

SASOL experiences in cost/risk optimization

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Introduction

This paper describes some of the methodologies, usage and results obtained during the last four years at the Secunda plant of SASOL. In particular it describes the optimization of the major shutdown strategy, and some of the many individual decisions about what capital investment, maintenance or inspection is worthwhile, when.

SASOL in South Africa, is responsible for around 50% of the total domestic fuel and lubricants market, largely through its world-leading coal-to-gas-to-oil conversion technologies. The Secunda site comprises the largest such production facility, some 10km x 4km of integrated process plant, with over 23,000 pressure vessels and a feedstock obtained from 5 coal mines operating 24/7.

In the past, the company benefited from protected political and commercial status but these protections are rapidly disappearing and world markets are providing significant price competition. Accordingly, great pressure has been brought to bear on the unit production costs, product quality and operational flexibility of the plant, and significant investment has been made in new technologies and ways of working. Investment has been made in new technologies and ways of working. Significant investment has been made in new technologies and ways of working.

The Woodhouse Partnership Ltd (TWPL) comprises about 40 international experts in Operational Reliability and Asset Management (training, facilitation, tools), and works in the energy sector, public utilities, transport, mining and manufacturing industries in around 25 countries. TWPL has been working with SASOL for around 5 years, to establish better practices and implement modern Asset Management processes and tools.

Where it all began

In the 1980-90s, like many companies, SASOL had tried most of the 'three letter acronyms' (RCM, RBI, TPM, TQM etc) – and achieved varied, usually temporary successes with some of them. The move towards a more integrated Operational Reliability approach coincided with the appointment of Bram de Klerk as Managing Director of the Secunda operation, the researches of Ray Owen (Head of Shutdown Planning) and the first TWPL training courses in the subject. It was quickly apparent that this 'integrated roadmap' approach would be far reaching in education, organisation structure and in potential benefits.

The first pilot studies of component activities (maintenance tasks, spares requirements, problem-solving/root cause analysis) revealed scope for multi-million dollar potential savings or performance improvements. A Reliability group was established to coordinate and facilitate the adoption of such methods, and a more systematic (criticality targeted) roll-out of RCM and RBI studies ensued. At the same time, a number of further studies were performed using the APT cost/risk optimization tools to explore not just what is worth doing, but the optimal amount, interval or timing of the tasks. These showed further spectacular benefits in cases

ranging from turbo compressor inspections and maintenance, valve reliability and design, gas turbine rotor spares, pipeline corrosion monitoring and electrical protection system testing.

The big decisions

In 1999, with the emerging evidence of a) the practicality (particularly when faced with poor or missing data) and b) the value of the techniques, some of the critical strategic decisions of plant operations were tackled. In particular, the Synthol business unit, containing the catalytic heart of the gas-to-fuel conversion process, was under pressure to operate at higher uptime, for longer run-lengths. The current 2-yearly major turnaround was being challenged for change to a 4-year interval. However a considerable number of operational, metallurgical and inspection/maintenance issues would need to be considered to enable such a significant step.

The business unit manager, volunteered his team as a proving ground for a radical new way of evaluating and optimizing the total reliability, performance, cost and shutdown strategy. The following describes this process and the results obtained.

Optimization of shutdown work requirements and intervals

The study considered the top maintenance and risk areas, each modelled using the APT suite of optimization tools to allow exploration of data uncertainty. This modelling identified the optimum maintenance or inspection interval, and the cost/risk penalty for deviating from the optimum. In cases where a 4-yearly turnaround cycle was found to be unachievable (too costly and/or risky), alternative designs, configurations or operating strategies were also evaluated. Such de-bottlenecking revealed considerable scope for cost/risk/performance savings, worth a total of **R10.7 million/year** and representing a payback for the necessary capital investments involved averaging just **3 months**.

The cost, performance and risk implications of current 2-yearly and proposed 4-yearly

shutdown cycles were then quantified, and key decision drivers identified. This study revealed that an extension from the current 2-yearly shutdown to 4-yearly would hold net cost/risk improvements worth **R40 million/year**. Combined with the improvements available from the 'debottlenecking' actions identified in individual equipment studies, this represents a total benefit from the study of **R50.7 million/year**. This is based on conservative estimates for total cost, availability and risk effects, and includes 'worst case' projections for the associated risks (so the 'most likely' benefits are even greater).

Component studies performed

The studies considered the key maintenance, performance and risk items in the Synthol trains. Criticality analysis considered the 'risks if shutdowns were deferred' (i.e. the degradation rates) and the task costs (including downtime duration required). The identified critical issues and components included:

- SAS reactors: internals and structural integrity, vessel nozzles
- Hot Quench Tower: internals, shell integrity, safety relief valves
- HQT Pumparound system: valves, pump mechanical seals, pump around cooler
- Trim cooler: cleaning safety, design, bypass options
- Separator drum relief valves
- Overall train performance and reliability
- Shutdown total work co-ordination, duration, impact.

Other items and systems were also considered and examined for their possible effect upon the shutdown strategy, but were rejected for a number of reasons (low cost/criticality, maintenance can be done on-line, installed redundancy, or deterioration timescales already permit 4-yearly or longer maintenance intervals). Such items included the process pipework, instrumentation, pumps and motors, feedgas compressor and condenser, reactor pressure release valves and fin-fan coolers.

Analysis methodology

The study was performed over a 4-week period by 2 persons full time and 4 persons part-time, conducting a series of structured interviews and small multi-disciplined team reviews of component problem areas. In each case, a 2-stage modelling procedure was employed, based on the European MACRO project methodology¹.

This provided a structured format for range-estimating the costs, degradation patterns and effectiveness of alternative maintenance, design and operating scenarios. APT-MAINTENANCE, APT-INSPECTION and APT-PROJECT software tools (whose development was commissioned by the MACRO project sponsors) were used to calculate instantaneously the Total Business Impact of each option, allowing immediate 'what if?' exploration and sensitivity analysis (identifying which assumptions were critical and worth further research, and which made no difference to the optimal strategy).

The first, problem definition step is clearly very important. MACRO guidance in this area is a valuable way of avoiding many of the practical pitfalls: for example in the estimation of degradation rates when hard data is incomplete or of inadequate quality. In such a case, the questions focus on range-estimating the *cumulative effects* of degradation/failure (i.e. the survival curve) rather than trying to quantify the 'rate of change of risk' (hazard rate curve) that is really needed for a commercial evaluation.

APT software readily converted these survival projections into the implied probability patterns, and allowed us to explore different extremes of opinion in real time (as was obliged in step 3 anyway – to find which assumptions are critical to the decision and where uncertainty is worth investigating further).

The Analysis Process (for individual problem/activity)

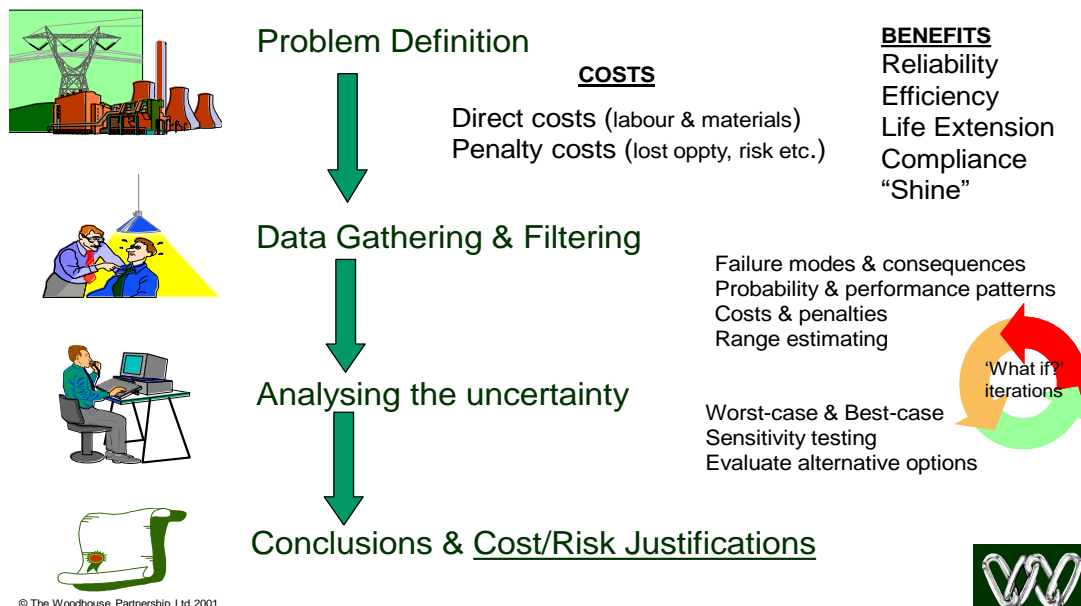


Figure 1. MACRO cost/risk optimization process

¹ European MACRO project: best practice Asset Management decision-making see www.MACROproject.org

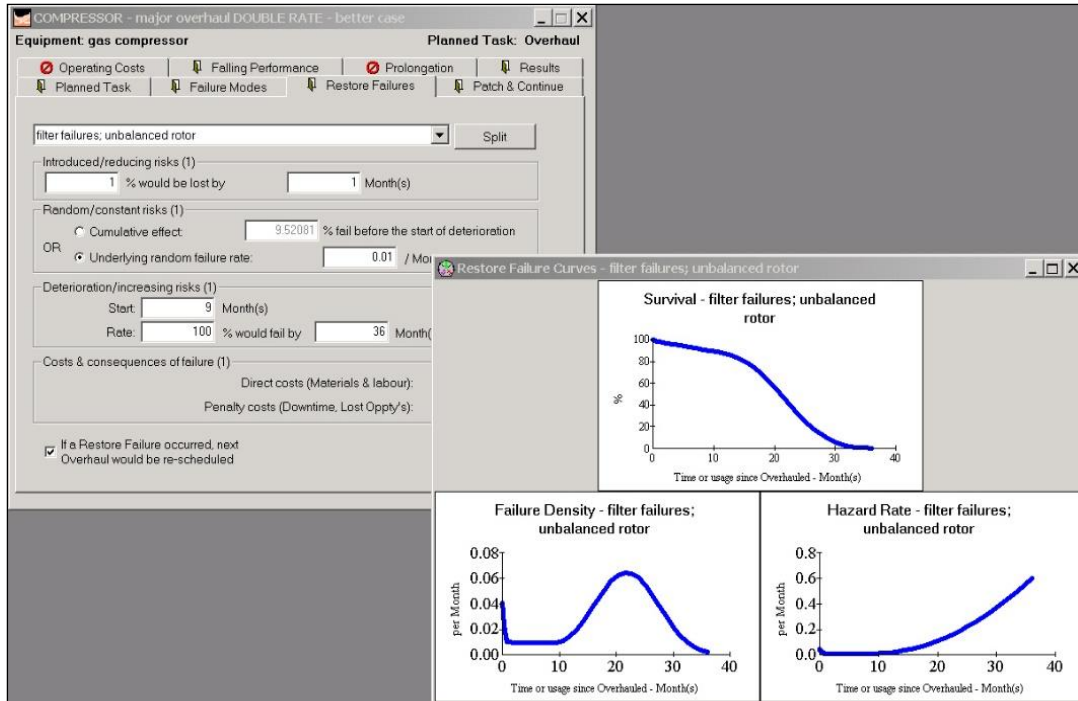


Figure 2. Typical reliability pattern estimation (APT-MAINTENANCE)

The final step is also important – converting the Analysis and technical descriptions into a common language: business impact in \$\$ values. Only then will a proposal be comparable with other, widely different options (expressed in the same value-for-money format). Moreover, financial managers will understand the costs, risks and benefits in language that they recognise!

In the case of activity *timing*, the commercial justification involves quantifying (and identifying the optimal combination of) capital and operating costs, operational efficiency, reliability/risks and planned/unplanned downtime. This involves very complex maths (including renewal theory, reliability engineering and modelling the *interaction* between individual failure modes, efficiency levels etc) – again the software enabled real-time modelling And “what if?” exploration.

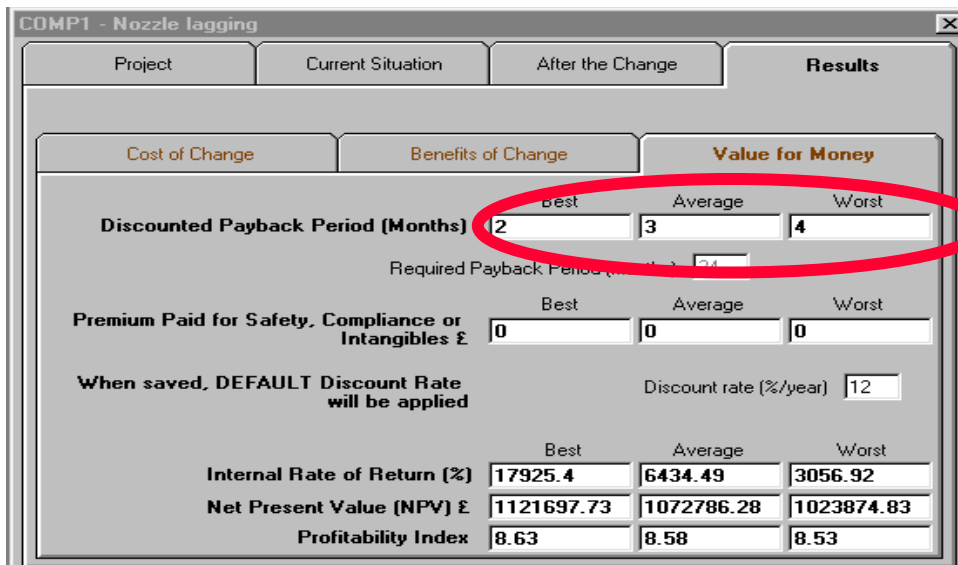


Figure 3. APT-PROJECT evaluation of investment (nozzle lagging), including sensitivity analysis to uncertain assumptions

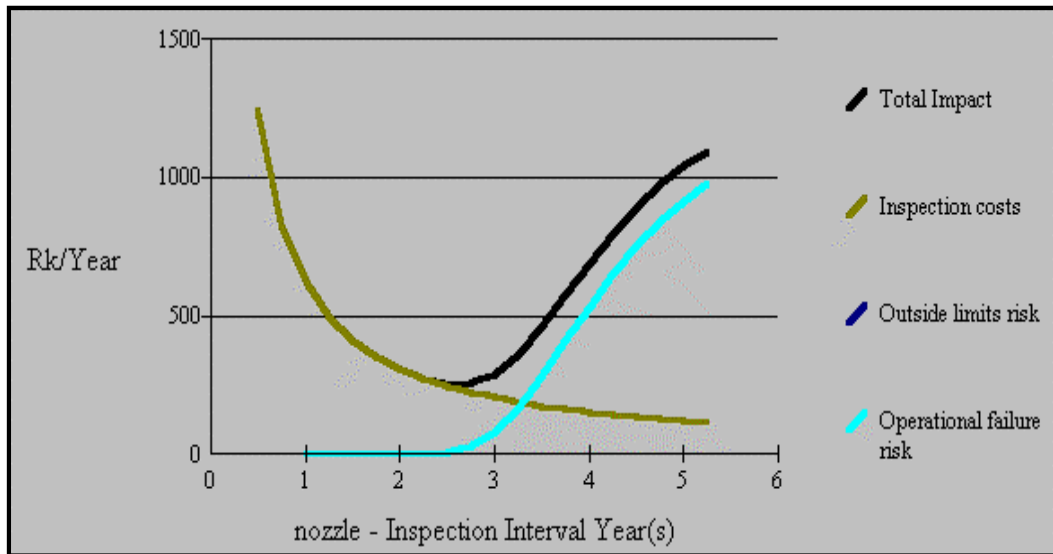


Figure 4. APT-INSPECTION: cost/risk trade-off for nozzle inspection interval

Example component study: Pilot Operated Relief Valves (015)

The HQT safety relief valves are in 4 critical service locations. Operating at high temperatures, there have been a number of failures of the pilot unit, and seal degradation has been discovered. If the pilot unit fails, the main valve seals are often damaged, and leaks to flare may result. The valves are maintained by valve workshop, full overhaul every 2 years, and our analysis considered the risks associated with extension to 4-yearly maintenance. When it became clear that resulting unreliability would be very expensive (see figure 5 below), alternative design options were considered. The possible design improvements included:

It was thought that a robust risk analysis would be needed to obtain permission to extend the maintenance interval for the 015 valves (currently required to be maintained every 2 years). The identical, but less critical, 024 valves on the Separator Unit may already be allowed to extend to 6-yearly. The base study (current design) showed the following cost/risk profile (sensitivity testing, showing worst case/best case/most likely interpretations):

- Change of seals from Viton to Kalrez material (very expensive but can tolerate the product attack).
- Installation of a second pilot unit on each valve, allowing online swapper and maintenance in event of pilot failure
- Inspection plan

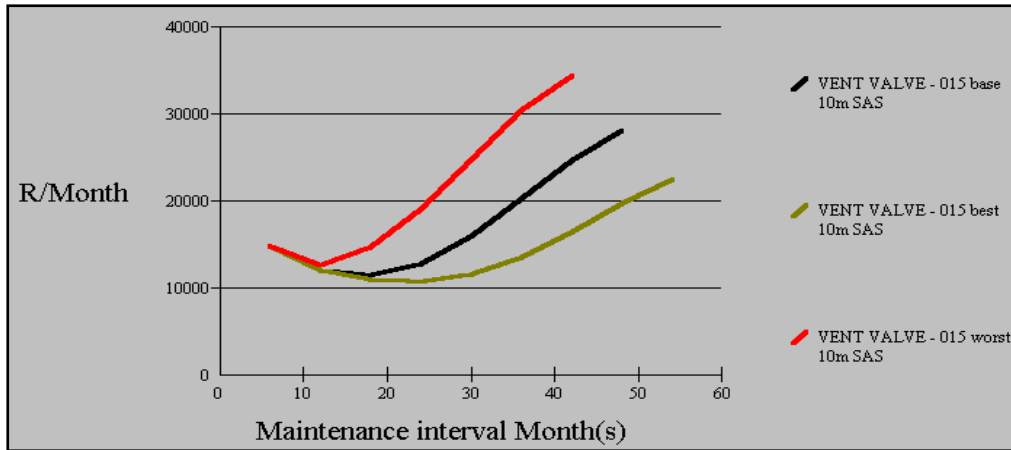


Figure 5. Total impact curves (Best, Likely and Worst interpretations) for 015 PORV's

Installation of Kalrez seals

The cost of the Kalrez material is extremely high (R93,000 per set, compared to current Viton costs of R4,800). Nevertheless, the longer life/higher reliability provides a payback for its use if maintenance intervals are extended. At the current 2-year interval, the high cost/low risk option of Kalrez is about the same Total Impact as the low cost/higher risk option of continuing with Viton.

payback period for this investment is less than 3 months. With 2 such valves per train, and a total site population of 24 units, the net total cost/risk improvement is worth **R3.4 million per year** if the turnaround cycle is extended to 4-yearly.

Installation of second pilot unit on each valve

The installation of a second pilot unit, allowing online changeover, shows an excellent payback for the 1-off costs involved. The total capital costs are estimated at R16,000 per valve, benefits of c.R12,000/valve/month, and the

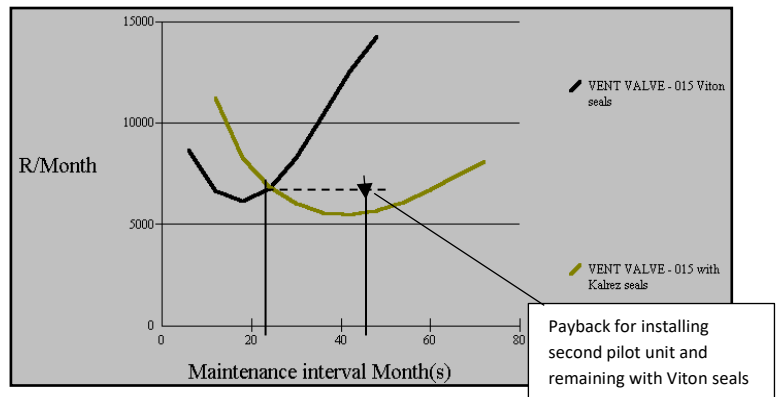


Figure 6. Viton versus Kalrez seals (PORV's on Hot Quench Tower in 8 am train)

Summary results of the key studies

The other studies were performed in a similar manner, with periodic tasks evaluated/optimized using APT-MAINTENANCE (pm work) and APT-INSPECTION (inspections and testing work). Other capital projects to address the shutdown cycle 'bottlenecks' were evaluated using the APT-PROJECT tool so that all options (and uncertainties) were considered in a common, structured format. Over 70 studies were performed during a 4-week period.

Their conclusions are summarised overleaf:

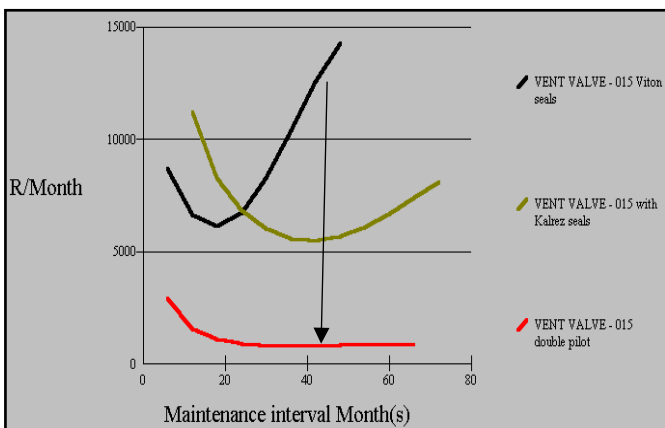


Figure 7. Current versus better seals dual pilot options



Study	Current policy	Recommendation	Business impact
SAS reactors: Coil guide beams	2 yearly inspection/repairs, revealing some deterioration and one case of total failure. New design (carbon steel) has been installed on one reactor and is being evaluated.	Change to new design, carbon steel or stainless steel to allowing 4-yearly inspection. New design carbon steel shows R4,000/month net benefit, but S/S is worth the additional R100k capital cost to double this to (R8000/month).	R96,000/year/reactor for changing to stainless steel. Payback period: 1 year compared to current, 2 years compared to new carbon steel design.
SAS reactors: vessel nozzles above catalyst level	2 yearly inspection, some with internal stainless cladding	Lagging to raise temperature and slow corrosion (better payback than cladding) but risk resulting from ineffective insulation	R120,000/year/reactor risk reduction (2 yrly current vs. 4-yearly with lagging, provided this is effective.)
SAS reactors: Plenum/shell weld	Inspect 2-yearly, some cracking detected	Inspect 4 yearly, additional risk exposure acceptable and is built into total shutdown cost/risk model	-R1,200/year (small additional risk)
Hot Quench Tower: Spray Nozzles & shell integrity	Inspect 2-yearly; cracking of 3 spray nozzles found recently. Erosion/corrosion found on shell internal surface.	New localised and focused inspection methods, selective additional spray cladding with stainless steel. Weld overlay too expensive, and does not justify total shell cladding (localised problem).	Selective spray cladding worthwhile (net benefit c. R170,000/year/HQT). Some additional risks in 4-yearly vs. 2 yearly (R40 000 to100,000/year)
Hot Quench Tower & Separator Drum: Pilot Operated Relief Valves	Overhaul 2-yearly; problems with seals and pilot reliability	Install second pilot unit on each valve, allowing on-line maintenance of pilot and 4-yearly on main valve. Also evaluated new seal material, but dual pilot gave better payback.	R3.4 million/year for the 24 x '015' valves. Payback for capital costs is 2 months (015 valves) and 4 months (024 valves).
Pumparound System: valves & pump seals	Overhaul 2-yearly; isolation valves failure to close prevents on-line cooler cleaning and pump/seal maintenance	Alternative design (ball valve) is NOT worthwhile, additional risk of 4-yearly maintenance built into total shutdown cost/risk model. Other design/filtering /cleaning options should be explored. Double block & bleed on cooler	-R40,000/year/cooling train (additional risk, given that proposed design change is not justified)
Pumparound Cooler	3-6 monthly cleaning, if isolation valves functional, otherwise 2-yearly cleaning	3-6 monthly cleaning: even if short shutdown is required to isolate. Urgently investigate options for filtration, reduced fouling or online cleaning. Pumps - replace vessel valves with gate valves when current valves need replacement.	Penalty for continuing to next opportunity can be up to R1 Million per month. Worth further study.
Trim cooler	Opportunity-based cleaning, with large impact of fouling upon separator drum temperature and performance	7 alternative design configurations and cleaning options were evaluated: best is online cleaning (need to check waterbox implications), or valves/pipes for water side bypass during cleaning. Stainless steel water boxes if shutdown duration impacted waterbox repair and painting.	R4 million/year benefit for best solution. Payback for installing bypass or online cleaning is 2-3 months.
Remainder of Synthol Trains	2 yearly planned maintenance plus online minor defects and breakdown repairs	4 yearly planned work, plus slightly higher rate of minor repairs and short downtime events, built into total shutdown cost/risk model.	Approximate cost/risk neutral (number of events, pm costs, inspection/repair costs).
Planned Shutdowns	2 yearly major turnaround (15 days), plus 2.5 events per month of avge 4 hours downtime (unplanned)	4-yearly turnaround, with slightly higher frequency of minor stoppages in second half of cycle.	R7-14 million per year average production increase (8m and 10.7m SAS trains respectively)
TOTAL SYNTHOL TURNAROUND	2 yearly, split into 2 factories on alternate years	4 yearly, split into phases, one per year. For 4x 8m SAS and 4x 10.7m SAS reactors	R40 million/year net improvement

Combining individual tasks into shared downtime opportunities

Comment from the team involved

The above studies were performed individually, and then aggregated manually to explore the combined effect (sharing shutdown opportunities and overhead costs etc). This process is now automated, to explore all feasible combinations of short, frequent 'pit-stop' work and larger, longer-interval major shutdowns. It uses artificial intelligence (genetic algorithms) to experiment with different work bundles, calculating the total cost/risk compromise for bringing some tasks earlier than optimal, and delaying others to take advantage of shared downtime opportunities. The APT-SCHEDULE tool performs this "what if?" task extremely fast, allowing the user to move individual tasks, add, constrain or eliminate work and instantly recalculate the entire work programme in present day \$\$-values.

"This study has caused a paradigm shift in the way that I think in managing the assets" Wiid Venter

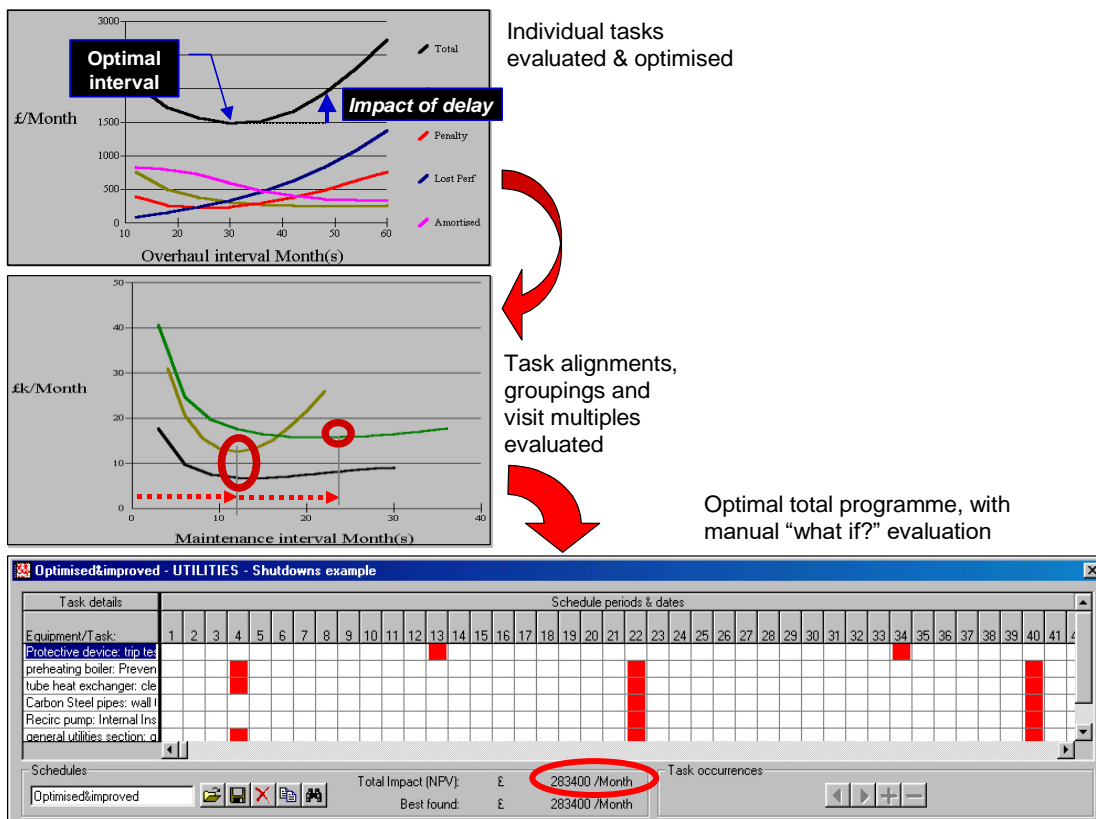


Figure 8. APT-SCHEDULE exploration of different task groupings and alignments

Implementation of the results

The shutdown study is now being progressively implemented, with 10 of the 13 recommendations implemented (of the other three, one can only be implemented at next shutdown, the second revealed further opportunities to be explored, and the third proved too costly at the engineering stage). The next shutdown has been deferred to September 2004. In hard numbers, some of the benefits are already being achieved:

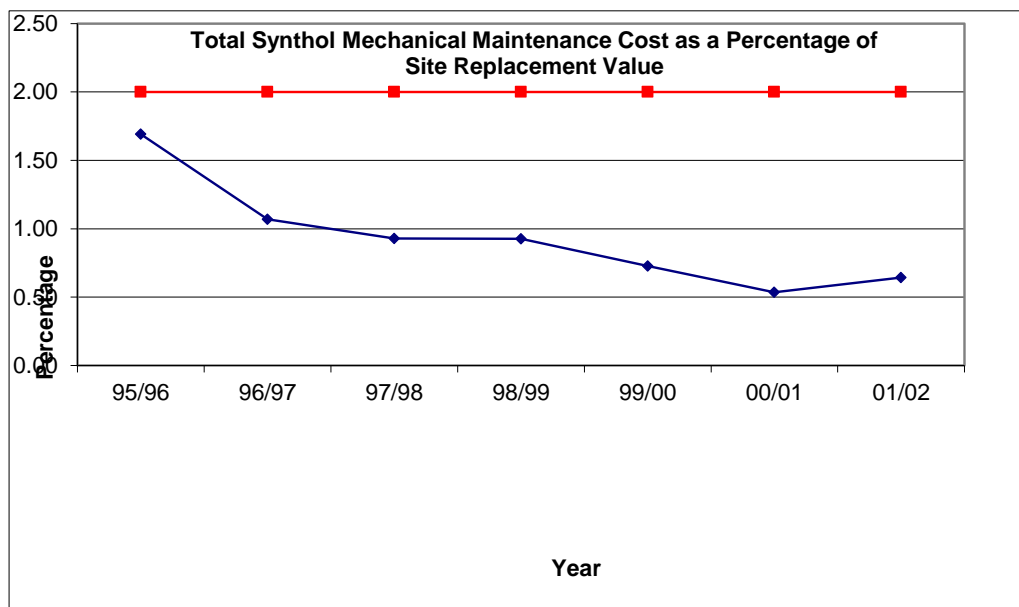


Figure 9. Sustainable maintenance cost reductions achieved

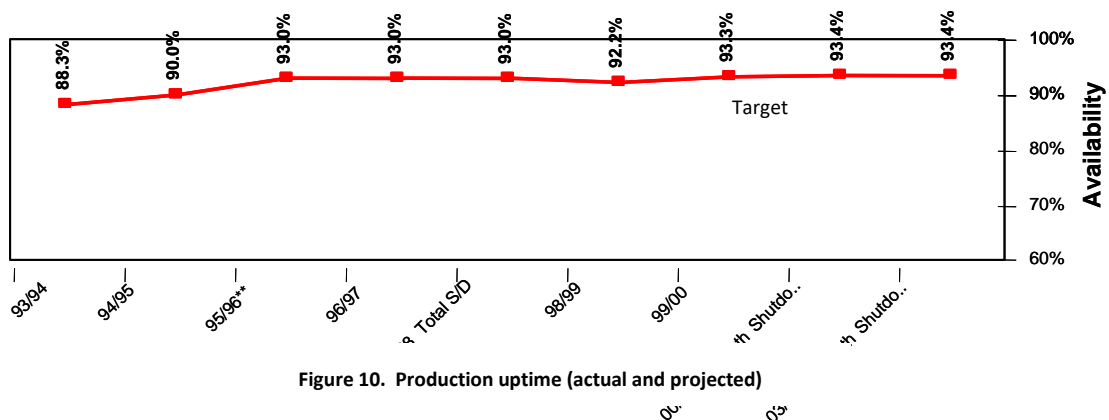


Figure 10. Production uptime (actual and projected)

Ongoing progress and further studies

In the last couple of years, considerable additional work has been done at the individual problem and decision level. Between July 2001 and April 2002, a further 88 APT studies were conducted, to the value of **R 88.06 million**.

In the next 12 month period (May 2002-July 2003), a further 100 Studies were conducted to a value of **R 304 million**, (with individual cases ranging from R20,000 to R50 million impact).

Typical studies in this period have considered the materials used for heat exchangers (life cycle analysis of various steel types), renewal of major equipment items, and further maintenance and inspection policies. In particular, with the acquisition of site-wide licenses in the entire APT suite (7 modules), the APT-LIFESPAN tool has enabled optimal timing and cost/risk justification of capital projects. These studies have revealed that ‘generic’ decisions (such as selection of heat exchanger bundle material) cannot be made safely: the evaluation must take account of local usage, criticality and accessibility to influence the choice of materials, the use of bypass options for cleaning etc.

In general, about 80% of the studies have been approved for taking forward – the balance have encountered barriers such as the results and implications have not been fully accepted by all parties yet (lack of training and understanding). Senior management, however, now insist that only projects evaluated as worthwhile by an APT study will be considered for approval.

Taking a rough cut of 80% of the anticipated benefits being achieved, this amounts to around **R 320 million (approx US\$42 million) impact** in addition to the Synthol shutdown strategy (**R 50 million or US\$6 million/year**).

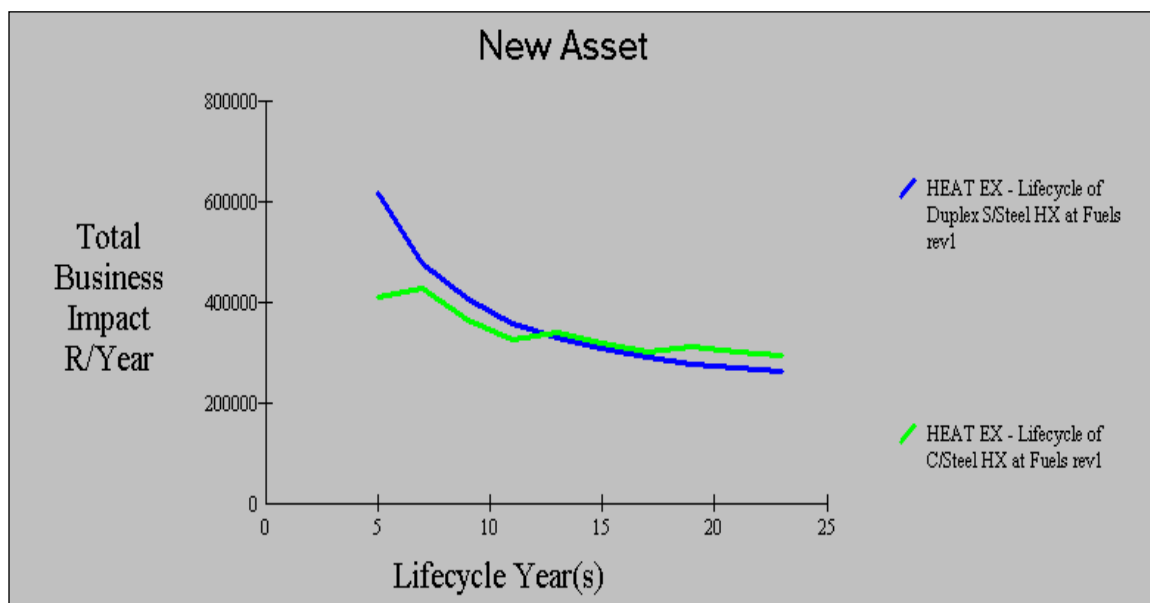


Figure 11. APT-LIFESPAN calculation of different materials and optimal renewal policies

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In subsequent studies, others in the Reliability Group, Gasification division and MSM team have 'taken up the torch' and now lead the continuous improvement process – and there is plenty still to do!

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