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Boiler Installation for Beer Brewery

Context

The task we've taken up is installation of a boiler system for a beer brewery plant. A beer brewery goes through multiple stages of production starting from raw materials all the way to the refined beer that ends up on shelves, our counter tops and cups. The process of beer production is a highly controlled process in order to create consistency in every bottle. A big part of being able to maintain this consistency are boilers. Boilers, as suggested by their names boil liquid and we know that water-based liquids evaporate on reaching their boiling points. Hence running the boiler for a second longer than required or using a low quality boiler creates a large deviation in multiple batches of boiled beer. This deviation creates inconsistency in the flavour of the beer as the step after boiling decides the bitterness of the beer and if the beer is already more concentrated, unwanted bitterness can enter the beer which intensifies during the fermentation process. Hence to maintain a tight control over this very crucial part of the process, our task is to commission a reliable boiler system that meets our production capacity in accordance to our inventory capacity.

Objectives & Scope of work

The main goal of the project is to install a boiler with a running capacity of at least 10000 litres per boiling cycle for a newly built beer brewery plant. The boiler feeds to a large mashing tank which further processes the beer. The major objectives of the project can be outlined as:

1. Selection of the most eco-friendly and energy efficient boiler that is compliant with all the required standards, protocols & sub-systems of the plant
2. Boiler throughput of at least 10000L liquid per boiling cycle
3. Proper routing of residual heat & steam to other parts of the plant for use in energy production subsystems of the plant

This installation is the heart of the brewery as the boiler is where the beer gets its most important flavours. After a brew has wort, which means sweetened, it's sterilized by boiling, which halts enzyme activity and condenses the beer liquid. Flavouring agents called Hops (flowers of the hop plant Humulus lulupus) are added during the boil which control its bitterness & aroma [1]. Hence the project's scope is tied directly to the product itself. These include:

1. Budgeting, taking into account buying & running costs which are dependent on energy costs, cleaning costs, regular maintenance costs & depreciation at the end of the boiler's usable life cycle
2. Verification of boiler's compliance with industry standards for beer production and targeted standards of the brew
3. Cross-checking quality of the brew based on multiple boiler parameters, using both in house experimental data collected by the R&D team with scaled down versions of boilers and taking into account reliable secondary data
4. Verification of targeted flavour profile from the boiler before final commissioning
5. Assessment of boiler's compliance with existing HVAC system
6. Experimental run of the installed boiler for final validation of compliance with all requirements & commencement of regular operation
7. Throughput of at least 10000L of liquid per boiling cycle

Some of the activities out of scope of this project are:

1. Creation of scaled down models of boilers for experimentation if testing facilities are unavailable or not already in existence
2. Upgradation of plant's HVAC components, namely heat transfer pipes, valves and outlets to preserve current temperature & humidity levels within acceptable limits to accommodate the boiler
3. Setup of the power generation system that is fed from the boiler's heat exchangers

Equipment Specifications

Given the in-house as well as third-party inventory capacity, it's possible to store a maximum of 10 million litres of brewed beer for fermentation. And beer needs to be fermented for up to 2 months. So calculating the required output

$$\frac{10^7 \ \mathit{litres}}{61 \ \mathit{days}} = 163934 \ \mathit{litres\ per\ day\ of\ production}$$

So we require approximately 164934 litres of production per day to fill out our inventory, & the factory uptime is 16 hours a day. Therefore we require

$$\frac{164934 \ \mathit{litres\ per\ day}}{16 \ \mathit{hours}} = 10245 \ \mathit{litres\ per\ hour}$$

So we require approx 10245 litres per hours of production. This is the key parameter to look for when choosing out our boiler. To sufficiently meet our requirements, we're choosing Bosch's Universal steam boiler CSB which is mentioned to be "the ideal solution for food and beverage manufacturing industries" [2]

Output (kg/h)	300 to 5200
Safety Pressure (bar)	Upto 16
Max. Temperature (°C)	204
No of units	2

Table 1: Technical Specifications Table [2]

With two units of the boilers, we can meet out long term inventory needs of the brewery & sufficiently meet daily production goals with an installed capacity of 10400 litres per hour. The unit kg/h can be converted to litres/h because of the conversion factor being nearly 1.

Safety & Regulatory Requirements

Boilers are high temperature systems. Therefore they can be hazardous if not properly secured and personnel not properly trained. Keeping this in mind, the following requirements must be fulfilled to ensure the proper safety and regulatory requirements of the plant as well as any possible government regulations are met by the boiler sub-system.

1. As mentioned in [2], the CSB type boiler uses high-pressure saturated steam as a heat transfer medium. The steam must be channelled safely through an outlet to desired part of the plant with a minimum vertical clearance of 3 meters (clearance of human height).
2. The boiler room must be kept clean to avoid contact with possible flammable liquids. Any such liquids must be kept out of the boiler room as subjecting them to high temperatures will certainly lead to an explosion of the boiler
3. Boiler room's ventilation system must be able to channel out residual heat from the surfaces of the boiler (not the heat exchanger)
4. Installation of emergency fire sprinkler system calibrated for the boiler room
5. Installation of anchors along with dampers to withstand vertical and horizontal vibrations generated by the boiler
6. Flexible but sturdy foundation structure for hosting multiple boiler units

Project Activities & Timeline (with WBS & Gantt chart)

List of activities for commissioning the project can be listed as:

1. Feasibility Study
2. Procurement
3. Validation & Testing
4. Installation
5. Operation & Training

Following these activities, the project can be completed in 2 major phases,

- Purchase
- Deployment

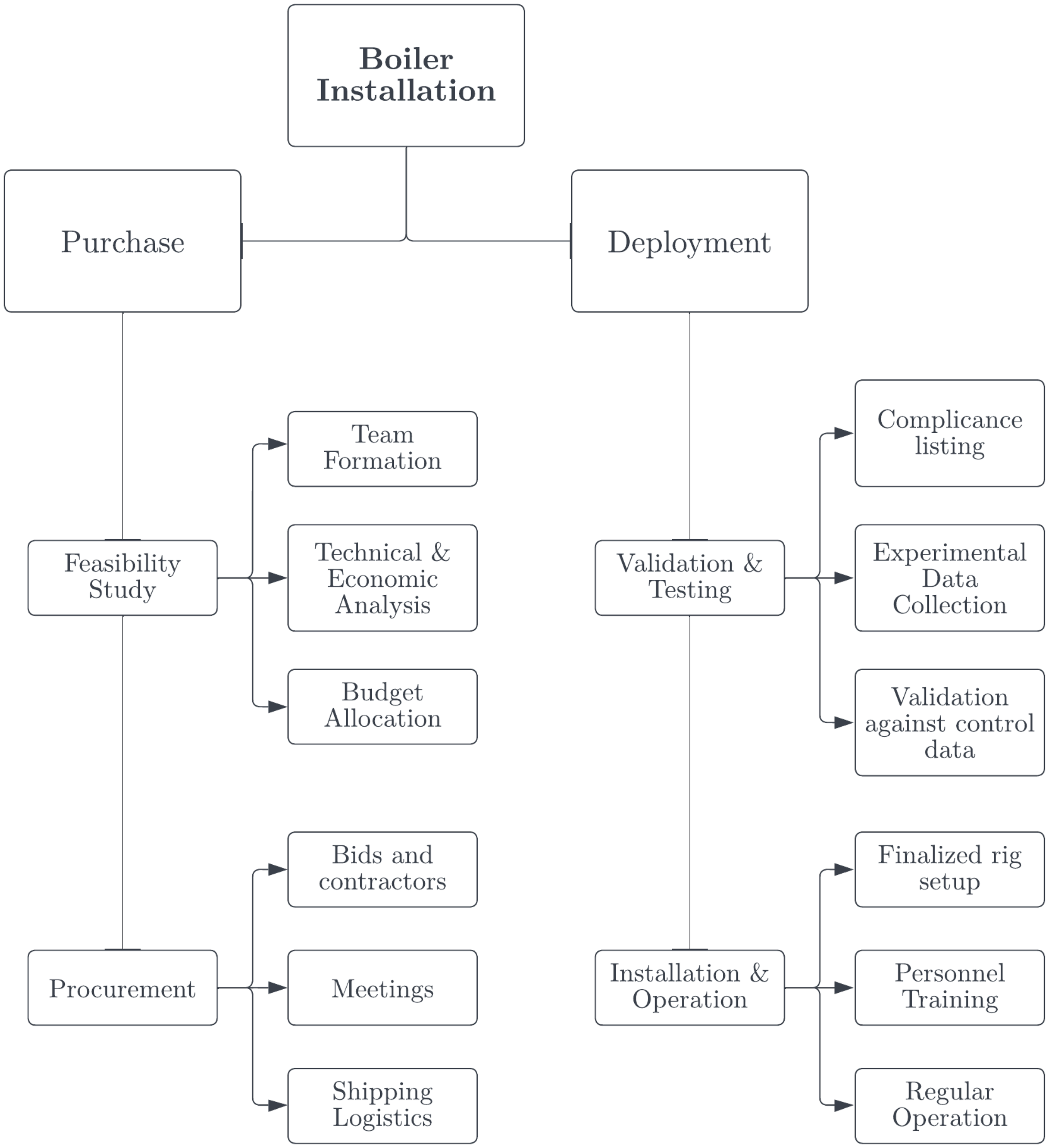

Figure 1: Work Breakdown Structure made with Lucidchart

The above WBS (Work Breakdown Structure) clarifies all the tasks and sub tasks that are to be accomplished under their respective activities. The time management schedule is presented as a timeline of the project is outlined in a Gantt chart below.

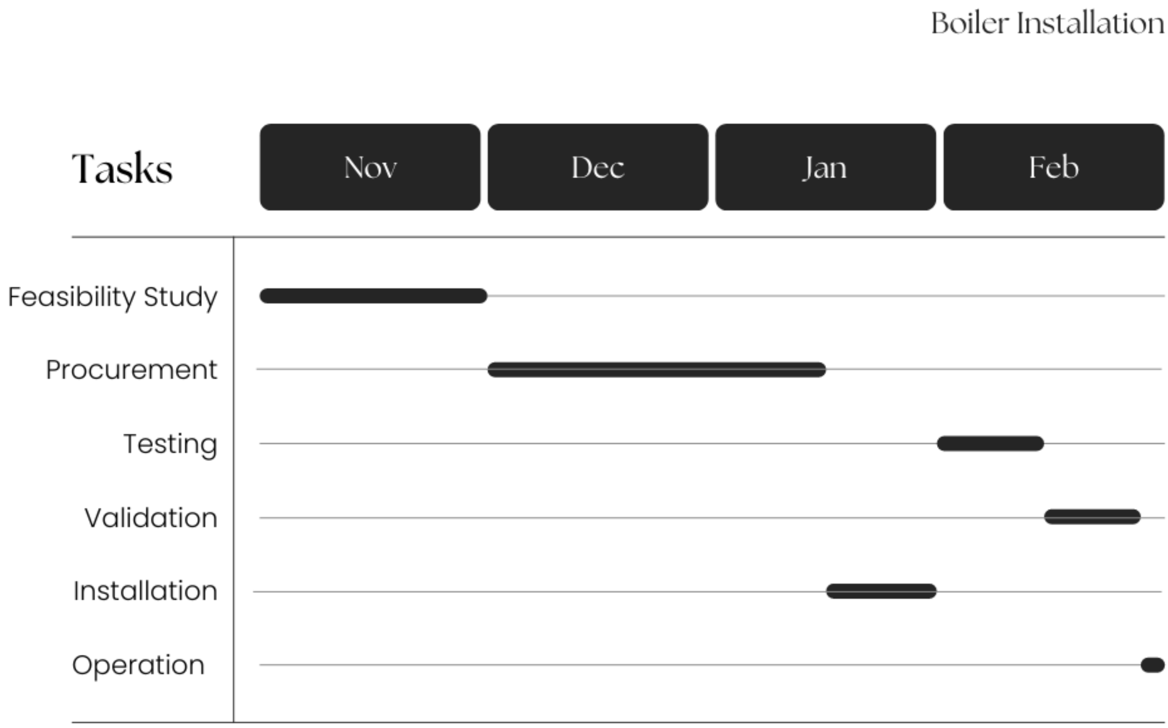

Figure 2: Gantt chart made with Canva

PERT Analysis

Program Evaluation Review Technique is a project management planning tool used to calculate the amount of time it will take to realistically finish a project. The PERT table is built from tasks in the project timeline.

Task	Optimistic (O)	Most Likely (M)	Pessimistic (P)
Feasibility Study	3 weeks	4 weeks	6 weeks
Procurement	4 weeks	6 weeks	10 weeks
Testing	1 week	2 weeks	3 weeks
Validation	1 week	2 weeks	3 weeks
Installation	2 weeks	2.5 weeks	3 weeks
Operation	0.1 weeks	0.2 weeks	1 week

Using the pert formula given as

$$Realistic\ \ time\ =\ \frac{(P+4M+O)}{6}$$

We can write out the above table and PERT formula in matrix multiplication form as

$$\begin{pmatrix} 3 & 4 & 6 \\ 4 & 6 & 10 \\ 1 & 2 & 3 \\ 1 & 2 & 3 \\ 2 & 2.5 & 3 \\ 0.1 & 0.2 & 1 \end{pmatrix} \begin{pmatrix} \frac{1}{6} \\ \frac{4}{6} \\ \frac{1}{6} \end{pmatrix} = \begin{pmatrix} 4.1667 \\ 6.3333 \\ 2.0000 \\ 2.0000 \\ 2.5000 \\ 0.3167 \end{pmatrix}$$

We took the dot products of this matrix to obtain the realistic time vector. Its entries can be summed up to find out realistic time = 17.3167 weeks which largely agrees with our Gantt estimate.

A question of discussion may arise, how reliable is this estimate?

Its answer would be the estimates from PERT are only as good as the data it's fed. The PERT formula is simply a weighted average sum which weighs our most likely estimate by a factor of 2/3 while other estimates by 1/6 each. There are only two ways to increase the accuracy of this estimate. First one is the expertise of the team on coming up with estimates on times for all the logistics as well as in-house times. This requires the expertise of an experienced project manager who really knows their team and how they operate as a unit. This is largely based on having a good understanding of the time they take to do their tasks and how coordinated they are amongst themselves.

Another way to increase the accuracy of this formula is by adjusting the weights themselves to account for the time taken. These weights are inherently multi-dimensional, and can depend on a multitude of factors which can be based on the trade activity of a particular day, traffic activity during the day and even the weather forecast for the day among others. This turns it into an optimization problem that can be solved daily to obtain very reliable weights which in turn allow for a human estimation error to be off by a large factor and still predict correctly the realistic amount of time it takes to complete the project. This is how PERT analysis helps in estimating the time cost of our project.

Food processing plant for dry milk production

Context

Milk processing is a large business, both financially and physically. Initial standardization of milk can be done in smaller plants but production of dry milk requires a large initial capital expenditure and being compliant with a wide variety of regulations which include things from standardization and quality control of produced milk to particulate matter & emission regulations for air pollution mitigation. It is the role of the project manager to make sure that all of these are broadly addressed all the way from the construction phase to the pilot operation. The factory itself and the technologies are already well refined and the process is well standardised. The major guiding vane in this construction project will be achieving desired production goals while being mindful of the environment and achieving long-term sustainability. So our task here is to manage all the parts of this project by creating incentives, managing communication and managing the flow of manpower to different parts of the project to meet the budget and construction duration requirements set by the board of directors of the company ordering the project.

Objectives & Scope of work

The project is a large interdisciplinary project with a lot of moving parts. The manpower and type of work required to complete the project is very broad. The major objectives can be laid out broadly as

1. Initialization
    a) Professionals (Engineers, Managers, Financiers & Auditors) recruiting
    b) Project scoping and DPR (Detailed Project Report) preparation
    c) Economic feasibility study
    d) EIA (Environmental Impact Analysis)
2. Planning
    a) Bidding, contractors and project release
    b) Project site selection
    c) Permissions and legal requirements fulfilment
    d) Procurement scheduling
    e) Project scheduling
    f) Preliminary hiring & formation of departments and departmental heads
    g) Pre-project operational planning and work hours division
    h) Technical needs, limitations & market availability study
    i) Order placements and preparation for start of construction
3. Execution
    a) Machinery setup and site preparation
    b) Overall workers hiring & build by various engineering teams
    c) Final field inspections of the facility
4. Completion
    a) Review of project deliverables (Financial & Commercial)
    b) Documentation of the project outcomes and activities accomplished

In fulfilling these objectives, there are a multitude of tasks to be overseen by the project manager to ensure every objective is met. They can be expanded on as:

1. Hiring team of multiple project managers in the beginning after being hired by stakeholders. These along with the civil, mechanical, electrical & environmental engineers, architects, analysts and stakeholders prepare and review the DPR
2. Scheduling of team meetings for the project duration and project phase division & allocation of manpower towards providing shareholders with regular updates about the progress of the project
3. Simultaneous deployment of team of engineers, namely geological, environmental & civil for site feasibility studies of probable project sites
4. Setup of legal team to deal with legal issues & regulations regarding plant construction
5. Scoping of market for modular products along with the mechanical engineering team to commission the major components of the plant, namely filtration, evaporation and spray drying systems & ordering the rest through bids and contracts
6. Structural dynamics design by civil & architectural team in collaboration with the mechanical team in the best designated site and start of construction
7. Installation of large spray dryer system in the central part of the plant
8. Electrical wiring and development of plant power system
9. Deployment of electrical team for power quality assessment in different parts of the plant and installation of power quality improving devices such as filter banks and voltage regulator and stabilizers.
10. Off-grid power generation system within the plant by mechanical and electrical teams to generate a power backup system in case of power grid shutdown or blackouts to keep the most essential parts of the plant running until start of an emergency shutdown cycle where all the machines use the available power to return to their normal states and turn off until the grid comes online
11. Integration of power quality control throughout the plant through AVS (Automatic Voltage Stabilizers) and compensators (filters)
12. Development of emergency shutdown system and detailed documentation of safety/emergency protocols in case of component failure or system shutdown

13. Installation of filtration and evaporation mechanisms along with preliminary milk processing stations to feed into the process
14. Installation of factory-wide HVAC system to utilize stray heat energy and control temperature & humidity throughout the plant
15. Development of a supervisory control system by the electrical team to be integrated into a central control room for the plant administrators and managers
16. Construction of office and employee with facilities for provision of basic amenities
17. Testing, pilot operation and overall validation of the project
18. Dissemination of information with shareholders about the project outcomes & project review to be followed by plant opening

Among the plethora of tasks we're required to accomplish during this project, some of the things that this project won't accomplish are:

1. Develop a supply chain to source the milk into the plant
2. Design & fabricate required components and materials themselves
3. Develop system for refining by-products of the process

Project Activities (with WBS)

The project activities for this project can be divided into:

1. Financial
2. Legal
3. Engineering

which are further broken down in the WBS below

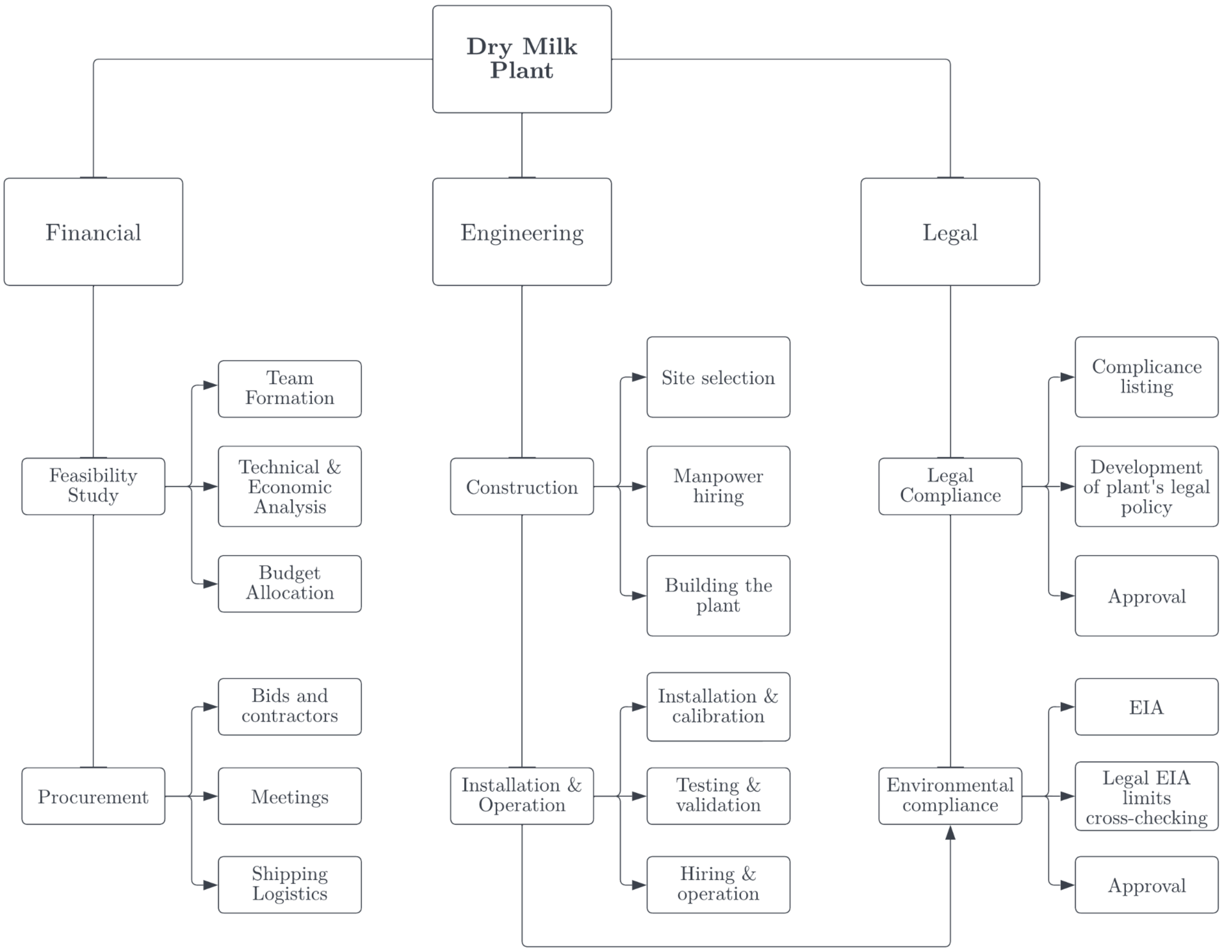

Figure 3: Work Breakdown Structure made with Lucidchart

Stakeholders

The stakeholders involved range from governments & corporate investors to smaller non-corporate independent investors who invest in the business directly or indirectly.

1. **Independent suppliers:** These are individuals who bring milk to the plant.
2. **Corporate & non-corporate large investors:** Organizations/agencies that fund building of the plant itself and look for ROIs through royalty deals or equity deals
3. **Wholesale buyers:** These are stakeholders who buy large volumes of the end product, which in our case is dry milk
4. **Normal and chain retailers:** These too buy large volumes of the end product in directly packaged forms and supply them
5. **Dry milk brands:** These are companies who outsource their production processes with strict QC(Quality Control) requirements to other plants and focus more on marketing, sales and customer service
6. **Larger consumers:** These are individuals or a group of individuals who source dry milk for their consumption directly through production plants. These don't include small customers who buy very small amounts of product from the plant. There's usually a limit set by the plant for a minimum order

Cost Breakdown

Type of Work	Details
Structural Engineering	Civil works of the plant including the foundation and structures to support large mechanical machinery that the plant uses to produce dry milk
Machinery & Equipment	Machinery used to process raw milk into dry milk, refine & package it
Asset Management	Land leases, rental agreements, utility trucks and other vehicles & inventory of raw materials
Operative Costs	Power supply and plant maintenance
Legal Dues	Consulting fees
Employee Compensation	Salaries for all individuals involved directly in the project

Table 2: Cost breakdown into tangible components

Cost Estimation

Type of Work	Details	Price Estimation (million AUDs)
Land Lease & Development	About 6000 sq. m	8.143
Vehicles Lease	Trucks & forklifts	2.3
Wages	200 engineers, 1000 workers	3.14
Rental Agreements	Inventory storage	0.241
Machinery Installation	Process components	68.031
Structural Costs	The plant building	22.843
Consulting Fees	Legal, Environmental	0.2
Miscellaneous	Accessories (Ex: Computers)	0.1

Table 3: Cost estimation table with reference to [3]. The mentioned plant has a capacity which was scaled ten times and divide by the INR to AUD exchange rate to obtain a regionally unadjusted cost estimate for the plant construction. It was then multiplied by the ratio of (GDP per capita of Australia/GDP per capita of India) to obtain a multiplying factor that multiplied all the costs

The total cost estimate of the project comes to roughly 105 million AUDs

Cost Control & Risk Management

The project faces a spectrum of risks ranging from day-to-day operational risks to long-term strategic risks. For example, the chosen site for the project might be logistically too far away from nearby brands offices such that any obstruction in routes or trucks is more likely, especially in the Australian heat. Other risks might include disruption of the ecosystem around the factory which might disrupt the ecological and water table cycles underneath causing structural issues such as small fissures which can render parts of the plant or the whole plant subject to reconstruction or relocation. To mitigate, an active risk management team, formed with the professional on board must continually asses all the types of risks that might be faced and quantify them through quantitative models built from a system of differential equations to model the risk. These systems of equations must incorporate factors from all fields to continuously assess risk.

Inputs to these systems can be a geological risk index, electrical failure risk index, structural risk index, mechanical risk index etc. Some other standard methods too can be used to assess risk such as:

1. Regression analysis of cost forecasting to keep track of anticipated spendings v/s the current spending patterns
2. Predictive models formulation for money spent on each activity compared to the allowed money from the budget
3. Analysis of time deviation for set times v/s achieved times
4. Performance review of all teams and regrouping

Progress Monitoring

Due to industries being largely data-driven, task scheduling software can track progress effortlessly. The team or sub-team manager creates a checklist of tasks, sorted by week, month and year and checks them off one by one as they are completed. The software can then show data on the working trends of the people and finds gaps where they can improve easily. Also, data analyst companies provide excellent data analytics which can help the team managers increase their overall team efficiency.

Another age-old but still effective way to monitor progress is by assigning a person to continually take updates from all of the teams on the planned tasks and the tasks they accomplished every day and create weekly and monthly reports of the project. The advantage of collecting progress data this way is that these personnel can also track team morale through their interactions with people and incorporate it into their reports as well so as to help team leaders make more concrete and practical decisions.

But by far the most effective way to track progress in industrial scenarios like these are a hybrid of both methods. Data-driven methods and unbiased but can't explain higher levels of abstraction such a human emotion & human-driven methods, though biased can explain abstract phenomena and how they affect the progress of the project. For example, a computer can't understand the nature of a given deal that was made with a contractor. Even if the details are on paper, on what grounds were the deal made may be unclear. Is this a long-term or a short-term deal? How good of a track record does the contractor has in the things we require? Such questions can only be answered by a human mind. Therefore a hybrid provides the best of both worlds.

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