

## IMPORTANCE OF RISK MANAGEMENT IN HIGHWAY AND RAILWAY CONSTRUCTIONS

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The paper focuses on the role and importance of the risk management during construction of highways and railways. For this purpose the engineering risk will be defined. The main principles of geotechnical risk will be explained. Some cases stories of undesirables events during construction of underground works will be presented and discussed.

In the conclusion author will underline main conditions of successful risk management principles to be respected.

**Key words:** civil engineering works, failure, geotechnical risk, monitoring, risk, risk manager, risk management, undesirable event

### 1 Introduction

The construction and operation of civil engineering works is associated with considerably higher risks than can be encountered with other types of structures. Tunnels, highways, railways, bridges are very closely interconnected with rock environment in/on which they are to be constructed. The area of this interconnection is manifold larger than with other structure types. The behavior of the rock – building structure contact interface is therefore of higher importance for trouble-free construction progress and operation of a finished work than for example in case of civil or industrial structures. This is because the rock environment together with the building structure itself creates an interconnected static system.

For this reason it holds true especially in civil engineering works that the surrounding rock becomes a building material. However, its mechanical properties are very changeable compared to other types of building materials; rock quality is usually worse and especially very hard to determinate. The values of mechanical parameters describing the rock properties which are reflected in statics calculations together with mechanical parameters of artificial materials such as concrete, steel, etc. are therefore always burdened with considerable uncertainty.

The construction of civil construction works becomes part of ambitious political or personal plans. These enter decision making processes which should be reserved for technical criteria only. Nevertheless, there are always less financial means available than required. Tasks are often requested to be accomplished faster than feasible with regard to necessary safety, quality and adhering to functional parameters and technical-quality conditions. This is naturally the source of further significant risks.

Another cause of the risk increase is the fact that the profits in building industry in our country as well as abroad are very low. Profit margins are usually only between 3 and 5 % (Staveren 2006). The

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growth in competition forces the proprietors to go down to the limit of acceptable quality and safety in their projects.

Such situations are always typical of enhanced risks. The consequence is that losses and damages stemming from breakdowns, averages, extra work and necessary prolonging of the civil engineering work construction period due to unexpected undesirable events during their construction and operation make up on average 10 % of all budget costs of a construction in the world. (Staveren 2006).

It is evident that unexpected geological conditions, geological anomalies and unpreparedness or unwillingness to take them into consideration during preparation and construction is the main cause of these losses. (Fookes et al 2000). Brandl (2004) states that according to European statistics, 80 - 85 % of all losses in the building industry are primarily caused by problems in structure subsoil. A Dutch federation of suppliers of foundation works and piles states that only their annual losses exceed EUR 100 million (which makes up 10 % of their annual turnover).

In 2003, total financial volumes associated with the building industry in the world were estimated to USD 3,500 trillion. In 2008, it was about USD 4,800 trillion and even USD 6,200 trillion is expected in 2013. This fact also explains a great global interest in the issue of construction management and the methodology of risk management.

The situation in the Czech Republic is similar. In 2010, about CZK 90 billion is expected to be spent just from the Fund for Transport Infrastructure. Although there is not statistics on how many percent of the amount spent for constructions is made up by losses including damages due to the occurrence of undesirable events during construction, there is no reason to assume that the numbers would considerably differ from those from world's statistics.

At the present time of economic crisis investments in civil engineering works are considered among others a stabilizing factor of the economy. On the other hand, there are justified pressures on the reduction in the costs of these structures, see e.g. the crisis plan of the Ministry of Transport of the Czech Republic of September 2008. The risk management method is undoubtedly one of the ways of how to make this reduction come true.

## 2 Engineering Approach to Risk Management

The aim of the risk management is not only to avoid major losses and averages during construction, but also to minimize the losses in consequence of hundreds and thousands minor undesirable phenomena every construction is associated with. Efficiency of such risk management is not negligible by far. The ratio between risk reduction and costs spent is approximately 1:10. (Smith 1996)

From engineering perspective, there are two basic approaches to risk management.

- Heuristic, based on the summary of previous pieces of experience and their collective continuous evaluation (the results are e.g. norms, standards, etc.).
- Technical, based on calculations, analyses, mathematical models, etc.

Fundamental principles of engineering risk management are quite simple: at first, scenarios of possible undesirable phenomena are identified and then their consequences and probability of occurrence are evaluated, risks are quantified and in the end, priorities of their reduction are specified and optimal risk management methods are identified. The resulting risks are either completely eliminated or reduced. Then, measures for residual risks are adopted.

In general, efficient engineering risk management enables:

- to increase awareness of the consequences of the risks occurred during building work construction

- to focus on a more structured approach to risk management during construction preparation and implementation
- to better transfer information about risks among direct construction participants and those responsible for such issues
- to reduce long-term losses and expenditures stemming especially from breakdowns, averages, etc. and therefore to increase profit accordingly.

In longer-term perspective, engineering risk management of all entities active in the building industry should be included in standard company management processes; it should become their integral part. All managers should have their responsibilities for specific risks in given areas unambiguously specified.

### 3 Risk Definition

Nowadays there is common accord that a risk in context of the risk management methodology is defined as the concurrence of the probability of occurrence of any undesirable phenomenon and its consequences (damages) for the risk bearer. Mathematically, the relation can be described using the following equation:

$$R = P \cdot D$$

R = risk

P = probability that an undesirable phenomenon will occur

D = consequences that the occurrence of the undesirable phenomenon will have in financial enumeration

The undesirable phenomenon (event) is the occurrence of the state that was not anticipated and therefore was not taken into consideration during construction preparation or implementation. Therefore, if such phenomenon occurs, it has adverse consequences (damage) for a proprietor or construction participants which can be financially enumerated in a final evaluation. The probability of occurrence of an undesirable phenomenon can be evaluated either quantitatively using probability methods or more simply qualitatively through expert appreciation from zero to one. The consequences of the occurrence of an undesirable phenomenon are expressed using financial amount. This is used to evaluate the damages occurred or costs required for the removal of the consequences of the undesirable phenomenon.

When thinking whether or not an undesirable phenomenon will occur, the level of certainty or uncertainty that such issue will be finally dealt with is decisive. It can be said that the problem of uncertainty is the crux of every risk determination.

It needs to be emphasized that the risk defined in this way is an economic category. It has a significant effect because in practical risk management this fact enables searching for a balance between the costs of the risk reduction and the actual value of the risk reduction. Therefore, it also enables optimal designing of the scope of geotechnical surveying and monitoring, which consequently becomes one of the fundamental components of the risk management method of civil engineering works.

In consequence, the risks during construction of civil engineering works can have the form of:

- extra work due to complications occurred during the construction implementation,
- a failure to adhere to a contractual deadline for the work handover,
- a failure to adhere to a budget or other financial parameters,
- a failure to adhere to required technical standards for quality or suitability for a given purpose,
- the occurrence of work injuries,
- a failure to finish a work.

In principle, consequences are always financial. The need of controlling and managing risks is therefore evident. At present, a fundamental methodology of risk management in the building industry has been already established and is available to the construction participation if required.

There are many various types of risks: a legal risk, environmental risk, financial risk, business risk, engineering risk, technical risk, etc. according to types of undesirable phenomena that may occur. In case of civil engineering works, a geotechnical risk is the most frequent. It consists in the uncertainty of geological conditions in which a structure is built and risks of unexpected response of the rock environment to structure implementation

## 4 Geotechnical Risk

Besides organizational risks, geotechnical risks are the biggest threads existing in the civil engineering works. They originate in the risk that actual geological conditions on site will differ from those anticipated by a design. Other than usual cause may be the fact that the response of the rock pillar to the construction of the civil engineering work is different than anticipated by the design.

It usually means the occurrence of various undesirable phenomena and situations. Dealing with them causes additional financial costs, extra work, prolongation of works, occurrence of direct damages, major material costs, etc. In an extreme case it can involve an average, financial failure of the project or even death toll.

Such specific undesirable phenomena causing geotechnical risks during the construction of the civil engineering works may include the following situations:

- Deeper bedrock or on the other hand higher level of underground water or unexpected presence of geologic disturbances in the footing bottom of a structure or in the line of a road, tunnel, etc.  
The consequences may include increase in the costs of works, construction delay, additional modifications of design, technology and construction process, the necessity of additional surveying. In an extreme case, also averages may occur both during construction and operation of a finished work.
- Mechanical properties as defined by a geotechnical survey considerably differ from actual conditions. A consequence may be incorrectly set calculation parameters and the necessity to additionally modify a design solution. Another consequence is a wrong calculation upon incorrect classification of rocks according to workability and drillability, etc.
- Water relations of underground as well as surface water change due to unusual precipitations. An example can be unexpected submersion of trenches, sumps in a river, underground areas, damage to pressure insulation, decrease in slope stability, etc.  
A consequence may be especially failure to meet the works schedule, extra costs of additional water pumping not paid by an investor, deteriorated work or damaged parts of a structure, higher demands for slope redevelopment, etc.
- Deformation and stress response of rock pillar to the implementation of a civil engineering work is considerably different than anticipated by a design. Such undesirable phenomena show themselves e.g. as too uneven settling below complex structures, unacceptable development of subsidence troughs above underground stopes, too high pressures on tunnel lining, occurrence of disruptions on load-bearing structures and therefore also damages to building objects.  
Consequences in such cases may include legal disputes with investors and owners of affected real property, additional statics proceedings and resulting design adjustments or adjustments/complete changes of technological processes, additional costs as well as financial losses from a construction delay and for redevelopment measures.
- The course of geodynamic processes, rock weathering, aging of building materials or rheological processes was underestimated. In such a case unacceptable transformation of subsoil, ground and

above-ground structures, unexpected loss of stability of load-bearing structures or slides of seemingly long-term stable slopes, etc. can occur.

The consequences in these cases can be very dramatic, associated with death toll and considerable material losses. Responsible entities also usually suffer a considerable moral damage especially upon publishing such events in media.

- Unexpected presence of underground cavities and rooms close to driven underground works or their gradual expansion towards the area surface.

A consequence may be problems during the driving process, incurred need of redeveloping such cavities and rooms. Excluded cannot be also considerable damages to affected real property above ground or risk to human lives.

- Affecting and damage to the environment in consequence of accidents during the construction works. Typical examples are leakage of pollutants during storage of communal, industrial and toxic waste, destroying or limiting underground water sources, failures of settling pit dams, failure of dikes or dams with catastrophic area flooding.

Consequences, if only local events are concerned, can be often very hard to financially enumerate. In extreme cases the damages may have all-society scope. For a culprit they mean among others also a moral damage and a considerable financial penalty.

Other undesirable phenomena can stem in uncontrolled technology of construction implementation, in unsuitable technical solutions or even human mistakes during implementation of otherwise correct design. These types of undesirable effects can never be completely excluded. Samples of such mistakes are as follows:

- Unsuitably performed compensation grouting which can, besides required lifting of structures on the surface, cause damage to tunnel lining, floors of adjacent cellars or sewer systems due to too high pressures of a grouting mixture.
- Unsuitable time progression in performing filling on waterlogged subsoil can cause too high increase in pore pressure. A consequence is sinking of the filling into subsoil.
- Damage to a footing bottom by too strong dynamic effects of blasting operations.
- Failure to adhere to technological discipline when protecting exposed footing bottom against adverse climatic effects.
- Omitting some elements during the implementation of tunnel lining, their negligent and late implementation.
- Incautious fast lowering of underground water level close to shallow-founded structures which can lead to additional uneven settling.

The aforementioned text implies that managing geotechnical risks is crucial for successful designing and implementation of a civil engineering work. Despite this, geotechnics as an engineering discipline is less applied during structure preparation and designing than required according to its importance and below its undoubted potential for the help in economic management of preparation and construction.

There are three causes for this:

- Geotechnics often operates with too vague terms and therefore cannot establish itself in the strongly economic environment. Designers, investors and suppliers of civil engineering works are then forced to choose more conservative solutions. And in such situation they do not find it necessary to spend additional money for further specification of their findings on geotechnical risks.

- Financial means invested in geotechnical surveys, analyses of geotechnical risks and monitoring are very concrete costs. But effects in the form of future savings are indemonstrable. Geotechnicians lack a tool for efficient persuasion of investors about the suitability of spending more during preparation and saving manifold more during construction. An exact methodology which is directly the methodology of risk management has been missing so far.
- Costs of geotechnical surveys and analyses of geotechnical risks are usually paid from a different “pocket” than losses and damages occurred in consequence of the lack of information about rock environment and geotechnical risks during construction.
- Apparently significant is also the fact that the consequence of improper (too thrifty) approach to geotechnical surveying will show itself with a considerable delay. Competent entities then seldom feel personally responsible for them.

Geotechnical risk management enables:

- To optimize the costs of the reduction in geotechnical risks with work safety and the requirements for prescribed technical-qualitative conditions.
- To compare the costs of the reduction in geotechnical risks with possible reduction in the existing risk.
- To motivate to search for specific measures for the reduction in imminent damages by showing possible geotechnical risks in the form of a damage in financial enumeration to a specific bearer of a geotechnical risk.
- To enter directly into a decision making process both during preparation and designing and during construction of the civil engineering works.

## 5 The Problems of Risk Management of Complex Engineering Systems

A structure is always a very complex system whose resulting behavior depends in various ways on the behavior of higher or smaller quantity of its parts. System parts can be mutually dependent as well as independent. Characteristic for the behavior of every part of the system is the sequence of causes and consequences. Individual system parts also influence each other. Simultaneous, mostly accidental concurrence of adverse circumstances of several such sequences can cause extreme extraordinary undesirable situation, sometimes even a collapse of the entire system.

Also random phenomena have a considerable effect on the behavior of such a system. For example effects of forces of nature (floods, extreme weather, etc.), subjective effects of human factor (imperfect acting, unfamiliarity, mistake, negligence), external social-economic effects (unfavorable decision on the construction process acceleration, on omitting some safety measures from economic reasons), etc. can affect the construction process.

Therefore, it is very difficult to reliably foresee future behavior of every complex system which every huge engineering work is. From the same reason it is very difficult in advance to identify all possible adverse effects threatening the work, determine their causes, quantify probabilities of their occurrence, estimate implied losses and thus define overall risk of a given system that would be a clear impulse for technical, technological and organizational measures. The problem also consists in the fact that every structure together with its rock and social-economic environment represents a non-recurring original. The success rate of the trial and error method is naturally reduced in such conditions.

In addition, experience taught us that really huge averages of such systems with tremendous losses and death tolls usually do not occur only by one cause. Almost always there is accidental concurrence of several adverse phenomena none of which would cause the average in itself and if yes, then only in

considerably smaller extent. Implementing an efficient risk management system under such conditions is very complicated and even impossible without a truly professional approach.

## 6 Examples of Prague Metro Flooding

Flooding of the Prague metro in August 2002 is a typical example of an incident caused by the fact that the structure was exposed to the conditions that were not taken or cannot have been taken into consideration in the time of its designing. These “conditions” were the level of a high-flood-water wave which exceeded the level of the cent-year’s high water, for which the structure’s flood protection was designed according to the standards in force, by two meters during the flood. Although all designed flood controls were mobilized in fact on time and in compliance with a flood plan, water ran into the underground areas especially through metro entrances when it spilled over the protection barriers [11]. Other causes which did not however affect the manner of the metro flooding, propagation of the flood wave in the underground and the scope of the damages incurred, was the interruption of electric energy supply which caused stopping of seepage water pumping from metro underground areas. Further, the causes were failures of some elements of underground building structures, failures of cable bushings and non-closing of some line closures and entries. Overall volume of the flooded areas in the Prague metro was ca 1,104,000 m<sup>3</sup>. The damage incurred was about CZK 7 billion.

With regard to the course of the extraordinary event it was possible to distinguish several autonomous sections in the complex metro system with individual sequence of happenings. It was especially the Flood Plan of the Prague Metro which needed to be involved as late as possible in order to maintain the transport function of the metro as long as possible and also safely. In addition, there was a so called Metro Protection System which was designed as a shelter for Prague inhabitants in the event of a nuclear threat for the case that a 20 m high flood water wave would flush through Prague from blitzed dams of the Vltava Cascades. The Protection System worked independently of the Flood Plan. Another part of the system was a complex of the building part of the underground metro structures with tunnels, stations, entries and exits, etc. As far as the protection system is concerned, virtually all pressure closures separating the stations and tunnels from the external environment were closed successfully and on time. However, some cable bushings and other openings around the pressure closures could not have been closed as it would require at least several days. It would be surely possible to make it on time in case of a war threat, but the accession of the flood was considerably faster.

Therefore, water was running into the metro especially through its flooded stations spilling over from above. Through the metro, it spread around unclosed cable bushings. Sudden penetration of water into the underground areas behind pressure closures was not anticipated by the contract documents. Therefore, the complex of metro underground structures faced another unexpected situation – its very fast uncontrolled flooding and the occurrence of an unexpected load case. In consequence hereof, further partial failures of some building elements which were not implemented in perfect quality occurred. However, their failure which unfortunately caused flooding of other parts of the underground areas would not occur without water penetration in the underground. Another fact which occurred due to flooding of the underground areas was the interruption in electric energy supply and subsequent stopping of water pumping.

Flooding of the metro is an illustration of how such average, its course and scope occurs as a concurrence of adverse sequences of various undesirable phenomena each of which participates at the overall amount of damages to a different degree. Most of them may have nothing in common with the occurrence of an average, but despite this may contribute to its scope and severity in a decisive manner after all. To identify a single entity responsible for such an average is therefore impossible.

## **7 The Main Reasons for the Occurrence of Extraordinary Situations in Constructions**

### **7.1 Unfavorable Financial Environment**

One of the causes of the occurrence of undesirable events in constructions may be financial conditions under which the entrepreneurial activity in the building industry is performed. Profits in the building industry are low over the world. Keen competition forces the contractors to go down to the limit of acceptable quality and safety in their offers for selection procedures. The rules for the selection procedures for the contractors of such structures, in which offers with the lowest prices are preferred without sufficiently insisting on quality and control, make this situation even worse.

Such project “financial settings” and the manner of the contractor selection are quite common over the world. Their consequence is that the construction itself is then burdened with additional risks.

Under such conditions the main cause of the occurrence of unexpected extraordinary events is the inability of the structure to react to their occurrence on time and sufficiently decisively in advance.

### **7.2 Construction Organization and Control**

Another very frequent group of causes of the occurrence of undesirable events and sometimes even averages is the manner of the construction control and organization. In practical life, short-term economic interests of the construction main participants and especially the investor are still often given priority over the criteria based on technical evaluation. It usually includes the effort not to exceed planned financial costs by any means, to prepare a design by certain deadline regardless of the absence of some necessary documents, e.g. appropriate geotechnical survey, etc.

The decision-making processes in every big civil engineering work have several levels. On the decision-making level where increasing signs of the occurrence of an undesirable phenomenon can be identified for certainty (e.g. on a tunnel face, during excavation of deep cuts, in a monitoring office, on site during installation of technological equipment, in a geotechnical laboratory or design atelier) the adoption of required measures for the avoidance or reduction in such a risk with final validity is usually not decided. Such decision is made one or more levels higher for it is usually associated with the need of some extra work, additional costs and prolongation of the construction period. Technical arguments may be often ceased to count in such a situation.

The reason is that other than technical criteria are sometimes used on higher decision-making levels during construction control. Strict requirements not to exceed budget costs in a given moment, to accelerate the construction process, save building material, reduce the time of special technology application, etc. are given priority. The decisions which do not take a technical aspect of the matter and associated risks seriously enough into consideration in doing so, result after all in extraordinary events, increase in costs, prolongation of the implementation period and affect work safety as well as work quality.

Evaluation of some recent averages of large tunnels abroad [12] revealed that these seldom occurred in consequence of a mere negligence. Frequent are not even averages caused by a designer who had exceeded the level of known empiric knowledge or whose knowledge or theoretical competences proved insufficient for a given project. Major tunnel averages (e.g. Heathrow, Munich, Toulouse, Madrid, Barcelona) occurred almost exclusively because the constructions were improperly prepared and especially poorly controlled. Respective contractual relations were incorrectly established and decision-making processes took too long. There was mostly no efficient risk management or public investor's political interests did not make it possible to devote enough time to necessary improvement of the

knowledge in the site's geological conditions. Another frequent cause of the averages was inadequate acceleration of the construction even when it was evident that further construction progress required additional information, adaptation of the project to different site conditions, providing for better conditions for the safety of work operations, adjustment of technologies and more time and materials.

### ***7.3 The Hindrances of the Risk Management Method Faster Propagation***

At present, many investors and other construction participants have a conscious interest in involving the risk management in the set of activities that are by default included in the preparation and common control of construction of a civil engineering work. However, there are still many objective reasons why the risk management is not completely usual.

Primarily, it is the legal environment. For the time being, it does not take into account the "probability" nature of phenomena which are associated with the construction of civil engineering works and is completely assumed by a "deterministic" approach which erroneously assumes that if the procedure is "correct", everything can be reliably calculated and foreseen. The risk management methodology means the implementation of probability approaches. In some circumstances it therefore also allows the use of probability calculus to determine the likelihood that adverse effects may occur. For common engineers, however, this mathematical tool is often somewhat unclear and may therefore be an obstacle for a wider expansion of the risk management methodology. In this context it should be emphasized that the mathematical apparatus of the probability calculus is only a mere supplement and a tool of the risk management method and not a condition of its application. Anyway, in most cases the information inputs in such calculations cannot be obtained otherwise than through expert estimates. Then, complex calculations may be completely misleading and it is better to be content with estimates of experienced professional experts.

The most common reasons why the risk bearers and the construction participants are not willing or able to effectively avoid the risks associated with the preparation and construction of an engineering work and to influence it sufficiently are elemental. These are primarily the following:

- the risk bearer is not sufficiently aware of the risk;
- they do not consider the risk up-to-date;
- the consequences of such risk may show themselves as late as in far future;
- the steps leading to the identification of the risk and its possible reduction are mostly at variance with immediate (usually economic) interests of the risk bearer;
- the risk bearer is often not the entity that can decide about the steps leading to the risk reduction.

These reasons can be often eliminated by a suitable organizational measure and thorough edification.

## **8 The Conditions of the Risk Management Methodology Successful Application**

### ***8.1 Active Approach***

The controlled risk philosophy enables one to imagine what can happen during construction under given circumstances, what are possible reactions to new unexpected situations. It is an active, not a passive approach. The risk itself also offers certain opportunities – it is not only a tool for limiting and eliminating undesirable events on site. When dealing with a risk, the influence over the development of events must be maintained. The development of the monitored phenomena must not get out of control. Otherwise the risk can become unmanageable and uncontrollable. This implies the need of application of an observation

approach, monitoring and ability to adapt to new conditions which were not originally anticipated, during construction.

## **8.2 Team Approach**

A specific feature of the risk management is also the fact that it leads to a team approach. Current engineering structures are complexly structured and organized systems with various financing methods using many modern technologies, new building materials, etc. Such structures must be controlled by teams of real experts not only in management, economy, financing but at the same time in a wide range of engineering branches. Modern engineering works provide many opportunities and impulses for further technical development. Without acceptance of a certain risk level this development would be hardly possible. Correctly conceived risk management can move along the border between the possible and the impossible but must never cross it. For the risk management to be successful, i.e. to lead in general to financially and technically successful implementation of an engineering work, it must be implemented generously enough. It means that sufficient human, material and financial resources must be invested.

## **8.3 Generosity**

Unfortunately, many investors still stick to the false philosophy that good quality of a construction work can be obtained for a very low price. They all should remember the words of John Ruskin (1818–1900) who wrote: “When somebody pays too much, they may lose some money. That is all. But if somebody wants to pay too little, they often lose everything. What they get does not meet their expectations from that thing. Economic laws in general do not allow one to get a high value for a too low price.” If an investor accepts an offer for work implementation with unreasonably low price, they usually need to add considerably more to cover risks and losses occurred during the construction. This experience has already been confirmed in engineering practices times out of number. Despite this, unreasonable economizing and subsequent need of paying more can be still encountered.

The risk management method efficiently fights back such approaches. The risk management is the most efficient prevention against additional costs, extra work and prolongation of the construction period. It is based on the optimization between economy, safety and quality.

## **8.4 Implementing the Risk Manager Position**

Big foreign building companies often establish a special position for the risk management focused exclusively on this activity. This position is usually called a risk manager [4], [5]. The task of the risk manager is especially to establish conditions for the risk management implementation and to prepare an optimal risk management strategy corresponding with a given structure and circumstances in which it is implemented. Further, they are responsible for efficient risk management not only during construction, but also during its design preparation if possible.

Through the mediation of the risk manager, all construction participants are lead within the risk management to the same opinion of risks, collective proceeding and using terms understandable to everybody. Herewith, prerequisites for actually efficient implementation of a uniform risk management strategy during construction of an engineering work are established. This is all the more important for this is a new approach whose principles are not always “natural” to all experts and managers of individual construction participants. Substantial is the fact that there is a function in the site manager’s team whose job scope specification includes comprehensive and unambiguous description of principles and obligations associated with identification, qualification and management of risks of a given structure.

The risk manager's function can be in a simplified manner compared to a task of a person who is responsible for work safety on site. The difference is that while the person charged with work safety only deals with the reduction in those undesirable phenomena which can threaten work safety, the risk manager is additionally focused on all undesirable phenomena that can cause construction period prolongation, rise in costs, failure to adhere to prescribed technical-qualitative conditions, etc. So the scope of their competences is larger beyond compare. That is why they need to be part of the team that is appointed by the investor for the construction management. It must be also a person with sufficient competences independent of other construction participants.

## 9 Conclusion

Nowadays, engineering risk management is efficiently used abroad for a construction preparation in order to reduce budgets, increase safety and quality as well as profitability of companies' prospectuses.

However, the risk management methodology represents a revolutionary change neither in control nor in engineering disciplines. Basically, it is only an attitude of mind whose basis is systematic and thorough thinking of what can happen, where it can happen, how it can happen and what consequences it will have (what other events and damages will occur). Another output of this thinking must be an overview of all possible measures that can come on force to prevent the occurrence of possible undesirable effects or to reduce the probability of their occurrence. It also needs to be considered in what times and for what price such measures can be engaged.

Decision making is always about money since a risk is an economic category. The risk management method is typical of the fact that the investor is purposefully involved in the decision-making process (just because money is concerned). The investor must co-decide what risk level is acceptable for them, to what extent they are able or willing to reduce the risk (and at what price) through the measures adopted. However, a risk specialist, risk manager or a specialized company offering such services must prepare an analysis for such investor's decision, which is exactly the risk analysis.

The snags of the risk analysis consist in the fact that its subject is complex systems whose behavior is influenced by lot of accidentalities. Therefore an experienced specialist needs to devote to their control and management. A characteristic feature is that the investors can participate at the decision-making process much more actively and don't have to put up with the requirement for absolutely sure and therefore very conservative solutions. The risk management method provides the construction participants with a uniform guideline to the procedure of work in preparation and implementation of big civil engineering works. It gives reasons for costs which are associated with the risk management. Important is the fact that the risk management methodology especially promotes accord in the principles of this procedure of work with all construction participants. This assures its efficiency. Nowadays, the introduction of the risk management is a fundamental precondition of successful implementation and operation of every big engineering work.

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