VALUE ENGINEERING IN AN ESCALATING BUSINESS ENVIRONMENT

David Nash, CB&I

3102 East Fifth Street
Tyler, Texas 75701
www.CBI.com

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SUMMARY

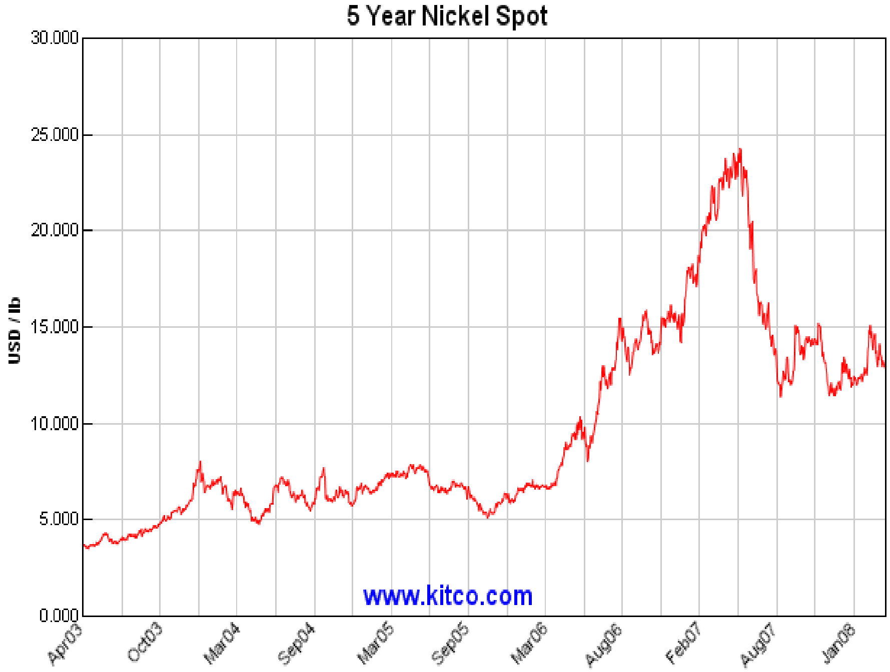
The EPFC (engineering, procurement, fabrication, and construction) business environment serving the hydrocarbon processing industry has experienced price escalation of services offered due to concurrent high demand, rising material costs, and rising labor costs—most notably since 2002. This paper documents the elements of the price escalation, and applies the concept of value engineering as a solution to move forward capital projects exposed to cost strains. Here, a few real-world examples are shared, offering lessons-learned and strategic considerations leading to successful value engineering.

CURRENT EPFC BUSINESS ENVIRONMENT

Worldwide demand from the hydrocarbon processing industry for EPFC services has increased dramatically since 2002. This higher demand, coupled with rising costs for material and labor, has led to increased price tags for projects. Part of the escalation appears to be due to rising raw material costs. Figure 1, Nickel Prices,[1] shows increases in price per pound from below $5 prior to 2005 to a peak of near $25 in mid-2007. This translates to higher costs for nickel containing alloys, and any downstream element of the value-chain containing nickel—including entire process units such as hydrotreaters and hydrocrackers.

[1] From website http://www.kitcometals.com/charts/nickel_historical, Jan 8, 2008.

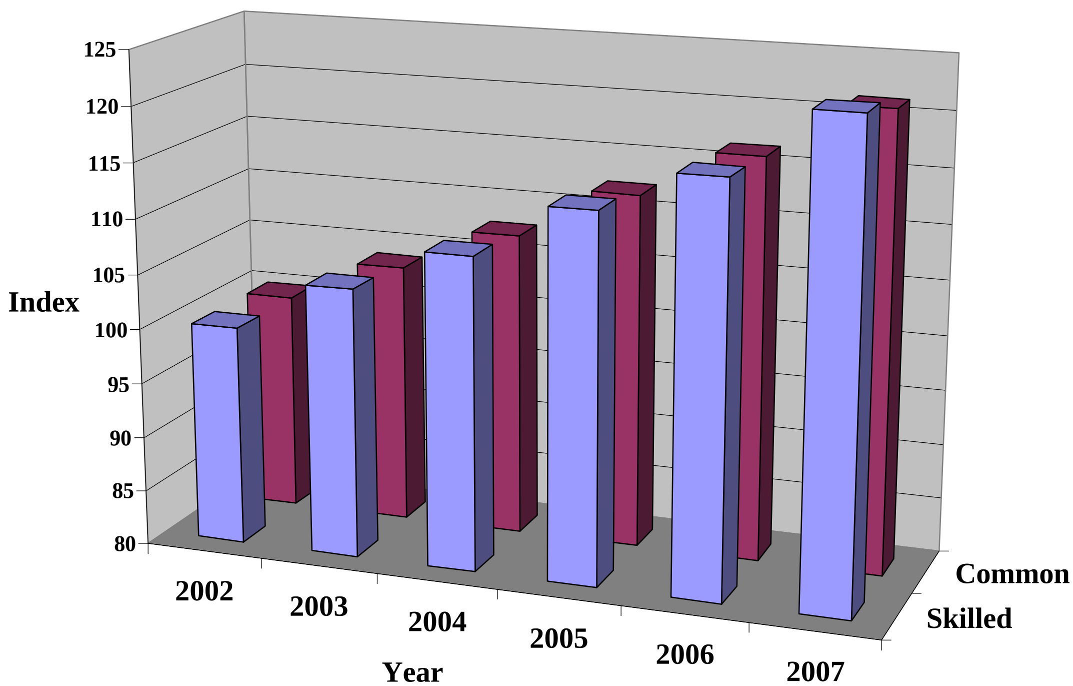
Figure 1



Nickel Prices

Refinery construction labor costs have also increased significantly. Figure 2, Construction Labor Index,[2] illustrates labor cost increases since 2002. Cost has risen more than 20% during a five-year period, however total construction costs have risen even higher due to lower productivity and labor incentives such as per diem cost increases.

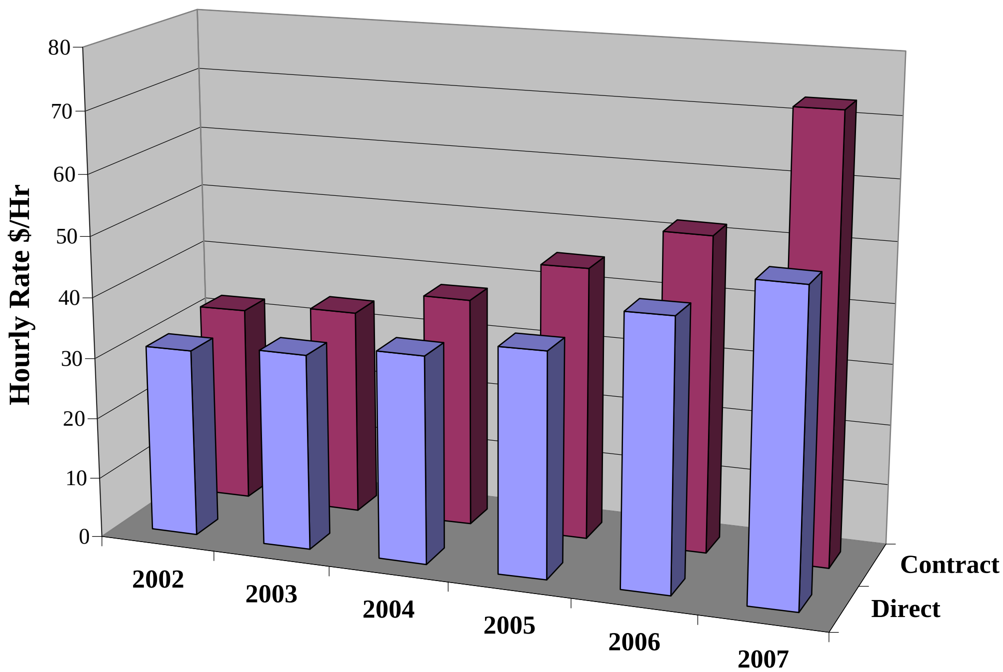
Figure 2 Construction Labor (hourly rate)
2002=100



Engineering costs have increased as well. Most notable is the cost of pipe drafting/design labor. This component of engineering has escalated more than 60% since 2002 and now commonly exceeds half of total engineering costs. Refer to Figure 3, Pipe Drafting Labor[3].

[2] *Oil & Gas Journal*, Jan. 7, 2008, p.55
[3] CB&I Internal Data

Figure 3
Pipe Drafting Labor Rates



Related to increases in raw material costs, equipment costs have also increased. However the increases can only partially be explained by raw material costs. Equipment supplier margins are healthy (due to demand) and certainly a contributor to price escalation. Take for evidence General Electrics' infrastructure division with a record $120B of backlog[4]. CB&I recently received re-quotes on equipment originally quoted in late 2004. Twenty-eight months had elapsed between quotes. Equipment quoted was identical (and incidentally, part of a ULSD process unit). Figure 4, Equipment Cost Escalation, illustrates the cost increases. Annualized cost increase is more than 25% for this time period.

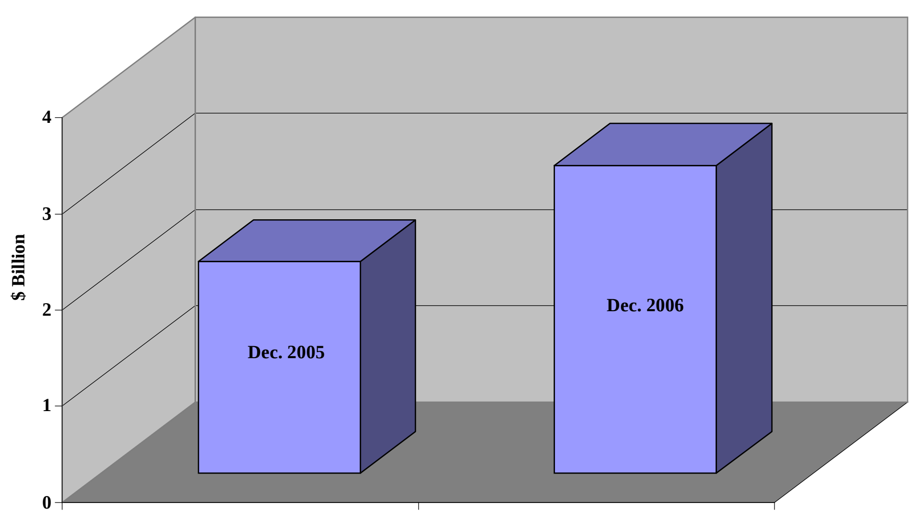
[4] General Electric 2006 Annual Report, p. 4.

Figure 4
Equipment Cost Escalation
ULSD HTU - Dec. 2004 to Apr. 2007

	% Increase	28 Months Avg. %/Mo.
Pressure Vessels	66.2%	2.4%
Heat Exchangers	47.4%	1.7%
Air Cooled Exchangers	59.4%	2.1%
Pumps	69.9%	2.5%
Compressors	61.3%	2.2%
Fired Equipment	50.0%	1.8%
Miscellaneous Equipment	58.9%	2.1%
	59.70%	2.1%

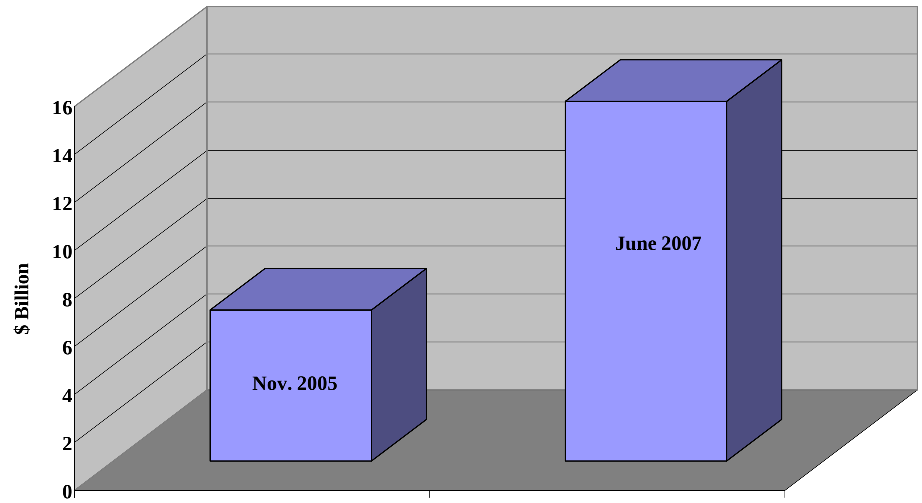
As to be expected, the escalation of labor, materials, and equipment has resulted in project escalation. Project escalation is evident in at least two well-known major refinery capital projects. Refer to Figure 5[5,6] and Figure 6[7,8]. Marathon's new Garyville 180 mbpd refinery expansion experienced an increase of nearly one-third in the space of a year; Kuwait National Petroleum's new 600+ mbpd grass roots refinery cost estimates have doubled in less than two years.

Figure 5
Marathon Garyville
180 mbpd Refinery Expansion



[5] Garyville Gains Piece of $2B Marathon Expansion, *New Orleans City Business*, Dec. 14, 2005
[6] Marathon Petroleum Company press release, Nov. 7, 2006
[7] Kuwait Sees Increase in Refining Capacity, *The Boston Globe*, April 2, 2006
[8] Kuwait Doubles Cost Estimate of New Refinery, *Arab News*, May 9, 2007

Figure 6
Kuwait National Petroleum
615 mbpd Grass Roots



How are management decisions relating to capital expenditures in this environment of escalation influenced? In most cases, negatively. Cash reserves are increasingly being spent on stock-repurchase. For example—Chevron recently announced a $15B stock repurchase[9]. Obviously capital ventures continue—albeit with trepidation. To tie these experiences with the current business environment of escalation, the concepts of value and value engineering will be considered.

VALUE ENGINEERING

Value engineering is defined as a systematic method to improve the value of goods and services by using an examination of function. Value in this context is defined as the ratio of function over cost. A primary tenet of value engineering is that function is at least maintained. So, you can improve the value by improving the function—or decreasing the cost. Decreasing the function violates the definition.

Value engineering was discovered at General Electric Co. during World War II. Due to shortages of labor, raw materials, and equipment parts Lawrence Miles and Harry Erlicher were looking into the use of acceptable substitutes[10]. An unexpected and surprising outcome resulted—some of the substitutes reduced costs, improved the product, or both! What started out as an accident of necessity was developed into a systematic process which at the time was named value analysis.

APPLICATION OF VALUE ENGINEERING – FIVE EXAMPLES

Even though the current situation is not as critical as during WWII, today's environment of high demand and escalation certainly lends itself to apply the concept of value engineering.

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[9] Chevron Corporation press release, Sept. 26, 2007
[10] Value Engineering, website *wikipedia.org*, Jan. 25, 2008

Following are a few examples of actual business experiences and varying approaches to challenges resulting from the current environment. The consideration of value engineering is relevant for each.

EXAMPLE 1 – DOA

A client requests a proposal for a new grass-roots crude unit with an integral gas plant. Given high energy costs, the crude heater is to be high efficiency, and the crude preheat train is to recover maximum heat. A dual-parallel heat exchange train allows greater heat recovery made possible by improved approach temperatures. The dual train also allows for mid-cycle cleaning of individual heat exchangers with less interruption to the operation—another advantage. As a result of increased equipment, capital cost is greater with a dual train. To provide for feedstock flexibility, metallurgical upgrades are specified for the high temperature equipment and piping to allow processing of high-acid crude feed. To allow mid-cycle heater decoking, the crude heater service is designed with two parallel heaters. These features improve the function of the proposed unit by providing reduced operating cost (utilities and maintenance) and feedstock flexibility.

During a three-month period the process design specification and an LSTK proposal are developed. The cost estimate for the proposal is based on firm quotations for equipment from suppliers. The proposal was received with a reaction of acute sticker-shock. Due to unanticipated escalation, the offering was rejected, as the price was much higher than expected. The proposal was dead-on-arrival—a victim of escalation. Suspicions arise on the accuracy and integrity of the proposal; the supplier's good-faith is questioned.

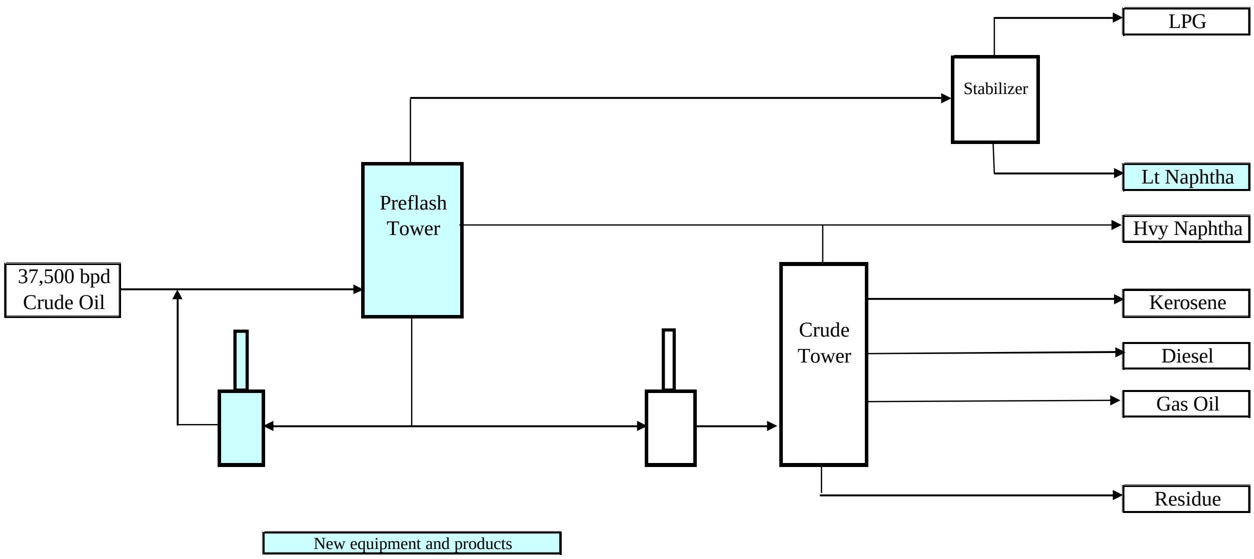
A resuscitation phase is then initiated in an attempt to reduce capital costs and revive the project. Capital cost reductions are attempted by eliminating some of the value added features mentioned above. After replacing the dual-parallel preheat train with a single train, use of a single crude heater, and lesser materials of construction, costs were reduced. Additionally, capacity was reduced and pre-investment for future crude capacity in key towers was eliminated. Despite these efforts, a re-estimate only dropped the project cost by 15%. To get to this price, however, function was severely compromised. Given the value of the deleted features, overall value engineering was negative. The ratio of function over cost actually decreased with attempts to reduce cost. Strictly following the definition of value engineering, whereby the function is either maintained or improved, any deviation from or elimination of function is considered to be "negative." As the cost-cutting had a decrease in function, the use of the term "negative" value engineering is used here.

Also at play here was an opposition to economy-of-scale; the throughput reduction, all else equal, resulted in an increase in CAPEX per barrel of feed.

EXAMPLE 2 – THE DEBOTTLENECK

Substitution is another tenet of value engineering. Debottlenecking as an alternate to a new grass-roots unit meets this criteria. Function can be met (increased capacity) with reduced cost (utilize existing infrastructure). Certainly the throughput increase is not as comparable to that of a new grass roots unit, however the incremental barrel increase does have a capital cost advantage—and is solid value engineering. In this example the client cleverly added some features to add value to the overall base operation; these features were not related to capacity increase. Among them was improved hexane recovery to meet benzene regulations. This was accomplished with a new light naphtha product stream. Figure 7 illustrates the proposed scheme. A new plot area adjacent to the existing crude plot includes a new preflash tower and its associated fired reboiler.

Figure 7
Proposed Scheme



Other value added features: improved heat recovery with a new pumparound on the preflash tower and a re-configuration of the preheat train that includes a parallel arrangement to allow mid-cycle maintenance. This same feature that was removed from the previous example works well here; function is increased at a small incremental cost (most of the cost was associated with the extra capacity). Also addressed is the ability to process a wider range of feedstocks and operate the unit at less than 50% of design feedrate. The latter was accomplished with isolation valves that allow the preflash tower to be bypassed such that the original process scheme can be operated. Here again function was improved at little cost, as revisions were necessary anyway for the capacity increase.

Economics are favorable, the project is approved and proceeds.

EXAMPLE 3 – OFF-THE-SHELF

Another client requests a proposal for a duplicate unit based on a CB&I Ultra-Low Sulfur Distillate (ULSD) hydrotreater designed and built in 2004. Duplication, as applied to value engineering will result in an identical function at reduced cost. Cost reductions are realized due to engineering; a copy of the same plot, piping, and process scheme saves over 50% on P&IDs, pipe design and drafting costs. However, as expected, a few issues regarding the use of a duplicate unit were challenged.

One necessary change was in the makeup hydrogen compressor service. The base unit had three stages of compression. For the new service only two stages of compression were required. A good fit was to introduce the makeup hydrogen to the second stage compressor suction. This worked well as deletion of the first stage did not compromise the piping and plot duplication cost advantage for the other stages.

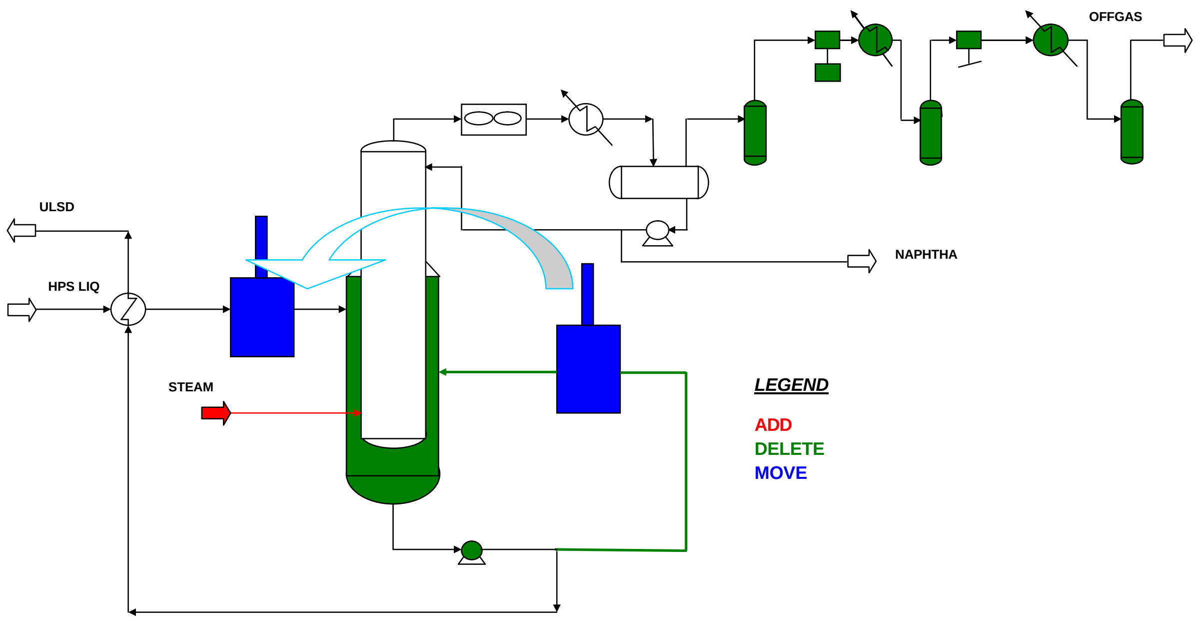
Another change to the duplicate base unit was driven by opportunity—not necessity. The stripper overhead has a two-stage overhead compressor that delivers sour gas to the refinery amine treating system. Recognizing recent equipment escalation, the client applies value engineering to the overhead scheme—and wonders—can the stripper pressure be raised to where the compressor can be eliminated? After careful consideration, the client determines, “Indeed it can.”

The tower would need to have the same function (meet product flash specification), however a substitute scheme, if possible, would need to be developed. Figure 8, Stripper Modifications, illustrates the revisions. Stripping vapors are now provided by live steam injection as vaporization of product is not practical at the higher operating pressure. The fired reboiler still has use as a feed heater and is relocated. With the elimination of the fired reboiler, the following can be deleted:

- reboiler circulation pumps, and
- related tower bottom sump inventory.

These eliminations result in additional cost reductions. True, overall capital cost is decreased but operating cost increases with the use of stripping steam. For this application, steam is available from the refinery steam system without investment. Overall life-cycle costs are reduced with a constant function of stripping product to meet flash point specification. This is a great example of the application of value engineering. The result is an improved substitute design without offgas compression. Function is maintained.

Figure 8
Stripper Modifications



EXAMPLE 4 – REVERSE ENGINEERING

A client requests a modest crude unit expansion and improvements to address reliability issues. The client is well aware of escalation issues, and asks for many checkpoint budgetary estimates that drive decisions and direction of the study at intermediate reviews. (In hindsight these checks later proved to be very useful as capital and scheduling constraints surfaced.)

Initially five cases were developed, with each case building on the previous case. Refer to Figure 9, Case Development and Definition. In this table improved function and increased capital costs are noted for subsequent cases (left to right).

Figure 9
Case Development and Definition

IMPROVED FUNCTION ========>
INCREASED CAPEX ========>

	Case 1	Case 2	Case 3	Case 4	Case 5
Improve Desalting	x	x	x	x	x
Feed pump upgrade		x	x	x	x
Add parallel crude preheat			x	x	x
Upgrade Crude Heater			x	x	x
Lower crude/vac pressures				x	x
Increase HVGO PA hx.					x

With numerous cases to examine, confusion was a concern. Documentation for each case was developed including scope description (including unit capacity), material balance, benefits, trade-offs/drawbacks, and budgetary capital cost. The presentation of this information as a menu of quick reference tables provided efficient and accurate communication.

As the study developed the following priorities became tied to an approaching turnaround:

1) Improve safety and reliability of unit. The reliability issues become higher priority late in the study as a result of unusual incidents including loss of containment and resulting fire on at least two occasions.
2) Minimize turnaround scope. Identify (and order) critical equipment that requires installation during the upcoming turnaround.
3) Identify pre-turnaround and post-turnaround scope.
4) Choose a case (or develop a sub-case) that maximizes value, can be implemented within the given time-frame, and does not exceed capital constraints.
5) Consider pre-investment in unselected future cases to reduce future costs.

The following Figures 10, and 11, illustrate examples of documentation provided for each case.

Figure 10

Case 1

Scope of Work	• Relocate existing desalter vessel from the Residfiner unit to the No 3 Crude unit as 2nd stage desalter. Install Petreco bielectric grid. • Install new Desalter water recycle pumps. • Install a new crude preheat line and steam-heated S&T exchanger parallel to the existing cold preheat train.
Unit capacity	• 92 MBPD (existing capacity)
Benefits	• Reduces water content in crude feed to Atmospheric tower, reducing fired heater duty required to boil the water (~8-9 MMBtu/hr reduction). • Corrects cold-train hydraulic restrictions.
Trade-offs /drawbacks	• No additional capacity provided • Higher utility usage than using pump-around exchangers to heat crude. • Does not address existing issues with heater feed control valves and heat flux rate.

Figure 11

Case 5

Scope of Work	• Increase HVGO PA cooling to allow tower operation at lower pressure. o Scope includes adding additional HVGO/ Crude PA exchangers.
Unit capacity	• 105 MBPD
Benefits	• Provides targeted unit capacity • Improves VGO yields, reducing coker feed rate • Avoids the need for high-temp alloy exchangers for HVGO PA service.
Trade-offs /drawbacks	• Highest cost

Figure 12, Capital Cost Table, illustrates the format for presenting the capital costs. Note a few additional sub-cases were developed and provided in this figure.

Figure 12
Alternative Design Cases - Cost Comparison

	Case 1 Total	Case 2 Total	Case 2.4 Total	Case 2.5 Total	Case 3 Total	Case 4 Total	Case 5 Total
Equipment	$1,507,300	$1,940,200	$3,858,000	$4,261,800	$6,715,500	$7,036,400	$7,377,900
Materials cost	$1,156,500	$1,158,200	$1,974,200	$2,241,700	$3,646,500	$3,826,100	$3,895,400
Construction Labor	$3,294,100	$3,415,700	$6,227,700	$7,025,500	$11,090,600	$11,616,200	$11,775,500
Construction Indirects	$1,755,300	$1,820,000	$3,318,400	$3,743,500	$5,909,600	$6,158,200	$6,274,500
Freight	$106,600	$123,900	$233,300	$260,100	$414,500	$434,500	$450,900
Engineering / Home Office	$1,563,900	$1,691,600	$3,122,300	$3,506,500	$5,555,300	$5,802,500	$5,954,900
Project Cost	$9,383,700	$10,149,600	$18,733,900	$21,039,100	$33,332,000	$34,873,900	$35,729,100

In this example it can be seen in the case selected (ultimately, case 2.4), the scope was chosen by reverse engineering from a set of priorities including capital and time constraints. This is another good example of value engineering. In this case value is maximized within scheduling and budgetary constraints.

EXAMPLE 5 – THE OVER-ZEALOUS PROJECT MANAGER

Raising the bar for setting a goal of exceptional achievement in project schedule is certainly a good cause. The term fast-track is the commonly used buzz word to communicate these stretch schedule targets. Several traps to executing these aggressive schedules:

1) In the current environment deliveries of equipment are extended.

2) The current environment supports having a longer schedule—not shorter—for value engineering in front-end design.

The above is obviously in conflict with achieving the promised fast-track project execution. Something has to give. What results is the fact that schedules are so short• they are practically unachievable, resulting in projects that are out-of-order from the start. The paradigm is the fact that longer front-end schedules will result in fewer changes in detailed engineering, and result in a net decrease in the schedule of overall project execution. The last person to recognize this is the over-zealous project manager who forces the short project schedule backwards from the unrealistic mechanical completion date to where process engineering has essentially zero schedule.

Detailed engineering should not begin until the basic design is frozen. Experience teaches that basic design changes are killers to cost and schedule. It makes sense to not begin detailed engineering until a decision is made about what is going to be built (the frozen basic design), and a plan is developed to guide execution and management. But this is, indeed, what can happen to most projects frequently driven by schedules that are too short.

To summarize, unrealistically short schedules result in negative value engineering:

- Missed functional improvements (no time to evaluate or plan, for example, deleting a stripper OH compressor as above).
- Project cost increases due to numerous revisions related to not following the proper work sequence.

CONCLUSION

Volatile material, equipment, labor, and energy prices underscore the need for value engineering more than ever, as part of front-end process engineering and design scope. The often used wait-and-see proposal approach with firm pricing should have intermediate stop gates to avoid surprises and project death-by-escalation. Scope development involves teamwork and communication between contractor and client. Proven relationships are invaluable in this regard. Be suspicious of any impressively short schedule that is offered in proposals; the current environment suggests otherwise for proper execution including practice of the proper work sequence; up-front design value improvement opportunities are likely never realized due to an overly aggressive project schedule.

The five tenets of value engineering discussed herein are:

1. Function
2. Substitution
3. Duplication

4. Reverse Engineering
5. Implement scheduling and budgetary constraints

Remember, in order to avoid negative value engineering, function, the primary tenet of value engineering, should at least be maintained or improved for project success.