Lessons from a major safety incident during a non-regulated 14-year turnaround maintenance cycle

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The aim of major refining investments is to make profit and or achieve strategic objectives. High complexity, high volume, and operational excellence practices have assured profitability of modern refineries in an environment of cyclical cost of raw materials, variable quality of feed stocks and low margins. When plants are kept idle for long periods and not properly preserved, they suffer degradation with threats to the safety barriers. For a refinery asset owned by a national oil company (NOC) that went through a privatization bidding process and reversal of ownership within a short interval, the safety barriers get stressed ranging from the regulatory framework to the governance system, sustainability goals, health safety security and environmental systems (HSSE), operational excellence practices, integrity of equipment, instrumentation, gas monitors and alarm systems.

The main flare tip suffered extensive damage from failure of refractory material and perforation of the molecular seal. This was consequence of flaring excessive amounts of LPG that could not be evacuated from the storage spheres (marketing failure or quality) or high molecular weight gases released from the fluid catalytic cracking unit (FCCU) during upsets and failure of evacuation pumps from the flare knock out drum. Dispersal of plumes of carbon particles (soot) was regular, which deposited in homes of neighbouring communities as well as fouling the air quality of residents.

Crude supply was irregular and inadequate as a consequence of attacks on the supply pipeline or limited purchased volumes. Electric power from steam turbine generators was epileptic and inadequate hence there was a high number of start-ups and shut-downs of the process units. Over time high level of silt build-up in the oily water pond of the waste water treatment unit occurred, reducing the holding time and stressed the treating facilities during emergencies and rain storms. Biological treatment facilities for phenol were overloaded each time an upstream unit to reduce the load was off-line, consequently treated water qualities were stretched beyond the regulated limits, as treated water released to the near-by river occasionally smelt pungent followed by public complaints.

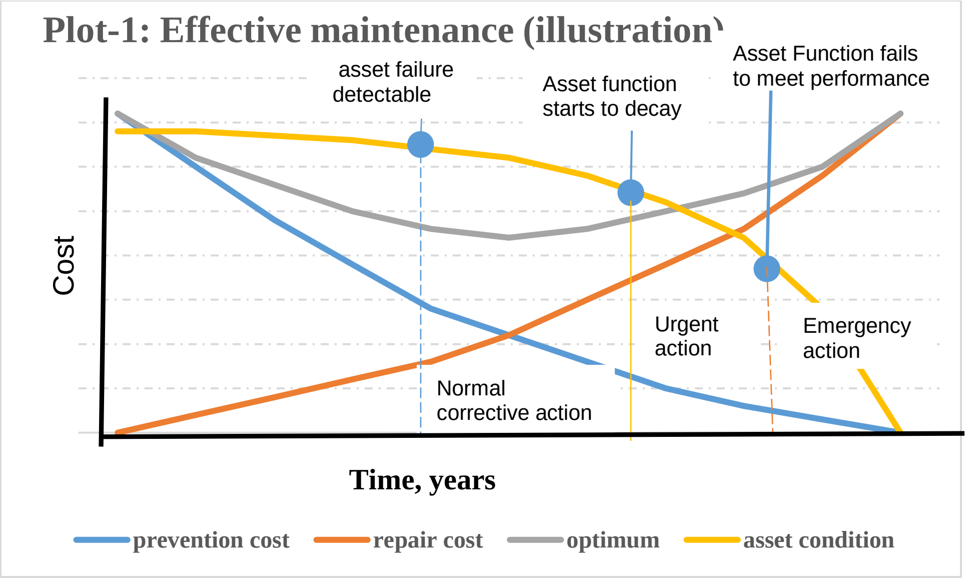
One of the metrics of successful turnaround maintenance and rehabilitation works, among others, is the restoration of the safety barriers and improve health safety security and environmental (HSSE) performance. The adoption of industry benchmarking and quality management system certification of the site was the route for sustainable improvement.

During the unusual 14-year non-regulated cycle of turnaround maintenance and rehabilitation under simultaneous maintenance and operations, there were numerous minor and major incidents. The climax was during the start-up of a sour water stripper unit, when a supervisor caught in a cloud of H2S from a perforated pipe leak suffered a fatal accident. This paper will attempt to analyse the root cause of failures of the safety barriers and share learned lessons on how to improve process safety performance in a challenging environment.

Keywords: safety incident, barriers, unusual-turnaround-cycle, refining

Introduction

The hydrocarbon industry investments are made to meet commercial and sustainable targets. Engineering designs, constructions, installations and operations are governed by codes, standards and regulations. The adoption of best practices assure margins are achieved to cover debt service commitments on the investment, health safety security and environment (HSSE) targets, organic growth and to meet shareholders' dividend expectations. Cost effective maintenance practices enable the assets to operate at industry average capacity utilisations of 85% - 90% for a number of years prior to a planned turnaround maintenance (TAM), as some statutory inspections and maintenance will require shut down and entry into enclosed areas such as vessels, reactors etc., except where remote or non-intrusive testing methods are allowed by regulators. The number of years between TAM depends on several factors such as severity of operations, engineering design tolerances, materials of construction, statutory and safety requirements, the mandatory inspection methods, maintenance and performance monitoring practices, availability of spare parts, planned CAPEX rehabilitation hook–up and design improvements planned, optimization activities and results, as well as equipment vendor recommendations. With delay in TAM implementation, there would be an increase of risk of failure, increase in cost of maintenance (operations) and consequently decrease in revenues.



A 14- year TAM cycle was therefore unusual and had its risks and consequences on the plant assets and personnel. A few years after the last TAM, a series of events that started with a successful invitation to bid (ITB) of an asset-sale program, submission of bids after carrying out due diligence, evaluation of bids, negotiation of a successful bid and payment by the successful bidder as required by the negotiated agreement. For reasons outside the control of the refinery management, the sale of the asset was reversed by the OWNER. During this period the plant was in normal operation and maintenance, although statutorily the asset was overdue for TAM, needed a review of work scope and contracting strategy, and procurement activities were far behind. The result was the invitation to the original refinery builder (ORB), an EPC contractor to submit a single bid for the revised TAM and rehabilitation work scope issued. The schedule could not be controlled as price negotiations could not be brought to a close. This triggered a change in strategy to utilise local contractors experienced in TAM, selected from competitive bids with work packages and costs within the refinery's limit of authority. During this period the refinery was continuously maintained and operated at low throughputs with consequences on safety, revenues, staff morale, reputation and sustainability metrics.

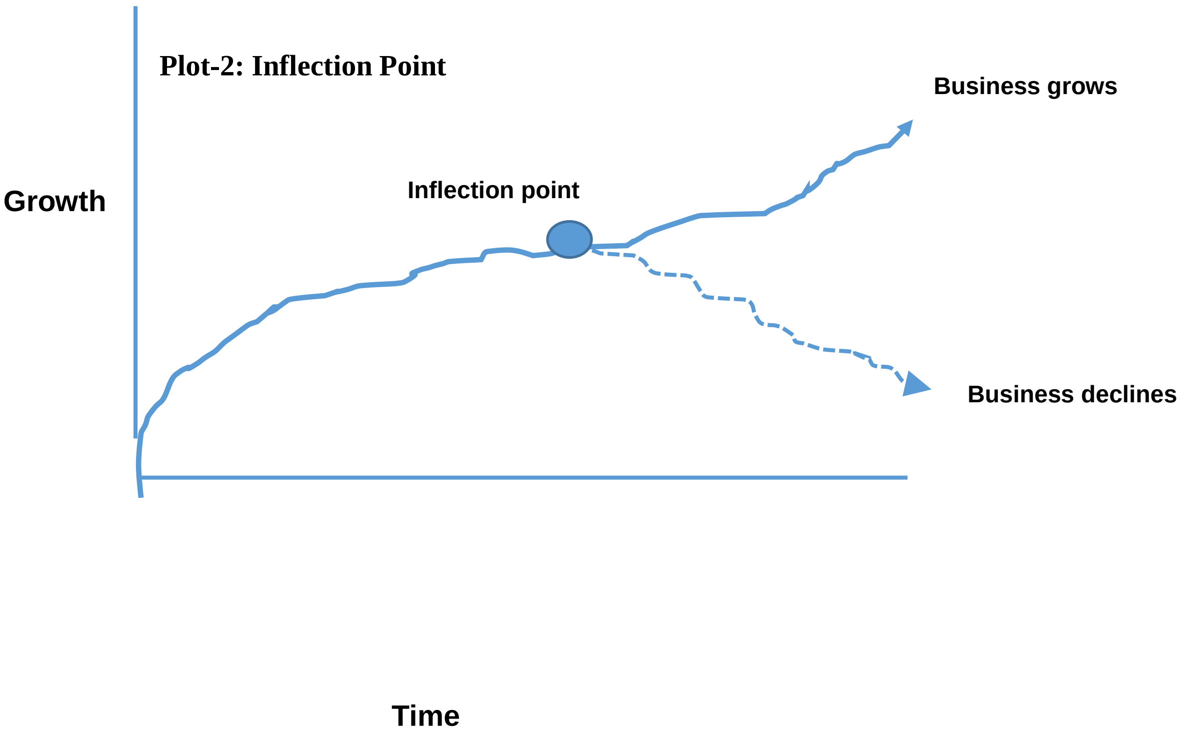
Take over syndrome: Stress and uncertainty

Businesses are acquired for several reasons which may include strategic, organisational, cultural fit or for the longer term view of expansion and technological upgrade (Byron F. Egan 2011). Human assets particularly where there is a desirable skill pool could also be the target of an acquisition. A merger or acquisition could cause cynicism and distrust among the staff in terms of downsizing and fears of being laid off, changes in leadership, shifts in strategy, security of employee salaries and benefits, spiralling stresses and emotional reactions that concerns management responsibilities and reporting relationships (Michael L. Marks, Philip Mirvis and Ron Ashkenas 2017).

During the due diligence and negotiations of the assets and liabilities to be taken over by the buyer, certain small and large improvement projects might be frozen to contain costs on which time may not permit recovery by the seller. Also affected are insurance coverages that are not assignable from the seller to the buyer and environmental liabilities that legally pass to the buyer that acquired substantially all the seller's assets to carry on the business and benefit from its continuation. In addition, the purchaser might be liable for the seller's unfair labour practices, employment discrimination and pension obligations and other liabilities to employees except there was an agreement on the limit of liabilities assumed (Byron F. Egan 2011). Refinery employees went through these uncertainties and discontinued several rehabilitation projects that would have improved the safety and environmental facilities of the plant. Unfortunately, when the sale was reversed, a new cycle of auditing and inspections, planning, approvals and funding had to be secured. Frustrated contracts had to be re-negotiated to achieve quick results. The sale reversal was supported by a strong labour union with several staged protests, therefore there was need for the Owner to justify and convince the other stakeholders that the asset would be more beneficial to the wider economy as a public asset than under a private management to rehabilitate, operate and maintain it as a commercial and profitable enterprise, that would pay taxes on its profits to the government in addition to meeting its corporate social responsibilities. This correct-decision justification by the Owner would require the plant to be run under simultaneous operation and maintenance, in view of the enormous work load outstanding, the time and resources required to restore the integrity of the asset.

Resistance to Change

Andrew S. Grove 1996, Co-founder and former CEO of INTEL was at the forefront in the manufacturing of microprocessors and grew INTEL into a high performance and competitive company that made substantial contributions in the development of the computer industry. He introduced the concept of strategic inflection point as a time in the life of a business when its fundamentals are about to change. As a key success factor, inflection points can be hard to recognize; missing one of them, one could find oneself on the decline curve even though one made no decision at all.



Plot-2: Inflection Point

Making the decisions required critical thinking at these inflection points. Through Research & Development (R&D) activities of companies e.g. original equipment manufacturers (OEMs), licensors, service providers or start-ups, new products and services emerge to change how the business is done or make existing production lines unprofitable. Without an effective monitoring program to identify the risks of obsolesce and respond timely and adequately, the profit making potential of the organization will be compromised or degraded. Organisations that provide services or operate production facilities will decline in efficiency and effectiveness, and the service eventually becomes unsustainable. The numerous challenges and decisions confronting operations and service delivery activities, though the resolution of some of these challenges could be within control and influence while others could be outside the control of the organisation.

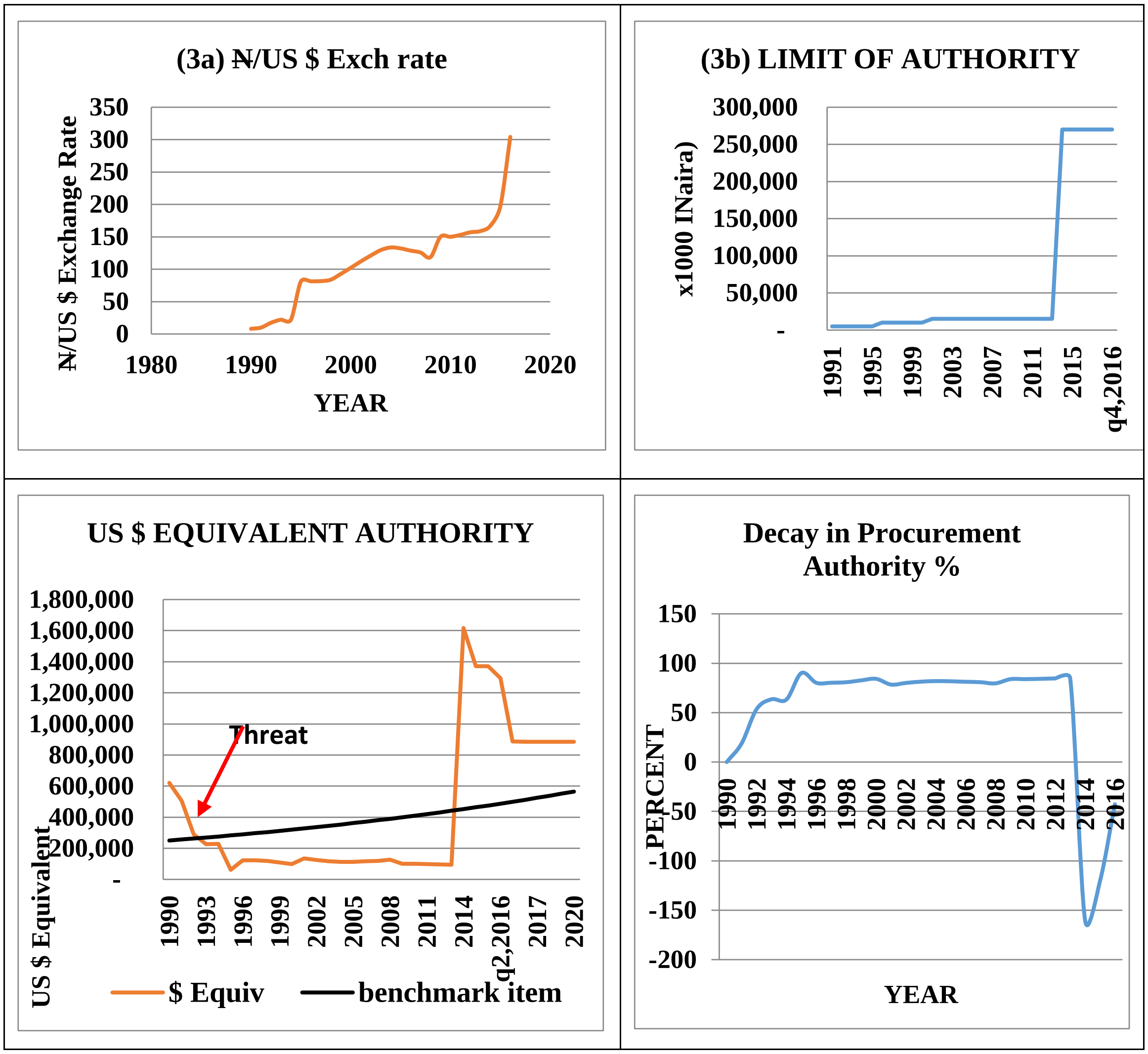
Resistance to change tends to be a weakness of organizations considering the dynamic operating and service delivery environment. The operating business or service model would be expected to change or adapt based on strategic planning outcomes to address common issues such as succession planning, attrition from aging staff, skill and talent loss, adoption of new technologies, standards and regulations, competency certification and maintenance programs, security to personnel or assets, changes in prices of commodities and products, defence of market share or the discovery of new markets and opportunities, changes in monetary and fiscal environments etc.

Materials, spare parts and services required to implement turnaround maintenance and asset renewal or replacement programs as well as implementation of new capital projects would be confronted with changes in monetary conditions such as inflation, commercial bank interest rates and foreign exchange rates. The schedule from initiation of planning to execution could take 18 – 24 months for TAM and sometimes beyond 36 months for capital projects. The importance of closely monitoring the key economic indicators as they affect the outcome of the TAM and asset improvement work cannot be over emphasised. The metrics of successful turnaround maintenance and asset renewal programs are implementation within budget, schedule, HSSE metrics and successful commissioning into operational phase to recover the investments. When currency devaluation, high inflation rate and in consequence high commercial bank rates emerge in the middle of a planning and execution campaign, price of local goods and services would rise way beyond budgetary plans. Beyond cost of goods and services, drastic changes in exchange rates also test the performance of the supply chain approval responsibilities within the governance structure of the organisation.

As an illustration, shown below (Plot -3) was the impact of devaluation of the local currency (Naira) on the responsibility and accountability of the governance structure with respect to the established delegations of authority. This impact was not limited to the efficiency and effectiveness of Government agencies and parastatals, it also applied to private organisations that were not vigilant and were resistant to change. Plot-3(c&d) show the effect of exchange rate changes on the limit of authority of the organisation and the capacity of its management to procure a critical spare part or equipment. The price of a benchmark item in US $ would normally be subject to industry annual average price increases, and might be subject to approval by different authorities, depending on the set authority levels, when the local currency is devalued drastically.

During this period, transfer of critical control functions would take place from the operating site or service, at the point the delegated authority plot crossed the inflation adjusted cost of the benchmark item. This authority and control function would pass to supervisors outside the location that are part of the governance structure. In situations where prompt actions were not taken and approval delays occur out of lack of understanding of consequences, or used the opportunity deliberately to control subsidiary costs, the result would be a catalogue of lost business and growth opportunities for the subsidiary, increase in fire and safety incidents in production facilities where those requests happened to be safety-critical. The changes in inflation over the review period also had effect on the capacity (in terms of resources) to procure materials and services to sustain TAM and asset renewal programs. In these cases, most of the time inspirational leadership practices or use of consultants and specialists only provide temporary solutions and relief but might not find a platform for improvement of the performance of these assets on the long term.

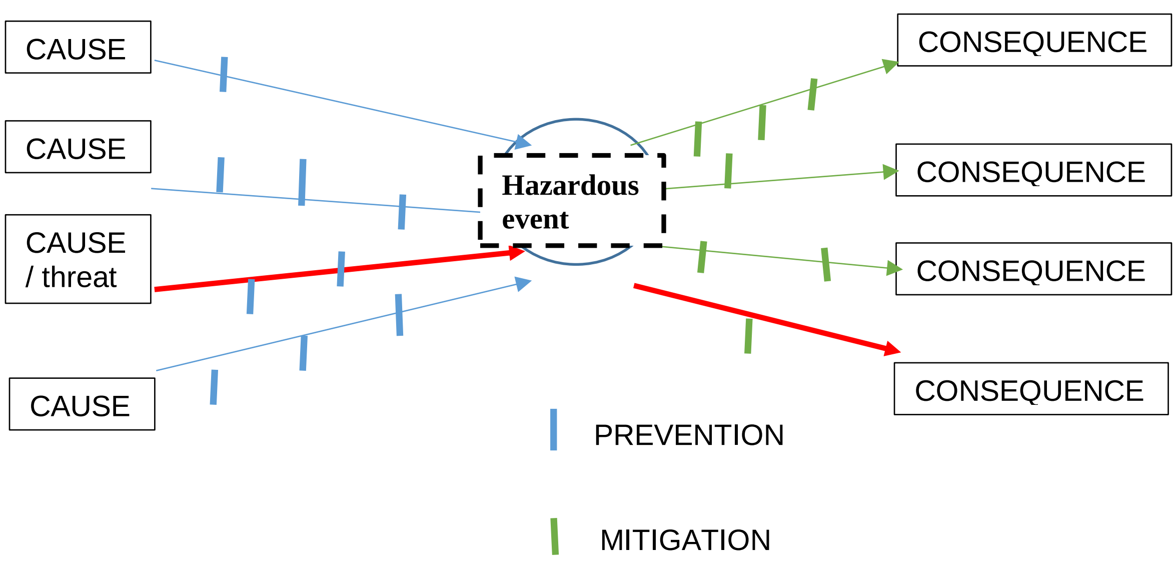
Plot-3: Effect of devaluation on delegated authority



Failure of barriers

A barrier functions to stop a hazard from developing into an accident (Hollnagel, 2004, pg 68-108) and a barrier system consists of several barrier elements of different types (technical, operational, human, software etc.). The Norwegian Petroleum Safety Authority (PSA) as Regulator states that "Failure or weakening of the barriers is a frequent cause of undesirable incidents in the petroleum industry", this is more apt for aging facilities that have deviated from original designs through improper maintenance practices. The Swiss cheese model and the Bow-tie are common methods for safety barrier analysis and management. The Bow-tie requires collaboration across disciplines and benefits plant engineers, operators and management in decision making to prioritise life extension initiatives and budgeting (Bard Jansen, 2016). The established and coordinated activities to maintain functional barriers lies within and outside the organisation starting from the HSSE management system, the Corporate governance (internal) and Regulations and standards (external). This is expanded further (Preben 2011) as Man, Technology and Organisation perspective on safety barriers involving market factors (competition, capacity and contracts), knowledge (research efforts and expertise), regulation (laws and regulations, principles and role of agencies), and civil society (unions, public opinion / media, organised interests and civil society). This had been the case for this company studied with significant impact on local production of petroleum products and minimisation of imports to meet the domestic market and save on foreign exchange. There were consistent pressures from the professional technical reports issued, staff comments, observations, the press, public opinion leaders, labour unions, law makers etc to have an early TAM.

Fig-1: A Bow-tie showing an incident pathway (Gary Pilkington, 2017)



During the unusual TAM period, the firefighting equipment and emergency response systems were regularly tested by the regulators and approved once audit queries were closed. However, within the process units, actual work done annually in corrective and preventive maintenance activities was observed to be less compared to planned and this was common for several years. Implementation of some Inspection recommendations were also often deferred, including safety critical corrective and preventive maintenance during the period of unusual TAM due to availability of materials and funding constraints. Therefore, the gradual failure of barriers of protection in static and non-static equipment would reach a level that would necessitate a complete plant shut down to aggregate adequate resources to address the worklist sufficiently to restore safe plant conditions and re-start of the plant. Where just in time (JIT) supply chain practice existed, the lead time for supply of spare parts was minimised while storage time for materials was also reduced. However, where a JIT was not practiced, the lead time for supply of materials was always long and more expensive to expedite due to the criticality in order to reduce plant down-time. During the periods of prolonged shut down, preservation activities increased to reduce corrosion that would degrade the integrity of the safety barriers such as pipes, vessels and internals, rotating equipment, instrumentation and monitoring systems.

One observation common during this period of deferment of corrective activities is the acceptance sometimes of incomplete inspections and impairment of the quality of the inspections by both contractors and owners. This led to frequent difficulties in cost-containment and schedule due to scope growth. Temporary operating procedures increased, hence relying on the ingenuity of operating staff to achieve safe operation outside of the normally approved operating and design modes and envelops and minimise HSSE risks.

Monthly, quarterly and yearly reports to senior management and ultimately to the Board would keep all informed on the status of the asset.

Consequences

There was a decay in safety barriers as TAM was delayed in the process units. The Fire and gas detection system was no longer supported by the OEM as an Upgrade or replacement became necessary. Therefore, when corrosion under insulation caused a perforation on a small pipe that leaked H2S in the SWS unit during a start-up, there was very little or no warning of the nature of the gas cloud that formed. Unfortunately, a supervisor trapped on an elevated platform tried to escape the cloud through some slippery oily platform but was overwhelmed and fatally fell to grade.

The distributed control system (DCS) which was installed in 1988 was several generations behind in 2012 and no longer supported by the original equipment manufacturer (OEM). The historian was no longer available to support panel operators and technical service personnel while the operator stations could only keep operational data for less than 8 hrs. The backend was also obsolete. This meant optimization activities and any innovation efforts could not be supported. Innovative programs such as RBI that used past operating conditions and inspection data to make strategic future failure predictions on the life of the equipment or asset and the consequence of failure was discontinued. Specific process Operator training simulators on the DCS could no longer support process training on start-up and shut down and how to deal with abnormal situations. This potentially could lead to decrease in skill and competence to achieve optimum asset performance and profit maximization, energy efficiency and plant-wide safety. This system therefore required a replacement or an upgrade to the latest generation of DCS.

The tank gauging system became obsolete with no further support of spare parts from the OEM. This meant that manual dips only were utilised in calculating receipts and evacuations. In few instances, this had led to loss of tank farm operator’s jobs when controversies arose with accuracy of volume of products exported. With the level alarms that were non-functional, occasionally unsafe situations have also developed with overfilling of tanks when process units were in operation and lined up to these tanks, short of a replication of the Buncefield incidence of 2005.

All the cells in one out of two cooling towers available collapsed and the other was degraded by 40% due to a fire incident. These required change in technology and complete replacement while simultaneously operating and maintaining / rehabilitating these cooling towers to meet the strategic requirements of the refinery.

The flare tip and molecular seal suffered serious damage due to persistent overload of the flare as a result of C3 and C4 that could not be recovered at the required specification in the FCC unit or lack of ullage in the storage spheres or run down from storage due to marketing failures. The combustion efficiency at the flare tip improved with injection of steam. In cases of either overload of hydrocarbon or lack of steam would result in incomplete combustion with soot dispersal to nearby residential communities, depending on the wind pattern. This essentially would be environmental air pollution from soot particles, capable of degrading the atmospheric living conditions and the aesthetics of buildings and interior decorations, which also might have immediate and future health implications.

The Phenol biological treaters were overloaded when the FCC was operated with feed from storage without the CDU running. The silt levels in the crude storage tanks increased as quality of crude oil supplied changed with respect to the basic sediments and water (BS&W) during the period, requiring de-silting and in some cases suffered floor damage with incidental seepage into the bund wall. This would effectively reduce the operating crude storage capacity, overloading of crude oil-water separation facilities (desalter), increase in rate of injection of chemicals to neutralize corrosive substances in the overhead system as a corrosion control measure. The silt level in the oily water pond increased with time reducing the capacity of the pond to store oily water during the rainy season.

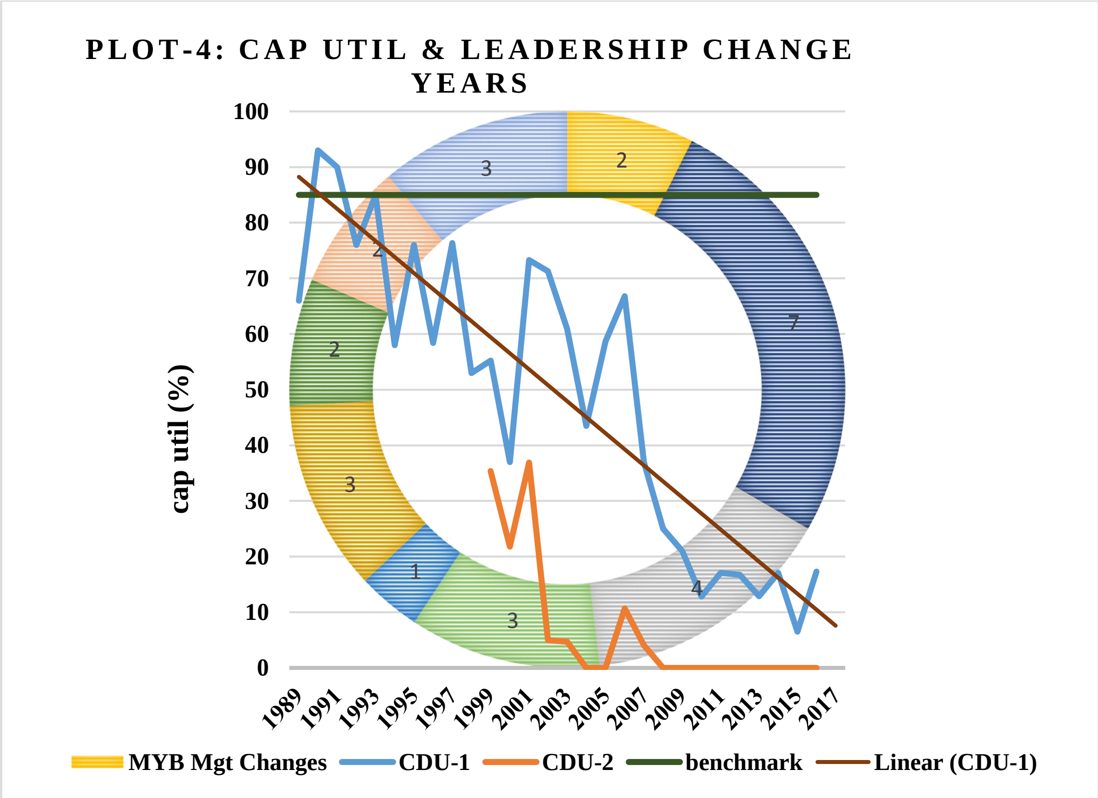
The maintenance plan was more reactive and less predictive as demand for spare parts rose and the supply chain had its constraints. Obsolescence of equipment, mergers and acquisitions of OEMs also made the supply chain activity difficult. Normally, the maintenance plan should be more predictive and less reactive. Some practices compromised compliance with API 752 & 753 with respect to permanent buildings in the refinery constructed to protect employees from explosions or toxic gas releases. The failure of the central air conditioner unit without support from the OEM led to installation of several split air conditioning units that required drilling holes through the wall of the explosion proof control room building, as the quality of filling infringed on the API 752 & 753 recommendations.

As bottlenecks increased, capacity utilization drastically declined followed by dwindling revenues, decreasing cash flows and net margins. In non-subsidised commercial organizations this is a situation that would prompt reduction of non-essential personnel by the human resources department (HR) with its implications on growth of unemployment in the national economy. Since a strong labour union existed, the labour force was well protected, however, inflation adjusted salaries and benefits and growth in the debt profile would be a nightmare for management.

The refinery investment was expected to provide some multiplier effect to the national economy and the immediate host community in form of support businesses and also pay taxes to the Government. Under the case of an unusual TAM, it was difficult to meet sustainability requirements. Hence there was a catalogue of deferred commitments and new business opportunities for expansion could not be taken to increase the complexity and efficiency of the refinery. Several process units that would have created more value were mothballed. In some cases, extensive pouching of spare parts took place to keep other more critical process units in operation.

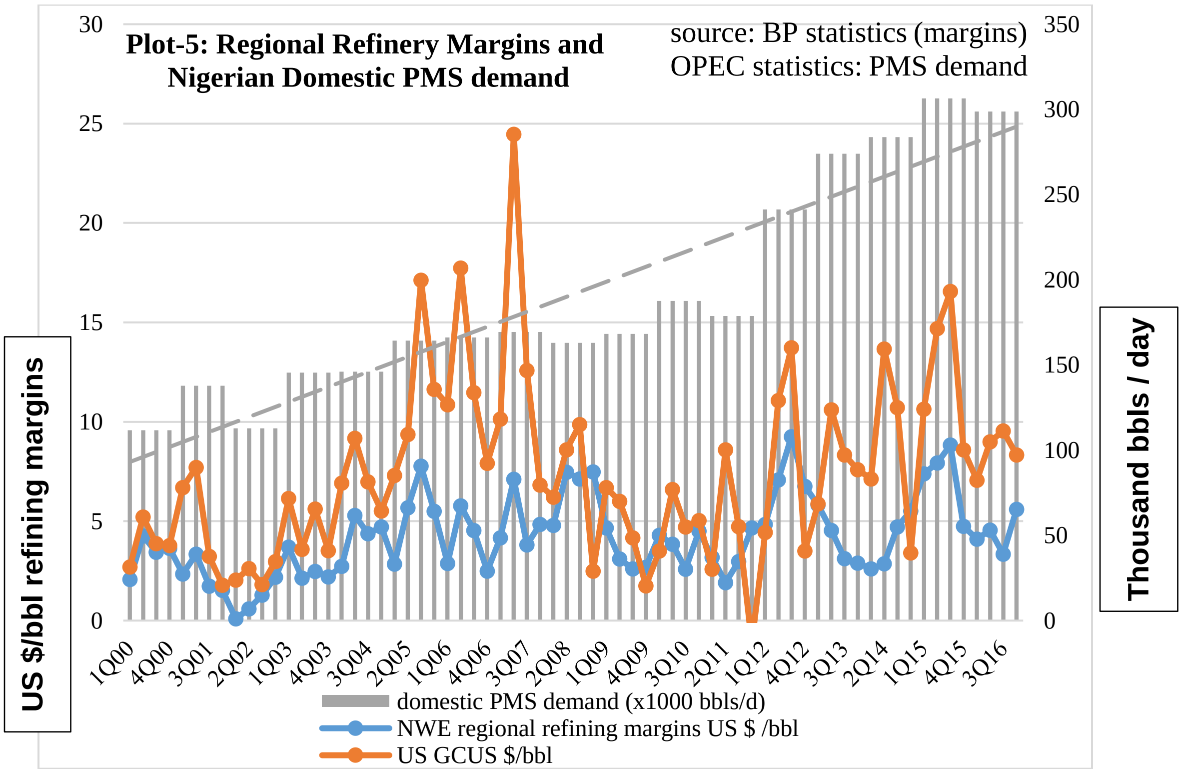
Executive turnover and Organisational culture

A review of the performance of the crude distillation unit (CDU), which provided feed for the catalytic reforming unit (CRU) and the fluid catalytic cracking unit (FCCU) from a 26-year period shows a trend on the operational culture of the organisation compared to industry benchmark. Plot-4 shows the frequency of executive turnovers, 2 in the first 10 years when the average capacity utilisation was above 75% and 7 in the next 16 years when the capacity utilisation was on a decline from 70% to less than 15%. This could be an indication of the level of the Owner's non-tolerance for non-competitive and unprofitable operating practices irrespective of the constraints, in addition to other reasons. The declining average capacity utilisation also affected not only the Nigerian refinery capacity performance, the national manufacturing index and considerably depressed the average African refinery capacity utilisation. On the contrary, it also shows lack of capacity on the part of the Owner to change the situation and also lacked the resources needed to act appropriately to reverse the unsafe state of the refinery.



Plot-5 shows the margins in the NWE and US GC regions for fluid catalytic cracking or hydrocracking refineries and this refinery operated with a low sulphur crude oil (Bonny Light) which was at a premium to Brent. The average capacity utilisations did not show any relationship to the attractive refining margins at the time. The refining business revenues normally are driven by volumes processed and the margins depending on the refinery complexity and the actual processing units in operation. Where the purpose of the investment was not for maximisation of profit, there should be other targets such as cost recovery and break even operations to meet the needs and requirements of the other stakeholders of the investment, in order to avoid value destruction. The other stakeholders in this instance would include the host communities, workers, the ecosystem, the national economy and the regulators. In addition, in this era of Internet of all things (IOT), there would be critical need to invest in cybersecurity to protect the assets and it would be from revenues from continuous operation that these essential investments would easily be implemented.

The growth in aggregate petroleum product consumption in Nigeria was driven by gasoline (PMS) which was the dominant fuel in the petroleum product mix. The daily average PMS demand rose from 18 million litres in 2000 to 48 million litres in 2015. This market in 2015 would have required a refining capacity of approximately 900,000 b/d (estimated from refinery configuration making 40% vol gasoline and operating at 85% capacity utilisation). Plot-5 showed that the capacity utilisation of the local refinery was falling from year 2000 to 2015 when there was great need for increasing refining capacity to meet the rising market demand. The lack of response was a clear indication that the local coastal refinery was more valued for its product storage tanks and marine jetty than its crude oil processing capacity. It was the local and international traders (on intensive competition with the local refineries) that supplied the bulk of the PMS demand on emergency basis from the world market rather than from local production, even when there was a regular national crude allocation to the limit of the name plate capacity, with generous credit purchase terms. Also practiced by the Owner organisation was trading on unprocessed crude allocation, offshore processing and crude oil swap contracts which were also in competition with local refinery processing of crude oil.



There were several reputable consultancies engaged to improve the performance of the refinery in its maintenance, HSSE, project management, supply chain, Production planning and quality control etc, but could not make any sustainable and significant improvement in capacity utilisation, but might have improved the safety management system. During these periods, Quality management systems practiced included TQM, and ISO certification, adoption of ERP (SAP platform) etc. There was resistance to change and slow or no absorption of mature technologies that would have improved the refining technology, economics and HSE performance in over 25 years of operation. This could be considered a hazard since operators were with time forced to run obsolete and non-OEM supported equipment, with frequent shut-downs and start-ups. Unfortunately, there was limited innovation, new product lines or optimisation activities within the system that added value to the process configuration. The problem might be traced to the business model adopted and practiced where key aspects of the operation such as crude oil supply and volume available for processing, product marketing and the price of the products were entirely outside the control of the refinery executives. Adequate funds were released for payment of personnel salaries and benefits due to the presence and activities of a strong Labour union while funds for maintenance and operations were usually constrained. The alternative to security of jobs in the situation where the refinery was out-competed would have been loss of jobs in the economy.

Over the fence influences

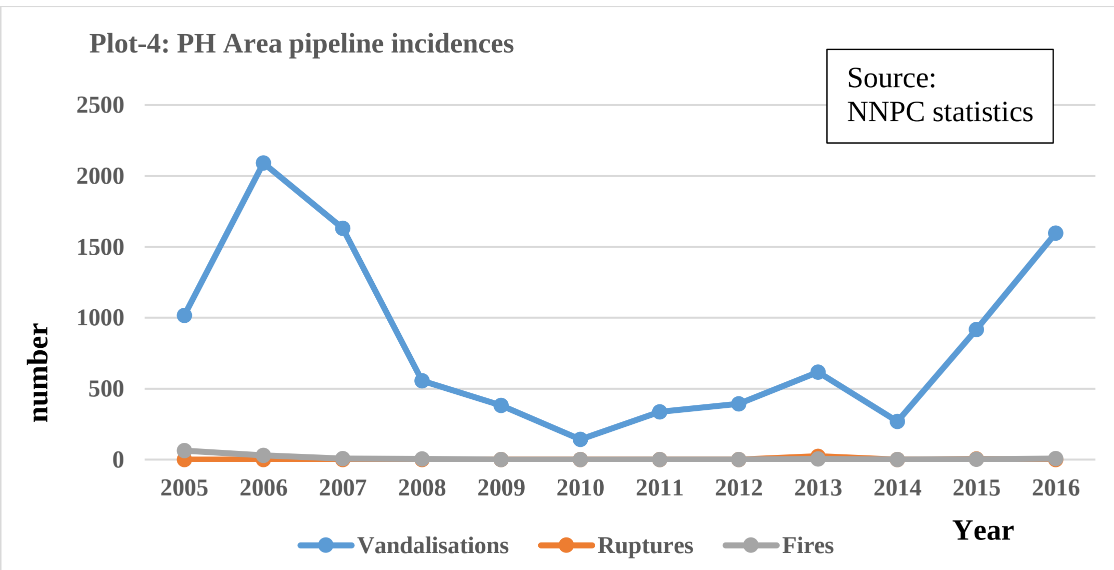
Very often the operational staff were influenced by activities in the larger society outside the organisation were they work that could be stressors and would affect productivity, effectiveness and in the extreme develop into a hazard that may require mitigation.

Typical situations are lack of adequate infrastructure outside the refinery such as roads, water, electricity supply and quality health facilities as individuals had to substantially shoulder these. Others are insecurity, high level of poverty, environmental pollution, social and cultural polarisation, communal disturbances, kidnapping, cultism, systemic class injustice etc.

There were several Intrusions in the night, of naked small-scale fuel thieves with 30 litre cans, into the process area battery limit, having rubbed fuel oil from head to toe to enable them to slip out of a physical arrest. This severely scared outside duty operators from being alone during the night shift, and also affected the effective performance of their work.

There were several incidences of marine pipeline vandalisations by dug-out boat crews, that resulted in fires and losses, one of which burnt down the marine export jetty with consequences on continuous plant operations. These desperate stealing activities occurred even when security was reinforced along the 7km access to the jetty as well as at the marine jetty platform.

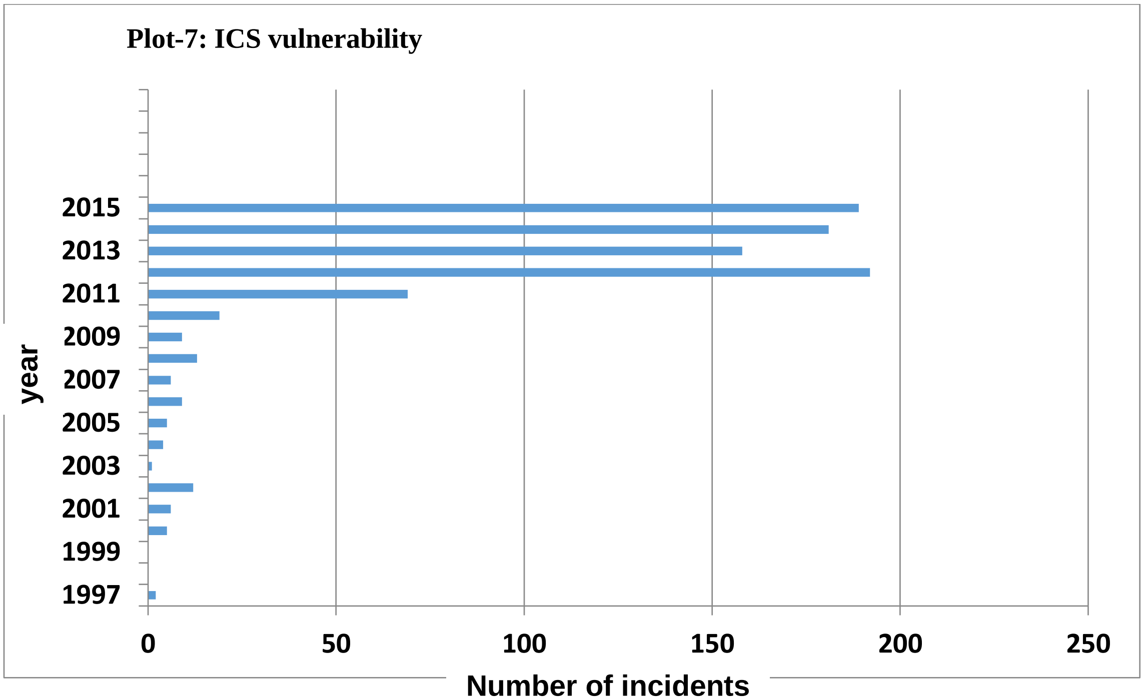
Shown below is a graph of vandalisations and ruptures (Plot-6) over the last 10 years on crude oil and product pipelines in the refinery operational area. There were very few ruptures from corrosion because the lines were well protected with cathodic protection. The number of pipeline vandalisations were very high due to activities of thieves. There were fires and losses of the line contents. Unfortunately, the refinery had only a single customer, which operated like a monopoly that supplied the crude oil and also evacuated the products. The losses from the vandalisations were uninsured and the cumulative risk over the years was a huge drain on the resources of the parent company, reducing its ability to supply enough crude oil to meet the available refinery capacity, which directly affected the revenue of the refinery and its operational budget to meet maintenance, HSSE and rehabilitation expenses. The operating environment could therefore be considered hostile and abnormal. With this background, the plant could not operate its assets continuously without frequent shut downs and start-ups, due to lack of crude oil to process. Most of the metrics that the refinery's resources were deployed to meet were outside the scope of the competitive metrics used by Solomon Associates in its world-wide refinery surveys to improve performance.



Being an overwhelmingly religious society, some high level staff would interpret lack of success in plant performance during their period of stewardship as working on a hunted site and would set out to make an appeasement to the unseen hand through a mediator or intermediary. The problem would be for those that would not align with such line of thought and would end up as victims of some sorts, creating ill feelings that would affect cooperation, creativity, value addition and provision of free and uninhibited suggestions of ideas for optimisation. In extreme cases, those could be accused wrongly for sabotage, neglecting the root cause of an incident.

Cyber threats

Criminal, competitive and state sponsored threats are on the rise attacking administrative computing and industrial control systems. Where there is not an adequate incident response program, it could lead to loss of critical assets and production losses. Harkers are increasingly targeting industrial control systems that are connected to the internet. We refer to the stuxnet virus attack on thousands of centrifuges at the Natanz uranium enrichment plant in Iran. The virus attacked the set speeds of the machines causing them to spin out of control and self - destroy. A steel mill in Germany sustained massive damage to its blast furnace in 2014/15 after attackers took control of its industrial control systems. In 2015, A small dam outside New York city that had its Control system connected to the internet was attacked. There have been several reports of Harvesting of confidential information from compromised computers during the 2016 USA presidential election campaigns. Industrial control systems vulnerabilities have risen from 2 incidents in 1997 to 189 in 2015. The most vulnerable industrial control system components are human machine interface (HMI), electric devices (pumps, relays, detectors and analysers), network devices, controllers, web servers, base stations and SCADA systems. No business is without risk of cyber-attacks. It is therefore necessary to operate profitably to generate revenues that could also be invested in cyber protection of the refinery assets and avoid cyber triggered accidents. This is crucial as the assets are upgraded with more modern models that are more visible on the internet with remote control facilities with OEMs and licensors.



To achieve security and safety in the cyber space, companies need to continuously invest in monitoring of cyber intrusions or detect inadvertent well –intentioned insider's actions that may be damaging.

Communication

Communication is the process of transmitting information and common understanding from one person to another (keyton, 2011). When this is done effectively at work place, successful project, process performance, maintenance and HSE goals are achieved to improve productivity and proper utilisation of resources among others. There are however barriers to effective communication. These include power and status barrier, physical separation, gender, culture and language can potentially distort effective communication. Monitoring, review, Communication and consultation are integral processes and essential in barrier management. (Rausand, 2011).

During a post-TAM operation of the refinery, a CDU column suffered major damage to the internals. A maintenance Task-Team was set up to carry out urgent repairs and handover the column for operations. In response to the urgency for start-up, when requested, a schedule of one week was provided as that was exactly what the management was expecting to hear. As the work progressed, the schedule kept growing and was eventually completed in 3 months using a reinforced multi-departmental Taskforce working 24 hrs /day. The other impacts of this barrier in communication was lack of resource optimisation and the inability to utilise the window available to effectively plan other less critical rehabilitation / maintenance activities needed in the refinery.

Operational Excellence

To assure cost recovery from investments on rehabilitation and TAM, it was very important to have in place a quality management system and have structures that could aspire to operational excellence. Operational excellence (OP Ex) is a framework that governs and coordinates all value improving processes, practices, procedures and technology within the organization. The strategy for operational Excellence is to define, identify, plan, implement, check, and improve. The program must be in compliance with ISO standards; ISO 55000, 14000 and 2001:2008 now updated to 9001:2015. Risk identification, analysis, and mitigation are important. Financial measures of performance are necessary to demonstrate the full value of operational excellence. They should be credible, measureable, accurate, and impartial. Life time cost tracking within the business value chain should be carried out that relates to the financial statements, overall equipment effectiveness, production processes and operating costs as well as value within an operating environment and value within operations and maintenance. The Elements of an operational excellence program are: Leadership, Program definition, Conformance requirements, Supporting practices and procedures, Working culture , Information Management , Results, Follow-up

Shown below is a typical Operational Management System (OMS) and major criteria on which to develop an OP Ex program (Penn Energy survey report, 2016 pg 13), that could be modified to suit the type of organisation and the challenges of the operating environment:

TABLE-1: OMS

1.**Leadership** - Operating leaders -Operating strategy -planning & Controls -Resources and Implementation -Communication and Engagement -Culture	2.**Organisation** -Organisation structure -People & Competence -Operating discipline -Organisational learning -Working with Contractors, collaborators and complementors	3. **Risk** -Risk assessment & mgt -People safety -Process safety -health & Industrial Hygiene -Security -Environment -Transportation	4. **Procedures** -Procedures & Practices -Mgt of Change -Information Mgt and Document Control -Incident Mgt -Control of work -Crisis & Continuity mgt & Emergency response
5.**Assets** -Project Mgt -Design & Construction -Asset Operation -Inspection & Maintenance -Decommissioning & Remediation - Marine Operations	6. **Optimisation** -Plant optimization -Energy -Feedstock, product & Inventory Scheduling -Quality Assurance -Technology incl. IT systems -Supply chain & warehouse Materials Mgt -Continuous improvement	7. **Privilege to operate** -Regulatory Compliance -Community & Stakeholder relationships -Social Responsibility -Customer Focus -Product stewardship	8. **Results** -Metrics (kpis) & Reporting -Assessment & Audit -Performance review -Budget management

Eight major criteria to enable firms in achieving world class operational excellence on a journey of continuous improvement:

1. Pursuit of Top Quartile Asset performance with best return on capital employed
2. Immaculate Reputation (offers stakeholders the highest valuation)
3. Distinctive capabilities with competitive advantage
4. High Reliability and Performance culture
5. World class Health, safety & Security for individuals and the Environment (HSSE)
6. Best in class processes and systems
7. Employees to take ownership, maintain and improve performance using the continuous improvement tools to support further growth
8. Be creative and innovative to remain competitive or lead the competition by developing new products and technology.

Conclusion

It is necessary to compare the cost of carrying out a good maintenance practice followed by regular TAM with the alternative of unusual TAM practice that has the consequences of production losses, present and future health risks, legal challenges from environmental pollution, higher re-insurance costs, inefficient plant operations from frequent starts and stops for a plant designed for continuous operations, and loss of reputation.

Designed, constructed and installed protective measures to prevent harmful incidents or for mitigation of the incidents should be properly maintained and regularly upgraded to meet and exceed current regulations and guidelines

Plant Inspection, HSE compliance soft wares and Training simulators for start-up and shut operations should be upgraded as the platform technology undergoes generational changes.

Personnel should be made aware of the barriers that are not in a fit- for- service condition. Ensure there is alignment of duty, budget and stakeholders from the level of the board members to the operator in the control room and maintenance technicians in the field while communicating the threats to the safety barriers, the mitigation options and the consequences of failure.

Subscription to and continuous certification of a quality management system is a prerequisite to support and sustain high performance organisational practices.

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