

SELECTION OF THE MOST SUITABLE ORGANISATIONAL MODEL FOR LONG TUNNELS

H. Ehrbar

Heinz Ehrbar Partners llc, Herrliberg, Switzerland

ABSTRACT: Choosing an appropriate organisational and contractual model is one of the key strategic decisions in major tunnel construction projects. It significantly influences project governance, the allocation and management of risks, and the opportunities for technical and organisational optimisation during both the planning and implementation phases.

In international infrastructure construction, a wide range of organisational models is used. These include traditional single-contract approaches, general designer and turnkey contractor models, design-build contracts, public-private partnership (PPP) schemes, and collaborative arrangements such as project alliances. The suitability of a particular model depends on several project-specific factors, notably the technical complexity of the project, the risk profile, the market environment and the capabilities of the project owner organisation.

Experience from major infrastructure projects indicates that collaborative contract models may offer advantages in projects characterised by significant uncertainties and a substantial potential for optimisation. However, such models do not eliminate the technical risks inherent in a project. Rather, they primarily influence how these risks are allocated and how they are jointly managed by the project partners.

The central question addressed in this paper is therefore: which criteria should guide the selection of the most suitable organisational and procurement model for long tunnel construction projects?

1. THE LIFECYCLE OF INFRASTRUCTURE PROJECTS

Major tunnel construction projects are typically initiated in response to a clearly identified need for transport, energy or utility infrastructure, or for scientific and research purposes. Based on a needs assessment, the project evolves through several planning and decision-making stages until the phases of planning, construction and operation are ultimately implemented (Figure 1).

The lifecycle of such infrastructure projects usually extends over several decades. The technical service life of a tunnel structure is commonly in the range of 80 to 120 years. At the end of this service life, the structure may be decommissioned, dismantled or upgraded through appropriate measures to enable its continued use, either for its original function or for a different purpose [1].

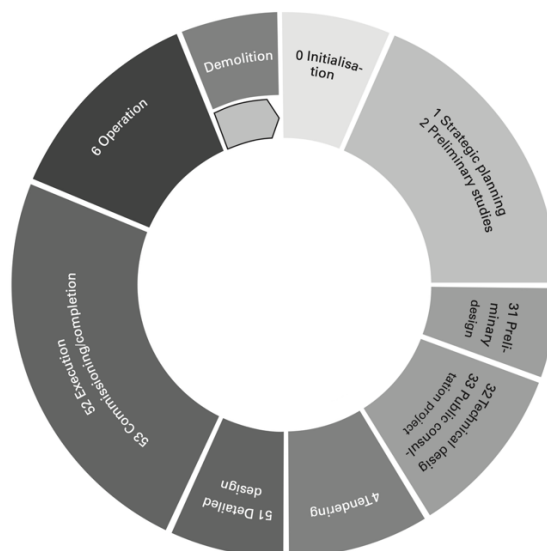


Figure 1 Lifecycle of an infrastructure project based on Model SIA 112 [2]

2. SERVICE PACKAGES

The services required for the planning, construction and operation of a tunnel project can be organised in different ways (Figure 2). In principle, several organisational models exist, which differ primarily in the way services are bundled and responsibilities allocated. The choice of an appropriate organisational model has a significant influence on the distribution of roles among the project participants and on the degree of coordination required between them.

In the traditional single-contract model, design, construction works and technical installations are procured under separate contracts. This approach provides the project owner with a high degree of flexibility and allows detailed control over the project. However, it also places a substantial coordination burden on the project owner's organisation.

Alternatively, several services may be bundled into larger contract packages, such as general contractor models, design-build contracts and turnkey arrangements. Under these models, planning and construction are transferred, either partially or entirely, to a single contractor. While this reduces the coordination effort required from the project owner, it simultaneously limits the project owner's ability to influence the project in detail.

A further category comprises partnership-based contractual models, in which the project owner and the non-owner participants non-owner participants work together within an integrated project organisation. Project alliances are a prominent example. One of the objectives of these models is to reduce the project owner's coordination effort while maintaining a direct involvement of the project owner in the management of the project.

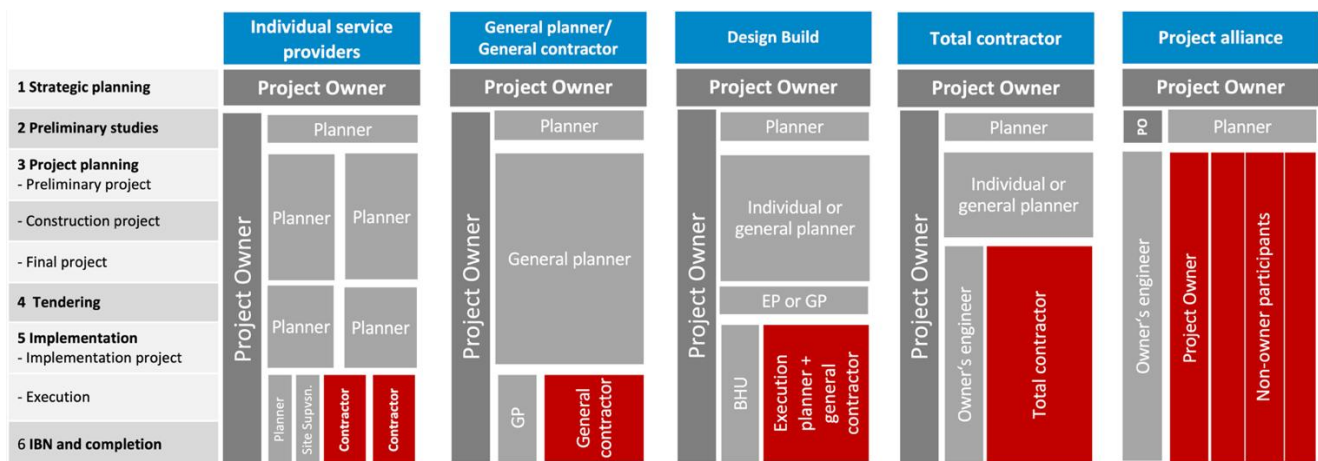


Figure 2 Comparison of different organisational models

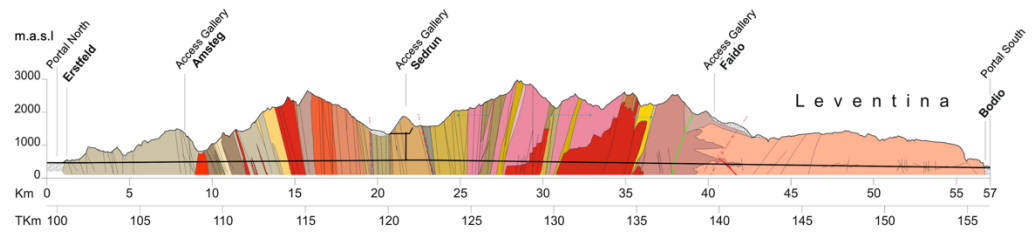
In theory, organisational models for infrastructure projects can be clearly distinguished. In practice, however, large projects often combine different procurement and organisational approaches within a single project, depending on the characteristics of the individual work packages.

The Gotthard Base Tunnel provides a well-known example of such a hybrid approach (Figure 3). The design of the underground structures was undertaken by two engineering consortia, while locally based engineering firms were responsible for the planning of the external facilities. The main structural works were executed under four major construction contracts awarded to three contractor consortia. Access works and site preparation were carried out under smaller works contracts, most of which were awarded to local contractors.

The railway systems, by contrast, were procured under a turnkey contract covering design, supply and installation. This approach was particularly appropriate because standardised railway systems had to be installed continuously from portal to portal. Other technical installations, such as ventilation fans, lift systems, doors and gates, were designed by the engineering consortia responsible for the structural works and subsequently supplied and installed by specialised contractors.

Payment under the engineering and construction contracts was based on a combination of unit-price and lump-sum arrangements. Unit-price contracts were generally applied for the structural works, while a

lump-sum contract was agreed only for the Erstfeld lot due to specific project constraints. The main contractor responsible for the railway systems, on the other hand, was remunerated on a lump-sum basis according to a predefined payment schedule.



Design and site supervision	Preliminary studies and design	Engineering contract			
	Design civil work	Engineering contract North		Engineering contract South	
	Site supervision civil work				
	Requirements railway technique	Various engineering contracts			
	Technical equipment	Engineering contract			
Execution	Initial civil work	Various contracts	Various contracts	Various contracts	Various contracts
	Construction lots tunnelling	Lot Erstfeld	Lot Amsteg	Lot Sedrun	Lot Combination Faido / Bodio
	Railway technique	Total contractor			
	Technical equipment	General contractor			

Figure 3 Contract structure of the Gotthard Base Tunnel

Overall, the project required the administration of approximately 600 contracts, including five major contracts with individual values exceeding CHF 400 million. Around 3,000 contract variations were processed during the execution phase. Thirteen cases involving differing interpretations of contractual provisions were referred to dispute resolution, all of which were ultimately settled amicably without recourse to legal proceedings.

The organisational structure of the Gotthard Base Tunnel therefore illustrates an important principle of major infrastructure projects: rather than applying a single organisational model, different procurement approaches may be combined in order to reflect the specific technical, organisational and market-related characteristics of the various project components.

At the same time, this example demonstrates that projects of such scale and complexity require a highly competent and well-resourced project owner organisation capable of managing a large number of contractual interfaces. When traditional procurement models with multiple separate contracts are used, the coordination effort on the project owner side is correspondingly high.

In retrospect, the management of the Gotthard Base Tunnel using predominantly traditional contract models is widely regarded as successful. The experience gained from this project suggests that the success of large infrastructure projects depends less on the choice of a particular contractual model than on the strength, competence and continuity of the project owner organisation responsible for managing the project.

Against this background, the question arises as to which criteria should guide the selection of an appropriate organisational and procurement model for major tunnel projects. The following sections therefore discuss key factors that should be considered when choosing a suitable model.

3. DEVELOPMENT OF KNOWLEDGE WITHIN A PROJECT

Large-scale tunnel construction projects are typically characterised by a high degree of uncertainty. This uncertainty arises primarily from geological conditions, technical challenges and the potential for changes in project requirements over the long duration of such projects.

At the beginning of a project, the proportion of unknown or only partially understood factors is particularly high. As planning progresses and construction advances, knowledge of the geological, technical and operational conditions gradually improves and uncertainties are progressively reduced (Figure 4).

Systematic risk management plays a key role in this process. It enables uncertainties to be identified at an early stage, their potential impacts to be assessed and appropriate measures to be developed to mitigate risks while making use of potential opportunities.

In tunnel construction projects, geological uncertainty in particular makes the accumulation and retention of project-specific knowledge essential. Changes in key project participants often lead to a loss of such knowledge.

In tunnel construction, where geological uncertainty plays a dominant role, continuity of the project organisation is therefore a key prerequisite for project success. Against this background, the choice of an appropriate organisational and contractual model becomes a crucial strategic decision in the management of major tunnel projects.

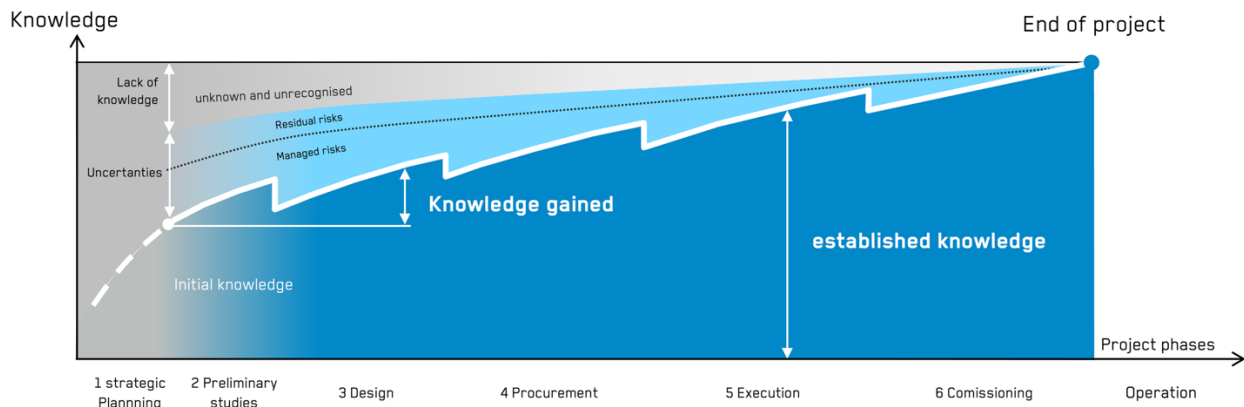


Figure 4 Typical progression of findings in a project where no countermeasures are taken

4. DEALING WITH THE UNKNOWN AND MANAGING RISKS

The choice of an appropriate organisational and contractual model is a key strategic decision in the development of major tunnel projects. Different procurement approaches distribute responsibilities, risks and decision-making authority in different ways and thus influence how effectively a project organisation can respond to the uncertainties inherent in underground construction.

In projects characterised by significant geological variability and long implementation periods, it is particularly important that the selected organisational structure allows new knowledge gained during planning and excavation to be efficiently integrated into the ongoing project. At the same time, the organisational model must provide clear responsibilities, effective coordination between project participants and an appropriate allocation of risks.

The suitability of a particular organisational and contractual model therefore depends on several project-specific factors. These include, among others, the level of geological uncertainty, the technical complexity of the project, the potential for optimisation during design and construction, the structure and capabilities of the construction market, and the organisational capacity of the project owner.

In practice, no single procurement model can be considered universally optimal for tunnel construction projects. Rather, the selection of an appropriate model requires a careful assessment of the specific characteristics and risks of each project.

In addition to the unknown and the unrecognised, every tunnel project also involves events that may occur with a certain probability and may have corresponding consequences for the project. These events constitute the project risks. Different contractual approaches address these risks in fundamentally different ways.

Traditional contract models generally follow a risk transfer approach (Figure 5). Risks are allocated individually to the contracting parties, each of whom bears its assigned share and seeks to protect its own interests. In practice, however, contractual provisions governing the treatment of risk events are often insufficiently precise, particularly with regard to cost reimbursement and schedule adjustments. As a

result, adequate financial provisions are frequently lacking, both in the contracts themselves and in the project owner's budgets.

The individual allocation of risks also tends to encourage each party to focus primarily on its own risk portfolio. Both before and after contract award, parties may therefore attempt to shift the consequences of risks to others or to derive the greatest possible advantage from them. Such behaviour can hinder meaningful optimisation, comprehensive contingency planning and constructive, timely problem-solving.

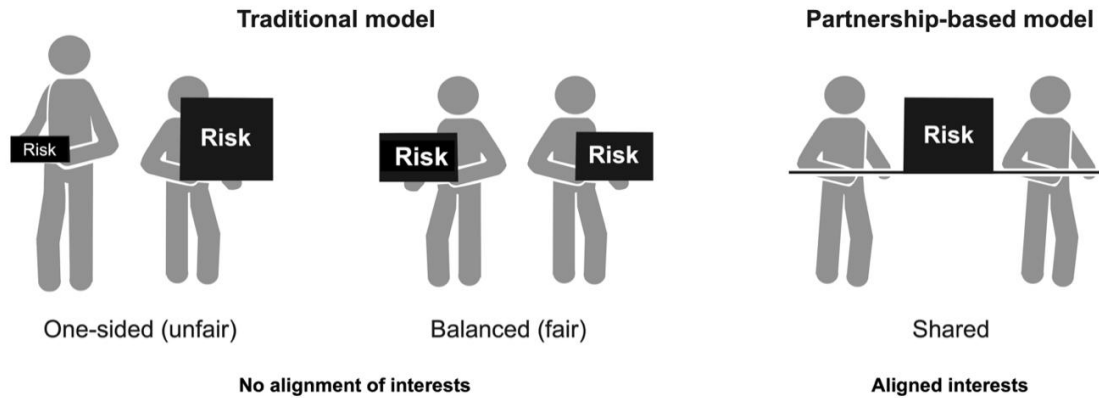


Figure 5 Different approaches to managing risks

An alternative approach is the risk sharing approach, in which project risks are managed collectively by the project partners. Instead of allocating risks strictly to individual parties, risks and opportunities are shared among the participants in accordance with their respective capacity to bear them. This approach aims to align the interests of all parties and to create incentives for joint problem-solving and optimisation throughout the project (Figure 5). The objective is to ensure that all project participants pursue common project goals and work together to manage uncertainties as they arise during the planning and construction process.

The fundamental difference between traditional and collaborative contract models therefore lies not in the existence of risks, but in the way these risks are managed. While traditional models emphasise the transfer of risks, collaborative approaches focus on their joint management.

5. ANALYSIS OF VARIOUS ORGANISATIONAL MODELS

5.1 TRADITIONAL ORGANISATIONAL MODELS

The so-called traditional contract models, ranging from individual contracts with unit-price remuneration to design-build contracts with lump-sum remuneration, have evolved over many years (Figure 2) and are generally well established in national legislation. As a result, these models offer a relatively high degree of legal certainty.

All traditional organisational models are based on the principle of a straightforward exchange of services. The project owner specifies the services required from the contractors with sufficient clarity and procures the corresponding work packages in varying sizes, either through individual contracts or through larger packages awarded under general contractor (GC) or total contractor (TC) agreements. However, the contractual arrangements themselves do not typically include mechanisms aimed at aligning the interests of the project participants through jointly defined project objectives.

This lack of alignment of interests may lead to adverse consequences, particularly when project boundary conditions change [3]. Typical effects may include:

- the absence of a comprehensive technical assessment of the project and its structures,
- insufficiently developed risk analyses, which—due to inadequate contingency planning—may increase the probability of hazardous incidents with potentially significant consequences and may also prevent opportunities from being realised,
- inadequate communication between project partners,

- missed opportunities to exploit synergies and optimisation potential, and
- disputes and mutual accusations when problems arise instead of a constructive search for solutions.

Various supporting measures can help to reduce the inherent potential for conflict in traditional contract models. These include more precise service specifications, detailed provisions governing changes (including prerequisites, procedures and consequences), a balanced allocation of risks, joint risk management processes, shared digital project platforms, clearly defined decision-making procedures and the agreement of out-of-court dispute resolution mechanisms.

Experience from several major projects has shown that such measures can enable successful project delivery even under traditional contract models, as demonstrated by the construction of the Alpine base tunnels in Switzerland.

However, these supporting measures do not fundamentally change the underlying contractual logic of traditional models, which is based on the allocation and transfer of risks between the contracting parties. In recent years, this has led to the development of alternative procurement approaches that seek to align the interests of the project participants more closely and to manage project risks jointly. These collaborative contractual models, such as project alliances, aim to create a framework in which project partners work together towards common project objectives and share both risks and opportunities.

5.2 PARTNERSHIP-BASED MODELS

In the Anglo-Saxon world, a shift in procurement practice began more than 30 years ago. The underlying idea was to prevent the sources of conflict described in Section 5.1 from arising in the first place by adopting contractual models that better align the interests of all project participants. These partnership-based models aim to create a framework in which the contracting parties work together towards common project objectives.

The following characteristics are typical of such partnership models:

- Joint determination of scope, costs and schedule through a structured dialogue process.
- Integrated project organisation, in which the project owner and the non-owner participants jointly manage the project and take decisions according to the principle of "best for the project".
- Incentive-based and performance-related remuneration, structured according to a "win-win" or "lose-lose" mechanism.
- Collective identification, analysis and management of risks, including both opportunities and threats, with mutual liability largely excluded.
- A collaborative culture, replacing the traditional blame-oriented approach with a solution-focused "no-blame" environment.

In countries, such as Australia [4], New Zealand and Finland, where such models have been introduced, they have in many cases contributed significantly to achieving project objectives more effectively. This applies not only to cost and schedule performance, but also to other project requirements such as quality, innovation and stakeholder satisfaction.

Partnership-based models should not be confused with design-build procurement. In design-build contracts, planning and construction responsibilities are transferred to a single contractor, but the underlying contractual logic generally remains based on the allocation and transfer of risks. By contrast, partnership models are based on the principle of joint project governance and the shared management of risks and opportunities within an integrated project organisation.

However, partnership models generally require greater effort in the early project phases than traditional procurement approaches. In particular, additional resources are needed during the selection of implementation partners through dialogue-based procedures. In the public sector, this process is often conducted with several bidders until the project has reached an appropriate level of maturity.

For this reason, partnership models are typically most suitable for projects of sufficient scale and complexity. Moreover, their successful implementation requires all parties involved to be willing to depart

from conventional practices and, where necessary, to operate within legal and organisational frameworks that may still be relatively unfamiliar.

In conceptual terms, design–build primarily changes the distribution of responsibilities between the project owner and the contractor, whereas partnership models fundamentally change the way project partners collaborate and manage risks. Partnership models therefore do not eliminate uncertainty in tunnel construction; rather, they change the way uncertainty is addressed and managed.

6. CRITERIA FOR SELECTING THE OPTIMAL ORGANISATIONAL MODEL

6.1 THE ‘CALL AN ENGINEER SYNDROME’

Even today, it is still common practice in many projects that, once the feasibility of a project has been satisfactorily demonstrated within the available budget framework, the project owner instinctively proceeds by commissioning consultants to design the project before later engaging contractors for its execution. Sir Michael Latham referred to this behaviour in his report *Constructing the Team* as the “ring up an architect/engineer” syndrome. Sir Michael Latham observed:

“That takes a crucial step too quickly, and closes off potential procurement options. The next step should be the use of internal risk assessment to devise a contract strategy. The project owner should decide how much risk to accept. No construction project is risk free. Risk can be managed, minimised, shared, transferred or accepted. It cannot be ignored. The project owner who wishes to accept little or no risk should take different routes for procuring advice from the project owner who places importance on detailed, hands-on control.”
[5]

These observations remain highly relevant today. They underline the importance of considering possible organisational and contractual models at an early stage of project development. The selection of an appropriate model should therefore be based on a systematic assessment of project risks, objectives and boundary conditions rather than on established routines or institutional habits.

This is particularly important in tunnel construction projects. Due to geological uncertainty, long implementation periods and the considerable technical complexity involved, the choice of the organisational and contractual model has a significant influence on how effectively emerging knowledge can be integrated into the project and how project risks are managed.

For this reason, the decision on the appropriate procurement and organisational model should be taken consciously and at an early stage of project development. Otherwise, there is a risk that the project will fall into the pattern described by Latham as the call-the-engineer syndrome, thereby prematurely excluding procurement strategies that might offer advantages in dealing with the specific challenges of underground construction.

6.2 QUALIFICATION CRITERIA

Before selecting a specific organisational model, it is essential to determine which models are fundamentally suitable for the project in question. The choice of a procurement and organisational model should therefore follow a structured decision-making process.

Criteria 1 – Assessment of legal feasibility

Partnership models, particularly alliance-type arrangements, often rely on multi-party agreements. However, explicit statutory provisions for such contracts exist in only a few countries. In many jurisdictions, such arrangements are neither explicitly regulated nor prohibited and therefore fall under general contract law. As a consequence, relevant case law may be limited, which can be perceived as a degree of legal uncertainty.

Criteria 2 – Assessment of market conditions

An important prerequisite for the successful implementation of any organisational model is the availability of a sufficient number of qualified providers to ensure effective competition, typically at least three bidders. This requirement may be difficult to fulfil in certain sectors, particularly in specialised equipment supply markets such as the rail and energy industries.

Criteria 3 – Definition of the project owner’s strategic objectives

The project owner must define the fundamental principles governing the organisation of the project. Key questions include:

- How should the project’s target system be structured (project-specific or company-wide objectives)?
- Should the project partners’ interests be explicitly aligned, or should each party pursue its own interests within a contractual framework?
- What is the project owner’s risk strategy (individual allocation of risks or shared risk management)?

Criteria 4 – Assessment of organisational implications

The successful implementation of partnership models therefore requires not only an appropriate legal framework but also a willingness on the part of all project participants to depart from conventional contractual practices. In particular, the parties must be prepared to align their interests with the overall objectives of the project and to jointly manage risks and opportunities. The successful implementation of a partnership model requires adequate human resources and a strong commitment from the participating organisations. Without these prerequisites, such models are generally not suitable.

Table 1 summarises selected criteria for assessing the qualification of different organisational models in tunnel construction projects.

Table 1 Key criteria for selecting an organisation model in tunnel projects

Criterion	Traditional models	Design-Build	Partnership models / Alliances
Legal framework	Well established in most jurisdictions and supported by extensive case law.	Widely used and generally supported by procurement legislation.	May require dialogue procedures or multi-party agreements; legal frameworks vary between countries.
Market structure	Suitable where a sufficient number of specialised contractors and consultants are available.	Suitable where contractors have strong design capabilities.	Requires a mature market with experienced partners and willingness to collaborate.
Risk strategy	Risks are allocated individually to contracting parties.	Significant risks may be transferred to the contractor.	Risks and opportunities are managed and shared collectively.
Project owner’s organisational capacity	Requires a strong and well-resourced project owner organisation capable of managing multiple contracts and interfaces.	Lower coordination effort for the project owner.	Requires an experienced project owner capable of working within an integrated project organisation.

6.3 PROJECT-SPECIFIC SELECTION CRITERIA

Unlike the qualification criteria discussed in Section 6.2, the assessment of the selection criteria does not lead to a clear-cut decision. Instead, it allows for a certain degree of discretion on the part of the evaluators or the project owner organisation.

Typical project-related selection criteria may include the following questions:

To what extent are changes to the project likely, given the current list of requirements and the level of detail in the tender documentation?

- How should the service packages be structured or divided?
- How complex is the overall project as a result?
- What is the size and structure of the project's risk portfolio?
- How strong is the pressure to minimise overall project costs?
- How tight is the schedule for commissioning?
- To what extent is there an interest in exploiting innovation potential?

These criteria may exhibit very different characteristics from one project to another, as illustrated in Figure 6. It is therefore the responsibility of the project owner organisation to assess these characteristics for the specific project and to draw the appropriate conclusions.

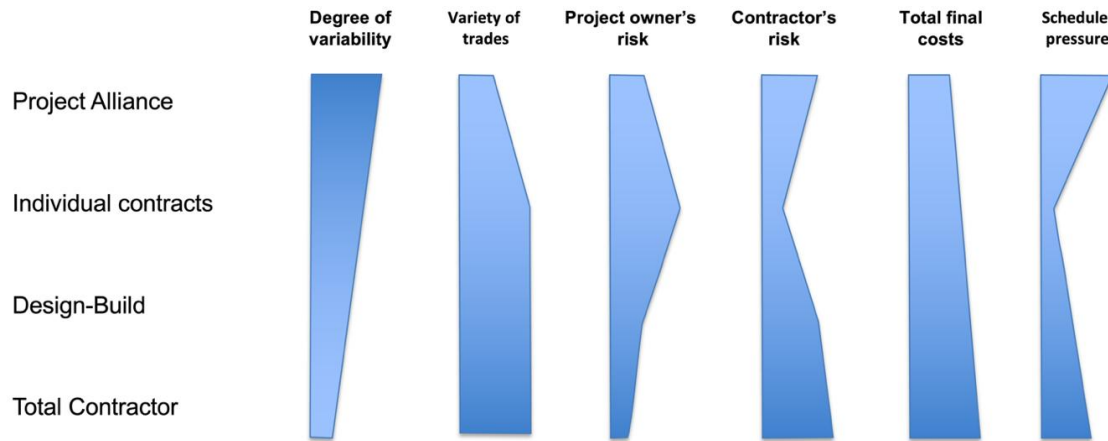


Figure 6 Examples of project-specific selection criteria

With regard to the use of project alliances, it can be observed that such models are particularly well suited to projects of a certain level of complexity. This is typically the case where a relatively high potential for changes exists, while the number of trades involved remains manageable - a condition that is often encountered in the construction of long tunnels.

In alliance models, risks are generally shared in a balanced manner among the project partners. However, this requires the project owner to possess sufficient capacity to bear risks. If this prerequisite is not met, procurement approaches such as total contractor agreements or design-build models may be more appropriate.

Because financial provisions for risks are jointly agreed within the alliance framework and the incentive-based remuneration structure encourages the prevention of risk events, alliance models may offer opportunities to reduce overall project costs. Compared with turnkey contracts, for example, lower risk premiums may be required. Furthermore, the reduction of interfaces, the possibility of increased parallel working, simplified procurement procedures and easier access to the benefits of innovations can accelerate project execution, making such models suitable even for projects with demanding schedules.

Ultimately, the choice of the most appropriate organisational model must be based on a project-specific assessment of the relevant selection criteria. The suitability of a procurement model therefore depends less on the model itself than on the characteristics of the project to which it is applied.

6.4 ORGANISATION-RELATED SELECTION CRITERIA

When shortlisting the most suitable organisational model, the project owner organisation must also assess whether it has the capability to implement the preferred model successfully. At a minimum, the following criteria should be examined:

1. To what extent does the project owner organisation possess the necessary competence to act as project owner?
2. Are sufficient staff available with the required professional and interpersonal skills to assume key management roles (on both the project owner and contractor sides)?
3. What is the risk tolerance and risk-bearing capacity of the contracting parties (project owner and contractors)?

First, it must be ensured that sufficient personnel are available, both in terms of numbers and in terms of their professional and interpersonal capabilities. In alliance-type models in particular, the project owner cannot delegate its responsibilities within the steering and management structures and must therefore be represented by suitably qualified personnel. Other procurement models, such as design-build or turnkey arrangements, generally place fewer demands on the project owner organisation in this respect, at least in terms of staffing requirements.

Second, as Sir Michael Latham has emphasised, the project risks must be analysed carefully. The magnitude and distribution of risks across the different categories of causes must be clearly understood in order to determine an appropriate organisational structure.

From the project owner's perspective, it might appear attractive in many long tunnel construction projects to transfer as many risks as possible to a single contractor, for example under a turnkey arrangement, as was the case in the construction of the Gotthard Railway Tunnel (1872–1882) [6]. However, market conditions have changed considerably since then. Today it is highly unlikely that a contractor would be willing to assume the full construction risk of a long and technically complex tunnel project.

It is therefore essential to select an organisational structure in which each contracting party contributes an appropriate level of risk-bearing capacity to the project. In this respect, alliance-type models offer certain advantages. The dialogue phase and the pain/gain share mechanisms make the participants' willingness and ability to bear risks transparent—something that is typically less explicit in traditional contractual arrangements.

Experience from modern tunnel projects shows that construction risks cannot simply be transferred to a single party; they must be managed in a way that reflects the actual distribution of risk-bearing capacity within the project organisation.

7. CONCLUSIONS

Determining the most appropriate organisational model for long tunnel construction projects is a complex task, even when the decision is based primarily on empirical evidence and experience from previous projects. Retrospective analyses of completed projects may indicate which organisational approaches have proven successful and which have not [7]. In this context, success should be assessed not only from the project owner's perspective but also from an economic standpoint that includes the commercial performance of the contractors.

There is no single best-practice solution, as illustrated by the wide variety of organisational models used internationally. This makes it all the more important to select the organisational model on the basis of the specific characteristics of the project. Particular attention should be paid to the project's risk profile and to the project owner's strategy for managing these risks—whether through individual risk allocation or through shared risk management.

By applying clearly defined suitability and selection criteria, the most appropriate organisational model can be identified in a transparent and structured manner.

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Heinz Ehrbar

Heinz Ehrbar Partners llc

info@heinzehrbarnpartners.com