DEWSBURY POWER STATION CONSTRUCTION PROJECT
A.A. 2020/2021 – PROJECT MANAGEMENT

POLITECNICO
DI TORINO

GROUP 14

2ST DELIVERY – 21/12/2020

AVAN FATAH – S278808

FRANCESCO DE ZORZI – S274899

FRANCESCO DEL FABBRO – S277515

GIULIA IOANNONE – S279009

MATTEO PIOVESAN – S277431

NOUR EL KHATIB – S269559

OTABEK RAZZAKOV – S274097

SIMONE ANZELINI – S277269

VINICIUS LOVATTO ROSTICHELLI – S270006

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Introduction

Objective of this report is to present a Contractor-side Construction Dewsbury Project Plan to Utilities and Operations Inc (UO).

The plan has been developed by a team of Consultants, appointed by UO, the client, and requires the selection of an EPCC contractor who will carry on the project, according to the specifications expressed by the client and the schedule proposed by the consultant.
This document reports the main studies performed by the Consultant, starting with the identification of the EPCC scope of work and breakdown structures (WBS, OBS, ResBS, RBS). In this phase, different options concerning the schedule and the suppliers' appointment have been taken into consideration and the resulting best solution has been identified, mainly considering the optimal price-time trade-off.

This solution has then been deeply analyzed in order to produce a realistic estimation of every variable involved, including direct and indirect costs, risks and contingencies, planned duration and risk-weighted situations. Finally, based on the planned schedule and the cash flows analysis, a final price-duration combination has been proposed.

1. EPCC Scope

The EPCC lump sum turnkey contract concerns the provision of 50 MW rated CCGT – CHP power plant fueled by natural gas at the Dewsbury Power Plant site in West Yorkshire, England. The parties involved in the contract are the Owner of the Dewsbury Power Plant Utilities and Operations Inc., from now on referred to as "the Owner", and the EPCC Contractor, from now on referred to as "the Contractor". The Dewsbury Power Plant construction project will start on the 01/01/2021 and has to be completed within three years from the starting date.

The following scope of work of the Contractor has been redacted by the team of Consultants , taking as a reference the scope of work described in the QUAKER CHEMICAL CORPORATION and FMC TECHNOLOGIES, INC. EPC contract. The contract taken as reference can be consulted at link [1].

1. 1 Scope of supply and Services

The scope of supply of the Contractor involves the provision of engineering, procurement, construction and commissioning services as reported and bounded in paragraph 1.2. Through these services, the Contractor will provide a completely functioning CCGT - CHP plant fueled by natural gas in the Dewsbury Power Plant site. The plant will be delivered to the Owner fully equipped with equipment and systems (defined by the Owner and reported in the below) ready for operation, functional and integrated to local and national power and general infrastructures, such as medium and high voltage grid connection and district heating.

Major subsystems to be supplied by the Contractor for the Dewsbury Power Plant realization are:

- Gas Cycle:
  - Gas treatment and compression station
  - Gas turbine
- Electrical Medium and High Voltage System:
  - Generator and gear box
  - Transformer yard
- Steam and Thermal Cycle:
  - Heat recovery steam generator
  - Stack
  - Steam turbine
  - Steam boiler
  - Steam condenser
  - Two cooling water towers
  - Water spilling pump station
  - CHP Exchanger
  - CHP Reservoir and Pumping skid

1.2 Engineering, Procurement, Construction and Commissioning services

The Contractor proposes to execute the Engineering, Procurement, Construction and Commissioning of the Dewsbury Power Plant Project on a Turnkey basis as described below.

1.2.1 Engineering Services

The Engineering services will involve:

- Preliminary studies and Basic Design;
- Preparation and request to regulatory authorities of permits and authorizations based on Basic design;
- Detailed Engineering documents for civil, structural and architectural works;
- Detailed Engineering documents for gas cycle, steam and thermal cycle, medium and high voltage electrical systems;
- Engineering integration of systems equipment for Gas Cycle, Steam and Thermal cycle and High and Medium Voltage Electrical Systems.

The Contractor will not be responsible for delays caused by a late receiving of permits and authorizations based on basic design, provided that the delay is not due to errors in the basic design or in the procedure of permits request.

After the realization of the Detailed Engineering documentation, the Contractor, or third party on his/her behalf, has the responsibility to submit the set of drawings to the Owner. The Owner, or third party on his/her behalf, once received the set of drawings, will have the full responsibility for their approval. The Owner will also be responsible for:

- Collation and preparation of administrative and procedural documents to be filed for regulatory requirements and any interface with regulatory bodies other than mere technical assistance related to design and engineering documents.
- Liquidation and payments of sums due to third parties as required by regulatory procedures.
- The Owner will be responsible to submit any reasonable modification of the set of drawings, which does not require a change in the Contractor scope of work, in a reasonable time frame to allow the Contractor the integration of the required modification within forty working days from the Contractor submission of the set of drawings to the Owner. The consideration, due to the Contractor for the extra work for the set of drawings modification, will be under the responsibility of the Owner and not included in this contract. Any change of the set of drawings, which will entail a change of the Contractor scope of work, are not included in this contract and they have to be agreed between the Owner and the Contractor.

The Contractor will wait for Owner approval before starting the Procurement services. Any delay in delivering the approval within forty working days after the receiving of the set of drawings will be under the responsibility of the Owner.

1.2.2 Procurement services

Procurement services will include the procurement of supplies and systems (required by the Owner and reported in the section 1) and the procurement of the civil, structural and architectural subcontractor(s) for the Dewsbury Power Plant. The procurement services will be performed by the

Contractor team of specialized engineers, purchasing agents and technicians under the direction of the team of purchasing agents, with the supervision of the Project Manager. The responsibilities of this procurement group include the following, for which the Contractor has the fully responsibility toward the Owner:

- Prepare the bill of materials and the request for proposals for civil structural and architectural services and for the provision of the supplies and systems (reported in the section 1);
- Receive, organize and coordinate distribution of all the proposals from suppliers and subcontractors;
- Select the subcontractor(s), stipulate the contract and hire the subcontractor(s);
- Selected the suppliers, stipulate the contract and receive the confirmation of the order, formalizing the contract with the suppliers;
- Arrange the transportation of the items from the suppliers manufacturing plant to the Owner Dewsbury Power Plant site in West Yorkshire, England.

After receiving the confirmation of the order from the suppliers, the Contractor is responsible toward the Owner for the engineering integration of the gas cycle, steam and thermal cycle and high and medium voltage electrical systems before the suppliers can start the fabrication of the items.

The expediting activity will be needed before the transportation of the supplies and systems can happen. The expediting task will include pre-test of the supplies to the manufacturing plant of the suppliers and will be done by a team of specialized engineers and a team of technicians.

The Contractor will be responsible toward the Owner for any malfunctioning of supplies and delay of the procurement process not caused by Force Majeure.

1.2.3 Construction Services

The Dewsbury Power Plant site in West Yorkshire, England is a green field where the construction services will take place. On site activities will be under the supervision of the Contractor Site Manager which will report to the Contractor Project Manager. The Contractor will be responsible toward the Owner for the tasks executed on the site.

The site installation will be executed by the Contractor's technician team, after receiving the permits and the authorizations based on basic design from regulatory authorities.

On-Site civil, structural and architectural works shall be performed by local subcontractor(s), hired by the Contractor through the purchasing process (section 2.2). The subcontractor duties shall include:

- Excavations and foundations materials procurement;
- Realization of the above ground structures;
- Provision of high pressure rated piping;
- Balance of plant system, fluid piping and electrical networks;
- Control room and office buildings.

The Contractor technicians will execute the following activities, in parallel with the construction of the control room and offices building and after all the other subcontractor(s) activities:

- Erection and installation of the systems procured after their arrival on site;
- Balance of systems and minor items.

The Owner will provide to the Contractor the access to the site for the agreed time of the Plant construction, right after the communication of the Contractor which will grant the receiving of the permits and authorizations based on Basic Design. Any delay in the access of the Contractor or third parties on his / her behalf will be under the responsibility of the Owner. Out of the responsibility of the Contractor and within the responsibility of the Owner will be:

- The provision of the utilities and connection during the whole construction phase;
- Coordination, appointment and control of third parties for the realization of those works necessary for the connection of the plant to local and national networks as required as shown in design and engineering documents. As a general rule, junction facility shall be provided by network operators;
- The realization of car park or other facilities hereby not included;
- The training of the Owner's employees.

1.2.4 Commissioning Services

The Contractor will be responsible for the commissioning, testing and warranty of the Dewsbury Power Plant before delivering the plant to the Owner. Out of the responsibility of the Contractor, and within the responsibility of the Owner, will be the provision of the utilities and connections during the whole commissioning phase.

1.3 Clarifications

The section *1.1 Scope of supply and Services* and the section *1.2 Engineering, Procurement, Construction and Commissioning services*, represent the formulation of the general scope of the Contractor. In the following chapters the team of Consultants will present the evaluation of two options available to the Contractor, for which the scope definition is slightly different:

- **Base Option A,** in which the Contractor will subcontract the system integration of three major packages (Gas, Thermal and Electrical) respectively to three Prime Vendors. The Prime Vendors will take ownership and responsibility for turnkey delivery of their groups of items, being responsible also for the fabrication and transportation of the items to the Owner plant. The Contractor will still be liable toward the Owner for these activities, but the risks related will be transferred to the Prime Vendors. For bearing these risks and sustain the costs of transportation and system integration, the Prime Vendors will charge a 28% markup on the base supplies price to the Contractor.
- **Alternate Option B,** the Contractor will take charge of systems integration through his engineering staff, also he will take care for the transportation of the items from the supplier manufacturing plant to the Owner plant. Differently from the Option A, suppliers will deliver items at the EPCC risk.

2. Suppliers and Prime Vendors

With the purpose of providing to the Owner a realistic Project Plan, in terms of costs and duration estimation for the project, the team of consultants has conducted a research on the market to find the potential suppliers and Prime Vendors on which the contractor will rely for the two options under analysis. To select the potential suppliers and Prime Vendor the following criteria has been taken into consideration:

- Quality of the item manufactured
- Location of the purchaser
- Service provided

For the Option A the potential Prime Vendors are:

- Siemens Energy Global GmbH & Co. KG [2] , base in Germany, which will provide Gas Cycle System.
- Ansaldo Energia S.p.A., based in Italy [3], which will provide the Steam Cycle System.
- Brush Electrical Machines Limited [4], based in the United Kingdom, which will provide the MV & HV Electrical Cycle.

For the Option B the potential suppliers are:

- Siemens Energy Global GmbH & Co. KG [2], which will provide to the Contractor:
    - Gas Turbine
    - Gas treatment and compression station
    - Steam Turbine
- Shanghai Boiler Works Co Ltd. [5] which will provide to the Contractor:
    - Heat recovery steam generator
    - Stack
    - Steam boiler
    - Steam condenser
- Schlee Refrigerating Equipment Manufacturing Co., Ltd [6], which will provide to the Contractor:
    - Two cooling water towers
    - Water spilling pump station
- DFC Pressure Vessel Manufacture Co., Ltd [7], which will provide to the Contractor:
    - CHP Exchanger
    - CHP Reservoir and Pumping skid
- Shanghai SMEC Enterprise Co., Ltd [8], which will provide to the Contractor:
    - Generator and gear box
    - Transformer yard

In the Option B four suppliers out of five have manufacturing facilities in China, while Siemens Energy Global GmbH & Co. KG is based in Germany. Shanghai Boiler Works Co Ltd. and Shanghai SMEC Enterprise Co., Ltd are two affiliates of the Shanghai Electric Group Company Limited is a Chinese multinational power generation and electrical equipment manufacturing company headquartered in Shanghai. Siemens and Shanghai Electric have already collaborated in a Joint-Venture for the provision of supplies in the CHP plant, in JingQiao (Beijing Bridge) [9].

3. EPCC WBS

The scope of work of the Contractor defined in the previous chapter has been decomposed in smaller components using a Work-Breakdown Structure (WBS). The WBS provides a hierarchical decomposition of elements, applying the 100% rule, to the level necessary to plan and manage the work to satisfy the project objectives. Having two different options to analyze, the team of Consultants produced two different graphical WBSs, which can be seen in the Exhibit_1_WBS_A and Exhibit_2_WBS_B. In both the WBSs the consultants chose a function-oriented representation of the work for the first level of the WBS, dividing it into five main components: Engineering, Procurement, Constructions, Commissioning and Management. After the main groups were identified, each of them was divided into smaller sub-sections. The Engineering, Construction, Commission and Management are the same for the two options, while the Procurement section is organized differently according to the needs of the two options.

3.1 WBS Option A

In the Procurement section of the Option A, the work has been divided into Purchasing, Gas Cycle Supply, Steam Cycle Supply and MV & HV Electrical Supply. This division of the work is a mix between the product and function-oriented work decomposition, but it helps to visualize how the work will be carry out. Each Supply section has been divided in the next hierarchical level, in a functional way, into fabrication and transportation. Inside the fabrication, the manufacturing of the supplies related to a specific lot and the system integration of these items have been inserted.

3.2 WBS Option B

In the Procurement section of the Option B, the work is decomposed in a functional way into Purchasing, Fabrication and Transportation. Under Purchasing and Transportation, the work is divided by the name of the potential suppliers, while the fabrication is divided into System Integration and Manufacturing, as it is possible to see from the file Exhibit_2_WBS_B.

4. Sequence of the activities

Once the WBSs has been defined, the elementary activities in the last level of the each WBS have been sequenced using as quantitative model, the Network Technique, as the scheduling tool for the project. For each Option, a dependency matrix has been created by assigning to each activity a predecessor and a successor, leading finally to the graphical AOA-network representation, which is shown in Exhibit_3_AoA_Network_A and Exhibit_4_AoA_Network_B. The next paragraphs will explain in detail the differences occurring between the sequences of two options, A and B.

4.1 Option A Sequence of activities

In this Option the procurement and integration of the items is committed to Prime Vendors. The request for order to the suppliers takes place in parallel with the four blocks of the design phase. For all the different procurement activities, with the exception of the one related to the construction and civil works, the manufacturing of the main items in the supplier's sites takes place right after the system integration made by the Vendor. Depending on the durations, as soon as the manufacturing of all items is finished, the expediting on the manufacturing plant will be done, then the supplies will be sent to the plant by ship or truck. At their arrival, the erection of these items will begin. This can happen only provided that the plant and civil works have been performed. The last activities are in order the balance of systems and minor items and the final commissioning and testing, which will start after all the items have been erected and after the construction of the control room and office building has been completed.

In this Option the critical path is at first the one related to the design of the gas cycle. However, being the steam turbine fabrication a bottleneck in the procurement phase, it then switches to the thermal cycle path. For the last activities, the balance of system and minor items has to wait until the HRSG, and Stack are erected.

4.1 Option B Sequence of activities

The difference with Option A is that for the procurement phase there are five suppliers in different countries that are responsible for the manufacturing of different types of items. After the approval of the engineering drawings, five orders are sent to the five potential suppliers. Like in Option A, as soon as the fabrication finishes, the expediting to the supplier plant will be executed, and then the items will be shipped, lastly their erection will begin on their arrival on site. However, the erection will need to wait until the plant civil works are finished. As before, after the erection and the construction of control room and office building there will be the last two activities that are balance of systems and minor items and the final commissioning and testing.

The critical path until the procurement phase is equal to the one of Option A but then it follows the gas cycle as the fabrication and erection of the gas turbine becomes critical.

5. Estimate resource and activity duration

After sequencing the activities, the consultants redacted the organizational charts of the project from the point of view of the Contractor. This step was useful to the team of Consultants to define who, inside or outside the EPCC organization, is responsible for the work to be performed according to the WBS. Based on this, estimating the duration of the WBS elementary activities and the resources need to accomplish them, the consultants drafted the predictive draft of the Contractor for the Dewsbury Construction Project.

5.1 OBS

The Organizational Breakdown Structure (OBS) has been used as a tool to point out the hierarchical relationships within the organization and highlight relevant interfaces with the project stakeholders. Exhibit_5_OBS_A.pdf shows the EPCC organization's OBS A, whereas the Exhibit Exhibit_6_OBS_B.pdf represents the EPCC organization's OBS B. The two are similar in the sense that both are task force organizational chart models, where the project manager of the Contractor is responsible for the Engineering, Site and Procurement functions. Under the procurement function there is the purchasing agent which reports to the Contractor project manager. The purchasing agent will be the interface of the project manager with the three selected Prime Vendors in the Option A and with the selected suppliers in the Option B. The main difference is that the in the Option A the Prime Vendors will be responsible for the external transportation company, for the manufacturing suppliers and for the system integrators, while in the Option B the external transportation company and the suppliers is under the direct responsibility of the procurement function and the system integration will be performed by the engineering team of the Contractor. For both options, the Site requires a site manager reporting to the Contractor project manager, which will coordinate the technicians and the subcontractor(s) for building and civil works.

5.2 Microsoft Office Project

Microsoft Project has been used as a tool to obtain an interactive and adaptable representation of the project schedule under the two Option A and B, including tasks connections, resources assigned, costs expected and overall duration of the project. Activities have been inserted and scheduled based on the sequence illustrated in Chapter 3 of this report and resources units and work-hours amounts have been assigned, according to the activities list provided in the instructions. The MSP file for the options can be consulted at the Exhibit_7_Baseline_Schedule_A and Exhibit_8_Baseline_Schedule_B.mpp. One may notice that the Basic Design macro-activity has been fragmented into sub-activities for scheduling and planning - improvement purposes: at this extent, each sub-task's workhours have been computed according to the proportions existing among the corresponding Detailed Engineering activities' workloads, as it is possible to see in the Figure 1 below.

Afterwards, durations of the activities have been extracted from the activities list provided in the instructions: for activities having a fixed duration expressed in days, the value has been directly reported, while for "effort-driven" tasks the duration was automatically computed by MSP based on the workhours performed by the assigned resources, considering 8-hours workdays. Tasks performed internally have been assigned with human resources according to the specifications shown in project's exhibits, while subcontracts have been associated with "Building and Civil works" activities. With

MSP the project duration has been estimated to be 791 working days, in the Option A and 763working days in the Option B.

CALCULATION WORK H FOR BASIC DESIGN ACTIVITIES					
TASK NAME	RESOURCE NAME	WORK (hours)	WORK (hours) %	DURATION (working days)	# RESOURCE PER TEAM
BASIC DESIGN					
TOTAL BASIC DESIGN	Specialized engineer	1600	100%	100,00	2
	Project Engineer	800	100%	100,00	1
Basic Design Building& Civil works	Specialized engineer	276	17%	17,28	2
	Project Engineer	87	11%	10,83	1
Basic Design Gas Cycle System	Specialized engineer	503	31%	31,41	2
	Project Engineer	255	32%	31,85	1
Basic Design Steam Cycle System	Specialized engineer	410	26%	25,65	2
	Project Engineer	229	29%	28,66	1
Basic Design MV & HV Electrical System	Specialized engineer	410	26%	25,65	2
	Project Engineer	229	29%	28,66	1
TOTAL BASIC DESING (to verify the %)	Specialized engineer	1600		100	
	Project Engineer	800		100	
DETAILED DESIGN					
TOTAL DETAILED ENGINEERIGN (to verify the %)	Specialized engineer	3820	100%		
	Project Engineer	628	100%		
Detailed Engineering Building& Civil works	Specialized engineer	660	17%	41,25	2
	Project Engineer	68	11%	8,50	1
Detailed Engineering Gas Cycle System	Specialized engineer	1200	31%	75,00	2
	Project Engineer	200	32%	25,00	1
Detailed Engineering Steam Cycle System	Specialized engineer	980	26%	61,25	2
	Project Engineer	180	29%	22,50	1
Detailed Engineering MV & HV Electrical System	Specialized engineer	980	26%	61,25	2
	Project Engineer	180	29%	22,50	1

Figure 1 - Calculation work hours Basic Design

5.3 Resources Workload

Exhibit_9_Reource_workload_A_B shows the distribution of resources' workload over the project duration. As expected, the comparison between the two options analyzed highlights some similarities: in each solution, the highest peaks of workhours are reached by the same resources in the same timeframes. Technicians account for a consistent part of the work performed during the construction phase, while Project and Specialized Engineers are mostly employed in the Engineering phases. Although, this is only partially true for the two B scenario graphs: due to the need of employing internal resources in the system integration of the purchased items, also the amount of work requested to those resources in the Procurement phase is significant.
These peaks characterize only Project Engineers, Specialized Engineer, Purchasing Agents and Technicians workload profiles, due to their activity being tied to the number of hours requested to complete a task and to the level of resources and overtime employed. For what concerns the Project Manager however, the workload profile is constant and equally distributed along project's duration, while the Site Manager on the other hand follows this same pattern but only works during the Construction phase of the project.

6. Estimate Costs

After estimating the activities duration and the resources, the Contractor direct costs of the project have been estimated and reported in the MSP files of the Option A and B, defining the baseline schedule for the two options. The data have been exported and the indirect and contingency costs has been estimated. The data have been reported in the preliminary budget costs of the two options and they have been graphically represented by the S-Curve, as it is possible to see in the Exhibit_10_Estimate_Costs.

6.1 Preliminary budget costs

In the Option A the direct cost of supplies entails the base price of the item plus a mark-up of the Prime Vendors. In the mark-up is considered the system integration costs plus the cost of transportation of the related items, which in Option A is up to the Prime Vendors. In the Option B instead the direct cost of supplies entails just the base price of the items.
The transportation costs of the Option B have been estimated apart, using the 'transportation costs reference table' consultable at the Exhibit_10_Estimate_Costs. Being the transportation costs in Euro, an exchange rate EUR/ GBP of 0,9 it has been applied, according to the one in the market [1].
Being in both the options the duration of the project greater than the three years required by the Owner, contingency cost of the Liquidated Damage on takeover delay has been added to the budget. The Liquidated Damage were calculated by multiplying the base value (£ 83.000,00 per day of delay) by the working days of delay the 3-year project duration.

The budget total costs for Option A has been estimated to be £ 43.851.638 while for Option B £32.391.356. At this stage it has been chosen to postpone the Risk Analysis and the calculation of the whole contingency for the project, mainly because the difference between the two budget costs was high. Even if the Option B is riskier for the Contractor than the Option A, in this preliminary analysis it has been estimated that the difference between the two contingency costs cannot be higher than £10 million, preventive the Option B choice.

6.2 Comparison between Option A and Option B

To graphically compare the two options, it has been constructed a graphical S-Curve, which, depicts the relationship between budget costs and the project duration (time), according to the realized tasks.

For both options A and B, the tasks were ordered from the start date. Their indirect costs, mobilization and overhead, were allocated over the whole project duration. For the purpose of the representation the *mobilization* has been inserted by multiplying each task's direct cost by the 0,5%. The *overhead cost*, in turn, was represented dividing the total overhead cost, calculated in the preliminary budget, equally to each task (£ 54.603,45 for the 58 tasks present in Option A, and £ 44.883,35 for the 68 tasks present in Option B). The liquidated damages on takeover delay costs have been allocated from the end of the 3-year agreed deadline. To graphically report the S-Curve it has been calculated the cumulative costs of the project. The graphs are showed in the Figure 2.

As it can be seen below, Option A's project goes from January 2021 to January 2024, while in Option B the project ends in December 2023

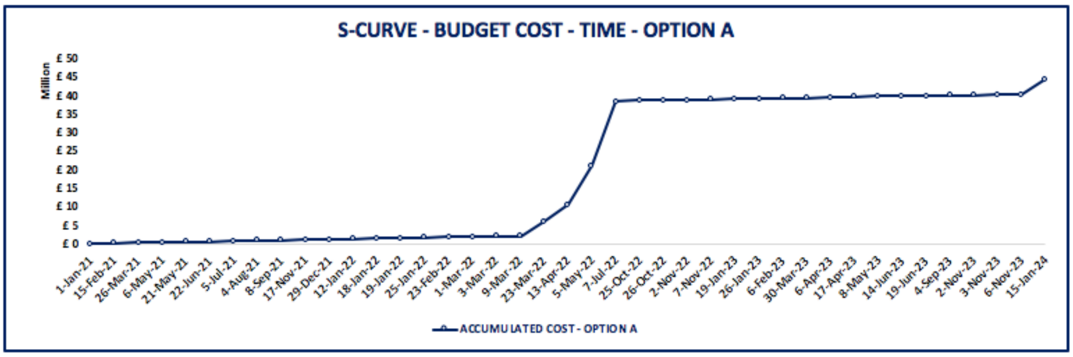

Figure 2 - S-Curve Option A

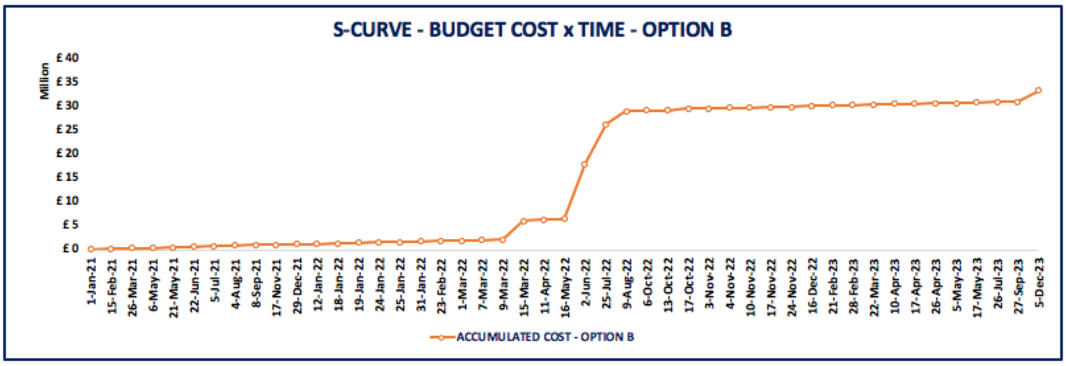

Figure 3 - S-Curve Option B

To identify the differences between both options, the graph below was developed to depict both S-Curves into the same graph. To clarify the comparison idea, instead of using each task beginning date, it was considered the sum of all the tasks executed within a month.

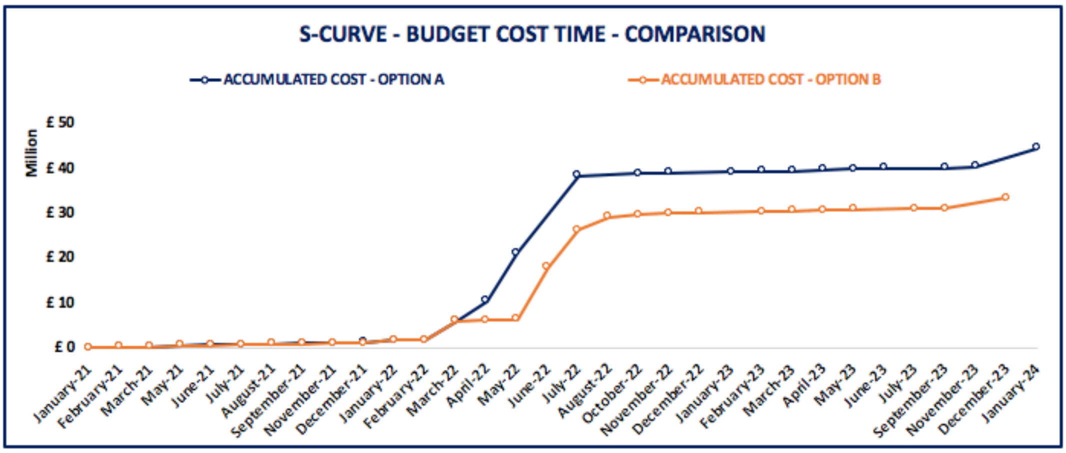

Figure 4 - S-Curve Comparison between Option A and B

The graph shows that for Option B, the costs for executing the tasks start getting higher later than the Option A by three months. This happened because in the Option B the purchasing process takes more time than in the Option A, being the purchasing processes 6 in the Option B and 4 in the Option A. The steeper increase in the Option A is due to the higher cost of supplies due to the markup applied on them by the Prime Vendors. At the same time, even if the tasks' costs start increasing later, under the Option B the project finishes earlier than in the Option A, this is mainly due to the fact that the expediting, and later the transportation, of the supplies in the Option A starts once the manufacturing activities of the items in the lot are have been accomplished, as well as for the Option B. However, in the Option A in both the lots of Gas Cycle and Steam cycle the fabrication of the turbines delays the delivery of the whole lot, which contains items, such as the HRSG and Stack, which require a lot of time for the erection. Instead, in the Option B turbines are provided by the same supplier and while they are being manufactured, the other steam cycle's items can be erected.

Overall, from the comparison of the two options in terms of costs and project duration estimated, the best choice is to make internally the system integration activities, by choosing the Option B.

7. Cost – Time tradeoff Analysis

Once the most advantageous Option (Option B) in term of costs and duration have been selected, the Critical Path Method technique has been applied with the aim of identifying an optimal duration of the project as a result of the optimization of the time-cost tradeoff. The optimal project duration has been found in the scenario **B.4.2**, for which the total project costs are minimized and represent a Pareto Optimum, as it is possible to see from the Figure 5 and Figure 6 below.

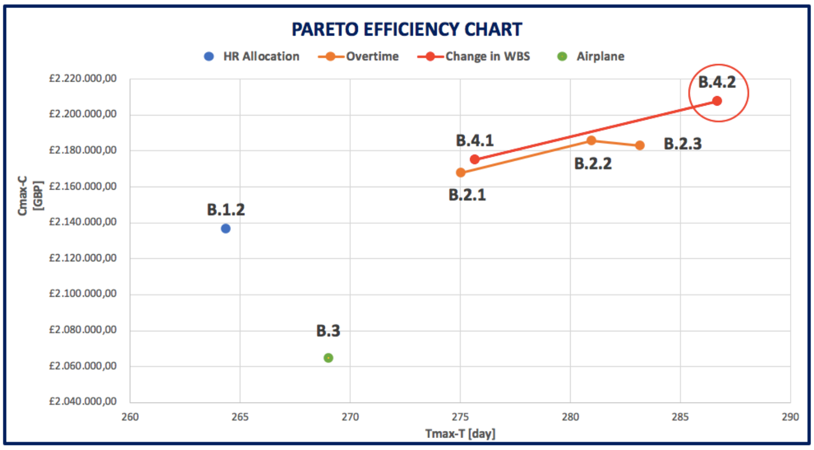

Figure 5 - Pareto Chart

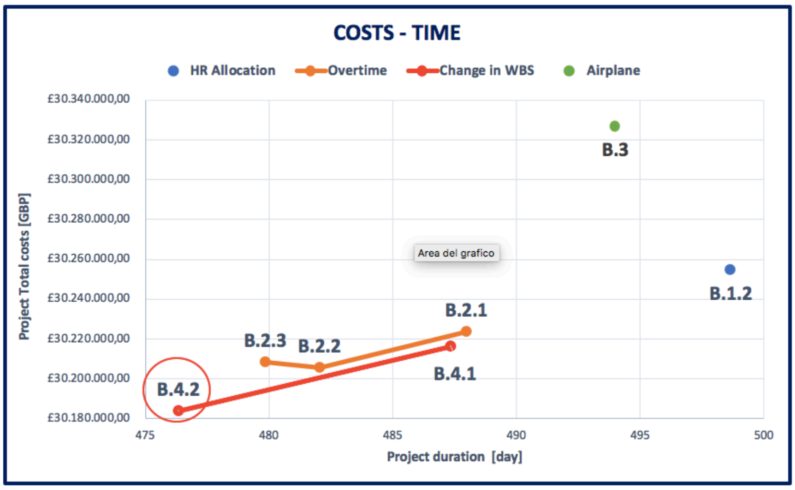

Figure 6 - Cost - Time trade-off

In the following paragraphs the method used to perform the project crashing has been described and the results can be consulted at the Exhibit_11_Crashing.

7.1 Allocation of extra human resources

Firstly, it has been considered the allocation of the Contractor's extra human resources to the project schedule, considering as constraint that technicians' decreasing productivity curve, according to the project specification. Being the cost of the activities calculated on the task's work hours requested, allocating extra resources to the task does not entails an increase in the task costs, and so in the overall project direct costs. Following this, extra resources have been allocated in both critical and not critical activities on the schedule, with the aim of decreasing the overall project duration by maximizing the use of human resources when solving the overallocation problems.

Scenario B.1.1

In the first scenario (**B.1.1**) in MS Project the maximum number of resources has been increased, by using the crashed number of resources according to the specifications. By doing so and levelling the resources the total project duration has been decreased from 763 to 649 working days, the direct costs have remained the same, while the indirect costs have been reduced by around £ 1,5 millions. In the graphs above this Option is not showed only for clearance of representation of the data.

Scenario B.1.2

In the second analyzed scenario (**B.1.2**), it has been increased the number of resources assigned to certain task with respect to the baseline case. Here follows a detailed explanation of the motivations leading to the assignment of resources on crashable tasks. Overall, in the scenario B.1.2 the duration of the project has been reduced from 649 to 499 working days and the direct costs have remained the same, while the indirect costs have been reduced by around £ 0,5 millions respect with the previous scenario B.1.1.

In the baseline configuration the Engineering activities are all on the critical path, except for the activity permit and authorization based on basic design. Basic design activities duration is driven by the project engineer's work, so even if they could be executed in parallel, according to the AOA established network, these activities are performed in sequence in order to solve the overallocation of project engineer. By increasing the total number of available project engineers from one to two, the duration of the basic design halves. According to the AOA network, all the detailed engineering tasks have the same successor, the permission and approval of set of drawings, so the aim is to minimize the duration of the whole block of the activities to shorten the overall project duration. According to this and considering that the bottleneck is represented by the specialized engineers, all the specialized engineers in the crashed configuration have been assigned to the detailed engineering tasks. While executing these activities in parallel, the project engineers result in being overallocated, so to minimize the duration of the detailed engineering tasks and solving the overallocation, it has been chosen to increase the duration of each detailed engineering task while keeping the amount of work fixed. In this way the project engineers have a constant maximized workload over time, and the duration of the detailed engineering activities is overall minimized.

Going on with the procurement phase, the purchasing processes can be executed in parallel according to the AOA network, and in the baseline schedule the only purchasing process activities on the critical path are the one performed by Siemens. To minimize the duration of each purchasing process the number of resources has been allocated to minimize each activity duration, as it is possible to see from the file. Being the six purchasing processes scheduled all in parallel, to solve the overallocation of resources an appropriate slack has been used with respect to the predecessor for the first activity of each purchasing process (B.O.M. and take-offs & Request for proposal).

System integration activities in the AOA network have been scheduled right after the related proposal selection processes. To minimize the duration of these activities it has been firstly allocated the maximum number of the resources available in the crashing scenario. Then it has been faced the overallocation of the resources, specialized and project engineers, between the gas system integration *and the remaining purchasing process activities. It has been found that the overall duration of the project was reduced by postponing the system integration activities after all the proposal selection processes, this because it allows to solve the overallocation of specialized and project engineers, and halves the duration of the system integration activities.*

The remaining activities, such as the expediting activities, all the erections and the final commissioning and testing involve technicians as human resources. To reduce the duration of these activities the decreasing productivity curve per number of technicians allocated to an activity has been considered, as it is possible to see in the Exhibit_11_Crashing, in the sheet 'Technicians Productivity'. *In both commissioning and testing and expediting, six technicians were allocated after re-computing the task duration considering the decreasing productivity. Allocating more technicians was not convenient because of the low resulting productivity. The erection activities instead, have as common successor the balance of plant and minor system. The number of technicians allocated to the erection tasks has been increased with respect to the baseline configuration only for the erection activity on the critical path.*

7.2 Human Resources Overtime

Overtime allows to furtherly decrease the duration of activities but on the other hand requires higher costs due to the higher overtime rate. Moreover, as reported in the book "Project Management for Facility Constructions" [10], workers productivity drops dramatically after 40 hours of work a week. However, for the purpose of this project the decreasing weekly productivity of resources has not been considered.
As a second step in the research of the optimal cost-time combination, overtime hours have been assigned to the resources working on crashable activities of the critical path. Given that the project schedule in the scenario B.1.2 is better than the baseline Option B in terms of both total costs and project duration, the crashing overtime has been applied to this project schedule. The application resulted into the three cases reported below, starting with the activities with lowest marginal costs of crashing. It has not been considered the overtime for the activities involving technicians.

Scenario B.2.1
The first step has been considering the overtime for the Basic Design activities, which are on the critical path. The overtime hours per resource assigned to a task are the 25% of the total work hours of the activity, according to the specification. As a result, the overall project duration has been decreased from 499 to 488 working days, the direct costs have increased by £11.440,00 while the indirect costs decreased by £ 42.623,00.

Scenario B.2.2
The second step considered the overtime for the activities B.O.M. and take-offs & Request for proposal and Proposal selection and order of all the purchasing processes, on the critical path. The overtime hours per resource assigned to a task as been calculate as 25% of the total duration of the activity, according to the specification. As a result, the overall project duration has been decreased from 488 to 482 working days, the direct costs have increased by £ 5.445,00 while the indirect costs have been reduced by around £ 23.733,00.

Scenario B.2.3

The third step has been considering the overtime for the system integration activities, on the critical path. The overtime hours per resource assigned to a task as been calculate as 25% of the total duration of the activity, according to the specification. As result, the overall project duration has been decreased from 482 to 480 working days, the direct costs have increased by £11.539,00 while the indirect costs have been reduced by around £8.700,00. It is clear that this reduction does not offset the increase in the direct costs, this scenario did not represent an efficient solution.

7.3 Airplane transportation

Scenario B.3

The crashing scenario considered the transportation by airplane of the gas and steam turbine, to reduce the duration of their transportation from the Siemens facilities to the Owner plant from 7 days to 2 working days, with an overall project duration decreases of 5 working days, being this activity on the critical path. The cost of the transportation of the steam and gas turbine using ships is £10.962,00, with the airplane would have costed £ 100.800,00. The difference was of £89.838,00 with a cost change per unit time of £ 17.967,60. This scenario has been evaluated by considering as a starting point the schedule of the scenario B.1.2 and changing the costs and the duration of the transportation. As it is possible to see from the total costs of the project, the decrease in duration and the related decrease in the indirect costs does not offset the increase in the direct costs due to airplane transportation, resulting in total project costs of scenario B.3 being higher than the one of the starting scenario B.1.2.

7.4 Change in the WBS

Scenario B.4.1

In crashing the project, usually a change of the activities defined in the WBS is not taken into consideration. However, by looking at the schedule of the project it has been found that the steam turbine fabrication, being a critical activity, delayed the overall expediting and transportation of the whole systems supplied by Siemens. Hence, by executing two separate expediting activities on the Siemens manufacturing plant, and hence allowing to schedule two separate transportation activities, it was possible to reduce the overall project duration with a little increase in the direct costs. Specifically, one expediting activity in the Siemens purchasing process and one transportation activity from the Siemens manufacturing plant have been added to the WBS of the Option B, with the related costs. The total direct costs under the scenario B.1.2 were £ 28.119.758, the cost of having one more expediting is £ 4.560,00 while the transportation of the steam turbine separated from the other Siemens supplies costs £ 2.052,00 more than in the Option B.1.2 (because using the ship transportation with less than 11 TEU has a high cost per TEU, according to the transportation reference table in the file). Hence, the schedule of the project under the scenario B.4.1 has a direct cost of £ 28.126.369,50 with a duration of 487 working days. Compared to the scenario B.1.2 the overall cost change per unit time is £ 585, with a saving in indirect costs of £38.594,94, hence this scenario can be considered more efficient than the B.1.2.

Scenario B.4.2

The final scenario that has been considered was applying the overtime for the Basic Engineering activities at the scenario B.4.1, being these tasks on the critical path. As a result, the overall project duration from 487 to 476 working days, the direct costs have increased by £11.440,00 while the indirect costs have been reduced by around £43.943,00. This final scenario has been considered as the final deterministic best case. No further scenarios have been evaluated because of a change in the critical path, as it is possible to see comparing the schedule in the MS Project file of the baseline Option B and the one of the deterministic best case. The final critical path follows at first the Engineering phase and then, after the permit and authorization based on basic design, proceeds with the site installation, civil works, the construction of control room and office building, leading to the last activity of final commissioning and testing.

8. Define Proposal

This chapter represents the final proposal that the consultants will submit to the Owner providing Contractor-side Construction Project Plan, which will be used as a basis for the Construction Contract formation for the Dewsbury Power Plant Construction Project.

8.1 EPCC Scope

The EPCC Contractor scope of work can be consulted in the Chapter 1, considering the selection of the Option B.

8.2 Optimum Project Plan WBS, OBS, ResBS

According to the analysis performed by the team of consultants in the previous Chapters, a new WBS for the Option B has been conceived, as mentioned in the Chapter 6.4, and it can be consulted at the Exhibit_12_WBS_Optimum_Project_Plan. The OBS of the EPCC Contractor for the project can be seen in the Exhibit_6_OBS_B, and it has remained unchanged. The last document Exhibit_13_ResBS_Optimum_Project_Plan contains the graphical Resource Breakdown Structure (ResBS), which reports the resources that will be required to execute Dewsbury Power Plant Construction Project. The diagram is broken down by function and type, and at the very least will cover the people and material needed to complete the project successfully. In the ResBS the project resources are split into internal and external resources, where the first includes human resources and equipment, and the latter involves the supplies divided into the different suppliers, the subcontractors and the shipments.

8.3 Deterministic Best-Case Schedule

The Deterministic Best-Case Schedule for the Dewsbury Power Plant Construction Project is available in the MSP file Exhibit_14_Deterministic_Best_Case_Schedule, and it the final schedule with the optimal duration, which minimize the total project costs.

8.4 Risks Management Plan

The Dewsbury Power Plant Construction Project risks have been identified and assessed according to ISO31000 definitions and response measures have been proposed. To redact the Risk Management Plans several books and article consulted and can be consulted in the bibliography [11] [12] [13] [14] [15] [16].Two separate Risk Management Plans, for Force Majeure and EPCC Contractor scope of responsibility, have been redacted by the team of consultants and they will be explained in the following paragraphs.

8.4.1 EPCC scope of responsibility Risks Management Plan

The identification, assessment and proposal of response measures for EPCC scope of responsibility risks (from now on ‘internal risks’) have been reported in Exhibit_15_Risk_Management_Plan_EPCC_Scope.

8.4.1.1 Risk Identification

To identify the internal risks the consultants team developed the Risk Breakdown Structure (RBS) of the project, which is a useful tool to identify the potential risks of a project during the planning phase. The RBS is divided into two categories, cost related and time related risks. Time related risks are the ones which can increase the overall project duration, causing time overruns, while the cost related risks are the one for which the project can incur in costs overruns. They can be related to:

- *Human Resource*: any fault, injury or productivity made by a human resource.
- *Technical:* any damages or malfunctioning of equipment during the installation phase.
- *Financial:* Economical changes and fluctuations
- *Supply:* risks affecting the procurement process, which are related also to the quality of the items.
- *Construction:* activities related to the construction and the construction site.
- *Legal:* legal work and liability risks that will increase the cost in the procurement phase
- *Technology:* activities related to the interconnection between the design phase and the construction phase.

8.4.1.2 Risk Assessment

The assessment of the internal risks has been performed using a quantitative method, by the Risk Breakdown Matrix (RBM), which represents the integration of the WBS with the RBS of the project. Time and cost related risks have been assessed by using separated RBM, as it is possible to see in the Exhibit_15_Risk_Management_Plan_EPCC_Scope.

For the *cost related risks*, each risk type mentioned above in the section *8*.4.1.1 has been divided into sub-categories identifying the risk, for which is possible to define an impact and a probability of occurrence on the tasks. Specific risks which will have an impact on specific tasks and not on all the tasks of the project. The risk for each task has been assessed in a quantitative way multiplying the probability and the impact of each risk and then summing them up. While for the calculation of the Expected Monetary Value (EMV) related to the cost overruns risk, the activity cost is multiplied by the risk score. This value will represent the total cost that will be paid in case of occurrence of any of the risks on the associated task.

For what concerns *time related risks*, it is important to highlight that the probabilities and impacts counts for the factors not considered in the previous general risk calculation. The calculation was realized defining a range of days of delay expressed in percentage, which can vary depending on each risk and task. This range starts at 10% delaying possibility and it is increased until 65% as it is applied to the task duration in under the Deterministic Best-Case Schedule. To define the task delay, it is necessary to choose a value in the range, meaning that the higher the percentage, the greater the number of days of delay.

Once the 'task delay' was defined, it has been analyzed if this delay would affect the overall project duration and for how much time it would happen by inserting the delay of each task in the MSProject Exhibit_14_Deterministic_Best_Case_Schedule. This information can be seen in the column 'Project Delay', where if the delay is zero the task delay will not affect the overall project.

The risk approach took into consideration some specific areas: the technical aspects, the construction site, supplying materials and the embedded technology. For each one of them, it was defined a

probability for the risk to happen associated with the *impact* it would cause, which for this case, is exactly the same amount, in days, of the project delay. If the task had a risk that would not affect the overall project development, its impact was considered as 0.
However, it was also necessary to define the expected monetary impact represented by the risks. To do so, the procedure was realized defining a risk score represented by the expected project delay (in days). For each task, there are two factors to consider: penalties and overhead daily costs. Regarding the penalties, there are two possibilities: paying penalties to the Owner due to delaying the project and/ or receiving the payment of penalties from the suppliers/subcontractors for not complying with their obligations. The penalties, both by the Owner and the suppliers/subcontractors are calculated multiplying the risk score to the activity cost and to the maximum penalties' cost per day, which is 0,001% of the activity cost. If the penalties exist due to the suppliers/subcontractor's responsibilities, the exact total amount paid by the Contractor to the Owner is received from the suppliers/subcontractors.
Finally, it was necessary to compute the Expected Monetary Value (EMV) to the time related tasks. Its value represents the total amount that would be paid due to the delays in the overall project which is directly related to the net penalties calculated before, as difference between the penalties due to the Owner and the ones paid by the subcontractor and/or suppliers. The calculation is made by multiplying the net penalties' value (penalties by Owner minus penalties by suppliers/subcontractors) to the risk score (expected project delay in days) to the overhead cost previously defined (£ 4.000,00/day).

8.4.3 Risk Mitigation

Once the risks have been identified and assessed, mitigation and preventive action have been defined. In this risk management plan the risk actions are divided into 3 parts, the *acceptance* of the risk, the *mitigation* of the risk, or taking *preventive actions* towards the risk. The choice between the three depends on the total EMV risk related to each task. The total EMV per task has been calculated by summing the EMV of the cost overruns risk and the EMV of the time overruns risk. The Total EMV is then divided into low (£4,000), medium (£4,000 - £200,000) and high (> £200,000) monetary values range, which will represent the criteria on which to choose between accepting the risk, mitigating or taking preventive actions. Hence, if the total EMV has a value less than or equal to £4,000, the risk is accepted. If the total EMV has a value between £4,000 & £200,000, then mitigation actions must be taken, while if the total EMV has a value higher than £200,000, then preventive actions must be taken.

Each task is later associated with mitigation activities, which are responsible to hinder the impact on each task. In the Exhibit_15_Risk_Management_Plan_EPCC_Scope, under the sheet "Mitigation", a table can be found, describing each mitigation action and the cost associated with each of them. Note that tasks having more mitigation activities will have a higher percentage of mitigation effect.

Mitigation actions breakdown: the mitigation actions taken can have a different effect on the impact and probability of the cost related risks and the time related ones. While for the first, the mitigation reduces the expected cost to pay for the risk by a fraction ('Mitigation effect on cost overruns risks'), the second reduces the expected days of delay in the task, and so in the overall project ('Mitigation effect on time overruns risks'), and consequently the penalties and the indirect costs, for which a residual value is obtained.

8.4.1.3 Contingency

The total contingency for the project is the estimated amount of money to keep aside in order to be able to cover for the risk's occurrence during the total project duration. The total value that represents the amount to pay for the risk (£2.405.750) is obtained by summing the mitigation actions costs (£884.162) and the residual risks (£1.521.589,21). The total amount has been considered by the consultants as reasonable given the total operating costs of the Dewsbury Power Plant Construction Project.

8.4.1.4 Contingency for Cash Flow Analysis

Since the activities have a different weight on the total contingency cost (due to a different EMV), the total cost of the mitigation is to be allocated to each task and depends on both the mitigation costs and the initial EMV risk associated to the task before the mitigations. First the mitigation cost is allocated: the weight of each risk on the mitigation cost is found by dividing the single activity EMV over the total EMV of all the activities affected by the mitigation action ('Risk scores affected by the mitigation (total)'). The weight indicator allows to allocate to each activity the correct portion of each mitigation cost, and their row sum allows to have a value that indicates how much mitigation cost is an activity absorbing ('cost of mitigation allocated per each activity'). Secondly, the residual risks are allocated: for each activity the cost related and time related EMV residual risks are summed, and the final sum of mitigation cost and residual risk provides the contingency amount for each task to be inserted in the cashflow calculations ('total contingency per task').

8.4.2 Force Majeure Risks Management Plan

The identification, assessment and proposed response measures for Force Majeure risks have been displayed by a risk register available at the following Exhibit_16_Risk_Management_Plan_Force_Majeure. The risk register was used as a tool to assess in a qualitative way the impact and probability of possible Force Majeure risks, Owner / Third Party risks. In this category collected risks which are not related to EPCC scope (Chapter 1), such as current macroeconomic or political factors natural and social risks, (i. e. Brexit, Covid or other known unforeseen). The risk register matrix is composed of 8 columns. The first one represents the risk identification phase, giving a brief description of the risk, while in the second are displayed the possible consequences that could happen if the risk will not be mitigated. In the next two columns the risk assessment has been displayed, by assigning a probability and an impact value to each risk of occurring, on a scale from 1 to 5 from the less impactful to the most. These two values are multiplied in the next column, and the result is the priority level of each risk. As can be seen from the file, the values' background is colored, from yellow (lowest priority) to red (highest priority). There were then introduced some mitigation notes, which give suggestions on how these risks can be reduced, or even eliminated completely.

The last two columns address the responsibility of each risk to a specific person, group of work or company. The difference is that while the first column indicates who will pay for the risk or its mitigation actions in monetary terms, the second exhibits who to address for the specific problem from the EPCC Contractor company's point of view. For Force Majeure risks the contingency has been considered as out of the scope of responsibility of the Contractor.

8.5 Risk Weighted-Case Schedule

After having released the Risk Management Plan, the team of Consultants have redacted a Risk Weighted- Case Schedule, which is possible to consult in the Exhibit_17_Risk_Weighted_Case_Schedule. This second scenario takes into account the time-related risks of each activity, adding to the duration of each task in the Deterministic Best-Case Schedule the residual delay deriving from the different risks. Also, in the file have been inserted the contingency deriving from the Risk Management Plan for EPCC scope. This delay, expressed in days, can be found in the Exhibit_15_Risk_Management_Plan_EPCC_Scope, under the 'Residual risk' sheet, last column. The residual delay has been calculated as the multiplication between task delay (in days), the probability of the risk to happen and the percentage of risk not mitigated. After having added the days of delay caused by the time-related risks, the total project duration increased to 504 days, with a planned end date on December 7th, 2022.

8.6 Budget

The Exhibit_18_Budget_&_Cash_Flow shows the final budget forecasted by the Consultants for the Dewsbury Power Plant Construction Project to be executed by the Contractor. The file also provides a detailed report of the project's Cash Flows, on which a more detailed explanation will be provided in the next paragraph.

The "Budget" sheet reports all the costs computed on the basis of:

- technical specifications provided in the initial project's exhibits;
- estimates based on real transportation fees;
- assumptions already described in previous chapters of this report.

The cost voices have been grouped into:

- direct costs (furtherly subdivided into supplies, transportation, subcontracts, human resources, rentals);
- indirect costs;
- contingency;
- financials.

Every macro-group of costs has been addressed in detail previously in this report. Financials have been computed according to the percentages specified in the exhibits, such as bond fees, interest rates and Contractors' all risks (CAR) assurance. It is worthy to mention that the CAR assurance is the most popular non-standard insurance policy in construction projects. It represents a way to transfer risks from the Contractor to the insurance company, by providing coverage for property damage and third-party injury or damage claims. In the following paragraph related to the cash flow analysis will be explained the way in which this voice enter in the Contractor cash flows. [17] [18]

For what concerns Revenues, the following choices have been taken: first of all, Milestone payments have been scheduled according to the end of major project's phases, specifically Engineering, Civil works and Erection activities. This allows the project to run over time without incurring into significant risks related to bank debts. The percentages established (in order, from first to last milestone payments, 35%, 45%, 20%) have been set with the objective of increasing the NPV of the project anticipating Revenues while at the same time maintaining an acceptable average Debt Service Coverage Ratio. For the same reasons, a cut in the advance payment percentage has been introduced, reducing it from 20% to 10%.

8.7 Cash Flow Analysis

As previously mentioned, the Excel file contains also a "Cash Flows" sheet, which provides a detailed summary of all the cash movement incurred during the project, aggregated monthly. Costs are grouped by cost centers and concur to the definition of the Total Operating costs budget, followed right after by the summary table of the Revenues schedule. Cash Flows are then subdivided into "from Operations" and "from Financing" and used to compute the "total Cash Flow" data. Under the finance section the CAR assurance has been calculated on the basis of the earned value, represented by the planned monthly total direct costs.

Overall, monthly cash movements reported in these sections are then used in the "Bank Service" table to estimate periodic financial data, that are then aggregated in the final "Bank Service" account which is finally used along with "Cash Flows from Operations" to compute the average DSCR.
Finally, it is important to notice how the NPV is computed using the total monthly Cash Flows and the monthly Weighted Average Cost of Capital after tax (r_{wacc}) which in turn is computed considering the cost of debt, the cost of equity, the tax rate and the percentage of Stabilization Equity and Overdraft defined (in this case, 84% and 16% respectively). These have been set according to the objective of obtaining an acceptable DSCR and a positive NPV.

Overall, from the Contractor cash flows analysis made by the consultant's team, the selected EPCC Contractor should have a solid financial position to minimize the financial risks of the Dewsbury Power Plant Construction Project.
The following graphs offer a graphical view over the distribution of the operational and financial cash flows, allowing to identify the time slots in which working capital variations occur – consequently to the milestone payments coming from the client – and costs incurred.

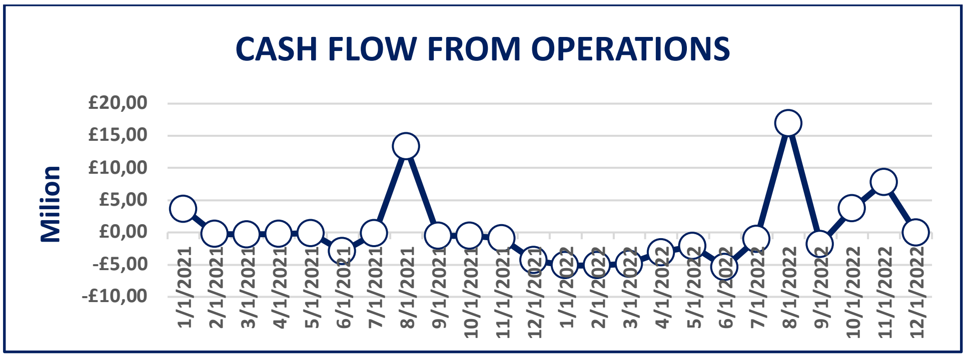

Figure 7 - Cash Flow from Operations

For what concerns cash flows from operations, the three peaks correspond to the three milestone payments (with a two-months shift due to the specifications regarding payments). The months in which cash flows are negative correspond instead to the scheduled payments to suppliers.

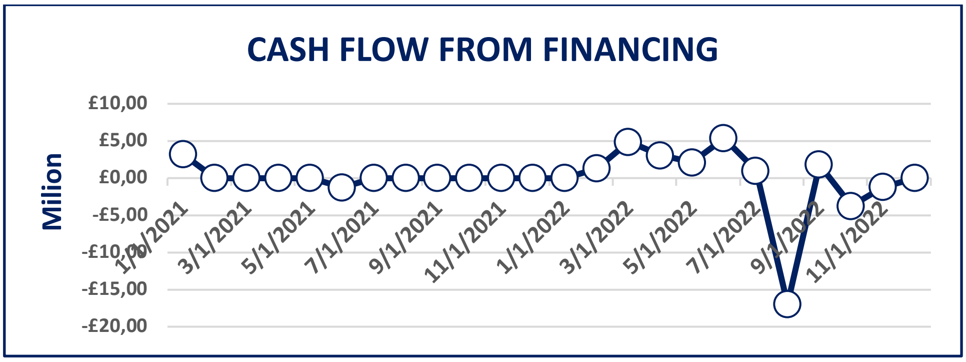

Figure 8 - Cash Flow from Financing

Regarding the financial cash flows, it is possible to notice how the curve tends to mirror the operations one in the second half of the project. This is due to the need of stabilization equity to cover the period expenses. These amounts shall be provided by the Contractor company, and this entails the need for an EPCC Contractor with a solid financial position.

8.8 EPCC Price

The final Contractor fixed price estimated by the Consultants is £ 39.107.532,00 , calculated as the sum of the Contractor profit margin, direct and indirect costs and contingency.

Exhibits

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