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Model for Compiling the Specifications for the Reconstruction of Critical Objects

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The Praha metro belongs to the critical transport infrastructure, and therefore, great care is taken to ensure its safety at all stages of the life cycle. Due to aging the structures, fittings and systems, and new requirements on serviceability and safety, the reconstruction of some parts needs to be performed. The paper deals with compilation of terms of references for reconstruction of critical object on example of one important metro station. At reconstruction, there are considered new legislative demands and knowledge on metro station operation in last period (more than forty years), namely in particular from flood in 2002 when station was seriously harmed. To ensure safe reconstruction process, the terms of references are very detailed, were reviewed by experts and verified in practice.

Keywords: Terms of references, risks, safety, reconstruction, specific requirements, metro station..

1. Introduction

The specifications of the technical object are an essential part of the design documentation of the technical object They contain technical, financial, time and other data that determine the fabrication of a functional technical object. They are also a basic document that ensures the safety of the technical object, since, in addition to a detailed inventory of works, supplies and services, a statement of quantities of the works requested and supplies, they must also contain detail information on risk management in a given case. They must consider the sources of risks which are connected with: territory in which technical object is placed; technical object itself; and expected reactions (conflicts) of the given territory to the implementation and operation of technical object.

Because no legislation on requirements of terms of references for reconstruction, present paper shows model for their compiling on example of important metro station in Praha. The Praha metro belongs to the critical transport infrastructure, and therefore, according to knowledge and legislation in force, great care must be taken to ensure its safety at all stages of the life cycle (Prochazkova 2015).

Due to aging the structures, fittings and systems, and new requirements on serviceability and safety, the reconstruction of some parts needs to be performed. Since it is not a greenfield construction and it is necessary to save material, finances and shorten the reconstruction time, the task is not easy. At reconstruction, there must be considered new legislative demands on building and knowledge on metro station operation in last period (more than forty years), namely in particular from flood in 2002 when studied station was seriously harmed. From these reasons, to ensure safe reconstruction process, the terms of references must be very detailed and must be reviewed by panel of experts.

2. Terms of References for Design of Technical Objects

A project of technical object is defined as a unique set of activities characterized by: limited resources and time; unrepeatability; temporality (it has its beginning and end); elements of uncertainty and risk; differentiating from routine activities in terms of both content and target focus; and the fact that all resources (human, material and financial) are managed to achieve the project

objective. The aim of management of project is to achieve the set project objectives within the constraints of time, budget, quality and resources (CR 2016, Prochazkova et al. 2018). Key aspects of project management are risk management, communication and planning, which are important for achieving project objectives. Successful project management also involves collaboration between all team members, including the project managers and other stakeholders, to ensure that the project is completed on time, on budget, and with the necessary quality.

A project of a technical object is influenced by a number of external factors, such as: the state of the market; projects of surrounding technical works; the size of the technical object; availability of resources; competence and experience of managers and employees (Prochazkova et al. 2019). In accordance with current knowledge, it is necessary to respect the "Sendai Framework" (UNISDR 2015), in which there is a strong emphasis on risk management from all possible disasters, when creating a technical object project. From the point of view of public interest, variants of the project of a technical object that have a risk lower than the specified level of acceptable risk can be accepted with the proviso that the level of variable risks will be regularly monitored with regard to the dynamic development of the world (Prochazkova 2015). Other options must be either excluded when deciding whether or not to issue a permit for the construction of a technical work or their parameters must be modified and, if the technical object is necessary in a given place, measures must be taken to mitigate the worst impacts on public protected assets in the event of risk realization - risk management plans (Prochazkova et al. 2018).

When designing and implementing the optimal variant of a technical object in a particular case, the following play a role: achieved level of safety of technical object and its surroundings; technical feasibility of measures to ensure a safe technical object, considering the suitability of measures for object and its surroundings; material demands of technical object; energy demands of technical object; speed of realization of technical object; demands of operation of object on qualified personnel; demands of technical object for transport and information support, i.e. communication networks; demands of construction of object; demands on finances during the construction and operation; demands of technical object for liability for safety; claims on territory management /organization associated with the technical object.

An essential part of the project documentation of a technical object are terms of references, which reflects: the risk management process; measures for prevention, mitigation and response to unacceptable situations. The unacceptable situations in question are caused by: internal, external and organizational sources of accidents and failures of elements, components and systems. From this reason, the terms of references contain technical, financial, time and other data, which determine the construction of functional technical object. In addition to a detailed list of works, supplies and services and a statement of quantities of the requested works and supplies, they include documentation of how the risks associated with both the territory in which the technical object is located and the technical object and the expected reactions and conflicts of the territory in the construction and operation of the technical object have been considered. Legal requirements in the Czech Republic are regulated by the Building Act (CR 2006a) and other laws, because these are demands financial, relationship, liability, environmental, insurance, information protection, etc.

According to the data in the work (Haugen et al. 2018), at creating the terms of references for technical object it is necessary to have knowledge and competencies for: application of the results of risk analysis and assessment methods; implementation of a methodology of analysis and risk assessment adapted to the problem; emergency and crisis management; analysis of situations / activities / accidents; turning the politics into real action; turning the accident statistics into action plans; strategic planning; hierarchy of problems; finding the right information and guidance; critical analysis; designing the right solutions; written and spoken communication; synthesizing and adapting wording intended for the public; and ethics.

Decisions on just mentioned items are based on the assessment of options based on qualified criteria that support the public interest and create main parts of pillars of project management that is used at present (Prochazkova et al. 2018, 2019). The benefits of project management include, for example: shortening the duration of project construction; refining the sequence of individual phases of construction; improving the financial flows (cash flow); improving the use of

human, material and financial resources; etc. For successful project management it is necessary according to (Haugen et al. 2018, Prochazkova et al. 2018): precise definition of the goal of the project (what the project should achieve, whether it is feasible or whether there are better alternatives); support of the client (from the beginning, including the delivery of the necessary resources – people, money, time, etc.); careful selection of collaborators; the division of powers and responsibilities into specific persons; determination of quality requirements (monitoring throughout the project and ensuring a control and test plan (LIC)); division into stages; planning (rough planning of the whole project, more detailed planning of the current implemented parts); monitoring the context (communication with all stakeholders, weighing risks and solutions in relation to other projects); keeping clear documentation throughout the project and for subsequent return to individual parts, completion and transmission of results; and final recap (to learn from mistakes).

Project management requires a certain level of investment to achieve a quality result, but the cost of project management can vary depending on the scope of the project, its complexity, and other factors. Proper project management can help minimize the uncertainty and risks associated with the project and ensure that the project is successful. This may include creating a project plan, setting clear goals and expectations, developing a project schedule and monitoring it over time.

3. Knowledge on Reconstruction

Reconstruction in architectural concept is the largely prototypical restoration of damaged, timeworn or destroyed architectural monuments, historical buildings or parts of buildings. The reconstruction of buildings has been a common practice for centuries (Guratz 2010). At present, there are a lot of legislative documents that defines "reconstruction" as the returning of a damaged building to an earlier state by the introduction of new materials. It is related to the architectural concepts of restoration (repairing existing building fabric) and preservation (the prevention of further decay), wherein the most extensive form of reconstruction is creating a replica of a destroyed building. There are different approaches to reconstruction, which differ in the degree of fidelity to the original and in the sensitivity to implementation. Each reconstruction must be pursued according to rules that are in national legislation.

A reconstruction of each entity needs to follow engineering knowledge and experiences, i.e. logical procedure summarized in legislative (Prochazkova et al. 2019). From mentioned book, if follows that reconstruction of each facility needs to consider both, the demands on design and the experiences from the past operation. Sometimes, it is needed to solve problems connected with errors that were originated in original design. Often, they cannot be eliminated, but only mitigated. Therefore, sometimes many difficulties at determination of reconstruction project occur.

The aim of complex facility reconstruction design is to create a production process that is profitable, economic, safe and does not threaten public assets, especially humans and environment. This can be achieved by optimizing the safeguard, economic and functional criteria (Prochazkova et al. 2019). The design covers a wide range of problems, for example, it goes on selection of: materials; technical principles; construction procedures; framework procedures; determination of critical construction and framework processes; and protection ways in domains physical, cyber etc. It, therefore, requires the participation of many different knowledge fields, i.e. the participation of a number of specialists from different fields.

In each complex object design from safety perspective, it is necessary to follow the requirements for: durability; manageability of equipment and processes; lifespan; human resources; costs; technical services; other service; and safety of employees, humans in surroundings and environment. Consideration and good provision of requirements in question determines the future costs of ensuring the safety and coexistence of technical facility with surroundings. Designing the reconstruction of complex facility is a very complex activity, and in each country is regulated by national legislation; e.g. in the Czech Republic (CR 2006 a, b) and in some cases also by international ones. Research results (Prochazkova et al. 2019) show that from safety viewpoint, the main goal is to avert unwanted combinations of incidents that have potential to cause accidents accompanied by major damages. To do this, proactive indicators or safety functions are used to control safety under border conditions, thereby the occurrence possibility of unlikely severe accident is reducing.

Risk-based design (Prochazkova et al. 2019) uses seven principles of resilience: backup; to insert ability of sleek and controlled degradation; to insert ability to return from degraded state; flexibility in both, the system and the organization; to insert ability to control limit conditions close to the performance interface; to insert optimal management models, to reduce complexity; and to reduce possible undesirable couplings. In design, it is necessary to include program for safety increase that ensures: safety and functionality of all fittings that corresponds to their missions; identification, evaluation, elimination or regulation of potential risks at acceptable level for important installations, systems and their various parts; risk management, which includes all possible disasters with resources inside and outside the complex systems that cannot be eliminated; protection of personnel, people in the vicinity, facilities and property; use of new materials or products and test techniques only in a way that is associated only with minimal risk; insertion of safety factors that ensure corrective measures that lead to improvement; and consideration of all appropriate historical data on ensuring the safety generated by similar safety-enhancing programs.

From engineering viewpoint, conditions and limits of operation are established, safety systems (active, passive and hybrid) are installed and appropriate backups are ensured; it is solved: what safety systems are appropriate and what must be their backup; where / in which places safety systems operate most effectively; why they must be used just there and not elsewhere, in what limits they work reliably.

Reconstruction of technical buildings has specifics, because they are not greenfield buildings and from an economic and time point of view it is necessary to make maximum use of existing buildings and equipment. Therefore, during the reconstruction it is necessary to consider that some:

- parts of the technical equipment must be taken over for practical (economic, time and possibly other) reasons, even if they are not ideal from the current point of view, but meet the requirements for safety, i.e. reliability and functionality,
- remaining risks (e.g. errors in the establishment of buildings, interconnection with networks in the area) cannot be eliminated (this would require changes in the extensive surroundings, finances and long-term service limitations),
- necessary reconstruction work cannot be carried out during operation, it is necessary to interrupt the operation, which limits the functionality and reliability of services for users and leads to unacceptable phenomena in human society (therefore, certain restrictions on the current standard of living are necessary).

Based on knowledge and experience (Prochazkova et al. 2019), it is necessary to:

- respect the principles of strategic management during the reconstruction, such as: systematic attention to the sources of risks that may disrupt the reconstruction; solving problems in the management of work; quick solution to material delivery delays; addressing the poor motivation of critical workers; improving the working conditions of critical workers; monitoring the quality of work and solving problems; material quality monitoring and problem solving, etc.
- improve permanently the level of the refurbishment process.

4. Data for Reconstruction of Metro Station

The Praha metro belongs to the critical transport infrastructure. Therefore, great care is taken to ensure its safety at all stages of the life cycle. Each metro station is an open complex system with type “system of systems” and its nature is socio-cyber-physical (Prochazkova et al. 2019). Therefore, in order to ensure its safety, we must also consider the risks associated with interconnections of individual systems. Due to aging the structures, fittings and systems, and new requirements on serviceability and safety, the reconstruction of metro station parts needs to be performed. The reconstruction of the Prague Metro station is an important project that aims to improve the quality and safety of passenger spaces (Strelbova 2023).

The metro station we are monitoring began to be built in 1966. It is located in the center of the capital city of Prague and lies at the intersection of two metro lines. The outer limit of the protection zone is a vertical surface running at a distance of 31.5 m from the outer contour of the building structure (METROPROJEKT 2021). Metro station, including the buffer zone, is threatened by many risks, the sources of which come from

phenomena natural, technical, organizational and human factor. The operation of the monitored station showed that some sources of risk were not sufficiently addressed during the design - e.g. flood protection measures. The flood in 2002 caused flooding of the station and caused great material damage (Metroweb 2021). Based on this experience, it is necessary to deal with all these sources of risk during the reconstruction, partly by preventive measures and partly by localizing the technical equipment that will allow a qualified response (Prochazkova et al. 2019).

Reconstruction is carried out gradually and has the parts shown in Figure 1.

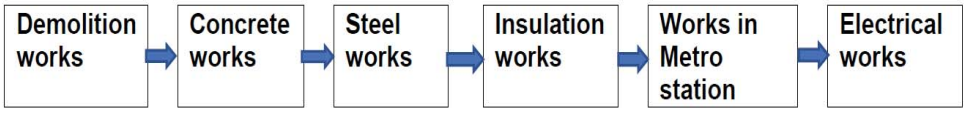

Fig. 1. Process model f reconstruction.

According to (Strelbova 2023) specific risks during the reconstruction are construction, technologic and project risks associated mainly with project documentation and construction, the financial and technical risks associated with:

- the technical installations and equipment themselves,
- the quality of the materials used,
- by the behavior of people
- and maintenance of the station itself.

Sources of risk during the real works are connected with:

- demolition works: asbestos pollution; noise; dust; vibrations; ceiling slab collapse; backfilling etc.
- concrete works: quality of material; problem of quality of work in winter and at high temperatures; vibration etc.
- works on steel structures: material quality; welding, handling of oversized structures, fire etc.
- insulation works: problems of working with hot materials; exposure to chemicals; inhalation of harmful substances; fire; explosion etc.
- work inside the metro station: interruption of metro operation; electric shock – 22 kV; short circuit; fire etc.,
- electrical installation works: electric shock; short circuit; fire; explosion etc.
- organization and harmony with legislation: non-compliance with reconstruction project documentation; work delays; low quality of management; problems with the supply of materials; low safety culture; poor work ethic, etc.

5. Method of Drawing up the Terms of References for Reconstruction

The reconstruction of a metro station is a demanding and complex process that requires careful planning and the correct setting of conditions for the successful implementation of the project. In the Czech Republic we distinguish two sorts of terms of references: one for public procurement with aim to obtain a contract and the other for designing.

The public procurement is governed not only by the Building Act (CR 2006a), but also by other legal regulations, such as acts CR (2005, 2006 b, c , 2008, 2012, 2016), tax and accounting regulations and laws relating to the protection of personal data, etc. These terms of references must comply with these laws and other legal regulations in order to be valid and to avoid possible inconsistencies and disputes. These laws lay down requirements for the content of the terms of reference, such as information on the contracting authority, the subject of the contract, requirements for the supplier, deadlines, payment terms, guarantee periods and other aspects. It is also important to pay attention to the protection of personal data and sensitive information that may be part of the terms of reference. The sponsor must ensure that this information is protected and not misused (CR 2016). The terms of reference are the key document that determines the conditions under which the public contract will be awarded and delivered. It is important that they are prepared carefully and with respect to the legislation

in order to ensure fair and transparent public procurement. The tender conditions are regulated by Decree (CR 2008). Specifically, in the case of railway constructions and buildings on the track, it is Annex No. 3 of this Decree, where the scope of documentation for the notification of construction or for the issuance of a building permit. Annex No. 4, on the other hand, deals with the scope and content of the project documentation for the execution of the construction.

In our paper we are concentrating to the second sort of terms of references, which create main part of design documentation. Their compilation must respect both, the above legal requirements and the professional requirements summarized in (Prochazkova et al 2019). The fulfilment of these professional requirements must be high-quality because they are crucial to ensure:

- the correct course of reconstruction,
- the requirements set in the contract authority,
- safety of both, the metro station and the surrounding.

6. Terms of References for Metro Station Reconstruction

In real engineering practice aimed at ensuring safe technical objects, it is necessary to separate the two basic activities that their creators must perform. The first activity evaluates the characteristics of the territory in which the object is located and its aim is to determine the conditions for designing the technical object so that it is secured against all external disasters. The second activity determines, on the basis of the terms of reference, how to reconstruct and operate a technical object so that it safety operates and does not endanger itself and its surroundings, even under its critical conditions (Prochazkova 2015).

The priorities of the reconstruction of the metro station (METROPROJEKT 2021, 2022) are:

- safety of passengers and staff - the highest priority,
- accessibility of the station for all passengers, including persons with disabilities,
- minimizing the impact of the reconstruction on the normal operation of the metro,
- and maximum efficiency in the use of financial and time resources.

In order to ensure the quality of the reconstruction, in accordance with Decree (CR 2009a)., the following is required: selection of quality materials; selection of skilled workers also for craft work; regular quality control – attestations, tests, compliance with standards; regular recapitulation – reports on the progress of work and their observance; and regular communication with suppliers and investors. From these reasons, compiled terms of reference for metro station contain 20 items (METROPROJEKT 2021, Strelbova 2023).

The first item summarizes data on external risk sources, sizes of their hazards and on counter measures for their prevention. The second one gives list of technical equipment, which must be inserted into the object for enabling the response to risks which are expected during the operation. The most important is third item, which contains safety culture requirements, which consider safety as an essential quality character of technical object according to (EU 1992). These requirements ensure: carrying out the quality control of all measures taken; using the work management system according to ISO 9001 in the latest version; taking the measures against human errors; performing the protection of people; performing the high-quality risk management (to know the sources of risks; the magnitude of the relevant risks; to consider uncertainties, both random and knowledge-based); performing the physical and cyber security of the object; and applying a risk management plan in case of danger (Strelbova, Prochazkova, Srytr 2022).

The forth item is the list of unfinished works that arose during the repairs in the past period, which need to be finished during the reconstruction, and set of measures for theirs finishing. The fifth item contains requirements for dealing with the specific sources of risk that have been identified at connection with works shown in Figure 1. The sixth item contains requirements for construction materials, products and technologies according to (CR 1997, 2001 a, b, 2002, 2006 a, b, 2009 a) and in harmony with documentation (TEN 2018) the requirements for: security devices; communication equipment for EPS, radio equipment, information systems, validators, ticket machines, dispatch control systems; electrical equipment as switchboards, transformers, cables; control systems; lighting; technical equipment and products for lifting equipment, air-conditioning equipment and ventilation, fire dampers, pumps, gates, measurement and regulation

systems, tracks, fire and flood protection equipment (doors, walls, passages, special equipment, etc.), insulation, etc.; and vehicles including the equipment, escalators, lifts and platforms.

The seventh item contain requirements for wiring and other technical equipment according to (CR 1995 a, b) and standards CSN: 33 1326, 33 2000, 50110 and 50122. The eighth item contains safety and fire protection requirements according to (CR 1985, 1994, 1995 a, b, 2000, 2001 a, b, 2011) and standard CSN 73 0834. The ninth item contains ventilation and air-conditioning requirements according to standards CSN 73 0540 and 16798-3. The tenth item contains accessibility requirements for persons with disabilities according to (CR 2009 a, 2016). The eleventh item contains requirements for information and navigation systems (TEN 2018). The twelfth item contains aesthetic and architectural requirements.

The thirteenth item contains requirements for dismantling the existing elements, repair and replacement of damaged parts (TEN 2018). The fourteenth item contains requirements for the durability of structures (TEN 2018).

The fifteenth item contains meeting the requirements of Decree (CR 2009 a, b). It deals with: safety of passengers and staff, i.e. provide well-signposted safe bypass routes for passengers and staff away from the construction site and a clear information system; accessibility for people with disabilities, i.e. ensuring barrier-free access (lifts, escalators, etc.); sufficient station capacity and traffic flow; aesthetic and architectural requirements, i.e. identification of suitable and durable materials for walls, floors, ceilings, etc.; the environmental aspect, i.e. the use of car transport that complies with Euro VI, proper waste management and minimization, the use of environmentally friendly materials; and only the necessary financial and time constraints – thorough planning of the budget and plan of work, appropriate distribution of metro closures.

The sixteenth item contains the requirement regularly (1x per month) to evaluate the integral risk of the reconstruction process using the decision support system (Strelbova 2023) in order to prevent many small deficiencies, the sudden accumulation of which in a short period of time can lead to a failure during the building or later during the operation. The seventeenth item contains requirement to install additional protective barriers, systems and technical elements that allow a rapid and effective response to critical situations, i.e. it defines tasks and clearly responsibilities in terms of managing the reconstruction process.

The eighteenth item contains requirements for construction works with aim to ensure acceptable impacts of reconstruction on both, the public property and the reconstruction operator. Based on the assessment of risk impact scenarios, they are accepted measures are for:

- demolition work: hygiene rules; installation of noise barriers;, regular sprinkling and extraction of air; installation of temporary ceilings above the metro vestibule; and use of appropriate technological procedure.
- concrete work: work in a tempered tent; use of suitable admixtures for concreting in winter; proper treatment of concrete (sprinkling, covering) and appropriate use of admixtures; use of appropriate technological procedures,
- work on steel structures: use of suitable technological procedures; prevent overloading the of cranes, etc.
- insulation work: use of appropriate protective equipment such as gloves, clothing, goggles; use of appropriate technological procedures,
- work inside the metro station: observing the working rules; paying the attention to the metro staff and passengers,
- electrical installation work: use of appropriate technological procedures; prevention to use damaged equipment; use of protective equipment,
- good management and compliance with legal regulations: organizational rules contained in the safety management system with clear obligations; OSH rules and motivation of critical personnel.

The nineteenth item contains requirement to draw up work schedules of works for processes shown in Figure 1 so that there is no downtime and stages follow each other. The twentieth item contains requirement for the correct application of risk management plan measures (Strelbova, Prochazkova , Srytr 2022) in order to increase the quality of reconstruction and eliminate conflicts, e.g. in ensuring the quality of materials and parts.

These terms of references were tested by experts in building and management and then were included into design documentation (METROPROJEKT (2021). Their application worked in practice (Strelbova 2023).

7. Conclusion

The submitted model for compiling the terms of references for design of reconstruction is based on knowledge gathered from the professional literature and from demands of legislation. It shows:

- priorities of the reconstruction,
- twenty items which must be considered and respected at preparation and during the reconstruction process with aim to ensure successful reconstruction and to fulfil the demand that safety is a basic feature of quality of process.

The experience gained during the reconstruction of the Praha metro station, which is located at the intersection of two metro lines in the center of the capital shows that proposed procedure for compiling the terms of references for reconstruction is viable and suitable for practice.

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