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EINSTEIN TELESCOPE

REVIEW OF IMPLENIA'S COST ESTIMATION FOR EINSTEIN TELESCOPE CONSTRUCTION

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References

Project	Document type	Document	Version
Einstein Telescope	Report	Mission 1	C

1. Introduction

Amberg Engineering has been appointed by Liege University as a technical assistant to review the cost estimation of the Einstein Telescope construction based on Implenia's current defined layout [1].

The following elements have been discussed along the chapters of this report:

- An overview of the project layout
- An identification of the main elements of Implenia's proposal and different assumptions used for their cost estimation
- An identification of the main factors affecting the cost estimation of the project at this preliminary stage
- A general assessment of the risks associated with such project and the possible mitigation measures
- A rough updated cost estimation

2. References

[1] Scope of work for the Civil Engineering Scan for Einstein Telescope, report from Implenia November 2019

[2] Centre d'Études des Tunnels 2016- Prix des tunnels

3. Project description and layout

The proposed layout evaluated in this report corresponds to the one assessed by Implenia in 2019 in their report titled "Scope of work for the Civil Engineering Scan for Einstein Telescope [1].

The subsurface configuration of tunnels forms a triangle with an approximate side length of 10,798 meters, excluding the access options. The schematic reference layout, based on [1] is illustrated in Figure 1.

Access for the assessed scenario is facilitated through either (1) a vertical shaft or (2) an inclined access tunnel, connecting the surface to the main caverns. Implenia's report [1] suggests that the access shafts serve as the primary points of entry during both construction and operation. The surrounding area includes several caverns with varying geometries near the intersection points. Additionally, a lined borehole, located away from the crucial and vibration-sensitive cavern structure, is proposed for water management during operation.

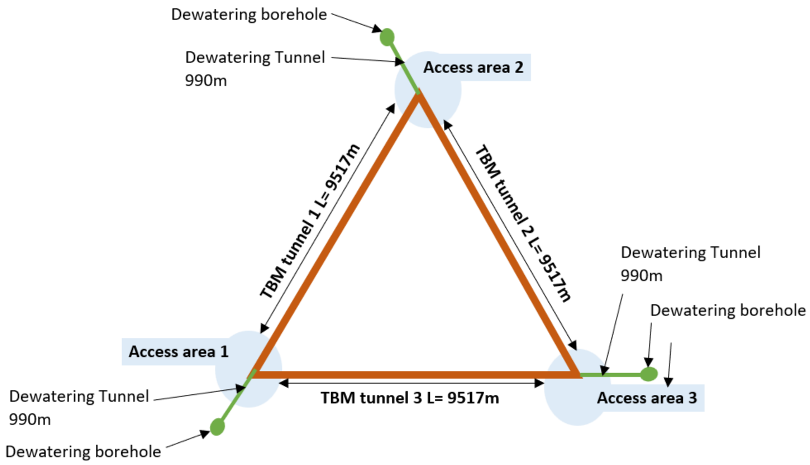

Figure 1.Schematic reference layout based on [1]

Figure 2 depicts the schematic reference layout and a perspective view of the project considering the vertical shafts access scenario, while Figure 3 illustrates the layout for the inclined access tunnel scenario.

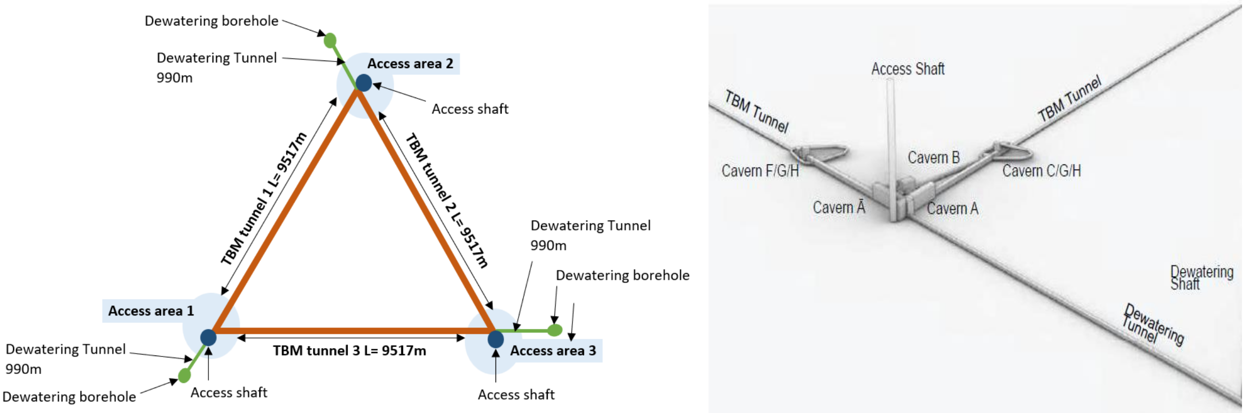

Figure 2. Schematic reference layout and perspective view of the project based on [1]&[2] considering the vertical shafts access scenario.

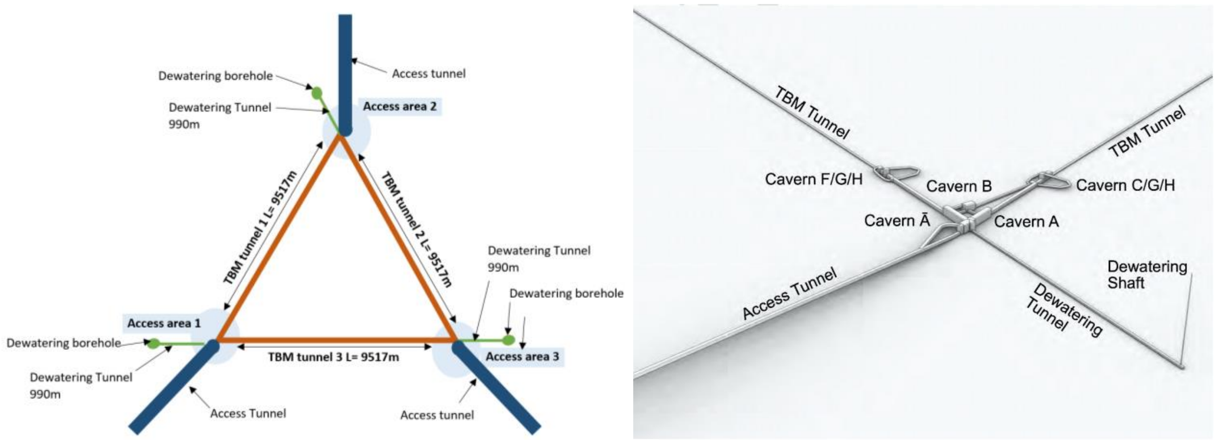

Figure 3. Schematic reference layout and perspective view of the project based on [1] considering the inclined access tunnel scenario.

The current layout designates "Cavern A" as the principal cavern structure for the underground laboratory, formed by the intersection of two caverns with an identical layout at an acute angle of 60°. The lengths of these caverns are 190 meters and 161 meters. The smaller cavern branch, denoted as Cross-Cavern Ā, extends into a "Dewatering Tunnel" (DT) with a proposed length of 990 meters. At the end of the tunnel, a vertical borehole is planned to dewater the Access Area separately. The length of the "Dewatering Tunnel" is contingent on the vibrational impact of the hydraulic pumping system and the tolerable water infiltration [1].

As outlined in [1], two identical Revision Tunnels extend from the branches of "Cavern A," each with a length of 465 meters. Each Revision Tunnel includes a series of three caverns (Cavern C-F/G/H) at the transition to the Tunnel Boring Machine (TBM) tunnel.

"Cavern B" is positioned along the bisecting line of the two branches of the Revision Tunnels. It connects to two branches of "Cavern A" and also has an additional connection to the shorter branch of the Revision Tunnel with Cavern C. "Cavern C" is located 343 meters away from "Cavern A." The three-dimensional arrangement of the corner points of the underground laboratory is illustrated in Figure 4.

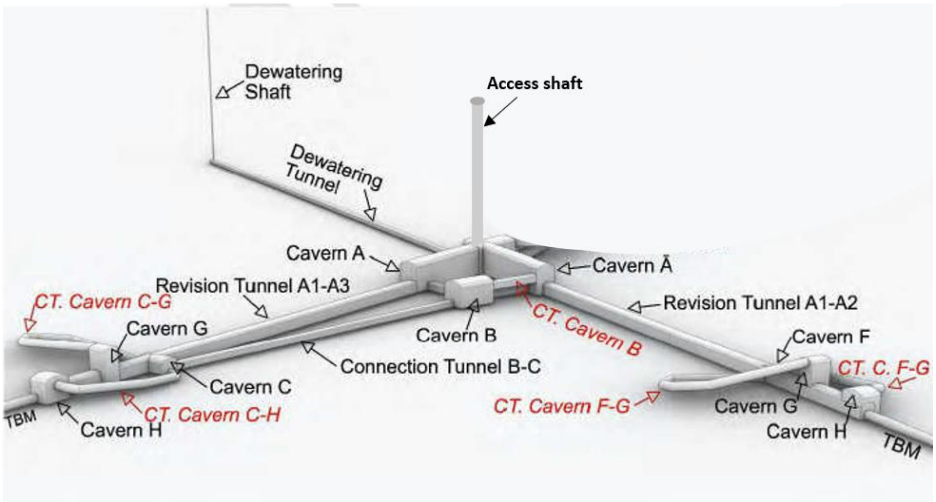

Figure 4. Perspective view of the underground structure at the intersection points with the classification of all caverns.

4. Implenia's proposal and assumptions:

4.1. Geomechanical and hydrogeological assumptions

Implenias' approach was based on a general overview of the geology found in the southern Limburg border region. Reasonably hard sandstone bedding and moderately hard Upper Carboniferous (Namurian) shale, as well as geological formations of the Upper Devonian Famennian Condroz Group, were expected. The geological conditions were therefore considered favourable, with the possibility of encountering some fault zones. These zones will require additional support and grouting measures. However, no specific support/lining class for the tunnel and caverns has been assessed for the cost estimate. The use of secondary lining for TBM tunnels was chosen conservatively, based on Implenia's experience.

Hydrogeological conditions considered mainly of tight rock types, with a typical storage coefficient of around 1% for fractured systems that require sealing of water paths to reduce water infiltration.

Pre- and post-grouting during TBMs excavation involves customized solutions for TBMs, which is already factored into the cost estimation of Implenia.

4.2. Adopted excavation/construction methods:

Each structural element of the project requires a specific excavation method which depends on the geological and hydrogeological conditions encountered. Implenia's report defined different excavation methods for the shaft, caverns, and the tunnels.

For the vertical shaft, conventional shaft sinking method was chosen which consists of a cycle of blasting, skip based mucking of the excavation material and immediate precast concrete lining of the shaft. A prefabricated segmental lining of 30 cm thickness was seen fit because of the need of installation of various guiding rails and transportation pipes and ventilation systems [1].

For the caverns and the revision tunnels, conventional methods were considered, hence, drill and blast. The excavation of the huge caverns would be done in phases dividing the section into different levels. A horseshoe-shaped design for these structures was preliminary defined.

For the tunnels, the mechanized option was favoured as it is more cost-effective for long tunnels such as the 10 km tunnel featured in the project. Two tunnel boring machine options were presented:

1- Shielded TBM with an excavation diameter of 8.4m and a 30cm thick segmental lining.

2- Open TBM with an excavation diameter of 7.3m and a 30cm thick shotcrete lining.

4.3. Defined clearance profiles for the different project structures

Based on the excavation methods, the required space for the instruments for the Einstein Telescope project and the predefined thickness of the linings, a clearance profile was defined for each of the project's structures. Table 1 presents the different dimensions based on which the cost could be estimated.

Table 1. Different structures clearance profiles as defined in [1]

Structure	Construction method	Dimensions			Unit/ Corner
		Approx Length, m	Width,m	Height,m	
Dewatering tunnel	Conventional	990	6	6	1
Tunnel - TBM	Shielded TBM	9517	-	8.4	1
	Open TBM	9517	-	7.3	1
Revision tunnel - linked to cavern A	Conventional	343	12	12	2
Revision tunnel - link between cavern A and cavern B	Conventional	65	6.5	6.5	1
	Conventional	58	6.5	6.5	1
	Conventional	59	6.5	6.5	1
Revision Tunnel between Cavern B and Cavern C	Conventional	316	8	8	1
Revision tunnel between Cavern C/G/H - F/G/H	Conventional	130	7	7	2
Revision tunnel between Cavern C/G - F/G	Conventional	250	7	7	2
Cavern A	Conventional	190	20	30	1
Cavern Ā	Conventional	161	20	30	1
Cross -Cavern- Ā	Conventional	39	17	30	1
Cavern A1	Conventional	11	25	30	1
Cavern C	Conventional	17	17	12	1
Cavern C-G	Conventional	14	20.7	20	1
Cavern C-H	Conventional	21	14	30	1
Cavern B	Conventional	40	25	25	1
Cavern F	Conventional	17	17	12	1
Cavern F-H	Conventional	14	20.7	20	1
Cavern F-G	Conventional	21	14	30	1
Vertical Borehole for dewatering	Conventional	250	-	0.36	1
Access tunnel	Shielded TBM	2650	-	8.4	1
	Open TBM	2650	-	7.3	1

4.4. Proposed logistical concepts and construction rates:

A total of eight different options have been evaluated in terms of cost and construction time. They essentially involve the use of two or three TBMs and an access shaft or tunnel. Options 1 to 4 involve two TBMs, one of which is reused for the excavation of the second tunnel, which means that there will be only two access to the project. A total of three TBMs have been chosen for options 5 to 8, as well as three shafts/tunnels.

Table 2 presents the different proposed construction options showing the main differences.

Table 2. Different logistical options for the project construction as defined in [1]

Options	TBM Type	Diameter of the tunnel	Access option	Number of access tunnel/shaft	Number of tunnels
Option 1	Open TBM	7.3 m	Access tunnel	2	2
Option 2	Open TBM	7.3 m	Access shaft		
Option 3	Shield TBM	8.4 m	Access tunnel		
Option 4	Shield TBM	8.4 m	Access shaft		
Option 5	Open TBM	7.3 m	Access tunnel	3	3
Option 6	Open TBM	7.3 m	Access shaft		
Option 7	Shield TBM	8.4 m	Access tunnel		
Option 8	Shield TBM	8.4 m	Access shaft		

The duration of construction was also calculated according to the daily excavation rate defined based on Implenia's previous experience for each structure. Conservative rates have been adopted (Table 3), which will eventually have to be refined in the light of more detailed geological input. These rates have yielded the duration of each option presented in Table 4.

Table 3. Adopted excavation rates.

	Implenia's excavation rate assumptions (m/day)			
	Option 2-6	Option 1-5	Option 4-8	Option 3-7
	Shaft Conventional + O TBM	Tunnel access + O TBM	Shaft Conventional + S TBM	Tunnel access + S TBM
Vertical shaft	0.8	-	0.8	-
Cavern A	1 to 2	1 to 2	1 to 2	1 to 2
Revision Tunnel 1A	3.4	3.4	3.4	3.4
Cavern C-G-H + revision tunnels	1	1	1	1
Cavern F-G-H + revision tunnels	1	1	1	1
Cavern A'	1 to 2	1 to 2	1 to 2	1 to 2
Revision Tunnel A'	3.4	3.4	3.4	3.4
Tunnel - Learning curve	12.5	12.5	12.5	12.5
Tunnel - Typical rate	12.5	12.5	12.5	12.5
Dewatering tunnel	8	8	8	8
Inclined access tunnel	-	5.1	-	5.1

Table 4. The construction duration with respect to each option.

Options	TBM Type	Duration in working days	Duration in years
Option 1	Open TBM	2953	8.6
Option 2	Open TBM	2605	7.6
Option 3	Shielded TBM	2953	8.6
Option 4	Shielded TBM	2605	7.6
Option 5	Open TBM	2102	6.1
Option 6	Open TBM	1867	5.4
Option 7	Shielded TBM	2102	6.1
Option 8	Shielded TBM	1867	5.4

5. Implenia's cost estimation of the construction

Table 5 shows the detailed cost estimate presented by Implenia by the year of 2019 for the different options. Figure 5 shows the price in function of the construction time with Option 2 and Option 6 the optimal ones in terms of price and duration for the 2 TBM and 3 TBMs scenarios respectively.

Table 5. Implenia's cost estimation.

	Prices in M €							
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Branch 1	195.9	190.4	205.5	199.9	195.9	190.4	205.5	199.9
Branch 2	183.4	177.9	188.1	182.4	195.9	190.4	205.5	199.9
Branch 3	195.9	190.4	205.5	199.9	195.9	190.4	205.5	199.9
Subtotal	575.2	558.7	599.1	582.2	587.7	571.2	616.5	599.7
Site installation (3%)	592.5	575.5	617.1	599.7	605.3	588.3	635.0	617.7
Contingency Measures (10%)	651.7	633.0	678.8	659.6	665.9	647.2	698.5	679.5
Overhead (12%)	729.9	709.0	760.2	738.8	745.8	724.8	782.3	761.0

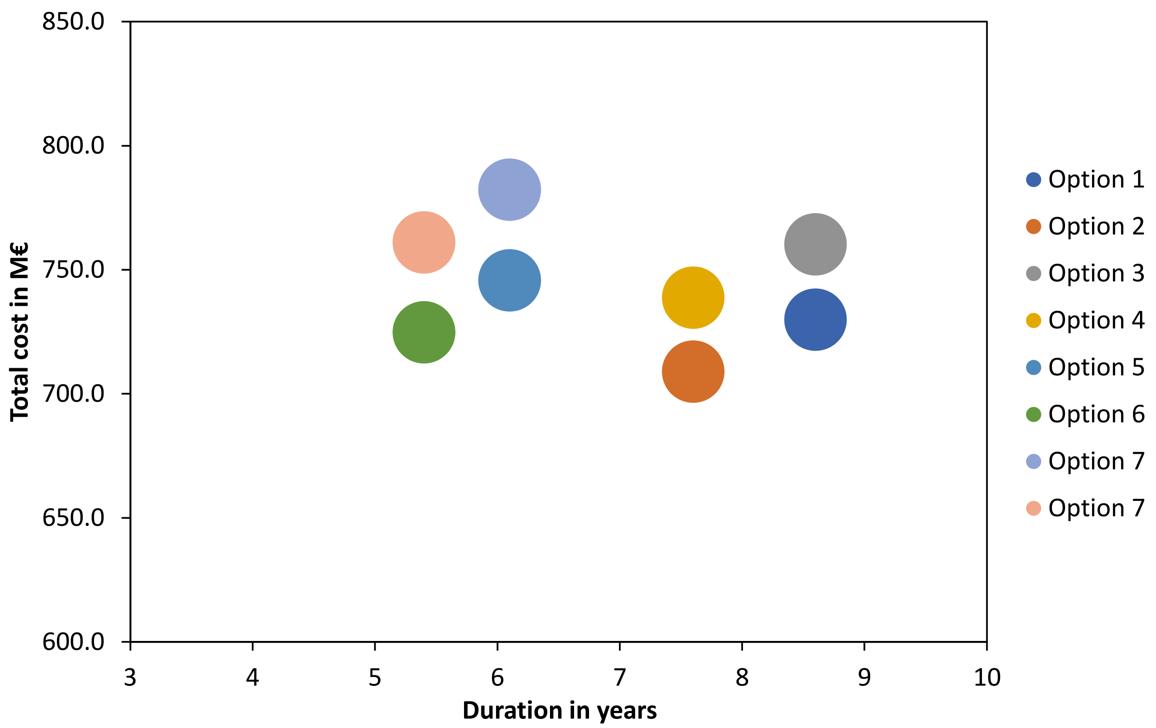

Figure 5. Perspective view of the underground structure at the intersection points with the classification of all caverns.

6. Main factors affecting the cost estimation

Estimating the cost of constructing the Einstein telescope, particularly in the context of strict environmental regulations, is influenced by a series of factors, not only those specific to the project, but also the impact of fluctuations in the global economy over the last five years. The main factors affecting the cost are the following:

1- Geological, geotechnical, and hydrogeological conditions: the project extends over more than 30 km of the subsurface with caverns up to 30 m high, which entails that different geological conditions will be encountered. These conditions will have an impact on the design and excavation methods. A detailed geological study is therefore required to enable the design to be refined, risks to be reduced and appropriate structural support and mitigation solutions to be chosen. The assumption of favourable geotechnical and hydrogeotechnical conditions would imply that a basic support system shall be sufficient to ensure stability. However, water presence during excavation would need of grouting and pretreatments to ensure safety excavation conditions, which would have an impact on overall cost and execution planning.

   Unforeseen challenges during excavation, such as encountering unexpected rock conditions or unrepaired faults, might need of implementation of mitigation measures (increasing construction costs) and might as well lead to project delays. A way to prevent this situation from having bigger impact on the project cost would be to foresee front bore drilling during excavation, reducing the level of uncertainty on the geotechnical context.

2- Tunnel Boring Machine (TBM) selection: The type and size of TBMs chosen for the project will have an impact on costs. Specialized TBMs designed for specific geological conditions or large tunnel diameters may be more expensive. Choosing between Open and Shield TBM would thus has an impact on both the cost and duration of the works.

3- Cavern excavation and shaft Sinking methods: The method chosen for cavern excavation and shaft sinking influences costs. Mechanized methods may have higher upfront costs but can lead to faster progress and reduced overall project duration to excavate the shaft. Semi-mechanized methods, as roadheaders, could be more suitable for the large cavern execution.

4- Structural design and clearance profile of the different structures: The thickness of the lining and the dimensions of the structures change the muck excavated volume and thus the time and cost of the construction. Over-excavation volumes should also be considered.

5- Dewatering solution during operation: Since noise level at caverns will be expected to be restricted because of underground laboratory operational requirements and since no slope is foreseen for the tunnels, specific dewatering solutions will have to be put in place, and therefore taken in account during cost assessment.

6- Support systems for large caverns: Secondary lining and support systems for large caverns require substantial materials delivery and engineering expertise. The need of such secondary lining (whether its architectural or structural) and the construction methods foreseen for such execution scenario will have a notorious impact on costs.

7- Safety measures: Enhanced security protocols that comply with regulations entail additional costs. In addition, specialist safety training for workers involved in the construction of deep tunnels and caverns and special safety measures must be implemented to prevent any risks. Measures such as adding safety niches and modifying the dimensions of the tunnel to include appropriate ventilation solutions would also have an impact on the overall budget.

8- Monitoring and control systems: Installation of monitoring systems to ensure appropriate management of for instance, hydrogeological impact during the construction, and therefore compliance with environmental standards. Continuous monitoring for early detection of potential issues may require ongoing investments.

9- Environmental Compliance: Compliance with the project's strict environmental regulations will likely require of additional mitigation measures, which shall be taken in account in the project costs. The main environmental issues to be resolved are: pollution, vibration and noise levels during construction, impact on hydric general environment and groundwater, and management of the large volume of excavated material. Mitigating environmental impact through specific construction practices or site adaptation measures (including finding suitable disposal zones for muck, using available rail network to transport waste and materials, controlling pollution, vibration and noise levels…) should be considered during the budgeting exercise.

10- Supply Chain Disruptions: The COVID-19 pandemic and geopolitical tensions disrupted the global supply chain, leading to shortages of critical materials and equipment. Delays in the delivery of construction materials and tunneling equipment may increase costs due to extended project timelines and potential price escalations.

11- Inflationary Pressures: Economic disruptions, supply chain issues, and increased demand for certain materials nowadays can contribute to inflationary pressures. Inflation has led to higher costs for construction materials, labor, and energy.

12- Contingency Budget: Allocating a contingency budget to cover unforeseen expenses due to unexpected challenges or changes in project scope.

It should be noted that the aforementioned factors are namely limited to those related to the project construction. Additional factors would impact the total cost were not included such as the legal and regulatory compliance , expropriations or community and stakeholder management.

7. Breakdown of Implenia's assumptions

Implenia's proposed cost is based on the following main assumptions:

1- Favourable ground conditions
2- Conventional methods for shaft sinking
3- A specific depth of 250 m
4- Drill and blast option for cavern and revision tunnel excavation
5- Only primary lining support based on a shotcrete lining for caverns
6- 2 TBM options: Open and Shielded
7- Dewatering during operation through an auxiliary tunnel and pumping borehole for each corner point
8- Horseshoe-shaped design of all cavern and revision tunnels
9- Pregrouting and postgrouting measures to minimize the water inflow
10- Segmental or shotcrete lining of 30 cm for tunnels and shafts

This cost estimate includes the following costs:

1- Cost of excavation of shaft and segmental lining
2- Cost of excavation of the tunnel with 2 types of TBM and 2 access options
3- Cost of water inflow management by pre-grouting and post-grouting
4- Cost of the premises of the construction (site deployment and installation)
5- Typical costs for protective housing structure on top of the shaft, for construction and operation
6- Costs associated with the provision of the safety chambers for the construction
7- Ventilation cost
8- Contingency measures
9- Overhead cost

In general, Implenia's cost estimates exhibit a conservative approach on assumptions, yet their estimation is constrained by inherent incertitude of this stage of the project. The preliminary stage of the project and the absence of comprehensive geological information limit the inclusion and the definition of various factors influencing construction costs, as outlined in Section 6. The presumptions of favourable rock conditions, even with the incorporation of support system costs, lack however a compelling justification. Notably, the omission of secondary lining costs for the cavern is a critical oversight with substantial implications for the total project cost. Further costs related to laboratory equipment and geological surveys have not been considered, presenting an incomplete financial picture.

The impact of excavation rates on costs is not included in the estimate as it is difficult to be predicted at this stage of the project. In addition, the option of using only two TBMs (Option 1 to 4) to excavate the tunnels seems impractical. With only one TBM excavating around 20km in the access shaft scenario and 23km in the access tunnel scenario, which is considerably long, there are concerns about the performance of the machine, potential delays, and the need for frequent repairs, all of which should be factored into the risk assessment.

In terms of alternative options for excavation methods, and given the ongoing innovation regarding the industry technology on excavation, evaluation of mechanized excavation methods for vertical shafts is an important option worth exploring.

8. Risk assessment and mitigations measures

Risks	Impact	Mitigation measures
Geological and geotechnical risks	Subsurface conditions are unpredictable leading to unforeseen challenges during the project construction and excavation. Geological faults, unstable rock formations and unexpected soil conditions may be encountered causing stability risks	A detailed and target oriented geological survey will help minimizing geological and geotechnical risks for a fact based choosing of the best location for the project construction. Implementation of real-time monitoring and front bore drilling during excavation for early detection of changes in geological conditions will help prevent the unexpected geological conditions during construction.
Hydrogeological and water inflow during excavation and operations risks	Presence of faults or fractures in rock formations contributing to water inflow which require grouting works of high cost and high environmental impact. Changes in water inflow or alterations in groundwater quality	Implement real-time groundwater monitoring and employ water management systems during construction to control water levels.
Design and construction risks	Inaccuracies in the design can lead to construction delays or cost overruns. Complex construction methods may introduce technical challenges and uncertainties.	Engaging experienced design and engineering teams and allocating sufficient resources on engineering during project definition stages. Regularly review and update the design based on site conditions (ie; results of geological surveys, hydrogeological modelling results, iterative approach).
Cavern Stability Risks	Concerns regarding the stability of large caverns	Design and implement robust support systems for caverns. Monitor cavern stability during and after excavation. Conduct geotechnical assessments to predict potential issues.
TBM-related Risks	TBM performance issues, breakdowns, or delays.	Use reliable and well-maintained TBMs. Have contingency plans for TBM repairs and replacements. Monitor TBM performance closely. Implement a proactive maintenance schedule.

Safety risks	Worker safety concerns during tunnel construction and during operations. No existing safety protocols for deep tunneling protocols which need to be approved by the three involved countries.	Develop and enforce stringent safety protocols specific for such project approved by the relevant authorities in Belgium, Germany and The Netherlands. Establish emergency response plans for potential incidents.
Limited Supplier Capacity	For a project as big as Einstein Telescope, insufficient production capacity from suppliers (concrete, machines…) to meet the project's demands could occur which will produce massive delays and problems.	Engage in early and open communication with contractors and suppliers to understand their production capacity. Consider strategic partnerships or agreements to secure dedicated production capacity. Consider the reuse of muck material for the production on concrete on-site.
Financial risks	Fluctuations in material costs, labor costs due to the inflation and geopolitical situation.	Implement financial risk management strategies. Contractual consideration of prizing evolution at foreseen rates. Include contingency funds in the budget.
Environmental risks	Changes in water inflow or alterations in groundwater quality Improper disposal of construction waste leading to environmental harm. Release of pollutants and dust into the air or water during excavation and construction. High level of noise and vibration during execution	Adhere to strict environmental regulations. Implement environmental management plans, including measures to minimize noise, vibration, and disruption, reusage of excavated materials on site, find suitable disposal site. Engage with regulatory authorities and stakeholders.
Community and stakeholder risks	Public opposition or community dissatisfaction.	Implement effective communication strategies. Engage with the community early and regularly. Address concerns transparently. Seek public input and feedback.

Utility infrastructure risks	Potential conflicts with existing underground utilities or infrastructure. Potential conflicts with investors as restricted surface areas would be defined to reduce any possible noise that could impact the underground laboratory functionality.	Conduct thorough utility surveys before construction. Coordinate with utility owners and authorities. Implement measures to avoid disruptions to existing services. Define the restricted areas before the construction and get the authorities approval. Study of buffer zones and mitigation measures in order to enhance coactivity of Einstein Telescope and industry activities whether possible.

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9. Updated cost estimation

The cost of construction of Einstein Telescope was reviewed to include:

- the cost of the excavation of caverns considering a basic primary lining and our estimate for the tunnel excavation prices on the basis of [2] and our expertise in previous projects (our database)

- the influence of the inflation from 2019 to 2024.

We sum up in the following figure the main factors affecting cost estimation as per described in chapter §5 , and it's relation with Implenia's assumptions.

Cost estimation: General overview of the factors impacting the preliminary cost

General Factors affecting cost	Implenia assumptions regarding general factors affecting cost	Review considerations
1. Geological, geotechnical, and hydrogeological conditions	1. Favourable conditions	
2. Tunnel Boring Machine (TBM) selection	2. Open and shield TBM	
3. Cavern excavation and shaft Sinking methods	3. Conventional methods, Drill and Blast	
4. Structural design and clearance profile of the different structures	4. Based on the proposed layout	
5. Dewatering solution during operation	5. Dewatering tunnel + water inflow measures by pregrouting	
6. Support systems for large caverns	6. Primary lining as shotcrete	
7. Safety measures	7. Included + ventilation	
8. Environmental Compliance	8. To be evaluated	
9. Supply Chain Disruptions due to COVID	9. Not included	Inflation rate from 2019 to 2024
10. Inflationary Pressures (Since 2019)	10. Not included	Inflation rate from 2019 to 2024
11. Contingency Budget	11. Included	

Figure 6. General overview of factors impacting cost

The 2024 estimation is based on Belgium inflation evolution rates in the past 5 years. Table 6 and Table 7 show cost review by the years of 2019 and 2024 respectively. Figure 6 shows the cost of each option with respect to its duration for both years.

Our estimate by the year of 2019 differs from the one predicted by Implenia (presented in chapter §5; Figure 5). This difference is due to the different estimates (database) for the cost of excavating large caverns and the type of support adopted.

Table 6. Cost estimation review for the year 2019.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Access type	Tunnel	Shaft	Tunnel	Shaft	Tunnel	Shaft	Tunnel	Shaft
Number of vertical shaft	0	2	0	2	0	3	0	3
Duration in wd	2953	2605	2953	2605	2102	1867	2102	1867
Duration in years	8.6	7.6	8.6	7.6	6.1	5.4	6.1	5.4
Cost in M€	959	915	994	945	996	932	1034	962
TBM Type	Open	Open	Shield	Shield	Open	Open	Shield	Shield
TBM number	2	2	2	2	3	3	3	3
TBM cost in M€	40	40	40	40	60	60	60	60
Total cost in M€	999	955	1034	985	1056	992	1094	1022
+ Site installation (3%)	1028	984	1065	1015	1087	1022	1127	1053
+ Contingency Measures (10%)	1131	1083	1171	1116	1196	1124	1239	1158
+ Overhead (12%)	***1267***	***1212***	***1312***	***1250***	***1340***	***1259***	***1388***	***1297***

Table 7. Cost estimation review for the year 2024 taking inflation into account.

	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Access type	Tunnel	Shaft	Tunnel	Shaft	Tunnel	Shaft	Tunnel	Shaft
Number of vertical shaft	0	2	0	2	0	3	0	3
Duration in wd	2953	2605	2953	2605	2102	1867	2102	1867
Duration in years	8.6	7.6	8.6	7.6	6.1	5.4	6.1	5.4
Cost in M€	1271	1208	1318	1247	1308	1225	1358	1264
TBM Type	Open	Open	Shield	Shield	Open	Open	Shield	Shield
TBM number	2	2	2	2	3	3	3	3
TBM cost in M€	40	40	40	40	60	60	60	60
Total cost in M€	1311	1248	1358	1287	1368	1285	1418	1324
+ Site installation (3%)	1350	1285	1399	1326	1409	1323	1460	1363
+ Contingency Measures (10%)	1485	1414	1539	1458	1550	1456	1606	1500
+ Overhead (12%)	***1663***	***1583***	***1723***	***1633***	***1736***	***1630***	***1799***	***1680***

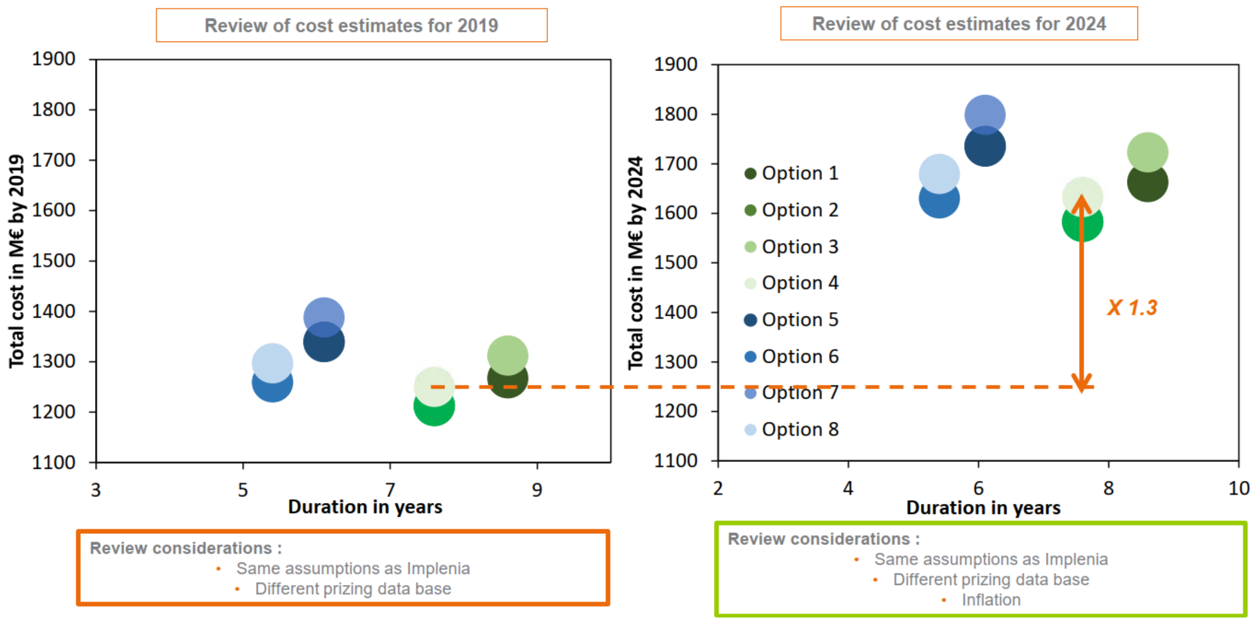

Figure 7. Cost estimation review of the project construction for the years of 2019 (Table 6) and 2024 (Table 7).

It is worth noting that the price of the secondary lining or the price of a robust primary support for the caverns has not been included nor for 2029 review nor for 2024 review. Estimation is based on good rock conditions geological context and therefore only spot bolting and light shotcrete layer has been considered as primary lining for caverns for this estimation. Both facts (secondary lining implementation and a heavier excavation support for the caverns) are anticipated to increase the overall price of the construction considerably (up to 25-35% of total costs).

10. Conclusion

This report examines Implenia's cost estimate for the construction of the Einstein Telescope in 2019.

It first presents the project layout, the main assumptions made by Implenia and their cost estimate (chapter§5). Factors affecting this cost were then identified, together with a list of the risk assessment and possible mitigation measures. Cost was revised considering our expertise in large caverns excavation cost estimation, different types of support systems and TBM excavation costs. A second review on top of this one has been done to take in account the rate of inflation between 2019 and 2014.

It is to be recalled that the conducted review is based on the set of assumptions taken by Implenia as per enounced in chapter §4 of this document.

Attention shall be attired to the fact that this first rough cost estimation shall be considered subdued to a non-negligible incertitude degree and will therefore be expected to evolve as different conditioning aspects of the project will be defined during upcoming project stages.