REQUIREMENTS FOR DEE AND LONG TUNNELS

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The demands for deep and long tunnels comes from various markets: national and international rail and high-speed networks; motorways; strait crossing projects; regional, inter-region, and inter-state water transfer projects.

Globalization drives for efficient mega-infrastructure projects which, in turn, demand for long and deep tunnels. Mega-infrastructure projects are strategic and represent future life-line projects for many generations to come. Thus, development of deep and long tunnels should be put in the perspective of sustainable development.

The sustainable development for deep and long tunnels from Designer perspective should include:

- the clear identification of project requirements;
- the capability to perform special studies to solve the peculiar problems related to the unique features of deep and long tunnels;
- the use of risk analysis techniques for assessing both initial and residual risks;
- the assumption of responsibility in making reliable estimates of cost and duration for determining the most appropriate construction method, construction sequence and procurement method;
- the systematic use of risk management that allows for cheap and reliable technical solutions through the industrialization of construction processes, once the unique features of deep and long tunnels are understood, designed for, and the identified risks are minimized in the design process and countermeasures are set to control residual risks.

The experiences gained worldwide in the design and construction of deep and long tunnels shows that many years are required to plan them - often 20 to 30 years – and long time for construction are involved - often 7 to 15, or even 20 years.

The current conditions of historical deep and long tunnel, such as the 130 years-old Frejus Railway Tunnel, show that durability and serviceability are not really a major issue, especially if the tunnel is well conceived in the perspective of future needs (e.g., two tracks in the historical Frejus Tunnel). Also the technical feasibility and the constructability are no longer an issue: the success of undersea tunnels (e.g., Seikan and Channel), traffic tunnels (e.g., Loetschberg and Abdalajis), hydraulic tunnels (e.g., Envinos, Wanjiazhai and Karahnjukar) are giving a clear demonstration. Furthermore the technological achievements permit great advance rates and very long headings.

The main issues related to deep and long tunnels are often related to: the support of a strong political will; the public understanding; the financial pressures that push for fast solutions with quick economic returns of the investment; the design of construction logistics; the contract management; the risk-sharing and management.

The presentation is focused on some of those issues:

- Managing the complexity of requirements
- Designing for unique features
- Systematic risk management

The unique features of deep and long tunnels are mainly related to three aspects:

- *Problem of scale*: long distance & depth; difficult to investigate; small tunnel section; no local precedents; alignment constraints; great uncertainties leading to high risks; time-consuming planning & investigations; environmentally demanding (e.g., areas to relocate the muck).
- *Complex ground conditions*: variability; in-situ stress; squeezing; swelling; presence of gases; heterogeneity; presence of water; active tectonism; high temperatures.
- *Constraints & restrictions*: budget (time vs. costs); problems of remoteness; climate and environment; durability and maintenance; access and logistics; redundancy.

Unique features demand for special thinking, particular approaches and innovative solutions.

The intrinsic unique features of deep and long tunnels have to be crossed with the main Client requirements to complete the overall picture of the complexity.

The main Client requirements are related to asset performance (Safe, to quality, functional), asset management (effective in exploitation, staged or phased implementation, easy and cheap to maintain; good serviceability and long durability); capital delivery (low cost, on time, financially sustainable); environmentally sustainable (low impact, consensus, architectural quality)

The clear identification of the requirements leads to identifying the disciplines to be dealt with, the specific studies to be developed, the interfaces, the sources of risk.

Present and past case histories show the setting of both a proper organization to manage disciplines and interfaces and proper procedures for managing risks to be the basic response to delivery the project at minimum cost and with a reliable time schedule.

At the same time, the technical studies have to focus on some key aspects:

- Develop a comprehensive and robust functional design – choice of system, cross-section, safety concept and maintenance strategies, offering sufficient space inside the tunnel (account for future needs!).
- Define the right balance between minimum site investigation and a comprehensive checklist of risks and catalogue of well-defined, adaptable technical solutions (section types) with pre-defined counter measures, based on probabilistic analysis.
- In both the functional and the technical design give due considerations to the needs for maintenance and durability.
- Give importance to the design of the logistics and worksites for construction, treating it equally like treating the technical design of the works.
- Implementation of a risk management plan from the early stage.

Most risks can be effectively managed through the use of a RMP - Risk Management Plan – a robust, transparent and effective methodology, which can be adopted from the early design stages to the construction and operation phases to minimize the occurrence of risks and/or their consequences.

According to the authors' experience, a typical RMP for deep and long tunnels can include the following key elements:

- A transparent risk identification, assessment and mitigation process.
  With a RMP the Parties involved in the project should timely and effectively identify and quantify the potential problems (hazards) and the associated initial risks, determine the risks that have to be reduced through implementation of preventive measures, and subsequently quantify the residual risks that have to be shared among the Parties and systematically controlled.
- An efficient and effective tool for quantifying the impacts of the identified risks in terms of the construction time and cost of the project.
  The system DAT - Decision Aids for Tunnelling – is a tool meeting the requirements of comparing easily the various outcomes corresponding to the adoption of different risk mitigation strategies or plans, allowing thus for the selection of the optimal design-construction solution with minimal residual risks. It can simulate the process of underground construction in a probabilistic manner accounting explicitly for the various uncertainties and risks involved in the different, feasible design-construction solutions for a project.
- Innovation in deeply understanding the unique features of deep and long tunnels in terms of complex ground conditions and ground response and in developing design solution to effectively deal with them.

The above key elements have been integrated and successfully applied in recent years to a series of important deep and long tunnel projects like the California high-speed rail, the Pajares and Guadarrama high-speed railway tunnels in Spain, the new Lyon-Turin high-speed railway link.