Maintenance Engineering and Management

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Preface

Maintenance is as old as mankind itself. The proof of this statement lies with homo erectus who lived one and a half million years ago, and who represented the transition to modern man. He was the first to use fire, to hunt and to manufacture tools. Those tools were the first ever capital goods. The hand axe was the favourite tool of the period, and it was a matter of life and death to keep the axe sharp: the first form of maintenance in the history of man.

From homo erectus, we gradually developed to become homo sapiens, the thinking man, who went on to use and create ever more tools. Neanderthal man even had a tool kit, containing a whole set of different (flint) tools. As man started to dress, build huts and farm the land, ever more tools were added to his arsenal, and those tools all required maintenance. Clothing and footwear had to be repaired, cart axles lubricated and ploughs sharpened. Nonetheless, maintenance was not a true profession; it was not undertaken according to specific processes by maintenance specialists. Homo maintainicus had not yet been born …

Professional maintenance: execution

Following the Middle Ages and the period of colonisation that required a fleet of warships and trading vessels, the number of complex capital goods rose exponentially, starting in the second half of the nineteenth century. Steam locomotives and steam ships, industrial weaving looms and agricultural machinery require far more maintenance than brick buildings and paved roads. The first maintenance engineers appeared during the industrial revolution. Although not employed full-time in maintenance work, there was someone who operated the machines and whose responsibility was to make sure they continued working. When it came to the dykes in the Netherlands, a maintenance division was soon established, albeit out of pure necessity if we wished to keep to keep our feet dry. The first signs of a professional maintenance function became evident in the army. Drivers of military vehicles learned how to execute basic maintenance tasks or carry out emergency repairs, in the field. Manuals were available for large-scale maintenance by maintenance engineers, in which every step of the maintenance task was clearly described.

Professional maintenance with a vision: monitoring maintenance behaviour

Since the nineteen fifties, capital goods have become many times more complex through the use of new materials, new techniques and ICT. The maintenance engineer of the past above all relied on his senses and his common sense to identify the heart of the problem. The motto today is ‘to measure is to know’. Breakdown analysis is carried out today on the basis of new measurement data either collected personally by the maintenance engineer or, increasingly, recorded by a variety of sensors. These are effectively the modern senses of the maintenance engineer. Whereas a car mechanic in the nineteen fifties would place a screwdriver between his ear and the engine block to identify the precise source of an annoyingly discordant tone, the modern passenger car is equipped with some 50 sensors that continuously monitor all the engine functions. They for example inform the on-board computer of the temperature of the exhaust gases, the air pressure in the inlet manifold and whether or not the pinging of the engine is at an acceptable level. The computer can then take corrective measures or issue a warning. Nonetheless, modern cars still require maintenance. And not just cars. Maintenance on capital goods always did and always will require human intervention. The difference now, however, is that it is today the work of true professionals.

Professional maintenance with a contribution to the world: design for maintenance

For many years, maintenance was seen as a necessary evil; a cost item. Things are very different today. Through smart maintenance, we can considerably extend the lifetime of capital goods. Not only does this save on major investments, it is also a sustainable approach that fits in seamlessly with the sea change currently taking place worldwide from a linear economy into a circular economy. As a consequence, maintenance work is becoming increasingly appreciated, and maintenance professionals are more proud than ever of their work. Maintenance is an ‘art’: the art of not letting it happen.

According to a more official definition of maintenance: maintenance refers to all those activities intended to keep or return a capital good to the condition required to fulfil its function. Maintenance is becoming increasingly preventive in nature. You can wait until something breaks down, but it makes more sense to avoid problems through preventive maintenance. This approach is not only cheaper - avoiding the costs of consequential damage - but is also safer and more sustainable. The project engineer with a contribution to make to the wellbeing of the installation and hence indirectly to the world has been born.

Professional maintenance in the Netherlands: risk reduction in technical systems

In the eyes of many foreign visitors, the Netherlands appears clean and well maintained. In that respect, the country has a reputation to uphold, with its roads without holes, shiny office buildings, polished cars, clean water from the tap and uninterrupted electricity. And always dry feet, with no more dyke failures since the building of the Delta works; the eighth wonder of the world. The Dutch understand the art of maintenance. Thanks to well-maintained (air)ports, roads, waterways and other infrastructure elements, the Netherlands has become a global logistic centre, all made possible by the superb maintenance of its installations. The Dutch maintenance sector currently employs some 300,000 people who together generate annual turnover of approx. 30 billion euro, making it a major contributor.

Professional maintenance in the future: innovation and cooperation

The mission of World Class Maintenance is to ensure a level of maintenance that helps improve the world. World Class Maintenance believes that this goal can be achieved through innovation. Innovation means smart maintenance: unmanned aircraft for working at altitude, wind turbine maintenance with sensors and robotics for industrial cleaning are just a few examples. Innovation also means collaboration, by involving all the players in the chain from the owners of the capital-intensive goods and the suppliers of installations via service providers through to education and research organisations and various levels of government. Only by joining forces can we make maintenance more efficient, more effective and smarter.

This updated translation of the book by Klaas Smit is the standard work for today's maintenance experts, that will assist them to manage the maintenance behaviour of technical system and direct their maintenance efforts. This book discusses the latest ideas on maintenance, against the background of contemporary situations. In that sense, this book is the start of the contribution by maintenance to a sustainable and safe future for our world.

Translated from the original Dutch by Tim Mitchell Vertalingen, Gendringen, The Netherlands

World Class Maintenance

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Contents

Process, Technical System, Operation and Environment. In the example below, we analyse and identify the causes of the non-availability of a fleet of technical systems as a consequence of the maintenance process. The primary influencing factors identified are: the maintenance process, the management and control of that process, the organisation and personnel, information provision and the fleet (of technical systems) itself. The secondary causes are the 'twigs' on the branches. As required, the analysis can be taken to even greater depth and even lower levels, by further analysing the 'twigs'. A weighting factor is then allocated to each of the branches, and a score to the twigs, for the occurrence and/or size of the influence (priority) of an individual cause. Through systematic verification and elimination, the most probable cause or combination of causes can be identified.

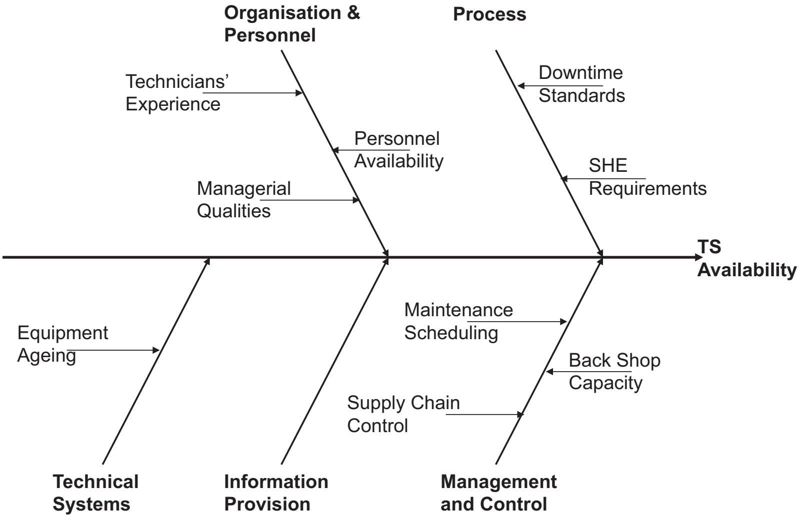

Figure 2.28 Cause and effect diagram

A more structured method for root cause analysis was developed and introduced to the market by (Kepner, 1997). This method makes use of a number of supporting techniques designated as problem analysis, incident mapping and decision-making analysis.

2.9.3 Improvement proposals

Once the primary cause of the failure mode has been identified, an improvement proposal is developed. The improvement may relate to the TS itself, the process, the operation or maintenance. Improvement proposals can however be more commercial in nature, and result in improvements to work processes, the management and control of those processes, the organisation (tasks, authorities and responsibilities) and the personnel (knowledge, training). See the example in Figure 2.28.

The improvement proposal must then be underpinned by estimating or calculating the necessary level of investment, and the expected savings. The decision on whether or not to introduce the proposal is generally based on the Return on Investment (ROI) or other financial evaluation methods, see § 4.10.5. Depending on the results of that analysis, the proposal will

In addition, the availability of parallel capacity and redundancy are important, as in the case of first and second product refining, which are consecutively provided with two and three parallel extruders for the product refining process. Failure of one of the extruders means that production can be continued, albeit at lower capacity.

The above described factors and operating time/capacity utilisation are determining factors for the consequences for failure, and hence for the level of maintenance-dependent costs.

The next stage is the functional breakdown of each subprocess or subsystem to component level. One method suitable for describing (sub) systems is the Structured Analysis and Design Technique (SADT) (Marca, 1988), or "Integration DEFinition for Function (Anon, 2001). Figure 3.11 provides an example of the functional description of a subsystem for the fuel supply for a propulsion installation on a ship, according to the SADT method. Once again, here, we observe the use of parallel systems and redundant components, in this case for the booster and service pumps, the heaters and the tanks. The decomposition of the technical system is as a rule continued to a level at which it is possible to identify the individual functions and failure modes of the TS elements, and to determine the effects at (sub)system level.

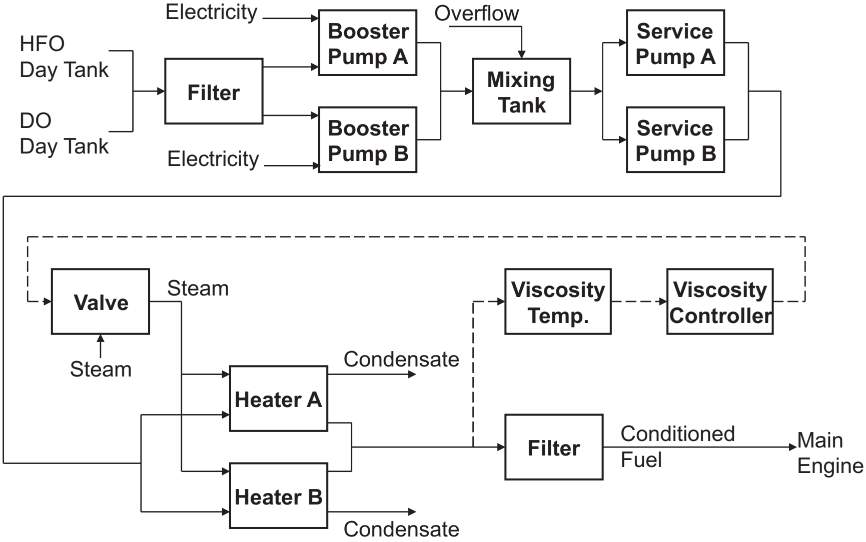

Figure 3.11 Analysis at component level

Identification of maintenance significant TS elements

In step 2, in Figure 3.9, for each of the specified component functions, a determination is made of the effects of functional failure or non-compliance with the functional requirements as a consequence of a failure, at subsystem and TS level, respectively. The failure effects are broken down into the following effect classes, see also § 2.3.3:

- safety (S), non-compliance with applicable HSE requirements;
- operation or production (O), in the form of TS downtime, capacity fall or product quality such as rejection, downgrading and reworking (performance killers);

The result of shortening the lead time, in turns out, can be very important. The generation of additional income thanks to the early availability of a TS can be of key importance for a business. This can not only be brought about by shortening the lead time, but above all by the fact that following commissioning, the specified production capacity is immediately fully available, thanks to the avoidance of start-up problems and teething troubles. This early availability offers the client a competitive edge. The application of Concurrent Engineering leads to the appointment of CE teams or Design, Build & Maintain (DBM) teams or integrated design teams. Depending on the nature of the TS and the project phase, as well as the involved engineering disciplines, these teams include such functions as marketing and sales, technical procurement, legal affairs, manufacturing, construction and maintenance or product support.

4.4.3 TS specifications

In the successive project phases, the TS specifications are laid down in ever greater detail. In the first instance, they appear as Top Level Requirements (TLR) in the form of functional specifications in the feasibility study and conceptual design phase. Subsequently at TS subsystem level in the basic engineering phase and finally in the detailed design phase, at detailed technical specifications at component, part and materials level, the Bill of Materials BOM. See § 2.2.2 and Figure 2.2. Determining the specifications and their values takes place according to the previously referred to systems engineering process, on the basis of functional analysis. The synthesis of those specifications leads to functional design variants, technological and subsequently technical choices, to make or buy decisions and supplier choices. See Figure 4.8.

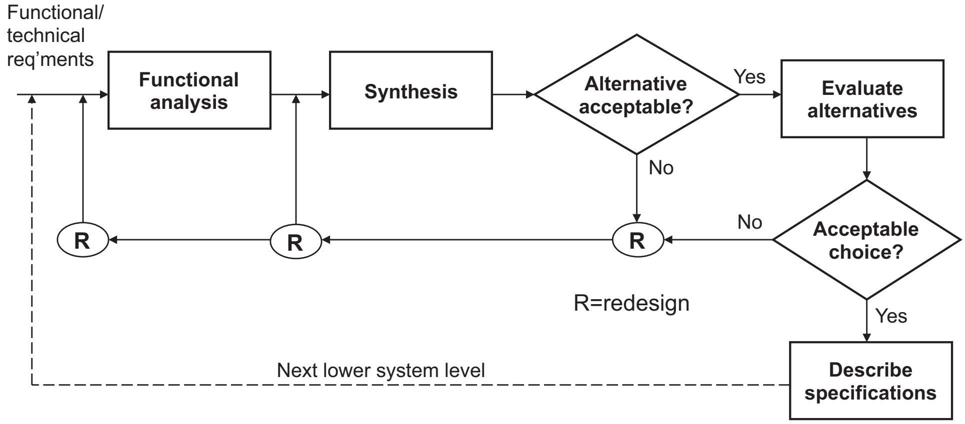

Figure 4.8 Systems Engineering process.

Following evaluation of acceptable alternatives, the alternative is selected that best meets the specifications. The assessment of alternative designs, undertaken during design reviews, is checked against the specifications at the next higher TS level, against the investment, the operating costs, the lead time and the risks. Once the specifications are met, they are described and subsequently elaborated one level deeper, in the next project phase. If none of the alternatives fulfils the requirements at higher system level, the response is redesign (R), follow-up of recovered failures is considered, and work requests are evaluated. Following more major incidents, disruptions or production losses, the decision may be taken to initiate ad hoc root cause analysis by a small team of a few operators and craftsmen, headed up by an ME, process technologist and/or production assistant, the aim of which is to identify the cause and possible solutions for the occurring event.

PROCESS MGT LEVEL	FINANCIAL CONTROL	RESOURCE MGT	WORK FLOW	PROJECT ENGIN-EERING	MAINT. CONCEPT CONTROL	CONFI-GURATION MGT	PERFOR-MANCE MGT
STRATEGIC CONSULTA-TION	Annual budget review	Personnel planning, appraisal, promotion, remune-ration	Maintenance projects plan	Investment projects plan	Maintenance downtime schedule	Modification budgets	Production schedule SHE plan
TACTICAL CONSULTA-TION	Monthly budget review Identification cost drivers	Personnel appraisal, promotion, remuneration Contractor evaluation	Capacity schedule & contracting Job schedule	Project budgets, Project progress review	Failure reduction plan Maintenance concept optimisation plan	Change committee, Proposal acceptance, authorisation	Identification performance killers
OPERA-TIONAL CONSULTA-TION	Weekly cost report, budget review	Work consultation	Morning meeting production, M&E Toolbox meetings TA	Investment project review	Ad hoc RCA analysis results Plant adoption teams	Modifications & change proposal review	Ad hoc RCA, T-P-M review

Table 7.6 M&E function consultation types.

Maintenance consultation

The results from the morning meeting give rise to coordination within the TD in the maintenance consultation, often for each craft and capacity group, with supervisors and work planners. During this consultation session, the measures are laid down arising from the desired follow-up and from work requests with a high priority from the morning meeting, which require rapid action and possible alterations within the weekly plan.

During the execution of a maintenance project, a progress meeting and/or toolbox (safety) meetings are usually held twice a day, during which project progress is updated, work is issued, progress is monitored and details harmonised.

Work consultation

The periodic work consultation between TD management and execution can be viewed as a form of operational consultation. This should not be taken as referring to the work consultation organised on the basis of representation, according to the Works Councils Act. Instead, work consultation in this sense refers to departmental consultation whereby the execution personnel are given an opportunity to present bottlenecks, suggestions and improvement initiatives, and where the management issues information about short and longer-term plans, and offers an opportunity for the execution personnel to respond. The result is greater involvement by execution and a greater willingness to accept decisions.