Strategies for Alumina Refinery Optimisation

Andrew Furlong[1] and Jock Armstrong[2]
1. Principal Process Engineer,
2. Global Subsector Leader, Bauxite and Alumina,
Advisian, Brisbane, Australia
Corresponding author: andrew.furlong@advisian.com

Abstract

Alumina refineries must continually improve to remain competitive. However, sustaining any improvement presents a challenge due to the complexity of the refining process. Cost reduction programs are often reactive involving personnel reductions and maintenance and capital deferrals. Frequently such cuts are ultimately unsustainable and degrade asset performance over the longer term. To achieve a sustainable improvement in cost curve position requires a combination of process optimisation, innovative enhancement, operational excellence and effective asset management, underpinned by robust systems and effective leadership. This entails an ongoing ability to maintain robust and efficient operation, nullify threats and identify and capture improvements even while the refinery assets are ageing over time and being further 'squeezed' for performance. This paper explores these improvement strategies and provides guidance on opportunity identification, the work processes and systems that drive the ongoing performance of the refinery and optimising improvement programs for maximum value.

Keywords: Cost Reduction, Improvement, Optimisation, Operational Excellence.

1. Introduction – the Improvement Conundrum

The Aluminium price, like many commodities, is cyclical in nature due to the delay between investment decisions and additional capacity. This results in oscillations between oversupply and excessive demand. Behind these cycles, however, there is a relentless reduction in real aluminium price over the long term, as shown in Figure 1. This is to be expected in a highly competitive commodity environment. Over time, improvements in technology and operational practices drive efficiencies that lower production costs. This trend places pressure on all operators to continuously improve in order to maintain profitability and the long term viability of their asset.

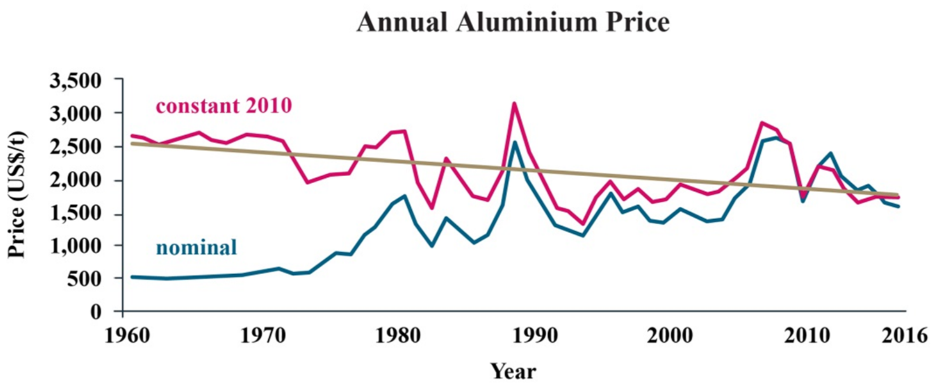

Figure 1. Declining Real Aluminium Price [1].

Whilst continuous improvement is desired, the complexity of the refining process and its associated plant and equipment presents a challenge to sustain any cost reduction. Additionally, improvement gains must be achieved whilst the refinery asset ages over time and often with declining bauxite feedstock quality.

The continuous improvement mantra is thus ‘get more out of what you’ve got’. But are improvement and optimisation really a case of ‘running the machine harder’, of ‘sweating the asset’? The definition of efficiency suggests otherwise: increasing efficiency requires less work and produces more with less effort. There are several industry studies that conclude the highest performing assets undertake least work, the lowest performing assets undertake the most work [2], [3]. Perhaps then improvement is more closely related to working smarter, not harder?

1.1. What Does Sustainable Improvement Look Like?

Optimisation strategies should deliver improvements in business performance that are sustained over the long run. But what does sustainable improvement look like? Sustainable improvement involves an ongoing ability to identify and capture a range of improvements, to manage and mitigate risks, to maintain or improve plant availability and reliability. It involves a proactive approach and a broad perspective.

Contrast sustainable improvement with the narrower perspective of reactive cost reduction. Such cost reduction programs target those savings that can be most rapidly implemented, typically personnel, maintenance reductions and capital deferrals. Often ‘the cart is put before the horse’ - we do away with people and spending before streamlining the processes and systems that allow us to do so. With sustainable improvement cost reductions are the outcome, not the action of a focus on efficient operation. The inherent philosophy is that efficiency improvements must be realised before cost saving. Otherwise cost reduction may have the opposite effect, removing resource and funds from an inefficient process and therefore risking degradation in asset performance over the longer term.

Sustainable improvement is closely aligned to operational excellence. In fact it can be considered as an outcome of an operationally excellent organisation. Such organisations exhibit a systemic and ever-evolving effective approach to their operations. Process efficiency and effectiveness is supported by the organisation’s values, leadership and culture, as well as its systems and structures which are optimised across functional boundaries. They do the right things, in the right way, to continuously improve business performance.

The output of a sustainable improvement program should simply be to improve the value of the business. Initiatives either capitalise on an opportunity (maximising value) or mitigate risks (minimising loss of value). Initiatives should be defined in terms of the value they create using measures of Net Present Value (NPV) or Return on Investment (ROI), and if they do not add value, simply not progressed.

2. Understand your Performance

Ideally, refinery operators look to implement those improvements which provide the greatest financial value to the business within existing resource constraints. Of course, refinery operators know their own plants best, but that doesn’t always translate into a full understanding of where the value opportunities lie. There can be a variety of reasons for this. Often, personnel may consider themselves ‘too busy’ firefighting daily emergencies to assess opportunities or threats and carry out root cause analyses, or simply the data required for assessment may be lacking.

Understanding your performance is a key, recommended component of any improvement program. It’s fundamental to understanding the value opportunities. In particular, benchmarking the performance of your refinery against key industry metrics, allows performance gaps to be identified. This high level "helicopter view" of the operation provides a simple but fundamental picture of how you measure up versus your competition.

To provide the most relevant information when benchmarking against industry data, it is important to make allowance or adjustment for the feedstock bauxite quality and installed refinery configuration. For example, a refinery's energy consumption will be influenced to some degree by the bauxite composition, by whether gibbsitic, boehmitic or diasporic bauxite is being processed, or a form of the sinter process is being utilised.

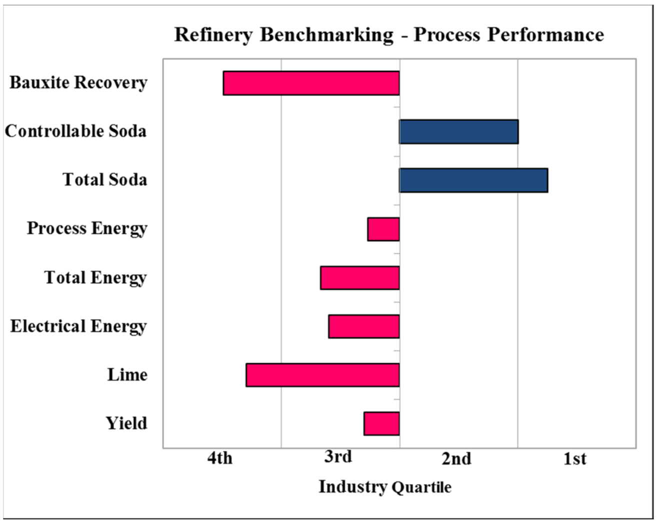

Figure 2. Example refinery benchmarking – process performance.

Once pricing information is applied, the financial impact of each performance gap versus benchmark can be defined, for example a bauxite recovery 'gap' can be translated to a monetary 'gap'. This allows further analysis and opportunity identification to be prioritised on the basis of maximum financial return. Thus, by aligning improvement plans against the identified value gaps, benchmarking provides a critical early input to the refinery optimisation planning process and assists in positioning the business securely over the long term.

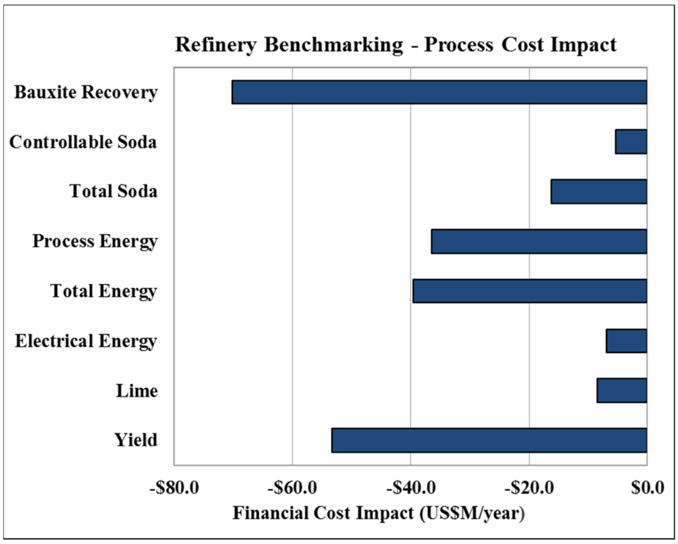

Figure 3. Example refinery benchmarking – process cost impact.

A word about the importance of data! Data is a pre-requisite for fact-based decision making and proactive root cause analysis. By definition, understanding your refinery relies on the availability of data. First, for the benchmarking process itself, and then for subsequent deeper investigation of value gaps and opportunity investigation.

2.1. Parameters to Assess

A key focus should be energy, bauxite and raw caustic consumptions as these represent the majority of refining costs, and provide an effective hunting ground for long term cost improvement. Plant availability and stability, maintenance cost per tonne, maintenance type, labour productivity, production rate versus the benchmarked capability of the major installed equipment, and product quality are other suggested valuable metrics.

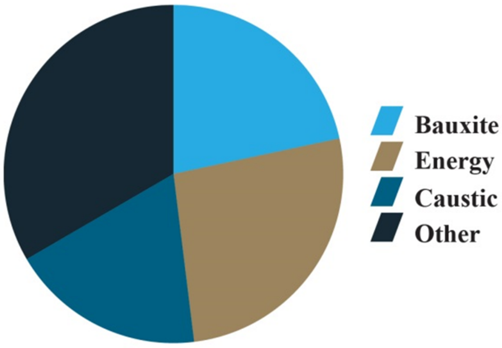

Figure 4. Illustrative alumina production operating cost breakdown.

3. Translating Performance Benchmarking into Technical Opportunities

Sometimes the benchmarking and gap analysis process will by itself reveal some seemingly obvious and specific opportunities. More frequently, it will point towards general areas and pathways for cost improvement and uncovering specific opportunities themselves may require more in-depth analyses and specialist knowledge.

As previously stated, sustainable improvement requires a broad perspective. Having one idea and subsequently implementing it is relatively straightforward. However, an operating alumina refinery is a multi-dimensional complex plant with many layers of working parts and inputs both human and non-human, inter-dependencies, recycles, reactions and side reactions, planning and routines. In that context, whilst generating an improvement roadmap with an optimised set of improvement initiatives is not quite an art form, it's important to have the correct 'recipe'.

Experience suggests one important ingredient is to assemble the right team of people to workshop, explore and generate a diverse range of opportunities, thereby providing vital initial impetus to the refinery optimisation program. Expected traits of such a team are that it would consist of industry experts with a strong balance of skills and experience across technical, operational, and maintenance aspects, meshed with a business focus, a view of the bigger picture, an ability to apply thinking skills.

Another ingredient is a wide focus, to be open to a broad range of opportunities. This includes initiatives based around process optimisation, operational improvements, asset management, control loop strategies, minor piping reconfigurations etc. which are typically zero or low capex; higher capex initiatives such as capacity debottleneck or expansion, technology upgrades etc.; and also innovative enhancements (which may be either 'low' or 'high' capex depending on their nature). The idea is not to target a certain initiative or type of initiatives for the sake of it, but to focus on where the value is, and go from there. Awareness of the value gaps and the financial benefits of unit changes in various norms such as bauxite recovery, plant availability, percent unplanned maintenance or evaporation increase etc. is thus very useful.

It's normally unrealistic to close all value gaps and therefore achieve benchmark performance across all metrics. This could require significant capital spending and therefore may not generate attractive returns. However, experience shows it is not unreasonable to consider up to ~40% closure of the total "gap" as a realistic achievable target at reasonable investment rates (~ two-year payback period). The majority of opportunities can be zero or low capex initiatives which can result in quick, upfront savings. After these early wins, there will likely be further longer terms items that involve more capex spend or maintenance systems overhaul etc.

3.1 Potential Targets

It is not the intent of this paper to provide a generic list of specific improvements that can be applied across multiple refineries. Each refinery is physically different, with different value gaps and drivers, and necessarily different solutions should be targeted. However some general areas that are typically worth targeting are listed below for consideration, and there can be others.

Table 1. Examples of items that may yield technical opportunities.

Item	Category	Benefit	Cost
Human behavioural issues	Operational	Production, efficiencies, maintenance	Zero, low
Equipment cleaning management and residual life	Asset management, operational	Production, efficiencies, maintenance	Zero, low
Process stability assessment	Operational, control, asset management	Production, efficiencies, maintenance	Zero, low
Water balance	Operational, process optimisation / technology, innovative enhancement	Production, efficiencies	Zero, low, high
Caustic, alumina and temperature profiles	Process optimisation, operational, innovative enhancement	Production, bauxite, energy	Zero, low, high
Repurpose existing spare or under- utilised equipment	Process optimisation, innovative enhancement	Production, efficiencies, maintenance	Low, high
Un-optimised / undesired chemical reactions	Process optimisation, innovative enhancement	Production, efficiencies, maintenance	Zero, low, high
Process trade-offs	Process optimisation	Production, efficiencies	Zero, low
Understanding of equipment capacity constraints	Process optimisation, innovative enhancement	Production	Low, high
Process and Equipment Technology review	Process technology / innovative enhancement	Production, efficiencies, maintenance	High
Flowsheet reconfigurations	Process technology / innovative enhancement	Production, efficiencies, maintenance	High

'Low hanging fruit' targets include behavioural type operational issues such as excessive water injection, bypassing of equipment or control valves, inadequate cleaning durations etc. Amongst these items, a common theme can be a lack of understanding at shop floor level that actions undertaken may be misaligned with business value. This itself can be symptomatic of larger systemic issues such as a lack of communication or training, asset management and procedural inadequacies, or cultural and leadership problems.

Common process optimisation trade-offs such as yield based production versus flow [4], [5], and production capacity versus alumina extraction [6], are covered elsewhere in the literature.

Various flowsheet configurations have also been widely covered such as double digestion [7], whilst Worsley Alumina's patent on improved causticization [8] is an example of an innovative enhancement that has examined chemical reaction extents and pathways. Whilst the decision on any technology upgrade should always be business value based, refinery operators would be wise to keep track of such enhancements and other equipment technology developments.

Plant stability is commonly understood to lead not only to improved production but all round better efficiency and raw material consumption performance. One way to statistically analyse this is through Weibull plots [9].

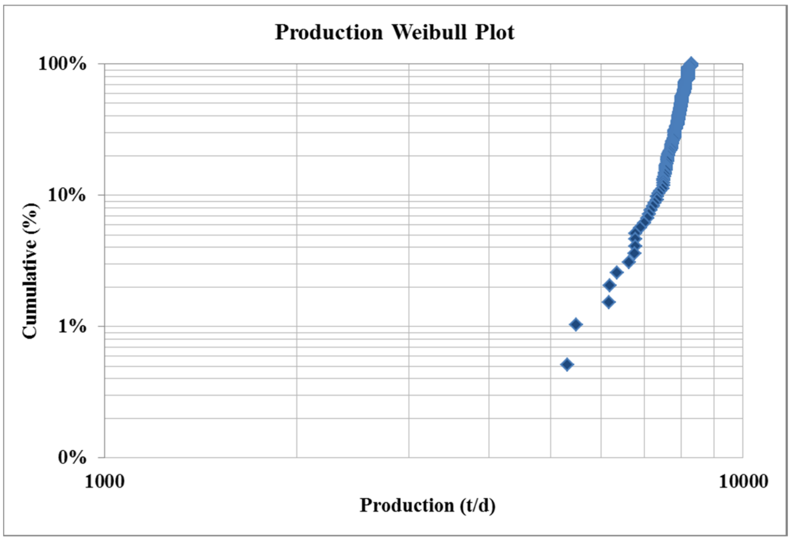

Figure 5. Production rate weibull plot.

Weibull plots may be used to examine reliability issues. They can assist with determining whether the reliability problem is with equipment or with the production process. This is worth understanding as the cost of process failures often far exceeds the cost of individual equipment failure. Figure 5 is an example of a Weibull plot for production rate in a refinery over a yearly period. It shows a plot of the log of daily production against the log of percent days below that daily production rate. The slope of the straight line section is an indication of process stability, steeper equates to less day to day variation. The length of the straight line provides a measure of reliability with the point at which the tail breaks from the line being the percent of days that are "special cause" events.

4. Operational Excellence and Refinery Systems of Work

The performance of every refinery is underpinned by the functioning of various processes and systems of work. These systems encompass all the various short, medium and long term aspects of the business. They include the people, safety, maintenance, operations, technical, information, business improvement and business planning processes. These systems provide robustness to the refinery operation and are the solid base upon which refinery performance depends.

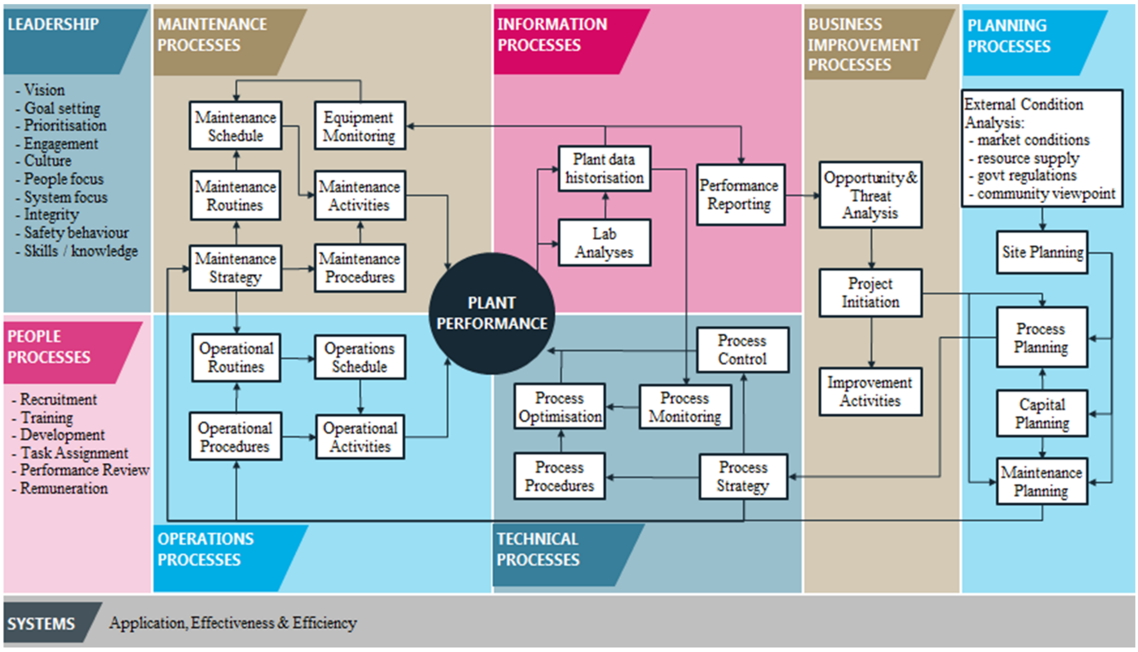

Figure 6. Refinery systems of work.

Just as it makes sense to benchmark key refinery performance parameters, it makes sense to periodically check the health of these various systems of work, and understand how they measure up to best practice. Deterioration in refinery performance due to inconsistency in operation, maintenance and process optimisation is a common issue for refineries. Often the root cause for poor operating stability can be traced back to ineffective systems (lack of training, operating strategies, scheduling, poor business improvement planning, failure to identify threats etc.). An operational systems ‘health check’ can identify emerging issues such that they can be addressed before they damage the bottom line. It can focus efforts on asset management and recovery from loss of performance, and provide a path forward for optimisation and improvement via embedding operational excellence.

Appropriate, well utilised and healthy systems of work are vital for ensuring opportunities for plant improvement can continuously be realised and then sustained over the long term. Too often opportunities identified as “low hanging fruit” fail to deliver the expected benefits or fail to be implemented altogether as a result of deficient systems, culture and leadership. To be fully effective, an improvement program needs to understand the status of these systems. Are process and maintenance strategies reviewed / updated periodically? Are long term outlooks on raw materials monitored routinely (security of supply, quality, and price)? Are causes of deviation from target performance systematically reported and major deviations investigated? What formal processes exist for implementing improvement activities?

The leadership and culture of an organisation can often be reflected in the health of these systems and level of operational excellence. Culturally, improved excellence represents a transition from reactive to proactive, or from reactive to interdependent in the language of DuPont’s Bradley Curve [10], which is commonly used to visualise an organisation’s journey along this path. Interestingly, the Bradley Curve was developed using principles from Stephen R.Covey’s book ‘The 7 Habits of Highly Effective People” [11]. One of these habits is 'sharpening the saw' which has parallels for organisations wanting to move forward from a reactive culture. Consider what the young man said to the woodcutter in the parable, 'If you sharpen the saw, you would cut down the tree much faster.' The woodcutter replied, 'I don't have time to sharpen the saw. Don't you see I'm too busy?' It is leadership that sets the shared values and common purpose that sits behind that culture.

The effectiveness of a process engineer can be used as an example of proactive and reactive behaviours. Does the process engineer understand his core work? Figure 7 suggests it is appropriate to consider an equal combination of optimising activities (daily cycle) versus improving activities (monthly cycle).

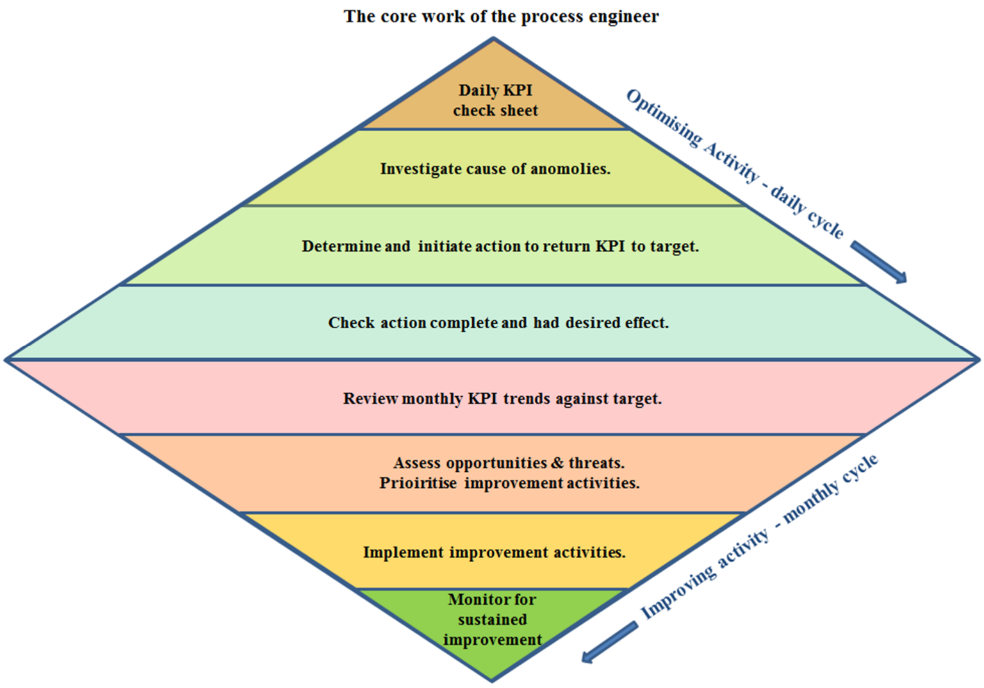

Figure 7. Process engineer optimising and improving cycle.

5. Managing the Improvement Program

An effective refinery improvement program helps to maximize the utilization of your limited people and capital resources by applying them to those improvement initiatives which deliver the greatest return. However, it needs to be managed correctly to deliver the expected outcomes.

There will often be a multitude of improvement initiatives competing against one another for these resources, along with other types of initiatives targeting different business drivers. These may include safety or environmental projects driven by regulatory compliance, as well as major maintenance and sustaining capital works for example, whose collective goal is to minimize future risks to the business rather than deliver a specific cost reduction. With such a range of drivers, both financial and non-financial, it can be difficult to compare, prioritise and select the right portfolio of projects. If not carried out effectively, the risk of the process being flawed is high and significant cost improvement opportunities may be overlooked. Often the focus defaults to selecting projects that can be easily implemented and address current challenges and desires of teams within the business. It's advisable to implement a structure that will select the projects that maximise value and reduce the likelihood of lost value, now and into the future. Some prioritisation guidelines to consider:

- Consistency: detail each potential initiative to a similar level of definition including the costs and benefits, risks, preliminary resource & schedule details.
- Establish a "value-based" approach: assess each initiative on a standardised NPV basis.
- Quantify risks: quantify non-technical risks and non-financial drivers (e.g. safety) in monetary ($) terms in accordance with agreed value criteria.
- Sensitivity analysis: evaluate the robustness of individual initiatives and the entire portfolio value over an agreed range for each value criterion and across a defined life cycle. Does the optimum portfolio change over these ranges?
- Determine project inter-relationships: will implementing one project alter the benefits of another or negate the need for the other etc.?

Following prioritisation, the selected initiatives need to be delivered effectively. Implementation should be managed to ensure initiatives are sequenced effectively.

Finally, an effective improvement program should verify that the initiatives delivered are meeting the business expectations and being sustained. This feedback loop allows for continual improvement of the overall process.

The whole cycle of benchmarking through to opportunity identification, ranking and selection should be repeated on a regular basis.

6. Conclusion

To achieve sustainable improvement in cost curve position requires a combination of process optimisation, innovative enhancement, operational excellence and effective asset management, underpinned by robust systems and effective leadership. From this solid operating base, return on appropriately prioritised improvement initiatives can be assured.

A structured methodology towards refinery optimisation is summarised below.

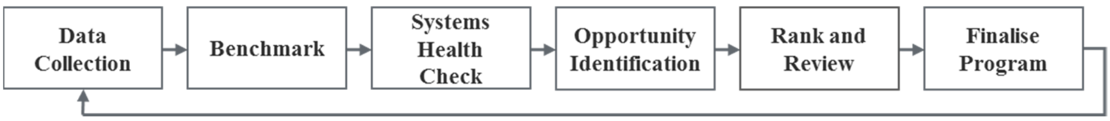

Figure 8. Improvement Program Development Process.

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