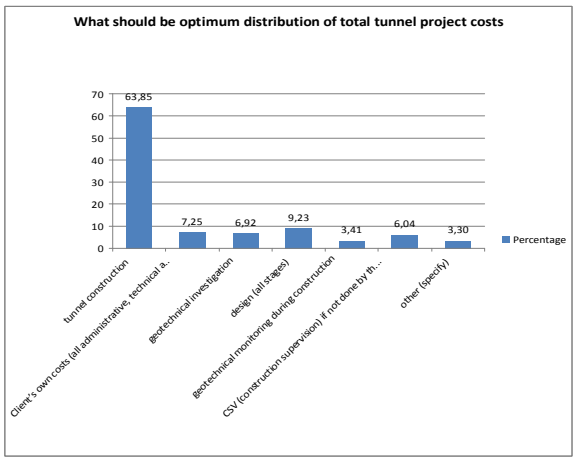
Foreign experts see significantly higher risk for the project type DB (design- build), the average for the type of BOT (build- operate -transfer) and the lowest for the standard way of project tendering and realization DBB (design- bid- build). These opinions are probably based on good experience with projects prepared and managed by competent and experienced clients in neighboring countries (Austria, Germany), where the detail design and geological conditions are client´s responsibility.





This seemingly obvious question, and almost unimous answers illustrate the general belief about the negative impact of the collaps/accident on the project. The specific method of project implementation and tendering can reduce these negative effects on the public sphere and limit or eliminate consequences for the public contracting authority by transfering responsibility to private partner (contractor, concessionaire for BOT projects). As an example, BOT project M6 Motorway in Hungary, which was put into operation on scheduled date, although there was a major accident and the collapse of the tunnel during construction.





Evaluation is affected by a small number of respondents, especially domestic ones. Foreign experts give higher importance (cost ratio) substantially all engineering activities (geological exploration , client's project preparation , design, supervision). .
Probably more precise would be submitting structure of the costs of real project and having expert's comments on distribution of the costs. Such data , however, is very difficult to obtain, in particcular for client's preparation costs as bifg projects are being prepared for decades.

3 METHODOLOGY AND LIMITATIONS OF THE QUESTIONNAIRE SURVEY, SUMMARY AND INTERPRETATIONS

When assessing the issue of accidents/collapses during tunnel excavation, a qualitative questionnaire survey method by a limited number of selected experts is considered reasonable. Due to the complexity of the causes of each individual accident is a summary of the causes and their relative importance and effects by other means very difficult. Conducted survey is affected by limited sample of respondents, their professional experience, qualifications and current positions in the tunneling industry. Due to the declared non-commercial use of survey, it is assumed that respondent's answers are influenced by their individual interests and positions only to a small extent. Predictive value is therefore considered as high.

3.1 *Conclusions*

- As the main causes of accidents/collapses during the excavation were determined:

  Geology + construction 60% (35% + 25%)

  Design + project organization and control 40% (13% + 27%)

- Main decision competences during excavation should have:

contractor	41%
client	28%
designer	15%
monitoring	12%
individual expert	4%

- Technical competence of client is important and may reduce risk of accident/collapse:

  Yes 95%

- What type of project (organization, tendering, financing) has highest risk of accident/collapse:

DB 45%
(DB - design-build, technical solutions within function requirements are made by the contractor. This model leads to cost savings, often with high risk and also to "cheap" solutions not effective on long term. Contractual conditions can be defined e.g. "Yellow" Fidic, as is the case of D1 Motorway in Slovakia (with 7km Visnovt Tunnel) or 9 km Patnitop tunnel in India. (ref. 1, 2).

BOT 35%
(build-oprate-transfer). Same as previous, detaiul technical solution is in competence of the contractor/concessionaire. However, Concessionaire, responsible for operation and maintenance for several decades should find optimum technical solution for construction, operation and maintenance, considering the whole concession period.

DBB 20%
(design-bid-build) This model does not allow technical optimization, client is (usually) responsible for detail design and geotechnical conditions. In neighboring countries (Austria, Germany) is considered as the best modet for tunnels, based on high level of client's competence. In Czech Republic is detail design for construction done by the contractor, usually by the same designer as previous design phases, which leads to conflict of interests as designer is repre-

senting both the client (tender design) and the contractor (detail design).

- Optimum distribution of the costs for the whole process of tunnel project preparation and realization:

contractor/construction	65%
client´s costs	7% (+6%)
(+ construction supervision)	
geological investigation	7%
designs (incl. tender)	9%
monitoring	3%
others (experts, opinions,...)	3%

Comment: Summarized results are based on the performed survey and do not have to be in agreement with author's opinion.

4 FINAL STATEMENT

The fact that the relative frequency of tunnel accidents/collapses is in the Czech Republic significantly higher than in neighboring countries is a challenge for the whole tunneling industry and individual subjects involved. Performed survey demonstrated a high degree of consensus between domestic and international experts on the issue.

Higher portion of spending on all supporting activities (investigation, design, client's activities, supervision) would reduce risk of tunnel accidents/collapses, and would also contribute to finalization of the projects on time and budget.

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