DELIVERING ASSET VALUE

CASE STUDY INCLUDED

A FRAMEWORK FOR ASSET RELIABILITY & INTEGRITY MANAGEMENT

STORK

A Fluor Company

CONTENTS

RELIABILITY AND INTEGRITY

1 RELIABILITY AND INTEGRITY; IT'S A BALANCING ACT?!

Put a business manager, cost controller and risk manager in the same room as an industrial asset owner and ask them to define the optimum objectives for their complex capital assets. You can expect a lively discussion about how to balance asset output objectives against compliancy requirements and total cost of ownership. The discussion will become even more heated if we take the total expected asset lifetime into account, together with the effects of corporate strategy.

But… for the sake of the story, let's assume these people are professionals and they find a smart way to set the objectives that they can all agree to. Then, the next challenge will be implementation and alignment between the different disciplines, which – all together – will have an impact on meeting the ultimo asset objectives.

We see many asset owners struggle with challenges like how to optimise the performance of their assets in a sustainable way, how to comply with current regulations, which data to capture to predict asset failures, how to improve their maintenance strategy by closing the loop, and so on. We found the answers by designing a 'control tower' approach to connect the essential elements of availability, reliability and integrity. This white paper describes the integrated Asset Reliability & Integrity Management ('ARIM') framework.

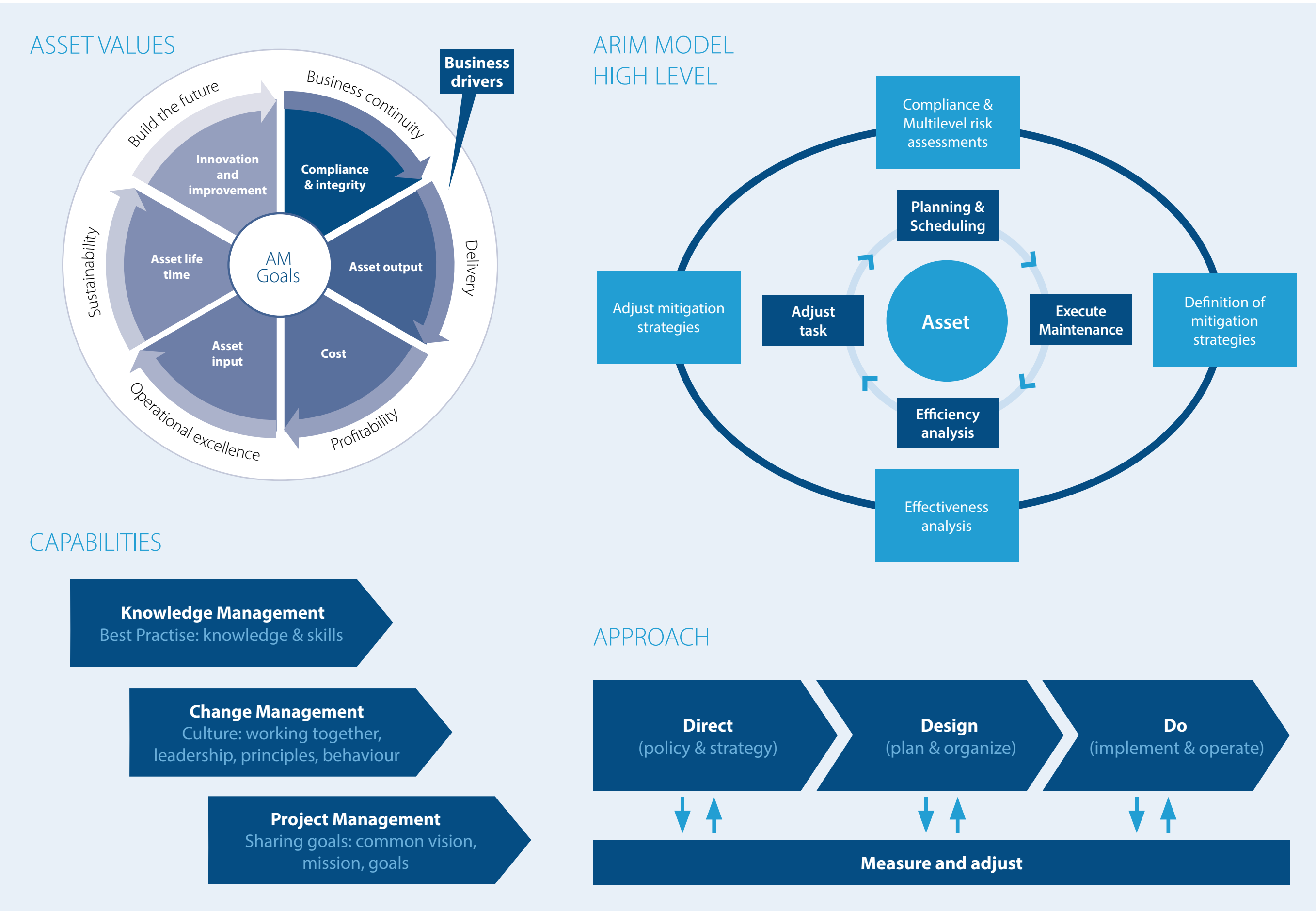

Figure 1: Stork Asset Reliability & Integrity Management Framework

This framework has been developed by Stork and implemented successfully for different asset owners. This field-proven framework integrates the reliability process with the maintenance process, and enables us to define risk-based maintenance strategies and tasks, proper and timely execution of the maintenance tasks, evaluation of the effectiveness of the strategy, and adjustment of the strategies and tasks. ARIM is based on the RIMAP (Risk Based Inspection And Maintenance Procedures for European Industries).

The scope of ARIM can cover many different assets: static, rotating, electrical, automation, machinery and supporting systems, with different levels of complexity and risk profiles. Because of this inherent complexity, maintenance of these assets involves multiple disciplines – either in-house or using contracted labour.

A pragmatic approach is described on how to implement ARIM in an effective and sustainable way. This approach is detailed in an ARIM Programme. Key success factors in an ARIM programme are Project Management, Change Management and Knowledge Management.

Asset owners who implemented this framework gained the following benefits:

- Awareness of their cost of ownership position, in which the effects of downtime and opportunity loss are weighed against maintenance costs
- A clear audit trail, from risk assessment up to the effectiveness of mitigating actions
- Compliance with the applicable standards and regulations
- Managed risk profile of the asset in line of sight
- Full focus on added value tasks in the maintenance process, eliminating non value adding maintenance activities
- Structured workflows in software tools like CMMS (Computerised Maintenance Management System) and Asset Performance Management systems like Meridium.

These benefits are also shown in the case study which is described in this paper.

Asset Reliability & Integrity Management (ARIM) has become an important cornerstone of Asset Management for successful delivery of Asset Value. Asset Management is defined as the optimum way to manage assets to achieve a desired and sustainable outcome. Asset Reliability & Integrity deals with the probability of failure of an asset, so ARIM can be defined as 'Ensuring the required functions of the asset over the life-cycle of the asset'.

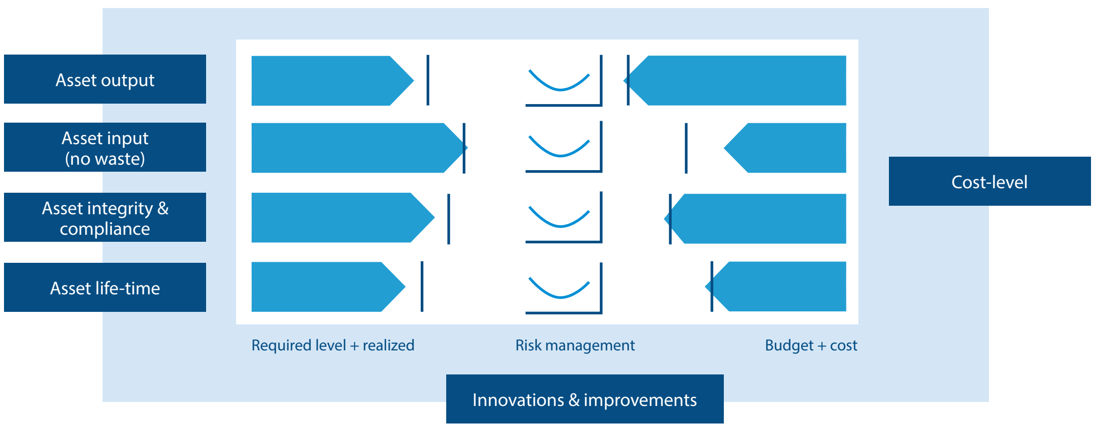

Figure 2: Relationship between Risk Management and Asset Management Objectives

2 DEFINITION OF ASSET RELIABILITY & INTEGRITY MANAGEMENT

Before dealing with the role of ARIM in the Asset Management Objectives, it may be useful to define what Asset Reliability & Integrity is, because there are many possible definitions.

Among the most important standards for Asset Reliability are the European Standard EN13306 and the Norwegian Standard NORSOK-Z-016. These define reliability as 'The ability of an item to perform a required function under given conditions for a given time interval'. The International Standards IEC61508 and IEC 61511 define a Safety Integrity Level (SIL) as a synonym for the reliability of a functional safety system: 'Probability of a (safety related) system satisfactorily performing the required (safety) functions under all the stated conditions within a stated period of time'.

The American Petroleum Institute defines integrity for pressure equipment in Standard API 580 as 'Maintaining the mechanical integrity of pressure equipment items and minimizing the risk of loss of containment due to deterioration'.

Keeping these standards in mind, in this paper we define Asset Reliability & Integrity Management, which includes asset integrity, as 'Ensuring the required functions of the asset over the life-cycle of the asset'.

3 ASSET RELIABILITY & INTEGRITY MANAGEMENT AND ASSET VALUE

The ultimate goal of a (private) company is to create value and to make profit to be able to continue its existence in the long term. Safety, Health, Environment, Reputation, Output, Cost and Quality must be in control to achieve optimal production output meeting customer requirements and complying with all stakeholders' requirements.
The management of risks is therefore a vital capability. Risk is expressed as Probability of Failure (PoF) multiplied by Consequence of Failure (CoF):
R = PoF x CoF

Risk Management as defined in ISO 31000 deals with analysing risks and defining the acceptable risk levels. One risk may be more acceptable than another, depending on the consequences and the costs of appropriate mitigating actions. ARIM identifies the potential risks and minimises those risks to the desired optimum levels of objectives and costs.

But how do we know the PoF and CoF? In known technologies it is possible to make a quantitative risk analysis and to calculate the values on the basis of historic data on the frequency of failures and the known consequences. For new technologies analysis will be more qualitative, using assumptions based on experience and knowledge of the involved people from different disciplines.
The cooperation between all disciplines is an important success factor for risk management.

The consequences of failures are linked to the Asset Management objectives. The consequences are defined as not meeting a specific objective, e.g. 'loss of asset output for one hour has a value of 10K euros'. The consequence classes are used as the basis for a systematic approach to Asset Reliability & Integrity Management.

- **Asset output:** generating the correct number of 'conforming' and 'quality' products at the required time.
- **Asset input:** management of 'input' losses, such as
  - energy
  - (raw) materials
  - labour/overhead (e.g. due to limited functioning of an asset)
- **Asset integrity and compliance**
  - meeting the safety, health & environmental requirements
  - complying with (internal and external) regulations and legislation
- **Asset lifetime:** achieve the required lifetime of an asset
- **Costs:** achieving the company objectives at optimum cost in the short and long term
- **Innovation and improvement:** continuous improvement of asset performance

4 ASSET RELIABILITY & INTEGRITY MANAGEMENT MODEL

Stork has developed an Asset Reliability & Integrity Management (ARIM) Model (Figure 3), based on the RIMAP model (Risk Based Inspection Aand Maintenance Procedures for European Industries) [1]. The model can be used for Oil & Gas, Chemical, Heavy Industry and Power Plants, combining Risk Based Inspection & Maintenance (RBIM) and Risk Based Life Cycle Management.

This model:

- o Provides guidance for implementing Risk Based Inspection & Maintenance (RBIM) and Risk Based Life Cycle Management, as well as quality assurance and follow-up of activities, tasks and work processes.
- o Aims to ensure that clearly defined and accepted levels of risk with respect to the Asset Management goals are achieved using cost-effective methods.
- o Generates value-adding maintenance tasks to mitigate risk on the basis of either qualitative or quantitative analysis.

The model closes the PDCA loop between definition and execution of risk-based maintenance tasks (Plan-Do) and analysis (Check) of the effects of plans on risk. Based on this analysis, the tasks can be adjusted in terms of either strategy or frequency (Adjust).

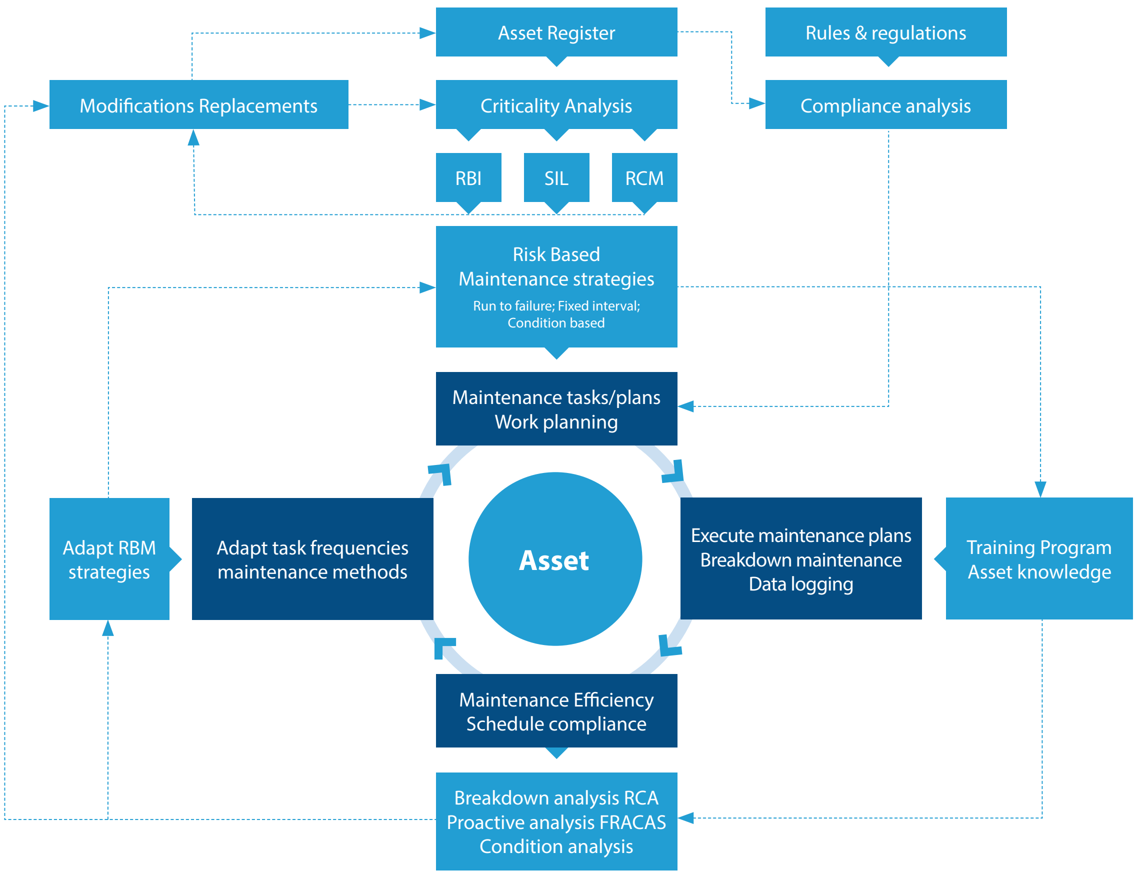

Figure 3: Asset Reliability & Integrity Management Model

To be able to close this loop, the maintenance management PDCA loop is needed. This loop also has to be closed. The main steps are Planning & Scheduling; Execution & Data Collection including failure and cause data (Plan Do); Analysis of the failure and cause data and planning and scheduling effectiveness; Adjustment of the maintenance plan or maintenance task (Check Adjust).

4.1 Closing the loop; overview of processes

The ARIM Model covers the following processes:

1. Set up of an Asset Register

An Asset Register is a structured system reflecting the function of the assets as shown in P&IDs (piping and instrumentation diagrams). It usually has five levels, going from a complete installation to the smallest composing parts. An Asset Register is usually managed in the CMMS (Computerized Maintenance Management System).

2. Verification of applicable rules and regulations and compliance analysis

The applicable laws, regulations and standards have to be screened on mandatory inspections or prescribed replacement tasks, such as tasks generated by management systems like ISO 14001 or regulations like the Seveso directive. Laws and regulations overrule standards as described in for example RBI (Risk Based Inspection) Systems.

3. Criticality Analysis

Ranking the critical functions in terms of risk. The ranking sets the priority for detailed risk analysis and usually has four defined risk classes. The risk matrix used is aligned with corporate risk management policies. The steps in criticality analysis are identifying hazards, defining dominant failure mode, CoF analysis, PoF analysis, definition of risk and classification of equipment. The PoF analysis is based on a combination of three sources: Expert judgement, historical data & statistics, forecasting and modelling. From the critical functions a division is made into static, rotating or safety instrumented systems. On these three categories multi-level risk assessments are applied.

4. Multi level risk assessments

The starting point for the detailed risk assessments is the output from earlier assessments, either existing or from the engineering phase; e.g. HAZOP analysis, RAMSHE (Reliability Availability Maintainability Safety Health Environment) or HAZOP (HAZard and OPerability).

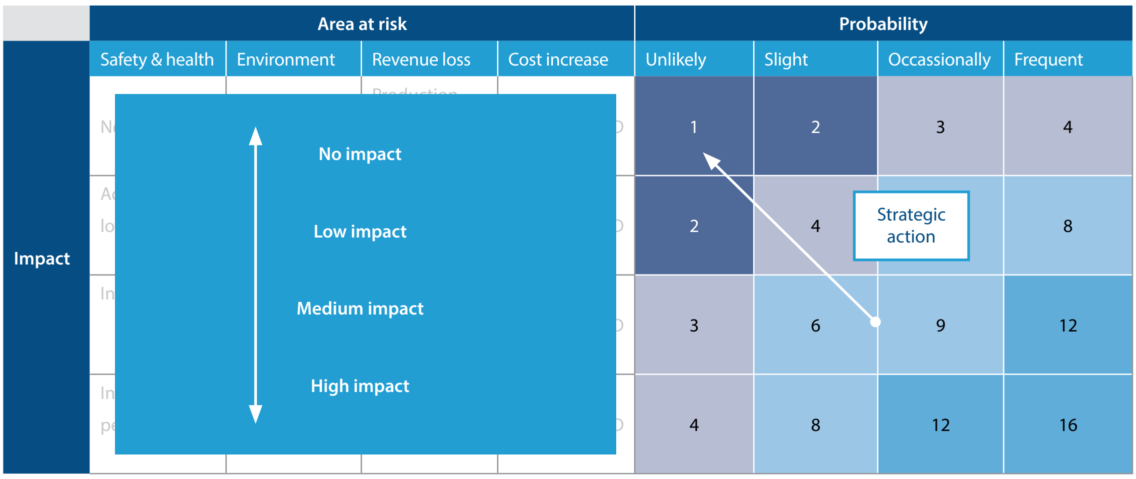

Figure 4: Risk Matrix

For static equipment, standard Risk Based Inspection methodologies are used. Methods in use are API 580/ 581 or EEMUA 159 for storage tanks where applicable.

For Safety Instrumented Systems the IEC 61508 standard is applicable. Safety Instrumented Systems consist of specific instrumentation such as PLCs, transmitters, valves used to form a layer of protection (LOPA) to maintain process safety or prevent loss of containment. Safety Integrity Levels (SIL) and testing intervals and procedures are defined by applying the IEC 61511 for the process industry. The risk is assessed by a risk graph as prescribed in the standard.

For rotating equipment and other equipment not covered by RBI or SIL, a streamlined RCM methodology is used.

5. Risk Based Management strategies
From the detailed analysis, the basic maintenance strategies Run to Failure, Condition Based or Time Based are set. The attributes of the associated tasks are defined in terms of description, frequency, craft, in or out of operation and location. The tasks can be clustered in relation to these attributes to allow maintenance plans and routes to be built.
The tasks are evaluated on their added value and in line with the ALARP (as low as reasonably possible) principle using the equation:

Cost of action + Cost of Mitigated risk
< Cost of Unmitigated risk

6. Training Program for Asset Knowledge
To make the maintenance plans work, a training plan has to be developed in which maintenance employees are taught the specific knowledge they need to perform the different tasks. For critical tasks it is desirable that detailed job plans are written, containing instructions and procedures.

7. Analysis
Data needed for analysis should be defined in advance and based on the defined work process steps. To analyse the data, techniques like FRACAS, RCA and Condition Analyses are used to determine the relevant KPIs (Key Performance Indicators) or to calculate the remaining lifetime of the assets, triggering replacement or modifications.

8. Adapting Maintenance Strategies
Based on the results of step 7, it may be necessary to review the maintenance strategy by adjusting the task frequency or the task itself.

9. Modifications and Replacements
Based on the results of step 7, it may be decided for assets to be modified or replaced. The modifications are managed in the project portfolio process. When new assets are introduced, all 9 steps of the model have to be gone through to define new or modified strategies and tasks.

4.2 Maintenance workflow

ARIM interacts with maintenance workflow management. Maintenance plans should be executed on-time and within budget to allow the risk to be controlled.

Workflow management also generates the data needed for Reliability& Integrity analysis. ISO standards sets requirements for data to be collected for Reliability performance.
The main data categories are:
- Equipment data, e.g. equipment class, attributes
- Failure data, e.g. failure impact, failure mode, failure cause
- Maintenance data, e.g. maintenance action, downtime

Notification and work orders are structured to capture the data needed for the analysis.
The workflow process can handle emergency work for unexpected failures, condition monitoring and risk-based preventive tasks.

Damage and cause codes are predefined in catalogues and registered at equipment level. Activity logging is another important input for reliability improvement. All work orders must be closed within a preset timeframe.

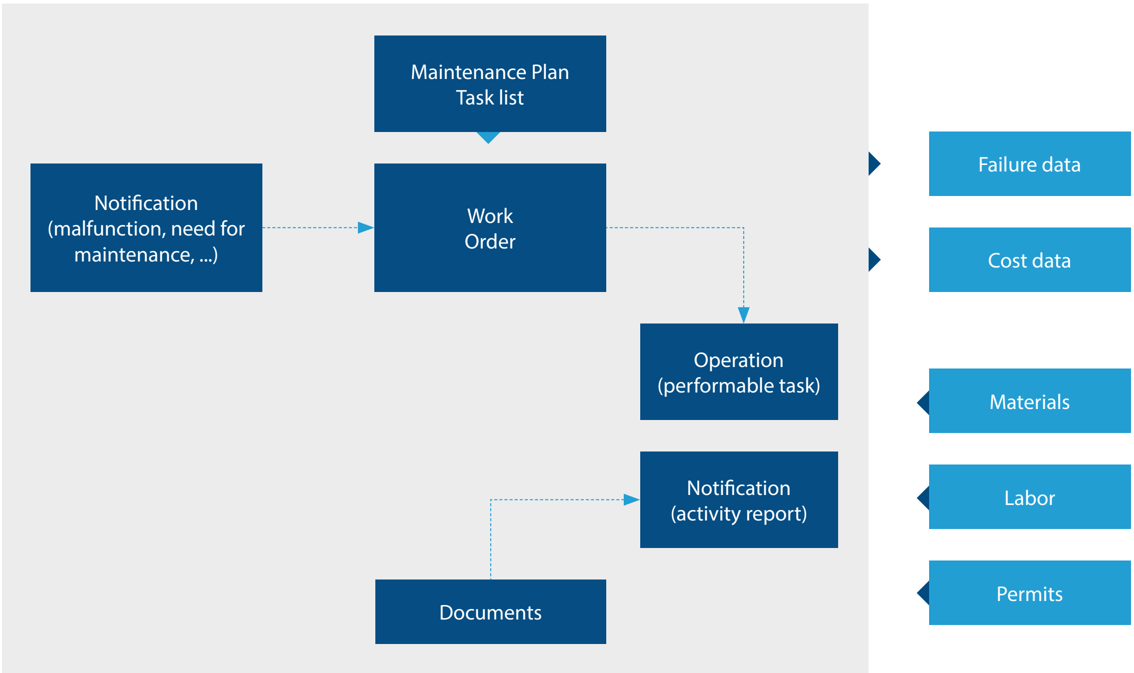

Figure 5: Asset Reliability & Integrity Management and Maintenance Workflow

So-called 'year orders' should be avoided as far as possible. For inspections, the values for readings are specified with upper and lower limits.

For the risk-based preventive and inspection tasks, it is important that all tasks are executed on-time. Scheduling and schedule compliance therefore need to be followed-up on a daily basis. 'Traffic lights' are used to visualise the status of the process. To follow-up work orders from inspections and emergency work, a strict gatekeeping stage is in place.

5 DEVELOPING AN ASSET RELIABILITY & INTEGRITY MANAGEMENT PROGRAMME

To implement the ARIM Model, a three-phased approach is used:

- Direct & Design
- Do
- Measure and Adjust

5.1 Direct & Design

The first step is to assess the existing situation in terms of maturity. The model uses 5 maturity levels, as shown in Fig. 6.

The maturity levels are defined as follows:

- Level 1: Starting: some failure elimination, compliance is in focus, acting after incidents
- Level 2: Developing: mechanical integrity & equipment reliability in focus, preventive actions
- Level 3: Organised: RCM / FMEA / RBI / SIL are started, first risk-based actions defined
- Level 4: Mature: all actions are on the basis of assessed risk. Performance analysis is starting
- Level 5: Excellence: continuous optimisation is reached through forecasting and simulation

Assessments need to be executed to identify the current ('AS IS') situation. The strategy must fill the gap between the 'AS IS' situation and the desired ('TO BE') situation (vision and goals). Assessments will clarify the maturity level of the current

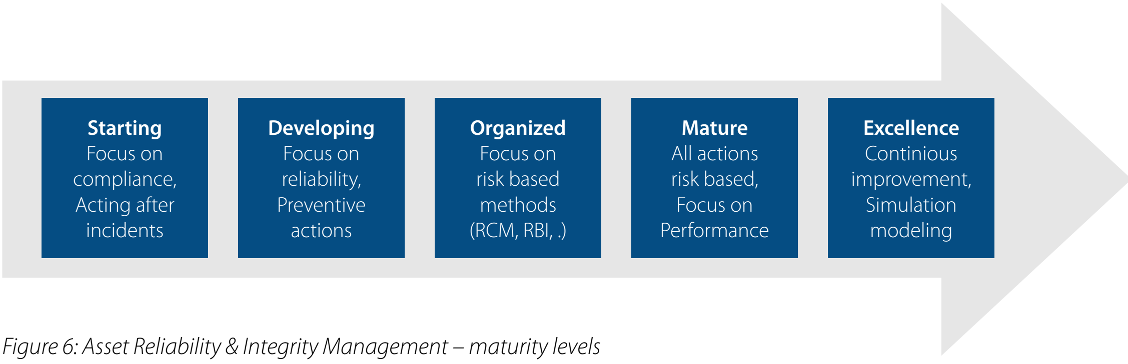

Figure 6: Asset Reliability & Integrity Management – maturity levels

activities related to ARIM (e.g. knowledge, competences, processes, tools). Different assessment methodologies can be applied such as risk assessment, SWOT analysis, auditing etc.

Data mining and analysis are also used to discover patterns in large data sets. To map the actual situation the Asset Management goals (compliance & integrity, asset output, cost, asset input, asset lifetime, innovation and improvement) are analysed in relation to reliability & integrity management aspects. Analyses of the assessment findings result in a categorisation of the company's reliability function. Reliability best practices differ for each category. The reliability methods and tools to be used are therefore related to the maturity level.

After determining the actual situation, actions can be defined to improve the asset management goals.

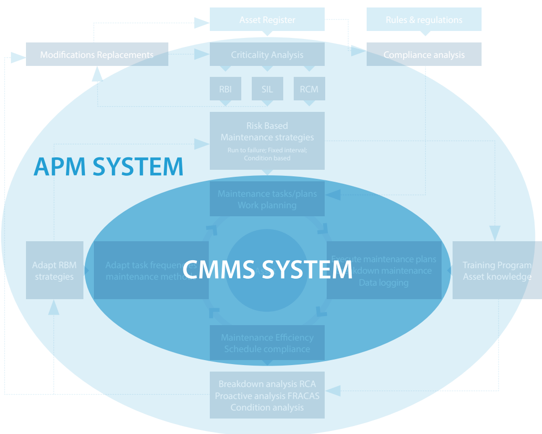

Figure 7: Functionality comparison of APM and CMMS

5.1.1 Supporting software tools

Most companies in the Oil & Gas, Chemicals, Power and Heavy Industry have implemented a system to reduce maintenance costs and improving spare parts management.

This is usually a CMMS system. Because such systems lack functionality for applying and documenting the methods for the ARIM model, dedicated and stand alone RBI or RCM tools or 'home-made' applications are often used. In the last few decade, Asset Performance Management (APM) tools have become available which can combine the functionality of CMMS with the requirements for the ARIM model. Figure 7 shows the functionalities of both systems.
In the implementation of an Asset Performance Management system, special attention is needed for legacy systems which are often Excel or Access applications.

5.1.2 Organisation role model

Many organisations traditionally have 'silos' which are obstacles to the successful implementation of the framework. To get the full benefit of the framework, close cooperation is required between Asset Management, Asset (Reliability & Integrity) Engineering and Maintenance.

A set of roles should be defined in the organization with clear responsibilities. Figure 8 shows the predefined role model.
The following roles and responsibilities are defined:

- **Governance** – define the internal standards, methods and tools; carry out internal auditing of the application of these standards, methods and tools.

Governance (Methods, systems, audits)			
Asset Owner	Asset Manager	Asset Engineer (plant level)	Service provider Maintenance Management Operations Management
Asset strategy Objectives Management review	Risk Management Budgets/Targets Project portfolio Contractor Management Performance monitoring Continual improvements	Operating procedure Maintenance program Asset improvement Configuration management	Safe and reliable operations Efficient maintenance execution Project delivery Tools, facilities, equipment

Figure 8: Organisation role model

- **Asset Owner** – define the operational strategic plan and Asset Strategy; maintain the line of sight.
- **Asset Manager** – define the AM plans in cooperation with Asset Engineer and Service Provider; monitor the KPIs and drive continuous improvement.
- **Asset Engineer** – define the maintenance strategies and operating procedures in relation to prevention of failures; analyse the effectiveness of the asset strategies; carry out root cause analysis of unexpected failures.
- **Service Provider Maintenance Management** – deliver the maintenance programme on-time and within budget; reporting and data collection; analysis of the efficiency of maintenance execution.
- **Operations Management** – operate the asset within the defined operating window; report deviations; cooperate in root cause analysis.

An RASCI matrix is used to define the responsibilities in the organisation based on this role model. It is important that the roles are not combined in one person to avoid any conflict of duties. For example if there is a large maintenance backlog, this is the problem of both the Maintenance Manager and the Asset Engineer.

5.2 Do: establishing a company-wide focus on Asset Reliability

Implementing Reliability & Integrity Management often requires changes in the working approach and culture.

Motivated people are needed to ensure the required assets performance and a coherent Reliability & Integrity management system. Empowerment, ownership, responsibility and breaking down virtual barriers between sections and disciplines are all needed to achieve sustainable success.

These changes can be achieved by creating multidisciplinary teams of maintenance technicians, operators and engineers, and having them analyse the effectiveness and efficiency of their daily operation in relation to cost, breakdown and output loss. In larger organisations it is often difficult to make people from different sections work together on collective problems because of the 'silos' between the different disciplines. Leadership is needed to make this work.
In multi-site situations, all sites of the company focus on reliability. Learning from each other obviously leads to better processes. It is possible to standardise assets and processes, using more or less the same reliability programmes.
Performance Management is key to achieve this. KPIs (Key Performance Indicators) for asset reliability are reported, and discussed at site, line and section level in monthly and quarterly meetings.
To create awareness, events are organised in which all employees are familiarised with the asset reliability strategy. By making a connection between mindset, safety, cost & reliability, and by achieving alignment, an important milestone can be reached in achieving the desired culture change.

Metrics or KPIs	Desirable trend relative to baseline
PM compliance	Up
PM labour hours as a percentage of total labour hours	Up
Predictive (on-condition or condition-directed) maintenance labour hours as a percentage of total labour hours	Up
Emergency / demand maintenance labour hours as a percentage of total labour hours	Down
Corrective maintenance labour hours as a percentage of total labour hours	Down
OEE	Up
Hours of unscheduled downtime	Down
Hours of scheduled downtime	Down
Total cost of replacement parts	Down
Overtime labour hours as a percentage of total maintenance labour	Down
Failure rates [Mean Time Between Failures]	Down
Repair rates [Mean Time To Repair]	Down
Maintenance backlog	Down

Table 1: Key Performance Indicators

5.3 Measure & Adjust: performance management

To monitor the effectiveness of implementation of the framework and the risk-based maintenance strategies, a set of performance indicators is used. Table 1 shows the KPIs which are used.

The indicators are used to measure the 'AS IS' performance and the desirable trend reflecting the rate of improvement.

The main effects which are monitored are:

- PM compliance increase to measure the effectiveness of the planning & scheduling and possible risk.
- Predictive (on-condition or condition-directed) maintenance labour hours as a percent of total labour hours to measure the increase in the number of condition based maintenance tasks.
- Emergency and corrective maintenance labour hours as a percent of total labour to measure the increase in reliability.
- Hours of unscheduled downtime to measure the improvement of availability.

6 ASSET RELIABILITY & INTEGRITY MANAGEMENT DELIVERING ASSET VALUE

As listed in Chapter 4 of this paper, we distinguish 6 asset values. In this chapter the added value of ARIM is described for each asset value.

6.1 Asset output

Applying ARIM results in added value maintenance strategies based on risk. Asset reliability and availability are optimised to ensure the asset performs its function.

The most common method to measure asset output is the Overall Equipment Efficiency (OEE). OEE is the product of the availability, performance and quality rates of the equipment. The impact of asset reliability on the output is often significant.

By optimising the reliability parameters, both OEE and asset output will increase.

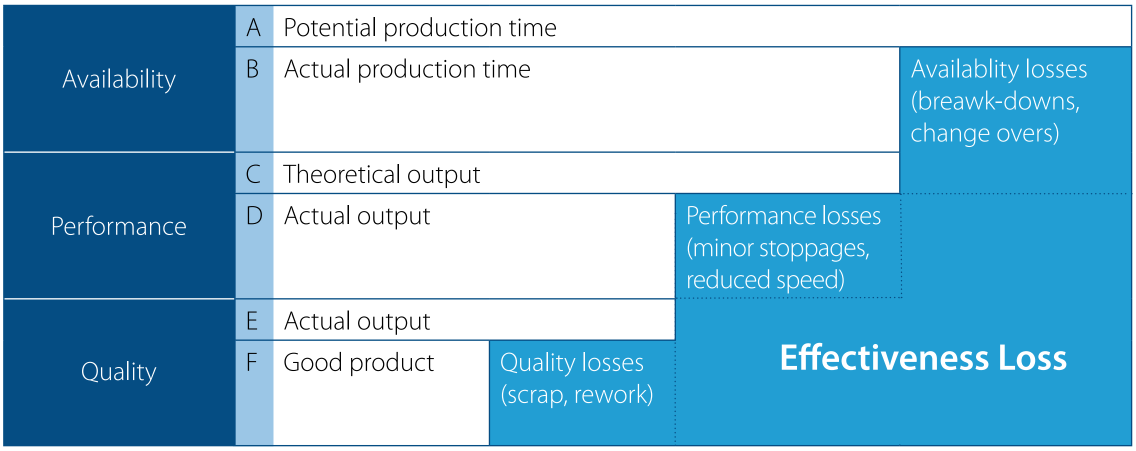

Figure 9: Asset output in terms of OEE

6.2 Asset input

Asset input means all possible waste in the process input. Performing ARIM provides an understanding of the real drivers. Mitigations actions are defined to reduced losses and efficiency. Waste can be caused by raw materials not conforming to the required specifications, energy losses such as power, compressed air or heating, and human factors such as insufficient knowledge or operating mistakes. Figure 10 shows the effect of waste on the process output.

As well as the input coming from outside the process, each process has an intrinsic conversion rate, for example waiting time between two process steps. Waste or loss is a product of this rate, and can only be reduced by changing the process.

6.3 Asset integrity and compliance

ARIM generates maintenance tasks as the result of applicable laws, regulations and standards – for example tasks generated by management systems such as ISO 14001, or regulations such as the Seveso directive. These tasks are defined, executed and monitoring demonstrably.

Risk matrices, as applied to define asset criticality, are connected to corporate risk management. This results in a managed risk profile of the assets which is fully in line of sight.

6.4 Asset Lifetime

The asset life-cycle runs from design, operation and maintenance right through to decommissioning. In all phases ARIM is applicable at strategic, tactical and operational level. It may sometimes be necessary or desirable to lengthen the lifetime of an asset. In that case, a cost–benefit analysis must be carried out. Ultimately, ARIM defines value-adding activities to be executed by Asset Service Providing.

6.5 Costs

ARIM strives to achieve the lowest possible Total Cost of Ownership (TCO) by keeping the manufacturing costs per unit as low as possible during the operational lifetime of the asset, without jeopardising safety, health and environmental requirements (‘License to Operate’). To ensure continuity, this is done in a sustainable manner.

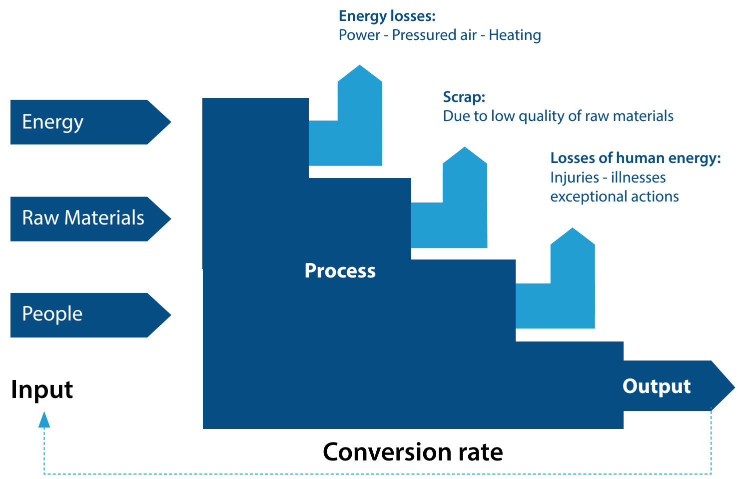

Figure 10: Effect of input losses on output

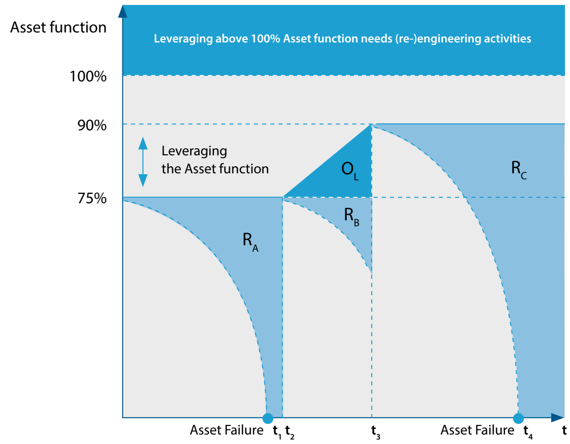

Figure 11: Leveraging the Asset Function versus Asset Failure

The optimum costs depend on the agreed risk of not meeting its objectives that a company is prepared to take.

6.6 Innovation and improvement

Developments like market expansion, innovation and higher quality standards can have an impact on the required reliability of an installation. Taking advantage of this is called Opportunity Management, which is the opposite of Risk Management. If the reliability of an asset needs to increase, its risk profile must be reviewed to allow maximum advantage to be taken of the opportunity benefits as the costs of the risk profile change.

If the required reliability level increases, the Probability of Failure (PoF) and/or the Consequence of Failure (CoF) must be reduced.

For reasons of simplicity the asset function as shown in the figure is defined as a percentage of the maximum function that an asset can fulfil. In the example, a Risk Analysis (RA) shows that the current average asset function level is 75% of the maximum asset capability. An asset failure is expected at t1. In this example the asset function should be extended to 90% of the function capability because of changed requirements. In that case not only does the risk RB of an asset failure have to be prevented or mitigated, but it is also necessary to define and implement new or changed conditions, asset opportunities OL, to raise the average asset function level to 90%.

The timeframe from t2 to t3 can be used to achieve this. The real length of the timeframe will depend on technical, organisational and financial parameters. Once the goal of 90% has been achieved, asset failure can be prevented by a new Risk Analysis (RC).

Two important points should be noted:

- The actions for RC are not necessarily the sum of RB and OL, since preventing risks is based a different philosophy from applying opportunities.
- Increasing asset function to more than 100% is not possible. If such a high level is required, (re-)engineering of the asset will be necessary.


STORK
outlet

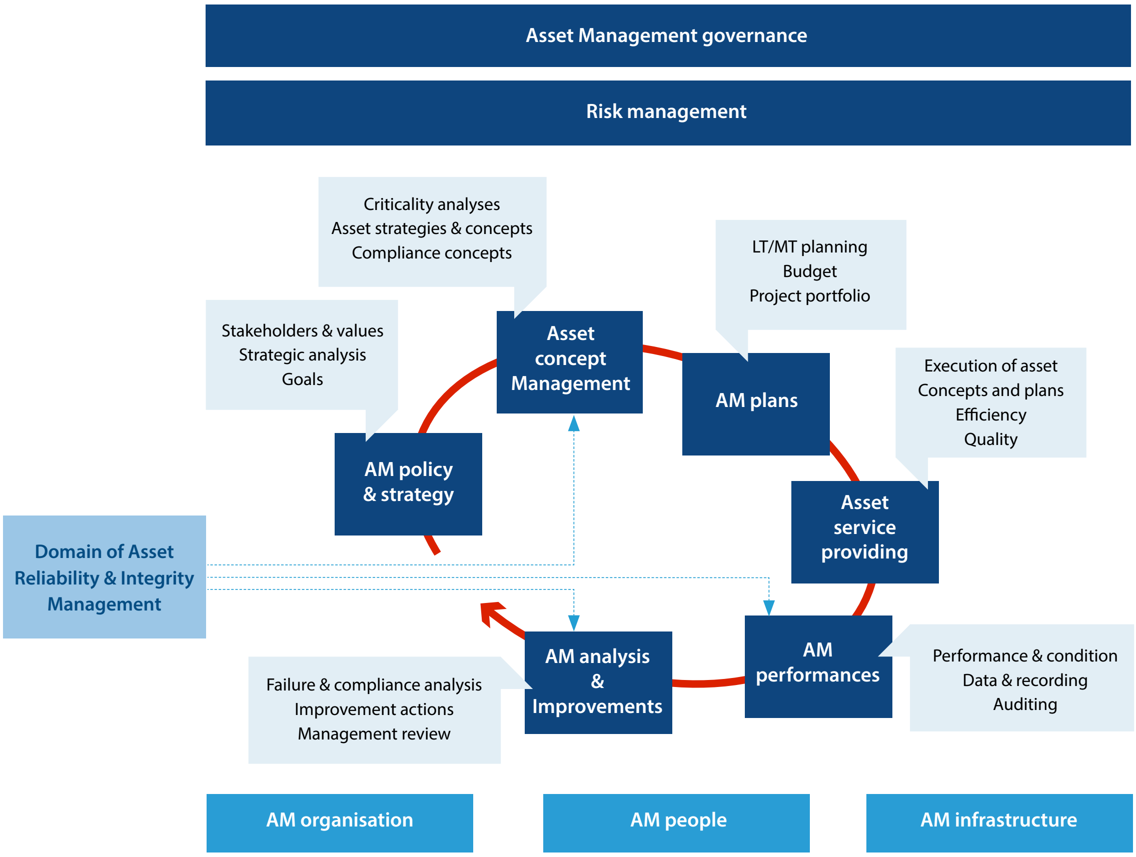

Figure 12: The ARIM domain within the Stork Asset Management Model

7 ASSET RELIABILITY & INTEGRITY MANAGEMENT AND ASSET MANAGEMENT

Asset Reliability & Integrity Management (ARIM) is an important cornerstone of successful Asset Management in order to deliver Asset Value.
In co-operation with several industrial companies (chemical, manufacturing and electricity generation) an Asset Management model is developed.

The model refers to the structure of the Asset Management system of PAS 55 / ISO 55000 [2]. An outline of this Asset Management model is given in the paper 'A Field Proven Vision on Asset Management' [3]. The ARIM Model fits in the Asset Management Model and translates the overall asset strategy into concrete concepts and strategies to mitigate the associated risk. The concept and strategies must be integrated in plans and tasks and their subsequently executed by service providing processes such as asset creation/acquisition, asset utilisation, asset care, asset improvement and asset disposal. Figure 12 shows the Stork Asset Management Model and the ARIM domain which forms part of it. If a company wants to improve the reliability of its assets, the ARIM Model offers support in ensuring the required function of assets:

- The performance of the assets should be continuously monitored to ensure the required function of the assets in relation to the Asset Management Objectives: Output, Input, Compliance, Lifetime and Costs.
- The sixth objective is Innovation & Improvement, which means that ARIM should focus on continuous improvement taking into account the balance between cost and risk levels and responding to opportunities that arise.
- The intention is to add value in all phases of the asset lifetime: Design – Operation & Maintenance – Decommissioning.
- Achieving optimal results requires close cooperation between Asset Management specialists, Engineering and Maintenance.

CASE STUDY

8 CASE STUDY

The ARIM framework is implemented in a Chemical company which operates multiple plants at one site. The case for action was an upward trend in maintenance cost/Net Replacement Value (NPV), which had a negative impact on cost per tonne of product. The main identified cause was an increase in unexpected losses and poor start-up after turnarounds.

The starting situation was a traditional technically-focused organisation. Little use was made of risk-based methods and there were 'silos' between inspection, mechanical, E&I and process automation. Implementing the ARIM model started with a gap analysis from which an ARIM programme was defined including action plan and business case.

The main actions were:
- Redefining work processes and procedure and introduction within CMMS.
- Introduction of risk-based maintenance: which risks can we mitigate or eliminate?
- Redefining roles and responsibilities and organisation. Implementing an Asset Manager function for each plant, and introducing a Maintenance Manager for each cluster of plants.
- Defining the Asset Engineer role and making this role operational under the Asset Manager.
- Training and on-the-job coaching for new job holders.
- Establishing a company-wide focus on asset reliability: spreading the message and embedding it throughout the organisation.

As part of the introduction of risk-based maintenance, corrective and preventive aspects were taken into account by using Reliability Centered Maintenance (RCM), Risk Based Inspection (RBI) as well as methods for RCA (Root Cause Analysis). Three types of assets are distinguished:

a. Mechanical/static assets, such as drums and piping.
b. Moving assets, such as E-motors, pumps and compressors.
c. Safety assets, such as alarm systems and safety valves.

To establish the right focus on asset reliability, multidisciplinary teams were composed. Operators, maintenance technicians and engineers are working together to analyse the effectiveness and efficiency of daily operations relating to cost, breakdowns and stop time. Especially in larger organisations, guidance is needed to create a more cooperative way of working and to embed asset reliability management in the daily operations.

To close the improvement loop, a process has been implemented with focus on actual added value created by the measures taken.

As a result of implementing the framework, the following results are reported:
- The maintenance factor (maintenance cost/ NPV) has stabilised at around 2.2% for the site.
- There is a better grip on unexpected losses. The turnarounds and a major part of the slowdowns are coordinated site-wide.
- Following the defined processes generates reliable data and transparency. This is the foundation for high-end projects like the introduction of Zero Based Budgeting.

9 REFERENCES

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