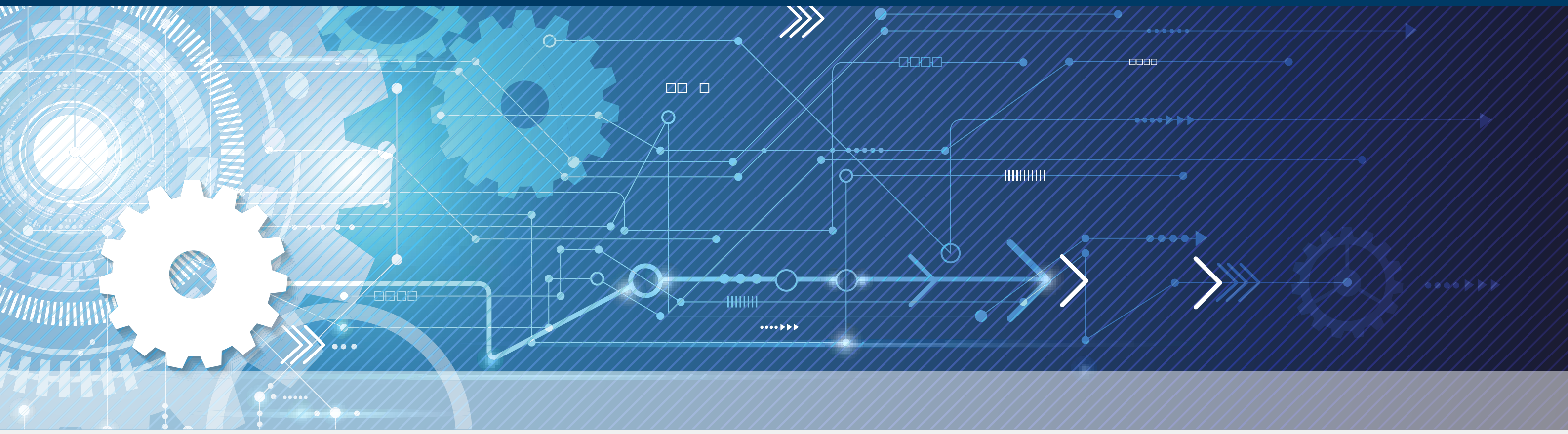
White Paper

Reducing the maintenance burden across oil and gas operations



The upstream oil and gas industry is cyclically faced with low oil prices and high operating costs, with the growing challenge of ageing assets and increasingly complex infrastructure. Similarly, the downstream market is struggling to maintain production uptime of ageing assets operating at maximum capacity. Whilst safety remains paramount, optimising asset reliability is just as crucial to stay competitive and to realise cost efficiencies.

Onshore and offshore facilities are costly to build, operate and maintain, so it's imperative that operators keep tight control over the total life-cycle cost of equipment.

Maintenance of both onshore and offshore facilities is a complex and demanding discipline. Maintenance can be viewed as a solely technical discipline, with little commercial consideration given to determining an appropriate and sufficient maintenance regime. Given that the cumulative cost of maintaining a facility over its lifetime can rival the capital costs required to design, construct and commission the facility, it makes the commercial context of maintenance noteworthy.

In a low oil price environment operators are pressured to maintain uptime and production, often postponing maintenance viewed as non-essential and stalling shutdowns and turnarounds. This is compounded by offshore accommodation limitations, the perpetual reduction in people resource to undertake tasks and uncertainty relating to the rationale for existing maintenance programs. However unjustified deferral is only a short term gain, affecting the medium to long term reliability of equipment, production levels and ultimately safety.

Operators often struggle under this unattainable maintenance burden, which leads to escalating maintenance backlogs and facility unreliability, frequently combined with an inability to liquidate production-enhancing or important asset integrity workscopes.

This challenge isn't a new one. As an industry we're accustomed to fluctuating prices and poor alignment in priorities. In 2008, the then US Chemicals Board Chairman (CSB), John Bresland, released a video safety message calling for Industry to remain focused on process safety and accident prevention during recession. He noted that the CSB investigation of the 2005 Texas City refinery disaster linked the accident to corporate spending decisions in the 1990s, when low oil prices triggered cutbacks in maintenance, training, and operator positions at the plant[1].

[1] In First Video Safety Message, CSB Chairman John Bresland Calls for Industry to Remain Focused on Process Safety, Accident Prevention During Recession (2008). U.S. Chemical Safety Board. [Online] Available at: http://www.csb.gov/in-first-video-safety-message-csb-chairman-john-bresland-calls-for-industry-to-remain-focused-on-process-safety-accident-prevention-during-recession/ [Accessed April 2017]

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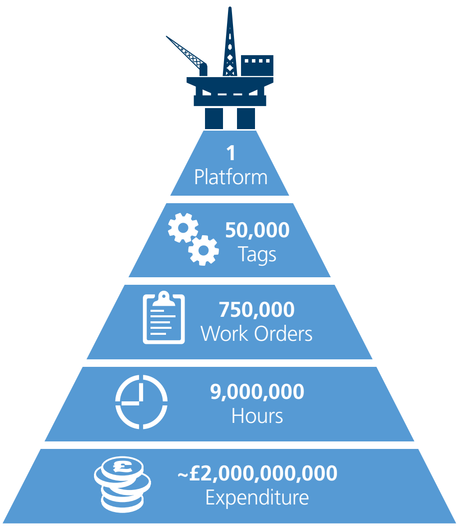
In the UK, the issue is highlighted in numerous industry reports including the Health and Safety Executive (HSE) KP3[2] and KP4[3] reports which focus primarily on the maintenance management of Safety Critical Elements (SCEs), Integrity Management and aging assets.

It is becoming more widely recognised that there are substantial gains to be realised through the optimisation of maintenance activity sets, and in gaining the maximum value from the deployment of valuable resources, both human and material. Engineering expertise and new technologies offer a means to leverage the abundance of industry data and historical asset data to rationalise and focus maintenance efforts based on criticality, product price and total cost of ownership, cost of maintenance and consequences of failure.

The maintenance burden

For a typical offshore installation with an operational life of 30 years and approximately 50,000 maintainable equipment items, in the region of 750,000 Work Orders will be generated, leading to some 9,000,000 hours of activity. In total this can represent a cumulative expenditure of up to £2 Billion and, with many facilities exceeding their original design life, the costs of maintenance can continue accumulating significantly beyond what was originally anticipated.



Up to 25% of offshore personnel can be engaged in the management, supervision, preparation and execution of maintenance activities on an offshore installation. Performing only the correct maintenance at the correct time is of paramount importance in order to maximise the utilisation of every available offshore bed.

The requirement to perform only appropriate maintenance is further reinforced when it is considered that 27% of all offshore injuries are associated with maintenance, and that 10% of all Hydrocarbon releases are directly attributed to maintenance activity[4].

Conversely, over-maintaining offshore equipment is also prevalent, compounding the backlog issue and introducing unnecessary personnel risks. Many assets operate with a maintenance strategy and plan which are a legacy of a past economic era, and have typically remained constant over the asset life, irrespective of changing production and commercial realities. Original Equipment Manufacturer (OEM) recommendations can go unchallenged resulting in unnecessary maintenance burdens which place significant pressure on asset teams and operational budgets.

Similarly, it is seldom the case that equipment with a safety-related function are maintained such that the required Functionality, Availability, Reliability or Survivability (FARS) criteria are able to be easily demonstrated, or intervals modulated according to the changing performance of the equipment.

Backlogs occur when maintenance hasn't been carried out when due. The issues can be attributed to factors including:

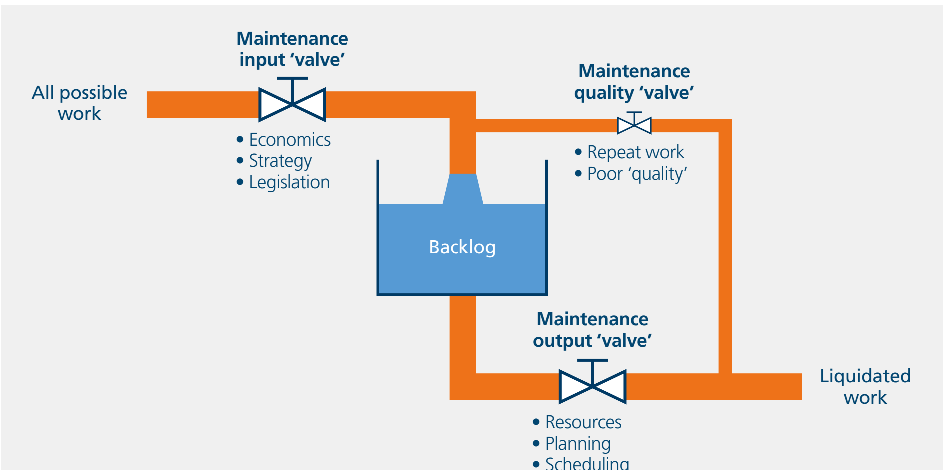
- The volume of Planned Maintenance (PM) work being discordant with the available resources
- Increased volumes of Corrective Maintenance (CM) due to facility ageing
- Inappropriate remedial timescales associated with CM activities
- The prioritisation of other workscopes

Over the years, a number of Improvement Notices been have served by the HSE in the UK, on operators that have significant maintenance backlogs, fuelled by their inability to demonstrate that the associated risks are understood and being managed. This further reinforces the need for an appropriately resourced, optimised maintenance activity set.

The ability to refine maintenance in response to changing criteria is key. Maintenance has to evolve as plants age and, as set out by the HSE[5], should take into consideration:

- Changes to operating parameters and other relevant modifications.
- Experience gained in the operation of equipment (condition findings, failures, efficiency of performance etc).
- Improvements in technology through the equipment's life-cycle (eg equipment design, maintenance and inspection techniques).
- The tolerability of failure and risk may change.
- The inclusion of commercial criteria when optimising maintenance.

Determining an optimal planned maintenance program that marries both technical and commercial considerations, and quantitatively determines the optimum periodicity for planned maintenance help abolish the burden and safely reduce operating costs.



Maintenance backlog map

[2]Health and Safety Executive (HSE), Key Programme 3, Asset Integrity Programme. [Online] Available at: http://www.hse.gov.uk/offshore/kp3.pdf [Accessed April 2017]
[3]Health and Safety Executive (HSE), Key Programme 4, Ageing and life extension programme. [Online] Available at: http://www.hse.gov.uk/offshore/ageing/kp4-report.pdf [Accessed April 2017]
[4]Health and Safety Executive (HSE), Maintenance - Reducing the risks, HSE, Offshore Technology Report (2001). [Online] Available at: http://www.hse.gov.uk/research/otopdf/2001/oto01007.pdf [Accessed April 2017]
[5]Health and Safety Executive (HSE), HID Inspection Guide Offshore. [Online]. Available at: http://www.hse.gov.uk/offshore/ed-sce-management-and-verification.pdf [Accessed April 2017]

The benefits of performing maintenance optimisation:

- Real-time and full-time asset awareness
- Increases asset reliability, availability and utilisation
- Improved production critical reliability and availability
- Focus limited resources on your critical assets
- Prioritises maintenance based on risk
- Unnecessary planned maintenance tasks eliminated
- Maintenance intervals extended where justifiable
- Reduced maintenance burden
- Creates understanding of predictable and non-predictable failure modes
- Schedule and manage work orders more efficiently
- Complies with safety standards and regulations
- Reduced OPEX costs

Optimised maintenance

Pre-operations

A planned maintenance program is normally determined during the pre-operational phase of the facility lifecycle and deployed immediately prior to operations in a Computerised Maintenance Management System (CMMS).

Common issues that can occur during maintenance program deployments include:

1. A lack of commercial or economic considerations
2. Little underpinning justification for the maintenance burden deployed
3. A maintenance program that is disproportionate to the resources available for execution

Once developed and deployed in the CMMS it becomes more onerous to make changes to the CMMS content, on the basis that the administration associated with relevant Management of Change (MoC) and securing the relevant technical approvals can be time consuming and demanding. Therefore, ensuring the initial maintenance program is robust takes on extra significance.

It is often difficult to retrospectively ascertain the rationale employed to determine the original maintenance program, resulting in data in the CMMS that has little documented foundation.

This lack of linkage between the operational maintenance program and the original justification can create issues throughout the lifetime of a facility, especially if changes of ownership occur or change is required. This is exacerbated as production throughputs vary over the operational lifetime, commodity prices fluctuate and equipment reliability changes.

When a CMMS is populated during a project phase of an asset lifecycle an approach can be adopted such that is efficient to attribute appropriate maintenance to categories of equipment, or equipment types. Given the volume of equipment items to be considered, it can be impractical to develop bespoke maintenance for every equipment item on an individual basis, and a generic approach can be adopted; equipment can be assigned a maintenance program based on the equipment type. For example, all Low Voltage (LV) motors may have an identical maintenance program assigned, irrespective of the driven unit connected to the motor.

Whilst this approach can have merit in that it is a cost-effective way of assigning maintenance to large numbers of equipment items, it can also suffer from the disadvantage that there is no discretion applied to individual equipment items, and their specific commercial criticality in the facility. However, the ability to commercially substantiate a maintenance program can be limited, resulting in conjecture as to the validity of maintenance and the attendant offshore labour burden. This can often result in excessive volumes of maintenance being generated from the CMMS and subsequent need to optimise maintenance and reduce the frequency of maintenance activities[6].

In Operation

As offshore assets mature and production declines, revenue declines proportionately if commodity values are constant. This changing revenue profile can result in a drive to reduce operational expenditure to maintain profit.

Maintenance costs come under increased scrutiny, both in terms of scope and frequency. For a maintenance activity defending against a commercial risk i.e. the failure of an equipment item, results in a commercial impact. If the value of the commodity being processed halves or doubles, how does the subsequent maintenance regime change, if at all? Should it?

There can often be a lack of understanding of the commercial drivers substantiating a maintenance program and this can lead to an inability to intelligently modulate a maintenance program when the underpinning assumptions change.

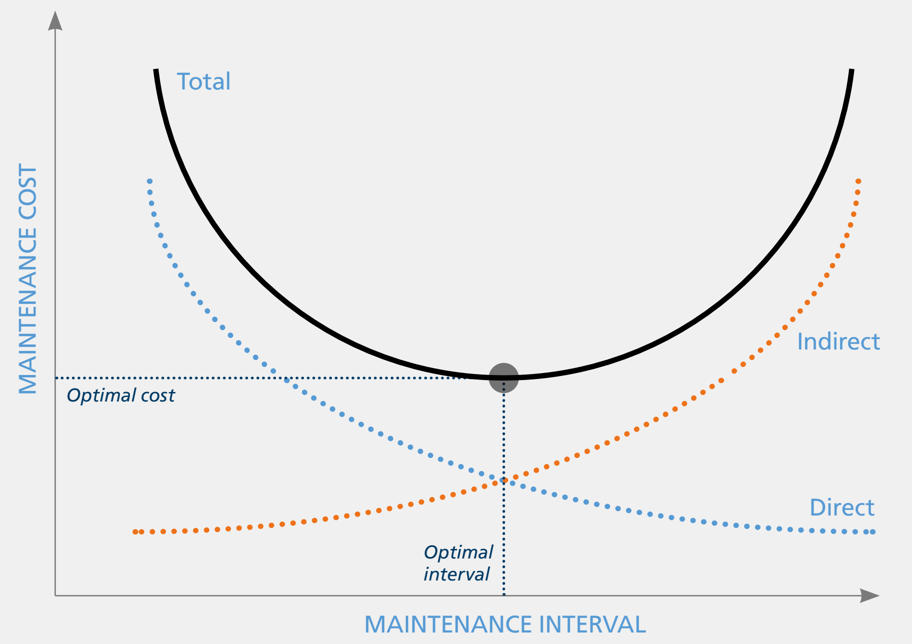
[6]Booz&C, Beat the Clock Increasing Workforce Productivity in Process Industries (2009). [Online] Available at: http://www.strategyand.pwc.com/media/file/Beat-the-clock.pdf [Accessed April 2017]

With any maintenance activity it is the aim to maintain equipment at its lowest total cost of ownership. Essentially this means that the sum of the direct costs of maintenance and the indirect costs of maintenance are at the minimum point. This is shown in Figure 1 which demonstrates that as the direct costs of maintenance increase, there is a decrease in the indirect (risked) costs.

The sum of the direct and risked costs of maintenance yields the total cost of maintenance, and the optimal condition is satisfied by the total cost minima.

The optimal maintenance condition is a target that is difficult to achieve as the optimum condition is ever-changing; economic considerations, performance assumptions, production capability, technology and personnel competence are not fixed but vary with time and mean that maintenance, that is regarded as being optimal today, may be sub-optimal in the future.

Figure 1 - Optimised cost of maintenance



Reliability-centred maintenance

A common maintenance development methodology is Reliability-Centred Maintenance (RCM) – a qualitative approach used to determine appropriate maintenance activities based on analysis of equipment failure modes. Typically, a qualitative approach is taken to determine maintenance activity intervals, relying on opinion and experience to determine a notionally optimal maintenance solution. By virtue of the fact that this is a qualitative approach, the ability to demonstrate a truly optimal position is limited.

This optimal position can be demonstrated by mathematical maintenance optimisation; a quantitative analysis requiring reliability data and mathematical modelling to precisely identify a solution and it is increasingly the case that the simpler quantitative approaches can bring benefits to maintenance optimisation and demonstrate the lowest total cost of ownership.

It is notable that such quantitative optimisation approaches allow operators of assets to effectively 'model' their facility, which yields substantial operational and commercial benefits:

- An ability to quickly tune the maintenance program in response to changing economic and reliability criteria such as changing commodity price, facility throughputs or equipment redundancy.
- The capability to perform sensitivity analysis on maintenance workloads and scenario plan.
- As each maintenance activity brings a 'Net Present Value' to the organisation, maintenance can be planned based on the business benefit realised.
- Matching of the maintenance burden to the organisational capability to deliver maintenance.

A number of examples of the benefits of maintenance optimisation are cited in more recent UK Oil and Gas publications[7], where the application of quantitative methodologies can pay significant dividends and allow operations to focus the effort and costs of maintenance on the areas of highest risk and largest return, both commercial and in terms of risk reduction.

Recent maintenance optimisation examples using such quantitative techniques have brought business benefits to operators in a short timeframe; typically, less than 6 months, with a significant Return On Investment (ROI) demonstrated. Furthermore, as facility maintenance models are built; the ability to repeatedly and continuously 'tune' the asset maintenance program is cost-effectively achieved.

[7]Oil & Gas UK, Maintenance Optimisation Reviews – Sharing Experience and Learning (HSE02) (2016). [Online]. Available at: http://oilandgasuk.co.uk/product/maintenance-optimisation-reviews-sharing-experience-and-learning/ [Accessed April 2017]

Case Study – Maintenance optimisation in action

To ensure cost efficiency in the current economic climate, an operator was scrutinising aspects of their maintenance regime to ensure that effort is optimised on equipment that does not have an immediate production or safety benefit.

This also including consideration of reducing preventative maintenance on items with low failure rates or those which can run-to-failure (RTF) with minimal adverse consequences.

It was recognised that the OPEX was too high and the Personnel On Board (POB) capacity insufficient to liquidate current maintenance burdens.

Maintenance optimisation

A study was conducted to provide optimised maintenance frequencies on Low Voltage (LV) Motor population. The ultimate aim was the optimisation of the maintenance burden which would allow a reduction in OPEX costs.

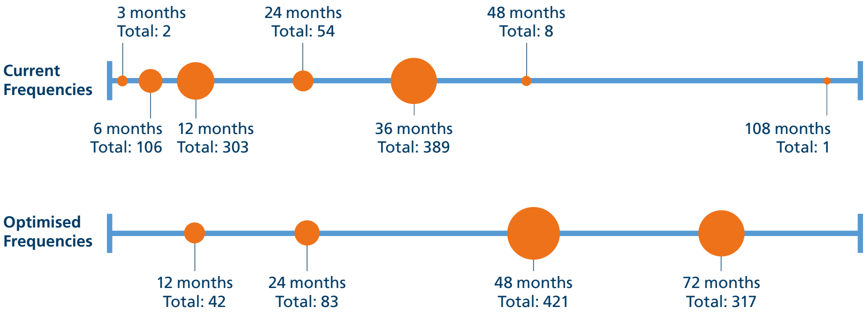
The study, which took three weeks, included 970 items. The analysis was broken down in to distinct areas to allow for new frequencies to be assigned to planned maintenance (PM) on LV Motors:

1. Interrogation of the data to determine failure rates for each of the facilities
2. Cost analysis
3. Assign the PMs an agreed severity
4. Optimise maintenance activities

The fully auditable study allowed for formal update of the necessary client strategies/ documents pertinent to LV Motors as well as the update of their work management system (WMS).

Analysis outcome

- 93 Planned Maintenance Routines (PMR) recommended for their frequency to increase
- 9 PMRs had no change to frequency
- 761 PMR frequency decreases



Results

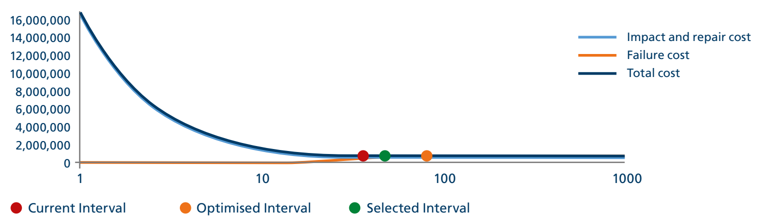
- With the implementation of the analysis and agreed commercial and time assumption, an estimated financial saving of 65% can be made on annual maintenance on LV Motors (determined by the previous maintenance outlay versus the proposed strategy).
- An estimated reduction of 7127 annualised man hours can be achieved.
- Recommendations were made in relation to greasing regime importance and for the strategy to be applied consistently to the population of LV Motors
- If the optimisation study had not occurred there would be a continued misuse of time and therefore cost in doing maintenance activities where it is not required.

Severity 1 LV Motors (Major)

Intervals

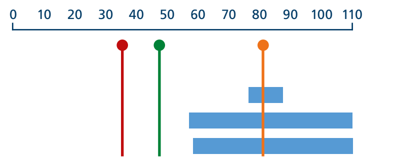
Current: 36.00m	Optimised: 82.96m	Benchmark:	Selected: 48.00m

Cost v Interval



Sensitivity Analysis

Parameter	Variance
Production Stream	25%
Labour	25%
Material	25%
Other	25%



Summary

In summary, it is clear that both offshore and onshore facility maintenance can be a significant expenditure for an operator, and that the consequences of inappropriate maintenance programs can impact severely the facility profitability, safety performance and result in regulatory compliance implications. Optimised maintenance programs offer material benefits to asset operators:

- Demonstrable, lowest total cost of ownership.
- A maintenance burden commensurate with the resourcing profile.
- Effective risk mitigation.

The ability to optimise maintenance at the pre-operation phase and continuously through the operational life of a facility can bring significant opportunities to an asset operation and to achieve this cost effectively demands a maintenance 'model' that can be readily tuned to changing reliability and economic parameters quickly and effectively. Such approaches are now readily available in the marketplace and offer a cost-effective means of maintenance optimisation through the life of facilities, delivering significant ROI and an almost immediate business benefit.

RTAMO™, brought to you by Lloyd's Register, is a software enabled service for optimising maintenance in upstream and downstream operations. Coupled with LR's engineering expertise in maintenance, RTAMO™ helps you eliminate unnecessary maintenance tasks, minimise maintenance backlogs, reduce operating costs and safely extend asset life.

RTAMO™ can be applied to a wide range of asset families across offshore oil and gas platforms, Floating Production, Storage and Offloading (FPSO) units, onshore refineries and chemical plants.

To find out more about how Lloyd's Register can help you optimise maintenance, visit www.lr.org/oilandgas, contact us at oilandgas@lr.org or call +44 (0)1224 267400.

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