Techno-Economic Comparison of Possible Options for Investment and Production Decisions on Projects

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Abstract

Nowadays, in an environment where technology is constantly developing and competition is intense, especially in refinery, petrochemical and gas processing plant projects, project leaders and project stakeholders need to perform a three-way integrated analysis not only with operations and cost calculations but also with environmental impact. Project assessments, including carbon footprint and environmental impacts, are now seen as the only real way to reach true economic feasibility tables for projects and processes in the long run. In this context, techno-economic evaluations simulate the technological, economic and environmental impacts of the processes and provide the most realistic cash flow and financial statements. Techno-economic evaluations reveal the long-term competitive strength of processes and technologies, making it easier for project leaders to make decisions.

In this study, techno-economic analysis of amine sweetening units used in the purification of H2S and CO2 contaminated gases in refinery and petrochemical plants is explained with a case study. Amine sweetening units are important units for reducing carbon footprint for refineries, petrochemicals and gas processing plants. However, these units (if not required by environmental regulations) are not preferred because of their high energy and raw material requirements. In this context, how an amine sweetening process can be economically feasible in many different technological and operational scenarios has been studied and the most effective process can be selected by comparing energy + raw material consumption, operation and maintenance costs and fixed costs of the process. Thus, in an exemplary application, techno-economic analysis of the amine sweetening unit with the obtained concrete data was made and it was facilitated in deciding the installation of these units.

Keywords: (3 to 5 key words) Amine sweetening units, decisions on projects, purification of H2S and CO2 techno-economic analysis

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1. Introduction

Project preparation consists analyzing and developing processes of an idea and/or view into a real-life project to ready for execution. All projects have a project cycle that shows the community of the projects, the schematic representation of the main elements and the sequence of their relations with each other (Project cycle design and quality enhancement WFWO's operation policy guide). The precise formulation of the project cycle and its phases depends on process type or company profile. Project preparation phase has to include feasibility study which covers all assessments such as technological, financial, logistical, environmental, political and human factors.

Technical and economic analysis that means techno-economic assessment is the core of a feasibility study. Techno-economic evaluation (TEA) is in principle a cost-benefit comparison using different options. An integral tool for both research and commercial project development, TEA combines process modeling and engineering design with economic evaluation (Techno-economic analysis, eliminating bottlenecks to scale-up). It helps to evaluate the economic development of the project and provides guidance, research, development, investment and policy formulation. It integrates well with the stage board analysis used by the world's private sector, engineering companies and R&D centers for project development. In order to be completely effective, it is necessary to make planning on this subject since there is a lot like TEA, literature, researches and vendor characteristics.

Eliminating bottlenecks and optimizing the process is a high priority in scale-up research and TEA is a powerful tool that helps us solve these problems. In principle, TEA is a cost-benefit comparison using different methods. Detailed TEA assessments and reports should be based on the needs of the project leader to include the following:

- Market Data: It covers projected future sales revenue based on estimated sales volumes and price.

- Raw Materials & Energy Consumption Data: It estimates the quality and quantity of raw materials for the project and the adequacy of energy consumption, calculating the estimated cost of all these inputs.

- Plot Plan, Location & Infrastructure Data: It evaluates the necessary infrastructure development works to establish the project with the existing infrastructure and the actions that will be needed for it. Also, plot plan drawings are made with this data.

- Project Technical Concept Data: This data is a core delivery product of the project and all process descriptions. It should include plant capacity, equipment dimensioning, warehouses, auxiliary facilities, system engineering, electrical engineering, civil engineering, control and automation engineering, quality control and assurance, captive power plant and waste heat recovery system (WHR) according to the project needs.

- Logistics Data: The work should include inbound and outbound logistics data and general logistics planning.
- Environmental Data: The report should include the legal obligation framework to be implemented and the environmental impacts of the project.
- Implementation Planning Data: It should consist of time scheduling and milestones of the project.
- Human Resources Data: This data should cover human requirement and labor cost.
- Investment Cost Data: This data should cover capital costs and funding needs.
- Operating Cost Data: It covers general expenses such as raw materials and utility expenses such as energy, water, steam and labor expenses.
- Financial Appraisal Data: Project profitability, IRR, NPV, reimbursement etc. risks. It acts as a Risks and Mitigation report.

In this study, techno-economic evaluation of projects for refineries, petrochemical plants and natural gas plants is analyzed and a case study is also performed. The case study is about amine sweetening unit that is used to clear off gas from H2S and CO2. Different case scenarios and options are compared and evaluated according to techno-economic assessments. Techno-economic analysis evaluates and estimates the economic, as well as operability and sustainability performance of alternative processes; hence, decision-making support for project alternatives could be easily executed by this way. Financial and technical assessment methods are used to achieve selection of the best option for amine sweetening projects.

2. Assessment Methods

It is widely accepted that not only programs and portfolios, but also individual projects should be linked to high-level objectives and strategies (i.e. group goals are more important than individual goals). In this context, the project management community is increasingly concerned about how projects create value and benefit (Volden, 2019). Some forecasting models focus on the front end, while others discuss benefit management throughout the project life cycle (LCA). Project managers were forced to shift their attention beyond the 'iron triangle' of increasing cost, time and quality in order to gain a broader and more strategic perspective of the projects. Projects are implemented to create benefits and value for end users (community or stakeholders, etc.), parent organization and / or society in general. Conducting financial assessments ensures that the processes, systems and regulations required to ensure efficient selection and presentation of relevant and applicable projects can be obtained clearly.

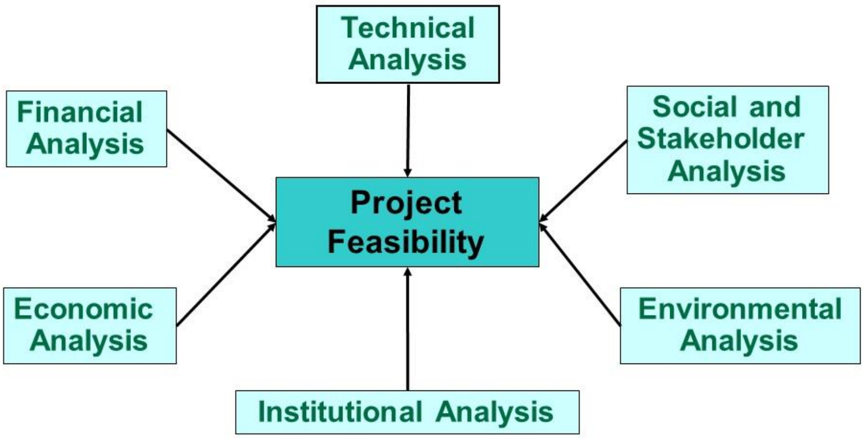
There are several different levels of measurement / evaluation for the project evaluation phases:

- Technical evaluation of existing services, physical system and implementation and recommendations for optimum use,
- Demand analysis and forecasting,
- Develop / calculate the gap between current demand and future demand,
- Developing technical alternatives / new technologies (design, technology, process, scale) that can meet all the outputs required for the project.

Whether an industrial project can be successfully implemented depends primarily on the investors' confidence in the project and the economic benefits of the project that will encourage decision-making (Zeng et al., 2019; Yuan et al., 2015; Zhu et al., 2016). Internal rate of return (IRR) is one of these methods to measure the profitability of a process. IRR is a parameter that expresses the discount rate where cash inflows are equal to cash outflows. When IRR is higher than the basic discount rate (BDR), the project is considered to be economically viable; otherwise, the project loses its economic feasibility. When the IRR is equal to the BDR, the project's starting point and NPV methods should also be considered as other economic evaluation parameters to verify economic performance under current technical and cost levels.

The integrated assessment method is a mixed method (focusing on the carbon fingerprint) which includes technical assessment, economic assessment and environmental assessment. This integrated evaluation method, different evaluations and their integration can be seen in Figure 1.

Figure 1: Relationship of assessment methods for project feasibility analysis (Perkins, 2019)



The integrated assessment method is a mixed method (focusing on the carbon fingerprint) which includes technical assessment, economic assessment and environmental assessment. The integrated system assessment includes mass and energy balance data for the technical assessment side; data on capital investments (CAPEX) and operating expenses (OPEX) for the financial evaluation party; on the environmental assessment side, it includes climate impact and carbon fingerprint data from raw material to final product in all processes (Chen et al., 2013). Process simulations can be performed with Aspen Plus® by estimating all technical data including the mass and energy balance data of the process and the characteristics of the different units. Economic assessments can be calculated using the Aspen Process Economic Analyzer®, using this program to estimate investment, energy, maintenance and operating costs. To predict climate impacts, the hybrid LCA approach can be applied by combining physical process data from technical assessment and economic data from techno-economic assessment.

Integrated assessment models are also widely used in the analysis of the environmental impacts of large-scale projects, and the outcomes of these assessments not only inform national decision-makers, but also contribute to international scientific assessments. Integrated assessment models of environmental impact have become increasingly important in informing the debate about climate policy and processes on carbon fingerprints. In addition, as an important step, it paves the way for the creation of suitable projects that will open the door to new developments that will conform to future technological assessments. Evaluation reports are also used in political impact assessments and environmental legislation analysis reports of government agencies (Krey et al., 2019). In addition, several national level integrated assessment models have been used to report governments' decisions to prepare nationally determined contributions to climate negotiations towards Paris-COP21 in 2015 (United Nations Framework Convention on Climate Change). At this stage, all processes, including the emissions from the supply chain, should be evaluated extensively to reveal the environmental impact of the projects and all processes in the project phases. While the carbon footprint of the project becomes predictable in the environmental assessments, the overall profitability analysis of the project is revised by adding the carbon tax to the calculations (Cristobal et al., 2018).

3. Case Study

As mentioned above, techno-economic assessment case is about a project for implementation of new amine sweetening unit to refineries, petrochemical plants or natural gas plants. Amine sweetening units are one of the most common methods of treating plant off gases for the removal of H2S and CO2 (Addington and Ness, 2019). A typical amine sweetener unit is comprised of two parts, mainly an absorber section and a regeneration section. In the absorber section (this column generally includes packaging materials), the downstream amine solution absorbs H2S and CO2 from the upstream dirty gas to produce a stream of sweetened gas (clean gas) as a product. The rich amine solution (amine containing H2S and CO2) is then directed to a regenerator column (a stripper column with a reboiler heater) to produce lean amine (amine solution without H2S and CO2) which is recycled for reuse in the absorber section.

The solvent used in an amine sweetening unit is usually an alkanolamine of which the following are the most frequently employed:

- Monoethanolamine (MEA)
- Diethanolamine (DEA)
- Di-isopropanolamine (DIPA)
- Methyl diethanolamine (MDEA)

There are two aspects for the proposed amine sweetening unit. One is boosting the off gas pressure at outlet of existing barometric seal drum to overcome the increased pressure drop of proposed amine contractor and the other is optimum scheme for downstream amine treatment.

The major challenge for an amine sweetening project is to boost the dirty off gas pressure at outlet from another plant to amine treatment plant to overcome the increased pressure drop of proposed amine system.

Five different options are developed for boosting the dirty off gas pressure, these are listed below:

- Option-1: Modification of existing dirty off gas system
- Option-2: Addition of a liquid jet eductor downstream of existing dirty off gas system using circulating amine solution as motive fluid
- Option-3: Addition of an ejector downstream of existing dirty off gas system using natural gas as motive fluid
- Option-4: Addition of an ejector downstream of existing dirty off gas system using fuel gas as motive fluid
- Option-5: Addition of liquid ring compressor at downstream of existing dirty off gas system using

The percentage comparison of utility requirement for options 1 to 5 is summarized in Table 1.

Table 1. Utility consumption comparison of one stage and two stage regenerator systems

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	Modification of Existing System	Addition of Liquid Jet Eductor	Addition of NG Ejector	Addition of FG Ejector	Addition of Liquid Ring Compressor
Electric Power	0.0	321.4	12.5	12.5	142.9
Steam	0.0	0.0	40.3	40.3	0.0
Cooling Water	0.0	0.0	42.7	42.7	8.4

CAPEX and OPEX for options 1 to 5 is summarized in Table 2, and the comparison of other parameters (plot plan requirements, operability and maintainability options and process reliabilities) for options 1 to 5 is summarized in Table 3.

Table 2. Economic comparison of one stage and two stage regenerator systems

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	Modification of Existing System	Addition of Liquid Jet Eductor	Addition of NG Ejector	Addition of FG Ejector	Addition of Liquid Ring Compressor
Ballpark Capital Cost	46.2	11.5	26.9	26.9	96.2
Cost for Utilities	60.6	15.2	37.9	37.9	7.6

Table 3. Comparison of other options for one stage and two stage regenerator systems

	Option-1	Option-2	Option-3	Option-4	Option-5
Description	Modification of Existing System	Addition of Liquid Jet Eductor	Addition of NG Ejector	Addition of FG Ejector	Addition of Liquid Ring Compressor
Plot Area Requirement	+	++	+	+	+++
Operability & Maintainability	+	++	+	+	+++
Reliability	++	+	++	+	++

The comparison tables clearly indicate that Option-5 with liquid ring compressor has highest capital expenditure. Moreover, the liquid ring compressor requires considerable plot area and considerably higher operation and maintenance cost. Hence, this option could not be a preferred one.

The CAPEX for Option-1 with modification of existing system is also considerably higher. Moreover, this option required significantly higher amount of utilities leading to highest OPEX. Hence, this option also could not be considered. Options 2, 3 & 4 have comparable CAPEX. However, Option 4 with fuel gas ejector is not a preferred option as the pressure is quite low resulting higher flow requirement and thereby higher diameter absorber column. Moreover, since the composition of fuel gas normally varies with refinery and petrochemical plant operating option, it might lead to continuous fluctuation of dirty off gas pressure and thereby not desirable.

Among Option 2 & 3, the CAPEX is slightly higher for NG ejector due to higher dimension of absorber column. The OPEX for Option-3 is also slightly higher side due to circulation of higher amine solution resulting into higher reboiler & condenser duties. When we consider plot plan area requirement, operability and maintainability of the processes and reliability of the operations, Option 2 liquid jet eductor becomes less desirable than Options 3 & 4. Finally with all comparisons above, we could easily say that Options 3 has the most advantageous project option after the techno-economic evaluations.

4. Conclusions

Today, in which technology is constantly developing and competition is intense, project leaders and project stakeholders must ensure the continuity of their processes and projects by producing efficient and effective outputs in terms of operability and economy as well as environmental issues. For this purpose, it is becoming increasingly important that techno-economic evaluations including operations, finance and environmental trio are conducted simultaneously. In techno-economic assessments, the workflows of the process, all processes between input and output (including logistics activities) are determined step by step, resulting in an economic and environmentally friendly process, while increasing output efficiency.

In this study; the techno-economic evaluation of the project of the installation of amine sweetening unit holding H2S and CO2 from the dirty gas which reduces the carbon footprint of the refinery and petrochemical plants was carried out. In many different operational scenarios, the outputs of the process, the effect of the inputs and the energy + utility consumptions of the process were compared and the most effective process (in terms of economic + operability) was selected. Therefore, with the concrete data obtained, it is shown with a sample application how much can be facilitated by techno-economic analysis for the project manager and the stakeholders of the project.

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