Improving Return on Chemicals Assets Using Integrated Engineering, Operations, Maintenance and Compliance Management

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Executive Summary

The chemicals industries is very diverse in terms of products and processes, the nature and state of the assets. In the developed world, assets are on average older, intrinsically less reliable and efficient, but in these regions companies have the highest skilled personnel and most advanced methods in place to compensate for it. The regular economic cycles in petrochemicals and polymers have been replaced by irregular, more regional economic ups and downs, with high amplitude. The high growth in developing Asia is slowing down significantly. The oil and gas boom in North America has created growth in the chemical industry in the region in the recent years. The recent drop in oil price has created economic relief for chemical producers globally but demand may suffer because of the economic slowdown. The best strategy for the future is likely one of high flexibility and adaptability to react to global and regional market fluctuations, product innovations, feedstock costs and regulations.

A first step is to reduce the cost of assets throughout their lifecycle. This includes effective engineering, leading to more flexibly and lower cost designs that can be operational more quickly. Engineering and design cost can be reduced by make information transparent across disciplines, regions, offices and sites and easier to reuse. Sharing and transparency must be extended across the enterprise borders to engineering, procurement and construction firms (EPC’s), subcontractors, to achieve tighter collaboration. Collaboration during design and construction has significantly increased during the past years, and as contractors provide more and more services for plants in operation too, it is expected that the importance of efficient cross-enterprise collaboration will further increase.

Compliance of processes and equipment can be efficiently handled when requirement engineering is electronically linked to qualification processes. Information should also be reused across engineering, operations and maintenance within the corporation, and by their subcontractors. As all stakeholders work on the same asset, they should all work off the same asset information to coordinate and optimize their plans and actions. This concept is referred to as integrated engineering or integrated operations.

In a second stage, these efficient processes can be applied to more productive and flexible process designs using intensification, modularization, and mobile processing units.
Accurate asset information requires a state-of-the-art application and data repository that must be complemented by processes for keeping asset information up-to-date. People must be trained and motivated to use them. When these key success factors are in place, operations and maintenance can be optimized, to sustain a compliant and reliable asset at the lowest cost and with the lowest inventory of spare parts. This includes modern asset management strategies, such as predictive maintenance and condition monitoring, and the simultaneous optimization of asset capabilities and production requirements.

Companies that have pioneered these new practices, report increased engineering productivity, improved handover, accelerated operational readiness, reduction of regulatory compliance cost, reduced maintenance costs and improved reliability.

The Chemical Industry

The chemical industry is far from homogeneous. It ranges from the large-scale commodity production of petrochemicals and basic inorganic chemicals, to small-scale specialty and performance chemicals. Organic and inorganic chemicals and their production processes are as diverse as chemicals produced using chemical routes and those produced using biochemical processes that involve biological cells, yeasts or biocatalysts. Polymers are yet a completely different class of materials with their own associated processes. Processes can be divided into continuous and batch processes, and while this division largely corresponds to base chemicals versus specialty chemicals, there is a growing number of exceptions to this rule.

Petrochemicals
have long since had the reputation to go through cycles of oversupply and scarcity every five to six years. In times of scarcity, prices soar and production must be maximized. Plants are then extended and debottlenecked. The increases in production creates a surplus which causes supply to exceed demand, thus prices drop, and plants are optimized for production costs, including energy and material efficiency. This regular pattern has dramatically changed since ten years.

The chemicals production in Asia has grown by a factor of 2.5 since 2003. It has overtaken the US and European production and left these regions far behind in terms of global share. In developing Asia, growth has been very high, mainly coming from greenfield projects. As a result, assets are modern and asset age is low. Very recently growth in developing Asia is slowing down significantly and may move to new emerging countries.

In Europe, the average growth rate of chemicals sales during the five years preceding the crises was around 5 percent, and this dropped to an average of zero after the crises. The drop in sales after the crisis was 12 percent, followed by a year of growth of 10 percent, since then sales stagnate. Strong players concentrated production of chemicals in less plants, mothballing other plants for the time being. Smaller players had to live with less efficient, lower running rates.

While North American chemical companies suffered in a similar way during the crises, the recovery was much faster due to the shale oil and gas boom. While oil prices remained high until the end of 2014, the prices of feedstock from natural gas dropped considerably, providing opportunities for recovery and investment in the US.
The dramatic drop of the oil price impacted chemical feedstock prices globally, decreasing production cost and improving profitability.

From a technological perspective, the industry is on the brink of major changes. The pressure to improve sustainability and production cost as well as increasing flexibility, to be able to adapt to demand fluctuation, has led to new process technology concepts. During the past years, process intensification and modularization have proven their feasibility in a series of pilot plants in Europe and the US. The modular mini-plants can be adapted easily to products and product qualities, some are mobile and can travel to be ‘near shored’ close to demand or resources. Rather than scaled up, these plants are multiplied and put in parallel to meet demand, and can just as easily be decommissioned to be used for other types of production. In some cases these plants involve the transformation of batch to continuous production. The first of these plants are coming on-line, and it can be expected that the technology will transform the asset landscape of chemical production during the coming years and decades.

The industry as a whole has worked hard on its reputation and accepting its social responsibility. National and regional associations such as CEFIC, and the global, International Council of Chemical Associations communicate on the chemical industry’s ethic „Responsible Care“. The goal is to improve health, safety and environmental performance, sustainability improvements, and includes a long-term research initiative that aims at improving the understanding of the long-term impact of chemicals on health and environment.

Concrete examples are the joint efforts with the UN to promote safe management and transportation of chemicals. Furthermore the fact that the energy input per unit of chemicals produced in Europe has halved in a little more than twenty years is significant. Indeed, energy efficiency and sustainability in general have been an important area of investment by the chemical industry. In any case, the regulations the chemicals industry needs to comply to, will only become more stringent. Obligations to improve energy efficiency, regulations regarding process safety, Seveso
regulation as well as REACH, aim to protect people, wildlife, environment and ultimately the industry itself. This comes at a cost, unless implementation is efficient and effective.

**Asset Management Challenges for the Chemical Industries**

The chemical industry is very diverse and, depending on the region, features various characteristics. We can broadly distinguish the following categories:

- Aging, commodity producing assets. These are most likely to be found in advanced economies, and need to be operated and maintained at the lowest operating cost possible. At the same time, they need to operate reliably, safely and be compliant with regulations. Asset information is at risk of being dispersed on paper and in various systems.

- Recent assets for commodity products using classical, mostly continuous process technologies. These assets are mostly found in growing economies, for example in South-East Asia, but also in the USA. Asset information is more likely to be available in electronic format. Reliability, safety and compliance are likely to be satisfactory, but need to be maintained.

- Assets for specialty chemicals, specialty polymers, agrochemicals, food and pharmaceutical ingredients, mostly using traditional batch processing. The products have a high innovative content, and plants are regularly adapted and reengineered, or have been recently constructed. In these cases, it is likely that electronic asset information is available. Regulatory compliance is an increasing cost factor.

- Assets using modular and/or intensified process technology for chemicals or polymers. Existing plants are built for research and process development purposes. The first commercial modular plants are coming on-stream. Asset information is available in electronic form.

From an engineering and asset information management perspective, a number of challenges can be distinguished:

- In plants under construction by engineering procurement and construction firms (EPC’s), owner-operators (OO’s) require a tighter
collaboration than before. Being responsible for the plants performance and regulatory compliance at startup, they require design reviews in electronic form as well as the tracking of construction and commissioning progress against electronic documents. More and more qualification processes use electronic design and requirement documentation, with electronic sign-offs.

• In recently constructed plants, the asset information built up during engineering and construction is traditionally handed over on paper, and is often incomplete or outdated at the moment of transfer. NIST estimates that the cost of information losses during handover to be 1.8% of capital expenditure. There is a huge opportunity to improve the process by making it electronic, and make sure the information is reused.

• In existing plants, when engineering or maintenance trouble shoot an operational issue or need to start a modified project, they first spend time – sometimes weeks or months - to find out the actual status and performance of equipment and piping, the available or missing spare parts, etc., before starting their actual work. Further time is lost in ordering missing parts or equipment, increased time to repair, and multiplying travel times. In other cases wrong or excess parts are available, which increase working capital without benefit. Incomplete, inaccessible, and inaccurate asset information therefore leads to a longer project duration, longer “mean time to repair” (MTTR), higher operational and capital expenditure than necessary. Compliance costs increase, or compliance becomes impossible as accurate information cannot be produced at any point in time. NIST estimates the cost of information losses in the operate-maintain phases of the asset to 2.4% of
the capital expenditure cost, higher than the cost of losses during hand-over.

Chemical plants are usually part of large industrial complexes, where plants, and utilities and storage facilities are distributed over the premises. It is a real challenge to keep track of the asset state, as operations, maintenance and contractors work independently on the same assets.

These challenges imply that it is not a trivial task to obtain a complete, accurate and up-to-date virtual image of distributed assets, easily and rapidly accessible to office and field workers throughout a vast geographical area.

The different types of assets have partly different regulatory obligations, but for all of them regulatory pressure is increasing and will continue to increase in the future. The spirit of these regulations tends to evolve from describing the means for protection into a responsibility of the owner-operator to be able to demonstrate performance-based quantitative risk management.

How engineering information of greenfield or plant modification projects can be handed over efficiently to operations and maintenance is discussed in the next chapter “Integrated engineering and asset management”. The chapter “Integrating Asset Management with Risk and Compliance Management” discusses an extension of this concept. How good asset management can improve the efficiency and effectiveness of maintenance, and how asset information of existing plants can be converted efficiently to an electronic format is discussed in the chapter “Managing Assets Efficiently”.

### Integrated Engineering, Operations and Asset Management

Whether asset information is built up during engineering and construction, or by operations and maintenance of an existing installation, in the end there is always an installation in operation that undergoes maintenance...
activities and engineering projects related for reasons of improvement, troubleshooting or debottlenecking.

As a result, two or more organizational entities work on the same assets, using - ideally - the same asset information: engineering to design changes and improvements; operations and maintenance for day-to-day activities and long term asset management. To streamline the collaboration between those entities, the concept of “integrated engineering” was created.

The “Integrated Engineering” Concept

In 2005, Dr. Thomas Tauchnitz published a vision for “integrated engineering” (Tauchnitz, 2005), based on three basic principles: “[...] every information is generated and maintained at only one location, existing knowledge is reused where possible, and the software tools stay interfaced while the production plant is in operation.” He sketched the workflow as starting with process design followed by the transfer of the resulting process information to an engineering software tool, common to all engineering disciplines involved in front-end and detail engineering. To increase engineering efficiency, he proposed to implement modular engineering – using standardized, generic engineering modules comprising all functions built and maintained within the common tool.

For example, a module for a pressurized vessel would contain pressure measurement and control, valves for material transfer, level control, safety equipment and automation, stirring etc. The corresponding equipment lists, design documentation, safety procedures, testing and qualification procedures would be part of the template as well. Instead of engineering every new equipment, replacement, modernization or repair action from scratch, the engineer would instantiate a module from the library, adapt it as needed, and then integrate it within a larger system.

Since all disciplines have access to the same up-to-date information, collaboration is improved and errors and iterations are minimized.

Many plants apply a wide variety of control systems. To further increase engineering efficiency, control engineering should be done at a generic level, enabling reuse of designs. The designs would be used to configure systems, and compile the generic designs within different DCS brands.
The next step is the transfer of the engineering information to operations and maintenance and keeping it up to date with the goal to transform “as-built” information into “as-maintained” information to ensure accuracy and save time.

Therefore, “integrated engineering” incorporates different disciplines during design and build stages, and also integrates engineering, operations, maintenance and automation during operate and maintain stages of the installation life cycle.

Finally, the vision includes the implementation of standardized processes across the extended enterprise, reducing the number of systems and interfaces, and organizing centralized maintenance and support and promoting company-wide knowledge management.

**Integrating Engineering with Operations and Asset Management**

Today the COMOS software solution is used throughout many process industries, to implement this approach. Its centralized, object oriented data management capability, in conjunction with engineering and user libraries and collaborative workflow modeling facilitates this. Enabled for modular engineering, the solution is particularly efficient for designing modular production plant.

In the case of projects, engineering procurement and construction companies and their subcontractors do all their engineering work with computer-aided design software. However when an installation is commissioned, documentation is often still handed over on paper. Sometimes it arrives with delay or remains incomplete. As a result
critical engineering and configuration information is lost that could otherwise provide the owner-operators with significant operations and maintenance value.

With hard-copy paper documents for operations and maintenance, changes are documented as hand-written corrections, the so-called redlining. In the best case, electronic documents are updated afterwards. This process is both time-consuming and error prone, information is regularly out of date, and interactions between disciplines lead to unnecessary iterations.

Many engineering databases and systems do not have the functionality to support operations and maintenance (and vice versa). As a result, a maintenance management system must be primed with “as-built” information, extracted from the handover documents. When the company needs to modify, maintain or modernize a plant or a production line; plant personnel often have to start by tediously searching for as-built and as-maintained data to enter into the engineering systems. One can easily imagine the time this takes and the risk of inaccuracy and incomplete data this involves.

An application that covers both engineering and operations, makes handover electronic, avoids information losses, and allows to maintain asset information naturally, transforming it from “as-built” into “as-maintained”, resulting in an accurate electronic image of the installation. Now, any operator or maintenance engineer, can see any static or dynamic asset information from his desk or handheld in the field. This information is always up-to-date, at any point in time. It is important that the owner-operator owns the data and the information environment, as part of his responsibility for the proper functioning of the asset. His responsibility also includes managing and auditing the internal and inter-company processes concern-
ing the asset data (see also next section). As inter-company collaboration is becoming more frequent and important, a standard data exchange format between tools, supporting this collaboration is now required by the industry. The DEXPI working group of DECHHEMA addresses this by creating a standard compatible with ISO 15926 on data integration and hand-over.

In the case of maintenance and improvement projects related to automation and instrumentation, seamless, bi-directional integration with automation systems simplifies the changes to the automation systems significantly, by enabling the configuration of the control system directly from the design in the engineering tool. Vice versa, when a control system configuration is changed in the field, the control system would automatically update the application with the actual control system configuration.

Collaboration between internal or external engineering departments and maintenance (and/or operations) may occur during these projects or changes. It is of utmost importance that the stakeholders work off the same, up-to-date asset and engineering data. This has important benefits for engineering and modernization projects by simplifying the work, unloading personnel, while guaranteeing accurate and up-to-date asset information. It creates even more benefits by saving engineering work when the same changes need to be applied to several sites.

At Siemens, a bidirectional interface between COMOS and SIMATIC PCS 7 is currently operational. Based on the recent NAMUR NE 150 recommendation, other standard bidirectional interfaces can be created with any type of control system, provided the automation provider adopts the standard. This paves the way for enormous efficiency gains in control engineering and maintenance for the future. With its extended capabilities for engineering, as well as maintenance and vertical integration with Enterprise Resource Planning systems (ERP’s), and control systems as described above, and the
The usage of a central, consistent and up-to-date information source interfaced to all relevant business systems for design, engineering, construction, handover, operations and maintenance can help increasing productivity, shortening project time, accelerate operational readiness, and capability of real-time sharing of asset data to the different disciplines involved, integrated engineering, becomes an attainable target.

A recent case study, involving the worldwide rollout of COMOS at the pharmaceutical company Novartis, demonstrated that the integrated engineering vision implemented in this type of application can be applied successfully to both brownfield and greenfield projects, in engineering, operations and maintenance. Novartis decided not only to have all new asset information in electronic form, but also to transfer all existing paper documentation into COMOS over time. Today, Novartis estimates that the engineering effort is reduced by 10 to 15 percent on an ongoing basis. ARC believes it is very likely that the application of integrated operations will create similar benefits in chemicals. The case study is described in more detail in a white paper about the use of COMOS in the pharmaceutical industry.

Users report that the engineering effort is lowered considerably compared to former practices. Since modular engineering techniques and integrated, cross-discipline engineering practices affect people’s work processes and practices, a successful implementation also requires careful planning of change management, including user participation and continued management coaching and support.

**Good Asset Management Practices**

Good asset management is becoming an expected normal practice in mature organizations around the world. The formal documentation of good practices for management of physical assets, has been led by the British Standards Institute in cooperation with the Institute of Asset Management (IAM) and close to fifty organizations from fifteen industries in ten countries. The resulting PAS 55 standard has been published in 2004 and revised in 2008. It has been widely adopted and has become the basis of the ISO 55000 standard and describes the following important themes in the standard:

- Alignment of organizational objectives feeding clearly into asset management strategies, objectives, plans and day-to-day activities.
Whole life cycle asset management planning and cross-disciplinary collaboration to achieve the best value combined outcome.

Risk management and risk-based decision-making.

The enablers for integration and sustainability; particularly leadership, consultation, communication, competency development and information management, but also quality control and continuous improvement.

The requirements for audit and documented information are also defined by the standard. ISO standards refer to each other for specific aspects. Respectively, for risk management, it refers to the ISO 31000 standard. The standard gives all principles for good management and governance of the asset management system and process, however it leaves it in the responsibility of the operator, how and at which level of detail to implement the standard. The benefits of good asset management practices documented by Woodhouse of the IAM, range from significant reduction in downtime, reduce production costs, reduced total cost of ownership of assets, in-
increased throughput and reduced maintenance costs and increased output at no extra cost. An application that supports the implementation of such a system, and in particular the management of asset information as COMOS can provide and enable these practices, in an efficient manner.

In Germany, an effort is undertaken to specify how asset information can be modeled, and what the requirements for asset information attributes are. While this standard is not available yet, it expected that an international equivalent will be published, probably focused on industrial asset information and complimentary to the ISO 55000 standard.

**Integrating Asset Information With Risk And Compliance Management**

The concern for testing and qualification becomes evermore important in more and more industries and is a direct result of compliance pressure with regulations and standards other than ISO 55000, such as the Safe Chemicals actin the US, REACH in Europe, The EU Seveso directive, functional safety regulations IEC 61508 and 61511, etc.). Compliance management of asset characteristics, such as quality of materials, the use of design methodologies, regular inspection schemes, can be performed efficiently in the same software environment used for engineering. The analysis of risks related to the process and the equipment, on product quality and equipment reliabili-
ity can be derived from engineering information and partially automated by the engineering tool. The results of the analysis must be reflected in appropriate requirement specifications and designs. Once the design is finalized, testing and qualification plans can be derived automatically from the engineering information. In the medium term, testing and qualification in the plant will be supported by system access on tablets. Test and qualification results, can be linked back to equipment requirements and the risk analysis, providing compliant validation.

Novartis estimated that in their case, the implementation of integrated compliance management will lead to an additional 10 percent of savings in engineering effort. The case study is described in more detail in a white paper about the use of COMOS in the pharmaceutical industry.

**Expected Benefits and Impacts on Risk and Efficiency**

The use of a single, consistent and global data hub such as COMOS, kept up-to-date at all times by all disciplines, creates instantaneous and complete transparency of information for each plant object and for all parties. When engineering and asset information is handed over to operations it can be kept up to date with minimal effort. This makes trouble shooting operations faster, creates additional efficiency in routine maintenance and other involved activities, such as replacement or repair of equipment, capacity extensions or modernization of automation and instrumentation.

Expected gains that directly impact operational and maintenance cost include reduced effort, significantly shortened project times, reduced cost and effort for compliance with the requirement of up-to-date plant documentation. Furthermore, faster and more appropriate reactions to operations issues, reduce both unwanted downtime, including shorter mean-time to repair, and reduced operational risks. This entails improved reliability and asset longevity, both impacting capital expenditure.

Engineering productivity or efficiency gains of at least 5 percent are realistic expectations when using COMOS. Compliance cost can be decreased with e-compliance approaches integrated with engineering and maintenance. However the financial and performance improvement of greater reliability
has a much higher value, not to speak about the unmeasurable value of health and safety.

**Benefits in Engineering**

Can savings in engineering effort translate into shortened time to industrial production? When interviewed by ARC, users and EPC’s report that for companies that work sequentially, the proportion will be very high. Companies, whose major project constraint is time, use a high degree of engineering parallelism. To compensate for the iterations and rework related to the parallelism, those companies use additional resources. These companies will experience less shortening of engineering and scale-up phases. However, they will experience a higher-than-average impact on total engineering efficiency. This is because they will recover part of the non-productive iterations and effort by using an integrated engineering methodology and a common engineering repository such as COMOS. Very high degrees or parallelism are found in EPC companies, operating companies report parallelism from close to none, up to roughly two-thirds.

From interviews and testimonials we believe that increased engineering efficiency of at least five percent is a realistic expectation. Siemens reports that accepted business cases in chemicals estimate efficiency increases in a range of eight to twelve percent. Corporate implementations including e-compliance management could reach even higher degrees of improved efficiency in the range of fifteen to twenty percent. Some EPC companies mention they can increase engineering efficiencies year over year with a few percent using good engineering practices and tools.

**Recommendations**

ARC Advisory Group recommends that chemical companies:

- Optimize and improve asset management practices as described for example in the PAS55 or ISO 55000 standards, before implementing them in a software application. Make sure changes to the installations are consistently documented in the application.

- Apply the concept of integrated engineering and integrated operations. Follow the example of Novartis and implement paperless processes and documentation, consistently.
• Analyze process development and plant engineering, operations and maintenance processes, including information processes. Define global medium-term goals and evaluate processes and their results. Optimize the processes and IT landscape and re-evaluate. Make a business case to quantify the incremental benefits.

• Make sure organizational units are aligned in terms of goals, incentives are consistent, and common processes are understood and agreed upon. When implementing change, make sure the culture change aspect is given the time and attention required for sustainable improvement.

• Create oversight and monitor, evaluate, support, benchmark and continuously improve processes and applications globally through governance and/or corporate excellence initiatives.

• Promote the usage of the NE 150 standard, to create additional benefits in engineering, maintaining and modifying control systems.

References


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Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Research/IndustryTerms

AIM Asset Information Management
DCS Distributed Control System
EPC Engineering Procurement and Construction company
EU European Union
F3 Flexible Fast Future
IT Information Technology
MES Manufacturing Execution System
NIST National Institute of Standards and Technology
R&D Research and Development

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