

TBM First Option Assessment

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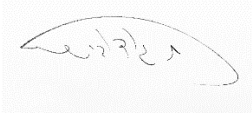
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1. INTRODUCTION

The objective of the report is to present the EMC evaluation of the proposal to alter the construction methodology of Red Line underground sections (Ben Gurion to Carlibach) from "Box first" to "TBM first", for the purpose of risk management and mitigating delays of the project as result of the stations' box completion current progress status estimated in several months of delay compare to the official schedule. The report discusses the information requested and received, the documents reviewed, assess the construction method, the EMC findings and positions and further recommendations and conditions to be satisfied in order to accept and monitor such changes in the construction method.

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2. REVIEW PROCESS

The EMC team was made aware of the proposal to launch the 4 TBMs from Gallei Gill (2 to the West and 2 to the East) and to proceed with the construction of the TBM tunnels prior to the excavation of the stations located between the launch and dismantling stations. This option is referred to as 'TBM first'.

It is noted that the information that was made available to the EMC, at the time this option was announced, was reviewed and evaluated from practicality and feasibility point of views. EMC felt that the details provided to justify the necessity to proceed with the tunnelling prior to station excavation was insufficient and that there was little evidence of the benefits this method could bring to the project cost and duration.

Furthermore, the proposal for TBM First was linked to the stations' dry excavation method. The EMC believe there is no direct justification for the proposed change, taking into consideration that wet excavation method was promoted in the past as the optimal and most efficient construction method under the present hydrogeological conditions. Clearly, it was self-explanatory that the wet method could not be implemented if the tunnels is constructed within stations as proposed by TBM first, as that would mean flooding of the tunnels.

Based on the information that was made available, the EMC developed an independent estimate of the duration of the various construction activities to approach and assess the current situation and to review this construction change proposal. The assessment comprised of the appreciation of the local constraints apparent to the stations along the alignment (i.e. utilities relocation), the stations' D-Wall construction progress achieved to-date and made comparison with other projects from EGIS experience in tunnelling and metro as well as local projects of construction. Using this approach, EMC considered the expected construction progress in accordance with the following:

- Utilization of conventional and commonly used equipment productivity rates (such as slurry equipment, excavators, earth movers, cranes, TBM, reinforcement and concreting works etc).
- Traffic and main utility diversions.
- Geographical and space limitations to undertake concurrent activities within the restricted available land at each station, the track movements, the ability of the cranes to facilitate lifting service, possibility to utilize excavation ramps, additional lifting equipment, etc.
- Obstructions to station excavation equipment imposed by the struts utilized as part of the the temporary retaining system as well as the pre-constructed tunnels.
- Tunnelling advance rates and station excavation productivity achieved at similar ground conditions based on experience of more or less comparable projects.
- Water pumping and discharge capabilities.

Furthermore, a comparison was made with regards to the latest TILOS program V10.6 with the official approved schedule 10.5 and the mitigation measures regarding acceleration and construction strategy amendments as they were reported at the time of review of schedule 10.5 .

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In response to the TBM first proposal, the EMC reviewed and commented on the risk matrix of the program, the cost and schedule. For that purpose more information and details were requested on the TBM First proposal actions taken, or to be taken, prior to this option's implementation in order to address the necessary mitigation measures aiming to reduce the likelihood and effect of the potential risks.

EMC produced a Risk assessment highlighting the potential risk to cost and program and hazards to life. In response the PMC provided further information and explanations in support of the TBM First Option and in response to the risks identified. The risk mitigation and PMC views were reviewed and more comments and recommendation were provided by EMC.

The list of documentation and other information reviewed is presented as an Annex at the last section of the present report.

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3. EMC POSITION

Following receipt of the TBM First proposal and the initial information provided, the EMC had and still maintain a high level of concern regarding the TBM tunnelling works posing additional restrictions for the timely construction of the project and in particular the completion of stations and the cross passages between tunnels.

EMC believe that TBM first is based on:

- [REDACTED]
- [REDACTED]
- [REDACTED]
- No effect on the Joint Venture local party works
- Not considering the situation at the East part of the Red Line, for which no mitigation measures are proposed.

As a result, EMC was not convinced in the benefits of TBM First method.

EMC main findings:

- Station boxes late completion dates did not seem to be affected in the revised TBM West TILOS compared to the official schedule 10.5 mostly due to additional tasks, such as: (i) awaiting for TBM break-in at final station and tunnelling related equipment removal, prohibiting station excavation reaching the tunnel level; (b) pumping shaft boring and water table lowered sufficiently, (c) tunnel dismantling from within the station, etc.
- Although it is acknowledged that tunnelling works will reduce the excavation volume within the station, there is substantial more work and time required for the sacrificial tunnel lining piecewise removal (breaking, loading and lifting) and the constraints imposed by the two tunnels for machinery manoeuvres within the station. EMC believe that as a result TBM first will not reduce, and may even possibly increase the duration of stations excavation works.
- Dry excavation can only partially benefit the works, as significant portion of the station box is above the ground water level. Some of the stations where originally predefined to implement Dry Excavation prior to the TBM First option being considered.
- Dry excavation will impose additional works and cost, compared with Wet excavation method, as defined by the contract rates and BOQ.
- Box excavation and bottom slab concreting durations have been shorten and squeezed in order to cope with current delays without changing the civil milestones.
- Impact to cross passage construction is not reflected in the program.
- Lack of buffers for unexpected future problems and delays, such as utility relocation and third party involvement.

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- D-Wall construction activities had not reached the optimized progress rate expected under TBM first to-date and it puts a question mark on the ability of the contractors to improve these rates after not being able to improve their learning curve until now.
- PMC has focused on the potential benefits and risk reduction of TBM First to tunnelling works and duration. However, the stations, EMC believe to be still on the critical path, are being affected by TBM first method caused by disturbance of the station excavation works during the TBM drive and tunnelling works.
- There is not enough reference to the pumping system installation (including pumping wells) and implementation of groundwater extraction and infiltration into the aquifer bottom (or removal to another drainage system). Water re-charging over long term may not be as effective as anticipated.

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4. WAY FORWARD

The EMC believe that the following points need further consideration and thus have been brought to the attention of the PMC:

- Investigate impact to Cross passage construction.
- Cross passage location fine tuning and investigation of feasibility of grouting from surface.
- Consideration of TBM stoppage outside a station and relevant mitigation measures.
- [REDACTED]
- Ensuring all necessary measures are taken in order to minimize risks from TBM boring through Ayalon River piles to avoid further delays.
- [REDACTED]
- Detailed design and implementation of appropriate ground treatment for TBM cutter head interventions, TBM break-in to stations, Ayalon river crossing, anticipated areas of TBM stoppage.
- Maintaining water level safely below the impact area,
- Expertise requirements for TBM engineers/operator and contractor's commitment to maintain the same crew in case of TBM stoppage to avoid re-starting a tunnelling learning curve.
- TBM cutting head teeth adjustments.
- Fall-back plan in case Ayalon river tunnelling method fails.
- Fall-back plan to allow flexibility to move back to Box first in case of TBM stop.
- New PMC schedule
- Entering to a box while head-wall is not finished yet

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5. REFERENCES

5.1 Information Received (files received in electronic format)

- **Risk assessment – TBM 1st + Pile cutting – pmc response ST-AC.xlsx (14.2.17)** - Responses to EMC TBM First Risk assessment and responses to
- **TBMFIRST eng update.pdf (24.01.17)** - TBM First Presentation from
- **Baseline narrative time schedule ver 0.pdf**- Contractor's narrative EAST-JV-0151-2016
- **MASTER SCHEDULE - Baseline Narrative 12.1.16.pdf**- Contractor's narrative WEST
- **160822 Signed 10-6 Tilos.pdf (9.8.16)** - Red Line Master Schedule 10.6
- **170126 Time-chainage TBM+box+stn.pdf (29.1.17)** - TBM West TILOS
- PMC Response to EMC Review - Ver 1.0 of Red Line Master Schedule 10.6
- **TBM First Tunnels – rev01.pdf (12.1.17)** - Evaluation of Contractor's proposal for passage of TBMs through station boxes before excavation (TBM First)
- **TBM First Dewatering forecast.pdf (12.1.17)**
- **COR1327-DP01 & DP03toDP07, DP4 Feasibility report - Rev2.pdf** - Dry Excavation Feasibility Studies
- **COR1327-risk assessment-concept-01-GSM-JS - TBM FIRST (1).xlsx**

5.2 Information Requested (not completed or presented verbally)

- Hydrogeological assessment to determine Design Feasibility & change justification
- TBM First Risk Assessment Model
- Mitigation measures addressing risks identified
- Updated and detailed project schedule (TILOS)
- Station works adjustments
- Remaining buffers (including hidden)
- Schedule risks to future works (Utility relocations, SDAG and Fit-Out delays)
- Budget and costs impacts (including for TBM East).

5.3 Other information reviewed (based on project available data and files):

- TBM alignment (contract)
- Project Bill of Quantities
- PMC monthly report (progress rate data)
- Indicative Geotechnical Factual Reports
- Concrete Quantities for each station
- Excavation volume for each station (contractors' narrative)
- D-wall progress status & S-curves (PMC report)
- Station layouts & diagrams