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TBM PROCUREMENT BY CLIENTS - WHO BENEFITS?

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ABSTRACT

Contractors are occasionally confronted with tunneling projects where TBMs, sometimes including segments, have been purchased by clients before the construction contract has been awarded. This situation creates a modified risk structure and exposure to the involved parties. The question of what the circumstances shall be that this procurement structure will work has been analyzed and representatives of all involved parties, namely clients, consultants, TBM manufacturer and contractors have been asked to provide their input and report from their mostly limited experience. As expected, the answer to the question: "who benefits?" is not an easy one and can be summarized as: "it depends!" It is the circumstances that determine whether such an alternative procurement makes sense and in fact accelerates the project implementation, and reduces the overall risks for clients in regard to completion in time and within budget.

What can be stated is that such process is typically driven by consultants and TBM manufacturers, for increased involvement and scope, and ahead of time TBM sales respectively. Rarely, client organizations are driving the process in this direction. Contractors are confronted with a tool they have to work with under usually challenging conditions. While this can be beneficial to all involved parties when all eventualities remain within the defined boundary, it also can put a substantial burden on clients when contractors will take advantage of out of boundary situations and claim for compensation on any such situation.

ABSTRAIT

Les entrepreneurs sont parfois confrontés à des projets de tunnel où les tunneliers, y compris certaines fois les cuvelages, sont achetés par les maîtres d'ouvrages avant même que le contrat de construction a été attribué. Cette situation à pour conséquence une modification de la structure de risque et de l'exposition pour les parties concernées.
Pour que cette procédure d'achat soit exécutable, la question des faits a été analysée et il a été demandé aux représentants des parties concernées, à savoir maîtres d'ouvrages, consultants, fabricants de tunnelier et entrepreneurs d'apporter leurs contributions et de rendre compte de leurs expérience souvent limitée. Comme prévu, la réponse à la question « qui en profite ? » n'est pas facile et peut être résumée à « ca dépend ! ». Ce sont les circonstances qui déterminent si cette procédure alternative d'achat est raisonnable et, en effet, accélère la mise en œuvre du projet et réduit l'ensemble des risques du maître d'ouvrage concernant l'achèvement dans le temps et selon le budget contractuel.

Cependant, nous pouvons constater que ce procédé est généralement animé par les consultants et les fabricants de tunnelier afin de s'impliquer d'avantage et l'augmentation de la gamme de leur produit, et surtout augmenter la vente prématurée de leurs tunneliers. Rarement, les organisations des maîtres d'ouvrages procèdent dans ce sens. Les entrepreneurs sont confrontés à un outil avec lequel ils doivent travailler dans des conditions généralement difficiles. Même si cela peut être favorable pour toutes les parties concernées dans le cas où toutes les éventualités restent dans les limites définies, il peut également présenter un fardeau considérable pour les maitres d'ouvrage, lorsque les entrepreneurs profitent des situations hors limites définies et demandent une indemnisation à chacune de ces situations.

1 INTRODUCTION

Traditionally, tunnel boring machines (TBMs) for tunneling projects are procured by the successful contractor. Occasionally, projects are procured with a TBM and precast segments already readily available and contractors are left with no other option than to accept what ever the client has ordered for them to work with.

When clients develop projects where tunnels are involved, usually extensive evaluations are taking place by client organizations, and/or by consultants to select the appropriate tunneling method(s). Upon many other factors i.e. surface structures, settlement restrictions, site access, length of tunnel, etc. the right selection is also and importantly dependent on the geo-hydrological conditions along the tunnel alignment. Utilizing the principle of the Geotechnical Baseline Report is one good and fair approach for clients and

contractors, which when applied appropriately, clearly defines parameters and risk allocation.

Once an excavation by tunnel boring machine is chosen as the method of choice the discussion starts on how to specify the appropriate TBM and TBM operations. A range from prescriptive to performance based is available. For the purpose of this paper all kinds of hard rock and soft ground tunneling boring machines are considered as being TMBs. TBMs are capital intensive investments. However, in relation to the overall cost for a tunneling project the costs of TBM and segments are subordinate. The magnitude is dependent on the size and complexity of the project.

Technology and experience with TBM tunneling advances steadily. Clients, often single project tunnel builders, are typically not at the forefront of latest developments and therefore ask for advice from experienced consultants and sometimes from TBM manufacturers.

Depending on their experience and strategy consultants will offer to their client's procurement methods which they consider most suitable and in compliance with the specific country procurement law. Specifically in regard to TBM selection these can include the following scenarios:

1. Client describes the geology and associated parameters (i.e. GBR) – contractor is left to choose the right TBM;

2. Client describes geology and associated parameters (i.e. GBR) and specifies the type of TBM to be used – contractor to negotiate with TBM manufacturers exact configuration;

3. Client describes geology and associated parameters (i.e. GBR) and defines the exact type and configuration of TBM – contractor to choose from pre-selected TBMs and negotiates last details and price with TBM supplier;

4. Client chooses and purchases the TBM, contractor is given the TBM to operate;

5. Client chooses and purchases the TBM, ownership of the TBM is transferred to the contractor once awarded the contract;

6. Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM, contractor to order TBM that partially or greatly reflects his understanding and input provided;

7. Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM and purchases the TBM in advance of contractor selection, contractor is given the TBM to operate;

8. Client involves pre-qualified contractors in an interactive process to find the most appropriate TBM and purchases the TBM in advance of contractor selection, ownership of the TBM is transferred to the contractor once awarded the contract.

In all cases clients are the combination of project owners and their associated and specialized consultants. It shall also be mentioned that in all cases TBM manufacturers/suppliers are involved more or less extensively in the process to advice clients, consultants and contractors. In some cases, TBM manufacturer also have been pre-qualified before entering the process.

Clients are left with the decision on how to proceed.

This paper specifically concentrates on options, where clients decide to get involved in the procurement of TBMs ahead of contractor selection and award.

2 CASE HISTORIES

With one exception in 1972, where one transit project in Australia started with the direct procurement of a TBM, it can generally be stated that the client procurement process started in the late 1980s, with a variety of projects, including mining, water, rail, nuclear waste and subways.

While the references of Table 1 below are the result of an international review of publications, project reports and questionnaires it cannot be concluded that the list is comprehensive.

What can be seen from the project summary is that the majority of projects are rail/subway/metro projects (9 out of 17), and the major TBM type used for owner procurement is the Earth Pressure Balance Machine (30 out of 43), which relates to more difficult soft ground conditions.

It seems that transit authorities, mining companies and wastewater companies with usually a network of tunnels to be built are amongst the potential applicants of the owner procurement method for TBMs. Only few single project entities.

One special case, which is not mentioned in the table and that does not completely fit into the categorization, is the City of Edmonton. The City purchased eight EBP machines and decided to operate them by themselves. In this case the City is owner and contractor in one entity.

Geographically it is interesting to note that 9 out of 17 projects/clients (53%) are bases in North America, followed by China with a share of 23%. None of the projects are located in Europe.

3 STAKEHOLDERS IN THE PROCESS

In the owner procured TBM process the following are the major stakeholders:

1. Client
2. Consultant
3. Contractor
4. TBM Manufacturer

Each of the stakeholders has certain priorities that need to be considered during the decision making process.

3.1 Clients

Clients have the task to implement a project or a network of projects. Their priority is to carry out the project(s) within schedule and budget. Specifically tunneling projects are associated with risks due to unanticipated ground conditions.

Priorities for clients in regard to TBM procurement are as follows:

- Minimize risk during implementation (by specifying as much as necessary)
- Create a competitive bid environment (maximize qualified number of contractors)
- Increase certainty during tunneling (high quality TBM by "over"-specifying the TBM)
- Build-up of experience (in case of a system or multiple implementation)
- Try to get the "best" machine available for the expected conditions

3.2 Consultants

Consultants have the task to advice clients in regard to procurement strategy and design projects technically. Their priorities include:

- Extended involvement in advising clients and managing projects during design and implementation
- Build-up of TBM experience
- Utilizing experiences from previous projects

Table 1: Reference Projects for Owner Procured TBM Projects

Project Name	Client	Location	Type	Specification	Year
Melbourne Rail Loop	Melbourne URL Authority	Australia	Rail	6.85 m, 4x2.8 km	1972
Stillwater Mine	Stillwater Mining Company	USA	Mine	4.1 m, ?	1987
London Water Ring Main	Thames Water Authority	UK	Water	2.95m EPBM, 33 km	1991
St. Clair River Tunnel	Canadian National Rail	Canada / USA	Rail	9.5m EPBM, 1.8 km	1992
Lower Kalamazoo Mine	Magma Copper Company	USA	Mine	4.6 m, 9.7 km	1993
Nuclear Waste Repository	US Dptm. of Energy	USA	Nuclear Waste	7.6 m, 7.3 km	1994
Rio Subterraneo	Aguas Argentina	Argentina	Water	4 m EPBM, 15.2 km	1995
Shepard Subway	Toronto Transit Comission	Canada	Subway	5.9 m EPBM, 2x3.9 km	1996
Stillwater Mine	Stillwater Mining Company	USA	Mine	2 x 4.6 m, 2 x 5.6 km	1996
Changi Metro	Land Transport Authority	Singapore	Subway	6.1 mEPBM, 3.5 km	2000
Singapore Downtown Line	Land Transport Authority	Singapore	Tender for 10 TBMs		2008
Spedina Subway	Toronto Transit Comission	Canada	Subway	4 EPBMs, 2 x 8.6 km	2009
Shanghai River Tunnel	Shanghai Highway Authority	China	Highway	Mixshield	2010
Downtown Line, Stage 3	Shanghai Metro	China	Subway	EPBM	2011
Southeast Collector Trunk Sewer	York Region	Canada	Sewer	3.5 m, 2x2.5 km, 2x5 km	2011
Metro Fortaleza	Metrofor	Brazil	Metro		2012
Eglinton Scarborough Subway	Toronto Transit Comission	Canada	Subway	5.75 m, 2 x 6.2 km	2012

- Potential acceleration of the project implementation once financing is secured and the construction contract can be awarded
- Stay within schedule and budget

3.3 Contractors

Contractors are typically the entities that get involved after all strategic decisions have been taken. They are "confronted" with project and procurement documents developed by clients and their consultants. Contractors' priorities include:

- Provide a competitive and best offer (by minimizing knowledge transfer and maintaining a competitive edge)

- Utilize and build-up on experience gained from previous projects and thereby maintain the competitive advantage

- Utilize inventory as appropriate (TBM, trailing gear, conveyor belt system, rolling stock, supply lines, rails, etc.)

- Want to know (specify) or be involved in the TBM selection (open vs. double shield, EPB vs. slurry)

- Be "in charge" of TBM configuration and operations

- Receive contract based on qualification and experience

3.4 TBM Manufacturers

TBM manufacturers are to provide appropriate tunnel boring machines for anticipated projects. They are active worldwide. Due to the specialized technology there is only a very limited number of TBM manufacturers available. Sometimes they are involved in early discussions with clients and/or consultants, where they try to sell their technology. Often the influence of this early involvement is reflected in tender documents by including specific features which are unique to one of the manufacturers (e.g. movable cutterhead, specific grouting concept).

Fig. 1: Owner procured EPBM

They are on the forefront of developing new tunneling technologies with their in-house resources as well as in cooperation with contractors by specifying particular features. Depending on the geographic location of the project the following factors need to be considered:

1. Cost of labor
2. Availability of experienced labor
3. Time for delivery of spare parts

The level of mechanization depends on above factors, the higher the cost of labor the more effort has to be put into the TBM design and configuration to limit the number of labor on the TBM (e.g. optimized logistics concept, automatic anchor drill unit).

Another feature that has an impact on the TBM and trailing gear layout is the mode of muck removal, e.g. rail bound transport or conveyor belt.

4 CLIENT PROCURED TBMS – PROS AND CONS

When considering the specific circumstances of each project, there might be situations where it can be beneficial for clients to apply the advance procurement process. Before analyzing such circumstances a general view is provided outlining specific pros and cons for each of the major stakeholders in the process.

A summary of pros and cons is provided in Table 2 below.

4.1 Clients

Decision making processes specifically within public entities (e.g. transportation authorities) usually follow a long path. From the project idea to implementation it often takes decades until all pieces of the puzzle are in place to finally start construction. A main reason for delays and uncertainty is the funding of these very capital intensive projects. Once the funding is secured the projects ideally should start immediately and be finished in the shortest time possible to make the infrastructure available to the public. This reason, the earlier start when the TBM is already readily available, is found to be the major argument for the client procurement process. It does, however, only hold true when the advance works have been completed to an extent that tunneling can start within a short period of time. Often projects require the construction of access points, e.g. shafts, portals, assembly caverns, etc. before the TBM can finally be assembled. With a lead time of 10 to 12 months until the TBM would be on site when using the "traditional" contractor procurement this benefit of early TBM start can be diminished when the advance works are not completed in time.

It also has been seen that the advanced TBM procurement option has been used as political measure. Once one or even more TBMs have been ordered (and paid for) the motivation to continue a project is higher than otherwise. Experience, however, shows that politics are sometimes not impressed with such facts, especially after elections, which result in new Governments, and still question, stall or cancel the process. The Shepard and Eglinton Line advance TBM procurement in the early 1990s is such a case where it was decided to cancel or substantially defer the project

after the decision of early TBM procurement has taken place.

Another major advantage has been seen by some public transport agencies (e.g. Singapore Metro) where it is expected that 10 TBMs of similar configuration will be utilized to implement the Downtown Line. Combined with the above statement of an accelerated implementation the argument of bulk procurement has been used. When various contractors would purchase 10 TBMs separately the price for the Authority would most likely be higher.

In order to get involved in such detailed negotiations with TBM manufacturers client organizations need to be prepared to mobilize accordingly and have sufficient experienced staff available. This staff would of course be supported by consultants that provide the specific advice, but clients usually do not like to be dependent on external experience only.

For single tunnel project clients this approach has therefore to be questioned. It only is worth the effort when a series of tunnel projects are planned to be implemented within a certain period of time. Pressure to cut cost on public entities counters this approach though.

Once the client staff has gained the experience it can define the TBM and all its features that it finds most appropriate for the project. Clients have to be aware that when following this trail risks are taken over which are usually allocated to contractors. Clients have to be aware that it is “their” machine and that all costs associated with any type of changed conditions, poor performance and resulting standstills and delays have to be compensated for. This statement extends also into wear and tear costs, when kept within the client risk portfolio. Various forms of risk sharing and ownership transfer have been seen already, including transfer of risk back to the contractors e.g. contractor involvement in TBM selection process, TBM ownership transfer to contractor once construction contract has been awarded, or transfer of performance risk to the contractor. The risk budget allocated in the contract price by the contractor will depend on the fairness of the contract and on the allocation of risk. As example it shall be mentioned that contractors will price the risk when confronted with TBM ownership or performance risk where no or limited input was provided.

Another reason to use the advance procurement of the TBM is the risk management by clients in difficult ground conditions. There have been projects that failed due to the selection of the wrong type of TBM or the wrongly equipped TBM. This problem can be overcome by specifying exactly what the contractor has to use, or to pre-purchase the TBM. Clients have to be aware that while actively managing this risk by “interfering” into the process they are taking on the risk themselves. The question remains who has more experience and who is in the better situation to handle this risk.

One interesting argument for the owner TBM procurement is the statement, that clients can expect more competition for their projects when the costs for the TBM (and segments) have been taken out of the scope, thereby reducing the contract amount. It is expected that more contractors would qualify or even apply for qualification, when already provided with a TBM and segments. This might partially be true when considering limited bonding capacity of contractors, but has to be questioned generally. A client should look for financially sound and experienced contractors rather than trying to maximize the pool of interested parties and thereby running into the risk of default situations during construction. Defaults can come from financial difficulties, when projects run into technical/contractual problems but also from technical problems when less experienced contractors are given a TBM to excavate a tunnel that experiences technical challenges. It sounds more like a compromise where a potentially lower price is traded off for less experience and financial strength. In order to compensate for such problems TBMs are likely to be over-specified (and therefore more expensive than need be) to cater for all eventualities.

Private clients (e.g. mining companies) have a different interest in the TBM procurement process. They usually want to stay in charge of the technical development of the machines and therefore often get involved intensively in research and developments of new machines or features. They are looking for contractors to install “their” machines and operate them.

4.2 Consultants

Consultants can be seen as the group that gains most out of this process without taking on substantial risk. Extensive involvement to advise clients in early phases, build-up of experience to be able to provide the highly specialized services, preparation of all specifications and documents for both procurement processes (TBM and construction), detailed design services for the segments (which would otherwise be carried out by the contractor), and increased involvement during construction to verify / justify their early decisions and configurations can be seen as their benefits.

A very high level of expertise and experience is required to be able to provide these services. Naturally, only few consultants will be able to cover all the tasks, resulting in a situation where competition for the consulting services is very limited or these services have to be outsourced.

4.3 Contractors

Contractors are faced with a typically unusual situation when being involved in a project where the TBM and segments are provided and their input in the decisions has not been given or is very limited. It can be seen that contractors are reduced to “operators for pre-purchased TBMs” and projects and specifically clients cannot gain from their experience.

In addition to the arguments mentioned already above, difficulties can arise out of the interface and relationship between client/TBM manufacturer/contractor, where often no direct contact between contractor and TBM manufacturer is allowed. Contractually this situation is “understandable”, but in the sense of partnering, team work and cooperation it is very detrimental to the cooperation of the parties. Assembly and start-up of the owner procured TBM by the contractor involves risks as well, specifically when not guided by the manufacturer. It is a difference whether assembling and starting up once own TBM or the client owned TBM.

Table 2: Pros and Cons of Advanced TBM Procurement

Party	*Advantages*	*Disadvantages*
Client	- build up of know-how (system projects) - specification according to client "wants" - potential earlier start of tunnelling - higher certainty on delivery schedule of TBM - control over TBM costs - "risk transfer to contractor" - economy of scale for multiple TBM procurement - reduced TBM contingencies in contract price - longer TBM procurement period - attraction of smaller less qualified contractors - centralization of spare parts	- early capital investment - risk on selection of "right" TBM - wear and tear risk (as specified) - build-up of detailed know how (not core competence) - client left with TBM or small buy-back value - TBM overspecified - interfface client / supplier / contractor - standstill and delay risk - dependence on consultants - client left with TBM but no project - responsible for "all" TBM related problems - maintenance and production trade-off by contractor - marketing efforts of TBM suppliers (unique features)
Consultant	- substantial additional efforts (specification, proccess) - increased site managements / control function - build-up of expertise / special advisor package	- build-up of expertise
Contractor	- no advance financing of investment - reduced efforts for advanced works - claim potential when problems with TBM - typically no TBM ownership after completion	- no utilization of inventory plant and equipment - loss of competitive edge (based on experience) - loss of or reduced influence on configuration - reduced revenues (smaller project size) - no direct contact with TBM manufacturer - no/reduced input of experience - risks for TBM without or limited involvement - refurbishment risk - no/limiited input on work flow on TBM - contractor's role reduced to TBM driver
TBM Manuacturer	- negotiation with client organization - early involvement with client - bulk procurement - higher security on payments - higher level of requirements	- contract with client / used by contractor - performance bond requirements

Tunneling contractors have a vast experience with all different types of tunneling methods and have built-up in-house knowledge (technical departments), whose task it is to look at every project and optimize the TBM, trailing gear, segment production and site installation. Their job in the advance procurement situation is reduced to supervise the assembly of the pre-purchased TBM. Any modification to the TBM and trailing gear is usually challenging due to the ownership of the TBM by the client, and due to the inherent risk transfer. Even a change from rail bound mucking to conveyor belt mucking is usually not possible, or requires a substantial effort.

Contractors like to be in charge of the tunnel production including logistics and operation of the various activities on the TBM. Optimizations resulting from experience gained elsewhere cannot be utilized. This includes potential mechanizations of activities (e.g. rock bolt drilling, grouting, etc.) to reduce manpower on the machine.

To also mention positive aspects in the vie of the contractor, the reduced advance financing requirements, no obligation to re-use or sell the TBM after use or the more “leaned-back” attitude can be mentioned. Eventually, the TBM has to work as specified and the contractor is such situation would still put all the effort in to make it work.

4.4 TBM Manufacturer

TBM manufacturer get involved very early in the selection and specification process when the TBM is procured in advance. On one side their substantial input is required to specify the appropriate machine and features, on the other hand they want to make sure that their machine is the one to be used for the project.

Negotiating with client organizations might be different than negotiating with experienced contractors. While

clients want to make sure that the TBM will work under any circumstance and will therefore be receptive to additional features, contactors will optimize the use of “bells and whistles” to stay competitive. Clients will intuitively specify and order a higher quality TBM with conservatively rated power, torque and thrust and include duplicate elements to minimize or even eliminate downtime.

One of the disadvantages mentioned by manufacturers was that performance bonds are usually required from clients, what manufacturers are not used to provide. This puts an additional financial burden on these organizations.

TBM manufacturer usually have performance criteria to fulfill as part of their contractual obligations towards the client. These performance criteria (e.g. minimum penetration rate) are usually not part of the requirement towards the contractor.

5 REASONS AND CRITERIA FOR CLIENT PROCURED TBM PROJECTS

Based on the findings above criteria shall be developed to outline situations where it is beneficial to use the client procured TBM process. Due to the many and substantial disadvantages as shown it can be clearly stated that this procurement process cannot and shall not be used on any standard tunnel project.

Reasons for a potential successful implementation of this process can be:

1. Accelerate construction schedule
2. Bulk procurement of multiple similar TBMs
3. TBM configuration according to client specification
4. Risk management /risk sharing

There are criteria associated with these reasons which have to be considered. One main criterion is that client organizations have to be prepared to seriously build-up in-house expertise and not only rely on consultants opinions. There has to be a clear understanding of technology, specification, processes and alternatives available in order to guide the team to the desired outcome. Also, clients have to be aware and prepared for taking the risks involved. Transferring the risks back to the contractor is detrimental to the process. Another general criterion is that the geological/geotechnical and hydrological conditions have to be well known in advance. Only once these conditions are clear to the extent possible the TBM selection can follow.

Following criteria apply:

1. Acceleration of schedule:
    a. Advance works have to be complete before tunnel contract starts
    b. Entire package (TBM, trailing gear, segments) have to be best suited for the project
    c. TBM has to be workshop tested (dry-run)

2. Bulk Procurement:
    a. Multiple very similar projects to be awarded in the very near future
    b. Experience to negotiate with manufacturers
    c. Geological/geotechnical/hydrological conditions known along entire alignment

3. TBM according to client specifications:
    a. High level of knowledge in client organization
    b. High level of involvement in an area which is not a core competence of the client
    c. All-embracing processing of knowledge and advise to come up with the best configuration

4. Risk management / risk sharing: awareness of risks associated with
    a. TBM configuration
    b. TBM performance
    c. Wear and tear allocation

6 CONCLUSION

When seen from a distance it appears that the client TBM procurement method will benefit the clients to a great extent due to early selection and a more timely process involved. The client gets what he wants.

There are many risks involved in the process, once the client starts with the procurement. Considerable risk is taken on, which is usually a contractor risk. Clients have to be aware that they take on the full responsibility on the capabilities of the TBM and on any additional costs due to changed ground conditions, when the TBM is not able to handle them.

Rather than taking away responsibilities from contractors by pre-purchasing the TBM including segments clients shall put more effort in pre-qualifying financially and technically capable contractors internationally, especially on demanding projects.

Only very few circumstances remain when the client procurement process eventually provides a benefit to the project, namely the schedule gain (once all pre-conditions are met), and the bulk procurement, when constructing a network of infrastructure or utility.

Geographically the client TBM procurement method seems to appear mainly in North America and parts of Asia. One could argue that there are specific circumstances that would motivate clients to separate the TBM procurement from the contractors. These circumstances could include lack of “trust” or anticipated experience of local contractors, and

convincing of clients by consultants. It is interesting to note that to date there are no cases of this procurement found in Europe.

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