

PRELIMINARY FEASIBILITY STUDIES IN
TIMES OF RAPID COST ESCALATION

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Introduction

Costs of solid fuels conversion have risen sharply, delaying projects, prompting political investigations to determine whether cost estimates had been deliberately distorted, and startling the project sponsors themselves. In the eight years starting in 1967, the estimated cost of a daily barrel of synthetic oil capacity has increased up to tenfold.

In 1967, testimony to Congress projected a commercial shale oil plant by 1970; none has yet been built, and the earliest possible start-up year in 1979. After deferral of an application submitted in 1962, a second generation tar sand oil plant was planned in 1969 for 1976 startup; it is now under construction, with startup due in 1979.

Many factors other than regulatory delays have been responsible for this unfortunate record. They can generally be classed as inflation, other forms of escalation, process development, and increase in project scope. This paper analyzes these factors and gives perspective for estimation of future changes and avoidance of pitfalls.

Cost Escalation

Figure 1 is a plot derived from published data. It shows how cost estimates have increased for an oil shale plant using the TOSCO II process and for a tar sands plant by Syncrude Canada Ltd. (SCL). The plot also shows that the increases far exceeded the increases of the CE Plant Cost Index published by Chemical Engineering magazine, which is intended to reflect the changes in cost of process plants. The CE Index correlates with a broader index of inflation, the GNP Deflator. In fact, a plot of the GNP Deflator would be indistinguishable from the plot of the CE Index at the scale of Figure 1. How is the obvious total failure of cost indexes to be explained?

Oil shale and tar sands plants are obviously special cases in that they use unproven processes, so we should inquire whether cost indexes have successfully reflected changes in costs of routine plants. The answer is a resounding "no." For example, a 1,200 ton-per-day ammonia plant completed in 1967 cost W. R. Grace \$33.6 million, compared with a cost of \$107.4 million for a similar plant to be completed in 1978.¹ The increase is 220 percent, compared with a probable increase of about 100 percent for the CE Index. Ammonia production is well developed and relatively non-polluting, so the increase should reflect escalation more than change in design.

The year 1974 gave a particular divergence of plant costs from indexes, when an engineering contractor reported typical increases of petroleum and petrochemical plants of 30 to 40 percent in 6 months while the index rose about 14 percent. The 1974 experience is partly explained by the overheating of the economy at that time and by the derivation of the index. The CE Plant Cost Index depends on 67 Bureau of Labor Statistics (BLS) indexes, for which all of the equipment indexes depend on list prices. List prices are a fiction not reflecting contract prices in slack periods, when deep discounts are available. List prices are not likely to be raised as soon as real prices when the economy improves. This analysis was confirmed by Savay.²

Aside from details, indexes have a basic problem. Indexes attempt the impossible in trying to give a single number representative of cost of dissimilar plants when component costs are changing at greatly different rates, as shown in Table 1 for the difficult two-year period from July 1973 to 1975. The extraordinary increases for heat exchangers and centrifugal compressors reflect supply and demand. Many exchanger manufacturers left the business in earlier periods of low profitability, and many foundries shut down rather than comply with new antipollution and job safety rules.

Even the largest price increases do not explain the increases in cost estimates in boom periods because escalation clauses make the final costs uncertain, schedule stretchouts increase costs of interest, insurance, and administration, and contingency allowances are likely to be increased. A related site-specific factor, local labor shortages, requires overtime pay and causes reduced productivity and further delays.

Oil Shale Case History

The previous section showed that remarkable escalation occurred in the capital costs of perfectly conventional process plants, and that this escalation is not fully revealed by cost indexes. Three other factors have

coincided with the inflationary forces to accelerate the escalation of synthetic oil plant costs. These factors are:

- Tightening environmental controls
- Shortages of conventional fuels
- Changes in design and scope resulting from developmental programs and definitive engineering analysis.

Table 1

COST INCREASES, JULY, 1973 TO JULY, 1975

<u>BLS Code</u>	<u>Item</u>	<u>Percent Increase</u>
1072010.03	Pressure Tanks	47 %
(Nelson Index)	Heat exchangers	97
11401.03	Centrifugal compressors	92
11401.02	Industrial pumps	42
1166.04	Chemical industry machinery	67
(CE Index)	Pipes, valves, and fittings	42
CE	Plant cost index	26

Source: SRI

All the estimates for TOSCO II oil shale plants considered herein are for the same shale rate (66,000 tons per stream day), but the assumed shale assay and net yield vary. The estimates were all reported by The Oil Shale Corporation (TOSCO).

In 1967, TOSCO estimated \$130 million would buy a plant capable of producing 52,200 BPCD (barrels per calendar day) of synthetic crude. A plant for the same amount of unhydrogenated pipeline oil would cost less than \$100 million. Natural gas was to be the source of hydrogen, so no

loss in yield resulted from upgrading. Shortages later forced TOSCO and partners to abandon this desirable source of hydrogen. Ironically, the same factor that increased the need for synthetic oil also made it more costly.

Reported costs paralleled general inflation through late 1968, but by 1972 costs had increased sharply. New environmental controls, including a change of plant site from the canyon to the mesa, were required. TOSCO and partners reduced the estimated shale assay and oil yield and made plant design changes as a result of the development program. The plan to market a low-sulfur fuel oil rather than refinery feedstock may have moderated the decrease in yield. Thus an increase of about 20 percent in the CE Index, which in this period was doing a reasonable job of measuring inflation, accompanied a doubling of cost per daily barrel.

The early 1974 estimate of \$9,900 per daily barrel was based on more definitive design and energy self-sufficiency for the plant, resulting in a lower yield. From this time on, design was fixed, but hyperinflation took its toll.

A paper on the confusing subject of cost escalation should mention the inadvertent confusion caused by failure of qualifying information to get into the reports. Within the space of a few days in autumn 1974, estimates of \$630 million and \$800 million were reported. The first was in constant dollars (as used in Figure 1), and the second included estimated escalation during the construction period at about 12 percent per year.

The estimates for March 1975 and autumn 1975 are more detailed than the earlier ones, and they show the need for caution in taking total estimates at face value.^{3,4} The first included \$79 million for acquisition of oil shale reserves not in the earlier estimates. The second increases this figure to \$155 million, mainly because the plant is assumed to run for 35 years instead of 20. The references also show a large increase in contingencies for nonplant facilities.

Tar Sands Case History

We consider the SCL Athabasca plant history herein but note in passing that the earlier Great Canadian Oil Sands (GCOS) plant was finished in 1967 with only about 25 percent overrun and that the estimate increased only about 25 percent during the last year of definitive engineering.

In early 1968 SCL estimated less than half the GCOS cost per daily barrel (\$2,400 Canadian) not including a power plant or pipeline, based on "second generation" economics, a better mine site, and a larger scale. In hindsight, economy of scale can be elusive when large plants are built in remote locations because the project aggravates labor shortages and much equipment is replicated rather than increased in size.

The 1968 estimate relied on several process steps that were in the development stage. For the summer 1971 estimate, draglines and unit trains replaced scrapers and belt conveyors for handling ore. However, abandoning energy self-sufficiency and substituting natural gas as fuel and as a source of hydrogen (and perhaps the larger scale) moderated the cost increases, so they were only a little above general inflation. SCL gave a range of expected costs at that time.

By 1973, GCOS had accumulated a \$90 million loss, and SCL was emphasizing proven reliability over development processes with theoretical advantages. For the removal of water and fines from the bitumen, dilution, centrifuging, and diluent recovery replaced flash dehydration. For upgrading of bitumen, fluid coking replaced hydrovisbreaking. The estimated syncrude yield was reduced. In a year and a half, process changes increased the cost more than 100 percent, and inclusion of a power plant and pipeline added another 25 percent to the increased amount.

After the 1973 estimate, Alberta entered an investment boom accompanied by extraordinary inflation until the end of the time covered in this study. The rapid increases in cost estimates prompted a political investigation to determine whether the oil companies had deliberately distorted the estimates. The investigation found no evidence of this but attributed the increases to severe and unanticipated escalation, additional preproduction costs from delays and increased manpower, and more definitive engineering. The December 1974 estimate was \$18,600 per daily barrel in constant dollars (used on Figure 1) and \$23,100 in current dollars for the initial capacity of 104,550 BPCD.

Learning Curves

Cost estimates usually increase as processes advance from the laboratory stage to commercial use, even without the extraordinary factors of recent years. Costs may decline because of the discovery of a new catalyst or corrosion inhibitor or the like, but usually optimism prevails until dispelled by hard data. After commercialization, unit costs often

decline as larger plants are built and safety factors are reduced. Figure 2 shows these tendencies and also the hazard of comparing directly an estimate for an advanced concept with a corresponding estimate for an established process.

Amortized production costs exclusive of raw material costs, in constant dollars (also called value added), correlate well with cumulative production of an industry.⁵ Typically this cost decreases 20 percent every time cumulative production doubles. In the early stages, an industry frequently grows exponentially with time, so a linear time scale may be superimposed on a logarithmic production scale, as shown in Figure 2. For capital intensive industries, the capital cost tends to dominate the cost of value added, but raw materials are affected too much by extraneous factors to be correlatable.

Decreasing trends will probably apply to synthetic fuel costs eventually, but the time to design and build a plant is so long that benefit of experience will be slow in coming.

Implications for Cost Estimating

Table 2 lists factors that apply during the various stages of process development. This table cannot quantify cost uncertainties, but it can alert a person to omissions and unresolved questions in an estimate.

How to account for the stage of process development in an estimate is partly a matter of philosophy. On a statistical basis, less developed processes justify higher contingency allowances, but too much caution inhibits desirable research and development. Hopefully, using Table 2 as a check list will lead to better estimates in the early stages.

In summary, the cost of developmental processes may be affected by factors other than escalation as follows:

- Raw material and product specifications
- Overall process yield
- Project scope and auxiliaries
- Process variables and subprocesses
- Materials of construction--corrosion, erosion.

The following factors may affect either developmental or commercial project costs:

- Energy and raw material availability
- Environmental regulations
- Optimization versus derating.

Derating refers to loss of capacity through installation of pollution control systems, change of raw material, and the like. Potential bias may affect estimates in the form of contingencies, redundancy for reliability, and accounting practices such as capitalizing development costs and some operating costs.

As to the future, the environmental movement and energy shortage have been with us long enough that they are unlikely to cause the surprises of the past. Equipment shortages tend to attract competition, although time is required for the competition to become affective. Thus plant costs at constant scope seem likely to parallel more closely those of the general economy. Estimators may temper early over-optimism in development projects by being aware of its prevalence and by considering what questions are unresolved at the time of the estimate.

Table 2

STAGES OF PROCESS DEVELOPMENT

Scale of Development	Possible Unresolved Questions	Inaccuracies in Estimates	Estimator
Bench	All but main reaction	Only major unit may be considered. May neglect: installation cost, engineering, indirect costs, upstream, downstream, and storage costs, effect on existing equipment and capacity, cost of capital.	Perhaps inexperienced estimator, such as lab personnel or professor. Perhaps estimate is only a publicity release.
Small pilot (process development)	Materials of construction Raw material specifications Product specifications Catalyst life and cost Process materials life Effect of simulated feeds Effect of long-term recycle operations Effect of scale-up on yield structure	May have major effect. May require pretreating process. May require purification process. Sometimes major. May affect operability as well as cost. Trace components may require major process changes. May require major process changes or different materials of construction. Affects capital as well as operating cost for a given product rate. Scale-up more difficult for processing solids than fluids.	Probably a process engineer

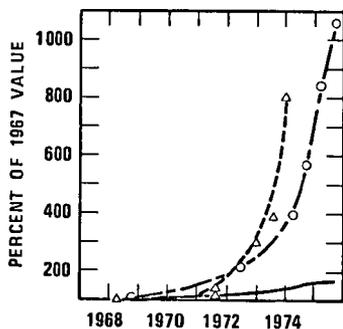
Table 2 (Concluded)

Scale of Development	Possible Unresolved Questions	Inaccuracies in Estimates	Estimator
Large pilot, prototype, or demonstration	Environmental requirements Complete integration with other processes Auxiliary unit process costs	May have a major effect. May create control problems. Historical data may not be valid because of changed requirements. Example: electrostatic precipitators.	Process engineer or engineering contractor
Commercial	Changing ground rules: unavailability of raw materials, unavailability of fuels, new environmental regulations, political opposition Remote area effects Potential bias Redundancy Capitalized development and operating costs Shortages and tight money Technological advances	Delays from changing ground rules, strikes, and bad weather are costly. Community and infrastructure development costs Licensors and promoters might tend to be low; companies seeking government support might tend to be high.	Engineering contractor
		Estimates based on historical costs may be high.	

Source: SRI

REFERENCES

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3. "TOSCO Proposes a Government/Industry Program to Reactivate Colony Dow West Oil Shale Project," Synthetic Fuels 12 (2), 2-1 (June 1975).
4. J. A. Whitcombe, "Oil Shale Developments: Status and Prospects," paper prepared for Soc. Pet. Engr. of AIME, 50th Annual Fall Meeting, Dallas, September 28-October 1, 1975.
5. D. M. Nathanson, "Forecasting Petrochemical Prices," Chemical Engineering Progress 68 (No. 11), pp. 89-96 (November 1972).



○ — — — TOSCO Oil Shale Plant
 △ — — — SCL Tar Sands Plant
 — — — CE Plant Cost Index

Plants based on constant dollar estimates in \$/BPCD of net synthetic crude.

FIGURE 1 CAPITAL COST INCREASES

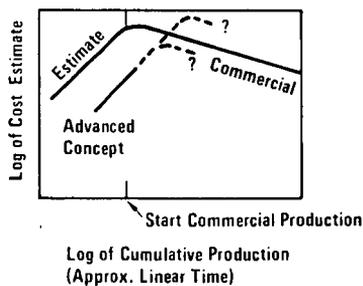


FIGURE 2 LEARNING CURVES