

How an Enlarged Maintenance Function Affects the Performance of Industrial Maintenance and Maintenance Services

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Abstract — Today, many companies struggle with maintenance work established by pre-requisites during purchasing, installation and start-up of plants, systems and machines. In search for improvements in existing maintenance organizations, it's easy to conclude that they look like and is a direct consequence of previous engineering decisions and activities.

Maintenance is, however, performed in the operation phase with weak coupling to what created it. Using an empirical knowledge base, several examples of this narrow view on maintenance is given along with the consequences it results in today.

It is argued, that the increasing need to create and preserve knowledge will be the driver for change and the main contribution to an enlarged and more efficient maintenance function. Improvements are pointed out using references to the leading actors creating the frontier today where most companies could be tomorrow. The paper hopefully will contribute to how maintenance processes and activities are being designed, set-up and carried out.

Keywords — Maintenance, Definition of, Improvement and Performance of Maintenance, Maintenance Services, Maintenance Processes, Enlarged Maintenance Function.

I. INTRODUCTION

Maintenance is a targeted activity area in industry today. As a profession, maintenance secure that infrastructures, plants, systems, components can be used for their purpose during the course of their life-length, by upholding asset properties such as functions and performance. As such, maintenance is an important contributor to sustainability and business economy.

The classical role of maintenance is clear— fix something when it's broke or prevent so it does not. Today, the number of faults and errors tend to decrease and times between failures increase, due to use of modern equipment with better quality. The knowledge acquired around a previous failure thus fade away. But modern equipment requires deeper knowledge difficult to obtain and retain over time. Together with the relatively small amount of events that occur inside company walls, productivity development of in-house resources is difficult and they can never compete with external specialists.

In search for improvements in existing maintenance organizations, it's easy to conclude that they look like and is a direct consequence of previous engineering decisions and activities. What you purchase, you install and use. In today's lowest bid environment it could mean very low performing systems to take care of and use in production.

Surprisingly, maintenance as a company function is seldom responsible for or even involved in the pre-work establishing their work content and pre-requisites.

Even more surprising is that what ultimately should govern and dimension the whole decision chain from what you need, what you buy, and what you use – the actual availability of the plant, system, machine or function – is often neither required or measured!

These are some of the findings from 15 years of industrial experience covering various companies in different lines of business; 11 outsourcing projects in manufacturing, food and mining, plus a 7 year development project in energy companies in several energy sectors and many countries.

During the time period it has been extremely difficult to grasp how companies set up, run and develop their maintenance activities as well as what they incorporate in and mean with maintenance. Searching for enlightenment in standards and textbooks gives precise answers. Looking for reasons to situations occurring in industry however, can seldom use that wisdom as guidance or sources for explanation. Despite the fact that availability issues are a result of what you buy, modern textbooks still state that the most important maintenance engineering frameworks are RCM and TPM [1].

The logical chain of events – in terms of engineering decisions and actions – that finally lead to activities needed to uphold functions and performance of an asset (plant, system, equipment or product), are cut into several organizational pieces. In each part managers with their short horizon budget steering try to optimize his or hers part respectively. Results are often obtained with no consideration to long time perspectives or a company perspective as a whole.

In practice this means that there exist something called maintenance in companies but it has very little to do with the circumstances that really has decisive influence on availability, expenditures and earnings in the company. Instead, those decisions are made by other company functions.

Looking at schools and university for guidance and hope for a change in the future, one finds no education programs covering maintenance issues and knowledge. In industry, most people working with such issues are “self-learned” through a long work experience. A manager for a maintenance department is in turn somebody that is lifted up from that working community. Instead of focusing on long term issues and economy, those guys or girls mostly dig into technical details – something they are familiar with.

All this continuously is supported by the narrow definitions of maintenance [2], [3]. It is clear that these traditional definitions must change and that the profession must recapture what constitute its meaning and role in a business environment. In many papers, this is implicated and even used as a point of departure, but often it all ends up in traditional work views and with no coupling between maintenance and what gave birth to the work done today in companies [4].

This paper will explain how an enlarged maintenance function will affect performance of industrial maintenance and services, thus contributing to a sounder development both of internal maintenance carried out and maintenance bought from service providers.

First, examples are given of how the particular work is carried out today using the empirical knowledge base. By explaining the coupling to the operative work, the logical chains of decisions and actions are exemplified. By linking together activities in the establishment life-cycle phase with the operation phase it is shown how an enlarged coherent maintenance function could improve the situation.

It is argued, that the increasing need to create and preserve knowledge will be the driver for change and the main contribution to an enlarged maintenance function; Suppliers could enlarge their product definition to include services useable for end users, and end users could use their part of different product populations to maximize the knowledge base within a company.

The key is to use the whole or the largest product population possible. This will in all cases create better knowledge, efficiency, and maintenance services.

Results after practical implementation are pointed out using references to the leading actors creating the frontier today where most companies could be tomorrow. The paper hopefully will contribute to how maintenance processes and activities are being designed, set-up and carried out.

II. EMPIRICAL FINDINGS

In this section, the findings from the empirical knowledge base will be described. Each finding constitutes a part of the logical links of decisions and activities that finally constitutes a maintenance function as an industrial business activity. For

each activity listed, there is a direct or indirect coupling to the maintenance function. This coupling is described and exemplified. For clarity the activities are grouped in a life cycle sequence:

A. Plant establishment phase

- No availability requirements in requirement specifications
 - o Without availability requirements the most important property, and the goal for all activities aiming at upholding an asset, is missing.
- Documentation, maintenance plans, spare parts required, etc. are not a part of project deliveries
 - o These deliveries establish the basis for the asset care activities and are normal job ingredients irrespective if the work is performed in house or by an external maintenance supplier.
- The service suppliers do not use the knowledge from a whole product population.
 - o This is the case when parts of a total maintenance organization work for themselves divided up by different organizational borders. Within the company, the knowledge and experience base gained around the very same systems or equipment is thereby not used.
 - o Today, suppliers of products also deliver maintenance. Several of those do not use their entire product population and the data and knowledge from all the usage of their products.
 - o External service suppliers should also use such specialization possibilities to increase the value of their service offers
- Decisions about what to buy is done by others, e.g., purchasing
 - o It is still uncommon that maintenance is involved in purchasing. In some companies internal rules state that they should, but they are not allowed, their requirements are not taken into consideration or they themselves do not prioritize the work and thus are not present.
- Decisions not based on present value life cycle analysis of costs and profits
 - o Many companies require a present discounted value calculation when a large amount of capital is involved. For smaller amounts no such calculation is performed. In some cases only the cost part is present in the calculation. Taking into account known costs for acquisition, activities for upholding

performance and functions, etc., the cost part is fundamental in decisions. Including the earnings part will show even more precise what alternative to choose in purchasing.

B. Plant operation phase

- Plant unavailability not measured and losses following from unavailability are not showing up in any economic footprint
 - o What you measure you can react upon. Production losses or increased costs due to unavailability are crucial in order to be able to prioritize activities that must be performed. Some companies are not interested since “the capacity installed is not fully used” – one is able to produce what could be delivered to the market. The losses could be considerable, but since it does not show up in any report, no one is, or can be held, responsible.
- Projects (how we cooperate) and investments (how we use capital) are not activities to uphold properties and functions of an asset.
 - o In some companies the maintenance expenditures are zero! Work items are put together in larger packages in order to be able to activate capital. Projects are by nature something where we exactly know (should know) what to do, so for such reasons they are often directed to tendering processes and put in separate accounts.
- Sub optimization in organization silos.
 - o Example: projects are carried out optimally in a local manager’s sense, e.g., based on day time work instead of 24h work schedule. On a company level the amount of money lost due to the longer plant unavailability is considerably larger than the difference between the 8 h and 24h work schedule. Sometimes losses are several total project budgets for the local manager only in one single case like this!
- Asset managers try to optimize their maintenance.
 - o The maintenance expenditures can be considerable large taking into account projects and investments. Unavailability (not being able to use) a plant or an infrastructure – and costs associated with that, could be considerable. Still, asset managers try optimize what’s being defined as maintenance expenditures - the direct cost for the resources doing what is considered as the maintenance work.

- o Managing an existing asset fleet is based on an experience among existing and former employees. That knowledge base is only a small part of the suppliers’ total product populations installed and used. It is clear that such optimization attempts are difficult if not meaningless.
- o Optimization even exists within companies where the maintenance organization does not work with the entire product population within that company! This means that the total knowledge and activity base is divided along with the maintenance organization. Since failures tend to be fewer and hence MTBF’s longer, experts on different equipment and systems need the entire population available in a company to develop their knowledge and their productivity.

C. Plant termination/life-end phase

- Maintenance records/information/experience are not reused in projects
 - o Even if the company will build up more or less exactly the same technical system, this does not occur. Information such as life costs, life earnings, life-lengths and failure data are lost.

III. DECISIONS AND ACTIONS BUILDING AN ENLARGED MAINTENANCE FUNCTION

The classical view upon maintenance has fortunately developed from the “fix broken items” or “replace” to preventive work using different means such as condition monitoring. But, it focuses only on what, should, or, could be done in the operations phase.

As indicated from the findings in the former section, many engineering decisions and activities successively end up in what maintenance is actually needed. In the same manner, many decisions in different parts of an organization successively establishes the prerequisites for the maintenance left to be done – maintenance as it looks like today.

The traditional maintenance function has to be enlarged to include the decisions and associated actions necessary to build up and uphold the properties of an asset (plant, system, component, etc.):

- Product design solution
- Specification of product requirements
- Specification of process and process requirements
- purchasing of systems and components that fulfill process requirements
- building or setting up the manufacturing system

- a system that can manufacture a product according to specification
- a product shipped to the end user in due time
- a useable product satisfying customer needs throughout the service life of the product

Actors are the suppliers delivering their solutions to the end users and the end users and their ambitions through requirements and specifications get what they need in their facilities. Hence several delivery-use chains could be involved in establishing an end user facility. The fundamental key to success lies in the establishment phase in each connection of a delivery-use chain. Here, the supplier could not only deliver a valuable product with high reliability, long life, and the correct functions and performance – but also connect to end users and the products life phase. There, valuable information could be obtained in order to improve existing or next generation products [5].

From an end user perspective, the establishment phase define what product to buy – the physical one only or a product where a part of a, or a complete, service package is included. Here, end users have an important task to require that suppliers take care of spare parts, maintenance and even being responsible for up time of their products.

A. Establishment Phase

The establishment phase defines functions, performance and the prerequisites for what is needed to be done due to wear and ageing in the operations phase.

Maintenance results in terms of availability or usability often becomes what the company in question regards as enough or, in infrastructure, what the public can tolerate. In some cases society has taken the role of the end-user and set up strict requirements to be followed in order to define the lowest threshold that companies must reach up to.

Department of Defence, as one of the largest product purchasers in the world, early understood the importance of requirements on and structure of early product development phases. They have developed a series of what, why and how specifications [6], [7]. Recent versions describe what is needed in order to reach goals stated on availability and maintainability. An important part is the requirements on a closed loop product development, e.g., the suppliers should monitor their products field performance, collect data about failures and other events of interest and feed these back to product improvement and development of existing and next generation products, se Fig. 1.

Outside the military industry only business areas governed by public authorities requirements, such as aviation and nuclear power production, have implemented early product development and coupled that to activities in the products' use phase [8]. There have been activities to increase the coupling between the establishment and operation phase for companies in general. In UK a study showed the increasing importance of maintenance costs and availability levels to the profitability of an industrial organization. The committee for Terotechnology started to try to influence industry to put greater efforts in the establishment phase. The work did not develop as it was

intended and that is considered as the main reason why it has not been accepted by or used in industry [9].

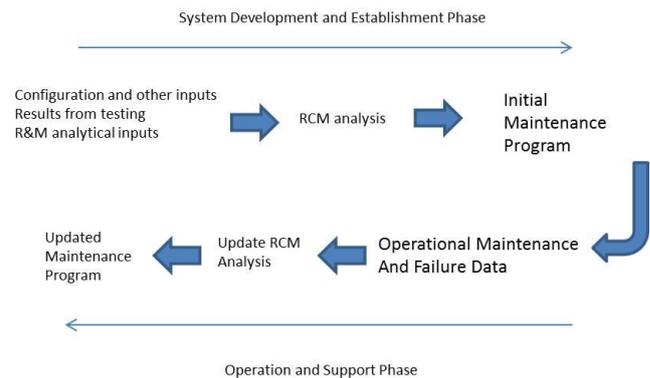


Fig 1 The Closed Loop (From [6])

Why organizations do not carry out the establishment phase more rigorously is a key question. Americas Society of Civil Engineers has conducted a study of the status of Americas Infrastructure. The 2009 Report Card for Americas Infrastructure is not an encouraging reading. Hearings held have pointed out that maintenance does not create “ribbon cutting” when bridges or tunnels are opened after a maintenance project. Politicians and decision makers don’t find maintenance as something interesting enough to put their time or effort in [10].

Another explanation is the division of the organization. Engineers must be put in the same room as the procurement people. Today most purchasing is done in the low-bid environment. Instead, the lowest life cycle cost should be in focus or preferably the bid with the highest discounted present value taking into account both cost and earnings! This is also something well known but not well established [11], [12].

It is important that end users of products to be purchased realize that it is the life cycle aspects that are important. As indicated in the empirical findings, several elements of such a cost structure are not measured or reported. There are even lines of businesses where faulty production units contribute to higher revenues for other working units!

B. Operation phase

Here it is clear that the major component affecting what activities needed to uphold functions and performance is knowledge. The knowledge chain is driven by a flow of information from end users to product manufacturers or suppliers as indicated above, but also from product manufacturers and suppliers to end users. Of course, long use periods of a plant or a system also create a lot of knowledge.

If we equal a products life cycle use period with the end users use of it, a system of systems have produced a product that will be used by end users. That product can in turn be put in a system of systems to produce another product. Such delivery chains can be very long for complex end products. In

each part, the maintenance function secures usability of the process built to produce a product, giving the asset owner a possibility to deliver products, e.g., in due time to users.

When a product is shipped to the end user, it should fully meet design requirements, be manufactured according to specifications, and be capable of satisfying customer needs throughout the service life of the product. The products ability to perform its intended functions - can be defined as quality over time or maintaining continuous customer satisfaction. Including necessary maintenance prerequisites is natural for a supplier caring about the market and customers there.

The importance of product quality and product reliability when customers start using it has been known for a long time [11], [12]. Ahmed [13] distinguishes between on and off line methods. Off line is during product design and manufacturing and on line are methods for measuring, monitoring and assessing product reliability that design engineers can act upon. He points out that the techniques available could be used to continuously monitor reliability performance of a total population of products in field use for product uplifts and engineering changes.

One of the practical problems at that period of time was collection of data in separate systems, each one targeted to a specific part of the organization (e.g. designers, service personnel). It was however easy to show that by using data from these systems, a detailed knowledge could be obtained about systems and components and their reliability [14], [15].

Closed loop approaches from user to manufacturer are today common practice in the semiconductor and telecommunication industry in order to monitor the product from the first second in use in order to increase field system MTBF. The approach has given companies lower warranty costs and early warning signals to take necessary corrective and preventive action to ensure product safety and effectiveness [16], [17]. It is evident that the entire process of controlling and increasing reliability must be based upon knowledge about the end use of a product.

In the aviation industry, product manufacturers such as Rolls Royce (RR) have developed Total Care program where RR gets paid per flying hour (performance contracting). RR (the Original Equipment Manufacturer) assumes the cost of maintenance and support services and has to consider operating performance and any disruptive events which take the engine out of operation. This will cause the engine to cease generating income for the OEM. In the concept, the performance of the product and its functions are monitored in order to feedback deviations for corrective actions, but also to prevent such deviations to occur in other products in the product population.

With the paid by the hour incentive, it has been shown that reliability is affected positively to a great extent [18]!

The extension of the concept is straightforward – a modelling of the costs over a life cycle. As more data continuously are gathered, the model get better and better to predict and quantify costs and inherent economy for both end users and RR themselves [19].

In order to be able to implement a closed loop product life cycle system, a key element is acquiring the information from the product in the field. Projects are ongoing such as those associated with the IMS in USA and the Promise project in Europe [20], [21].

By using smart embedded systems a seamless e-transformation enable product lifecycle information to be transferred to knowledge. In the Promise project, application scenarios include products early, middle and end of life product lifecycles. By introducing such means, manufacturers and suppliers of those products could improve product and service quality, efficiency and sustainability.

IV. CONCLUSIONS

Maintenance today is a limited and narrow part of what really is a large number of successive decisions and actions needed to build up the activities necessary to uphold functions and performance of an industrial plant, a system, a component or a product!

A key element in developing this enlarged future maintenance function is knowledge - about plants, systems, components and products. The connection between end users strive for value in their investments and the suppliers ambition of developing products with high end user value could be used to gain momentum.

Based on the user perspective it is clear that real value does not appear until the user is able to use the product bought and enjoy the benefits from a (well enough) functioning product. With such value proposals, market analysts and market developers try to get companies interested to develop their activities from the traditional product design, manufacture, deliver scheme to activities closer to the end-user, so the push is really existing from the suppliers side [22]-[27].

Many organizations and companies have understood the importance of the activities needed to uphold properties of assets such as plants and infrastructure. Most decision bodies within companies and government understand the importance of low unavailability (implies a good enough system or not the lowest bid taken) and the necessity of a good enough maintenance function able to continuously uphold asset properties maximizing life-length or profits or minimizing environmental impact. If this increased knowledge can be used to develop the maintenance function remains to be seen.

The use life cycle phase produce valuable feedback from product failures and other incidents that arise. By using root cause analysis and defining preventive actions, current and next generation design could be improved. Here, it is important that the information gained is forwarded to the users of the whole product population!

Without a larger knowledge base than the one that could be obtained in a single company, most maintenance functions will have severe difficulties to develop and reach good enough efficiency. In the same way, a large company must use the internal product population present to reach the maximum effects possible.

Finally, by not connecting the logical links of decisions and activities constituting the maintenance function, the benefits of an enlarged maintenance function could not be obtained.

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