DISCUSSION FORUM

TBM procurement, risk, and technology advancement

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Procurement of TBMs involves a combination of referencing technology, machine type and capability, contracting procedures, clarity of responsibilities, risk allocation, commercial issues, competition and geotechnical baseline reports. In particular the balance between the roles and responsibilities of the owner, engineer, contractor and TBM supplier are constants in these regards. **John Reilly** discusses current procurement considerations on making the choice of the TBM required for a given project.

The TBM procurement environment includes complex technical requirements, cost and schedule constraints, unknown ground conditions and risk. The basic requirements of the project owner include an environment that:

- Maximizes contractor competitiveness
- Results in a machine that will perform reliably, safely and productively in the prevailing geology
- That has necessary face control to avoid settlement and damage to adjacent buildings
- Addresses all essential design requirements and is deemed fit for purpose
- Protects the interests of the owner, all stakeholders and political representatives

To achieve these requirements, many and varied procurement options have been introduced and adopted over the decades. The most familiar procurement methods have included:

Design-build with early contractor engagement applied to the Seattle SR99 Alaskan Way highway project and its 17.5m diameter EPBM excavation system

Prescriptive models, where the owner and its design engineer, geotechnical engineer and other engaged experts, fully define the type and characteristics of the TBM, the tunneling processes and the ground support operations required. It is used on the basis that the owner maintains control of key parameters and specifies minimum technical requirements to avoid the shortcomings of a low-bidder-wins environment when contractors may select the least expensive machine that they believe is capable of constructing the facility.[1,2]

A performance-based procurement requires that the contractor meets defined performance requirements, with freedom of choice regarding machine type, components, means and methods. It is selected on the basis that the contractor is best able to determine the most appropriate equipment, methods and techniques to meet the specific geotechnical and other requirements. It is a method that is susceptible to the low-bid-wins syndrome. In practice, the approach is often a combination of performance and prescriptive methods such as in the design-build or turnkey model.

Direct procurement by the owner of the TBM, the lining system and other ancillary equipment and materials is an extreme prescriptive approach. The process specifies and procures the type of machine that the owner, with its advisors (design engineers, geotechnical experts, TBM manufacturers) believes is necessary to control the ground and meet project requirements. Advantages include the ability to accelerate the construction phase schedule and avoidance of inappropriate TBM selection and other low-bidder-wins concerns.

Lowest bidder versus advanced technology dilemma

The tension between technological advance and the lowest-bidder-wins procurement tradition was played out particularly in the USA where the choice of tunneling method allowed contractors to take the risk of investing less on tunneling equipment and techniques to produce the lowest bids, and the owners ending up paying for the downside of those risks through multi-million claims. Based on experiences in the 1980s and 1990s, and with a better than even chance of recovering ground modification or dewatering costs through successful changed-conditions claims, there was little incentive for contractors to invest in modern sophisticated technologies. The results were frequent construction mishaps, delays, cost overruns, and loss of political and public support on highly visible projects.[1,2]

Improving this low-bidder environment required a shift from performance to prescription-based specifications and for some owners to provide pre-purchased tunneling equipment of their choice for their projects. Some regarded this as a violation of conventional wisdom of never tell a contractor how to do his work, but in the USA where contractors were reluctant to apply new technologies, the impetus for progress was the genesis to development of additional progressive procurement methods.

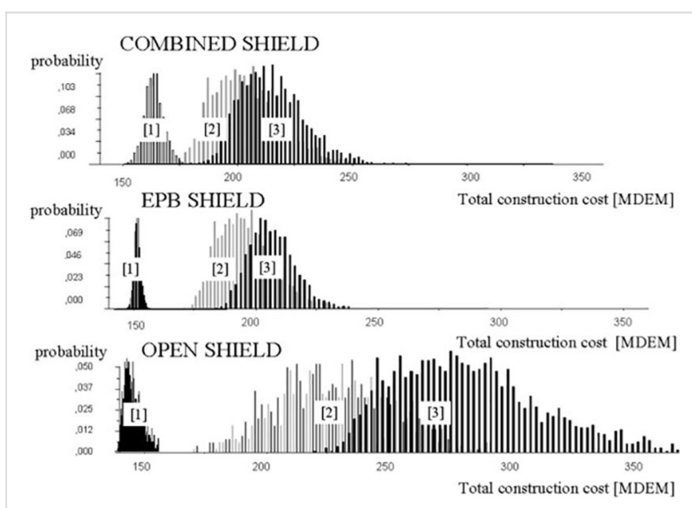
The design-build and turnkey approaches are a combination of a performance approach with prescriptive elements. Application of the method has been increasing since the mid 1990s and there are now several examples of projects that have adopted the method include the SR99 Alaskan Way Viaduct replacement highway tunnel in Seattle, recent contracts for the Los Angeles Metro Purple Line, and the DC Water CSO program of interceptors in Washington DC.[3,4,5] An early example was the Tren Urbano transit project in Puerto Rico, which was authorized under the 1991 Turnkey Demonstration program of the USA Federal Transportation Administration.[6]

Experience with these procurement methods has led to an evolution of variants including Engineering, Procurement and Construction (EPC), Progressive Design Build (PDB), Early Contractor Involvement (ECI), General Contractor/Construction Manager (GC/CM), Target Cost, and Alliancing.

These procurement methods, with a combination of performance and prescriptive elements, offer a middle way which aims to preserve schedule and financial benefits, but structures the contract documents to reflect a higher level of tunneling machine technology and procedural requirements. The goal is to limit the prescriptive details to fundamental elements and leave those that are best left to a knowledgeable and capable contractor in order to foster innovation and identify better alternatives. Projects, including the SR99 Alaskan Way Viaduct Replacement highway tunnel in Seattle, have used this procurement method to structure the contract documents with technical input from a shortlist of contractors to reflect the input from those contractors regarding means and methods and TBM technology.[7]

The Progressive Design-Build (PDB) procurement method uses a qualifications-based or best-value selection, followed by a process whereby the owner then progresses towards a design and contract price with the team. Through this process, PDB brings integration of the owner, engineer, contractor, subcontractors and suppliers to assist in the application of technology and pursuit of best value. For a tunnel project, this would include a more integrated evaluation of performance and risk issues related to the type and technology of the TBM to be used.

With this growing range of procurement alternatives, how to choose the best approach for a particular project might now be the more difficult decision for an underground construction project. An example of how to choose is the structured method that was adopted in 2012 to select the most suitable approach for the Los Angeles Metro Purple Line tunneling program, that would consider the owner's requirements, procurement precedents of the owner's organisation and applicable California State and USA Federal legislation.[4] Legislative restrictions limited Metro, the owner, to design-bid-build or design-build. Working with the Federal Transit Administration, the method adopted was the USA Transit Cooperative Research Program, TCRP, Procedure 131, Guidebook for the Evaluation of Project Delivery Methods. Under the process, the



Study of probable outturn cost for TBM selection, where [1] is base TBM cost [2] costs of probable risks [3] probable outturn cost

method considered:

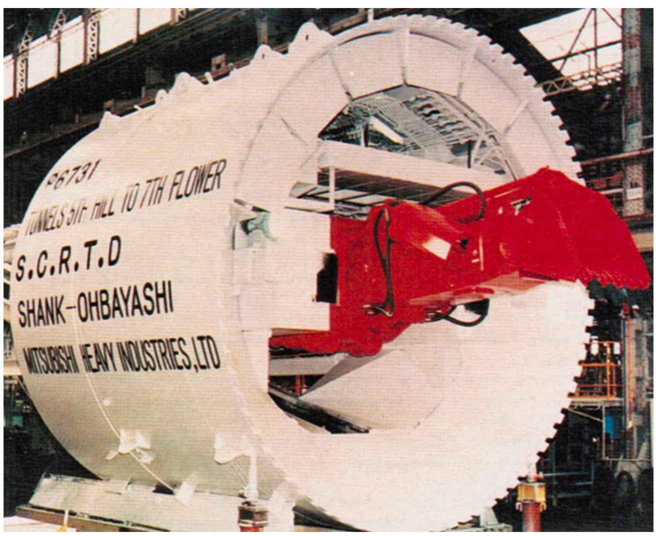
- Agency goals and objectives
- Risks related to the contracting and delivery method
- Characteristics of the contracting and delivery methods in terms of key attributes
- A checklist of elements related to the contracting and delivery method

The TCRP Procedure 131 includes consideration of key factors, some of which take precedence. These generally include:

- Schedule, with design-build generally resulting in a compressed schedule, which is often a priority
- Owner control of design details, which lends a bias towards design-bid-build
- Risk tolerance of the owner and contractual risk transfer methods, with the focus on improving the chance of success[8]
- Political and other considerations including insurance and bonding requirements

For the Los Angeles Metro Purple Line, the resulting decision was to use design-build, with substantial technical input and involvement of the agency and agency's design engineer to include a significant prescriptive element.

The above procurement alternatives do not completely address the characteristics of the TBM to be selected or who decides those characteristics. In practice, the actual process is usually somewhere between the extremes of full owner specification and procurement versus full performance specification with detailed decision and procurement of the TBM by the contractor. The middle way is based on some prescriptive owner requirements of the TBM, such as minimum face control method or convertibility, and some performance requirements, such as settlement limits and protection of adjacent properties. Collective treatment of risk and related compensation of any damages, such as allowances and shared contingency, must also be included.[9,10, 11]



Lowest-bidder-wins environment of early Los Angeles Metro contracts resulted in machines that were unable to control excavation and settlement

In soft ground, the selection of a TBM is often the choice between a slurry or EPB TBM or a convertible machine that combines both modes.[12] In hard rock, the decision is between an open gripper TBM or a single or double shielded machine, with a precast segmental lining. The differentiating factor is the tension between desired technical requirements and capabilities versus cost. In general, it can be argued that the more technologically capable machines are safer and better at avoiding delays due to difficult driving conditions. The additional costs may therefore be justified and considered similar to an insurance cost. An examples of this evolution in soft ground is the comparison between the less expensive open-face digger shields used on the Los Angeles Metro in the 1990s, that caused excessive settlements, and the intervention by a panel of international experts to move the agency to specify positive face control machines, at additional cost, for future Metro projects in Los Angeles.[13] Another example was the owner requirement for positive face control TBMs for Washington Metro projects in the 1970s, after serious settlement during excavation of the F-Route and related damages to the US Tariff Commission building.

Many of the procurement decisions also involve risk considerations. Good progress has been made in risk management processes and capabilities since the mid-1990s, including guidelines published by the ITA and UCA.[9,10,11] Discussions continue with regard to the owner's risk register, where risk identification and management is required for major projects, and the inclusion of that risk register in the contract documents (which is a topic for further discussion).

Nevertheless, identification, analysis and evaluation of significant risks related to TBM capability and operation should be a normal process in TBM procurement, both pre-bid and in the initial phases of design in a design-build contract. Several key topics such as ground conditioning, settlement control, thrust and advance, mechanical breakdown, and the operating impacts on seals and bearings while operating in the ground to be encountered would be essential areas for specific risk assessment. This assessment was undertaken in the pre-bid project development by the owner for the

SR99 Alaskan Way Replacement highway tunnel in Seattle, as part of the owner's CEVP® risk identification process, a standard procedure for major projects by the Washington State Department of Transportation (WSDOT), the owner of the SR99 Alaskan Way project.[14,15]

An area for development would be to use such a process to evaluate bids prior to construction contract award. Best value determination is an accepted process, however, a case is not known where a quantified risk profile, added to base cost, has been used to determine contract award. It could be that such an analysis would show that a more sophisticated and costly TBM would have a probable outturn cost which would be lower than a simpler less expensive machine. This approach was studied for the Grauholz highway tunnel in Switzerland, where a more expensive convertible TBM was estimated to have had a significantly lower probable outturn cost than a simpler less expensive open shield TBM.[16]

Lake Mead Intake No 3 project where design-build with an owner-contractor commitment to alignment and risk-management resulted in an advanced TBM

The above considerations can be viewed in the light of several factors.

- The evolution of increasing TBM capability and technology which is driven by competition, value, safety and reliability;
- The increasing awareness of owners that safety, performance and avoidance of risk is reasonable and necessary and that additional costs in this regard are justified; and
- Risk management as a process of risk sharing, rather than risk transfer.

Fundamentally, a good answer to the question of who should choose the TBM may require use of another management process – the process of alignment of the full project team, including owner, designer, contractor, TBM manufacturer and suppliers, to meet key goals and objectives.[17]

Procurement of underground works will continue to evolve, with the selection of the systems for TBM projects requiring additional consideration and risk assessment when so much of the project success is vested in one excavation method and on a single heading from launch to breakthrough.

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