Maintenance from Different Relevant Perspectives; Total Quality Maintenance (TQMain) for a Comprehensive Asset Maintenance

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Summary: Due to the interactions between the working areas involved in a production process, such as operation, quality, management, working environment, LCC management and analysis and maintenance, problems in these working areas are usually complex. It is well-known that maintenance is influenced by and influences these working areas. Maintenance role can be described technically using; failures, downtime, availability, planned stoppages, etc. or economically using; direct cost of maintenance, maintenance cost to production cost, spare part cost, etc. In order to highlight maintenance technical and economic role and quantify its impact on company profitability and competitiveness, it is necessary to cover all relevant working areas within plant where maintenance affect. Thus, maintenance should be considered from different perspectives due to its interplay with the working areas involved in the production process. In this paper, maintenance is recognised as a means for maintaining the quality of the working areas involved in a production process at a continuous reduced cost. Also, we introduce maintenance from different perspectives based on its role in company profitability and competitiveness. Further more, the paper give big attention to introduce and discuss Total Quality maintenance (TQMain) philosophy with respect to the maintenance broader definition. An industrial case highlights TQMain applicability & maintenance economic importance is also introduced.

Keywords: Working Areas, Total Quality Maintenance (TQMain), Maintenance Economic Impact, Maintenance Savings and Profit

1 INTRODUCTION

According to a study reported by Mobley (1990), from 15 to 40% (with an average of 28%) of the total cost of finished goods can be attributed to maintenance activities in factory, see Blanchard (1994). The study conducted by the Department of Trade and Industry in the UK revealed that poor and dangerous maintenance costs UK industry US$ 1.95x10^9 Ł 1.3 billion a year, Rao (1993). The implementation of vibration-based maintenance (VBM) policy provides possibilities for acquiring early indications of changes of machine-state, Al-Najjar (1997). These indications could be of great importance also in detecting deviations in the product quality early and before they show on quality control charts, Al-Najjar (2001). Cost-effectiveness is one of the criteria, which can be used to select a suitable maintenance policy. An effective CBM policy lets the machine run until just before failure. It can be defined by two defence-lines, which are proactive maintenance (activities and efforts of detecting and correcting the causes of damage initiation) and predictive maintenance (monitoring symptomatic conditions when the damage is initiated and it is under development), Al-Najjar (1996).
Real problems in production, quality and maintenance are complex, due to the interplay between many factors. Condition monitoring (CM) software programs especially for vibration became more popular in many industries, such as paper and pulp mills, refineries and power stations, and recently in manufacturing industry, Al-Najjar (1997) and the references cited there. In applications, the databases of these software programs are limited and in general not integrated with databases for operation, quality and management and accountancy. A database for a wider range of information is required for effective diagnosis and prognosis of equipment condition. The data required for this database can either be found in plant's different databases or collected from the field. The aim of this paper is to demonstrate the possible impact of using Total Quality Maintenance (TQMMain) concept on diagnosis/prognosis technique, product quality and company's profits and competitiveness especially when the downtime is expensive, such as the case in process and chemical industries.

2 MAINTENANCE ROLES
Maintenance definition and role in the company’s business is usually confused especially between practitioners. But in literature, we can find approximately the same confusion about maintenance role in company business. The main question to ask when it concerns maintenance role is whether maintenance is to repair, to do measurements such as applying condition monitoring (CM) or it is the management tools box required for maintenance activities that are decided according to CM indications/assessments or according to the time schedule following a statistical model. Also when investing in maintenance, it is always a serious question to answer, which is whether maintenance is for solving technical problems, such as reducing downtime or it is a means for handling economic problems influencing production process and consequently company profitability and competitiveness.

Maintenance is defined in this paper as: a combination of activities aims to maintain the quality of the work areas involved in production process. This is why its role is for detecting and controlling the deviations in the condition of a production process/equipment, production costs, working environment and product quality in order to interfere when it is possible to arrest or reduce the deterioration rate before the process condition and product characteristics are intolerably affected, and to perform the required action to restore the process or equipment/component to as good as new. All these should be performed while continuously reducing cost per unit of quality product.

Fig.1. Improvements in production and maintenance processes versus data.

Efficient maintenance is that which aims to reduce the production cost continuously by shortening downtime and maintaining the quality of the elements involved in the production process and consequently enhance company profitability and competitiveness. This is why it is a means for solving economic problems. In other words, we need maintenance to prolong machine effective-life and increase the return on investment. Improvements in the production and maintenance processes cannot be achieved cost-effectively without effective identification and localisation of damage and description of damage development mechanisms see also Fig. 1. The latter will not be easy to achieve without high
quality and better data coverage, i.e. in order to make a cost-effective maintenance decision, wide coverage data of high quality are required. These data should cover several relevant working areas, e.g. operation, Working environment, organisation and management, quality, accountancy system and life cycle cost management and analysis and personnel competence and skill. This is why it is necessary to evolve and apply a new maintenance concept providing all these demands that have become very crucial for enhancing the profitability and competitiveness of companies.

This maintenance concept should provide the possibility of handling production technical and economic problems with respect to maintenance, which demands better data coverage and quality that should be provided by it for detecting/identification, localisation and description of damage and its developing mechanisms.

3 MAINTENANCE AS PROFIT CONTRIBUTOR FROM DIFFERENT PERSPECTIVES

In many cases, the company profit, state of machines and product quality in a manufacturing company cannot be assessed and/or controlled effectively if the data gathered from these working areas are treated individually and separated from the rest of the plant information-technology (IT-system). The cost of breakdown in the production system can be very high, not only in the direct financial terms but also in poor moral of production staff and in unpleasant impact on the customers, environment and society. Staff competence, working environment, methods and procedures can also be maintained effectively through cost-effective and continuous improvement, modifications, training, health care and even entertainment. Maintaining all the essential elements (working areas) involved in the production is necessary for keeping them at high quality, because deviations in the quality of one or more of these factors may cause appreciable deviations in the output of the production process, i.e. in the product quality, production cost and working environment.

The ability of a machine to function satisfactorily over a period of time is known as reliability, i.e. the ability of equipment to meet the internal & external customers’ requirements over a period of time. Using relevant analysis and selection methods and tools, it would be possible to select a cost-effective maintenance policy for equipment/component and improve it continuously and cost-effectively. The selected cost-effective maintenance policy is not necessarily proceeds to be the most cost-effective after some years of application due to the changes in machinery, production methodology and procedures, operating and environmental conditions, instrumentation and software, etc. all of which may influence the failure behaviour of the monitored/maintained components. Thus, in order to keep the company competitive, continuous cyclic improvement of the effectiveness and accuracy of the selected policy is necessary. But, this cannot be achieved without better data coverage and quality in a reliable and wide database. Establishment of a common database in a particular company requires special investment, which can be motivated by the potential benefits that can be achieved when a wide range of high quality data is available and easily accessible. The result of several case studies that have been done by the author shows the possibility of a cyclic improvement of a vibration-based maintenance (VBM) policy using the available data, which are not necessary only failure data. Furthermore, it also shows how VBM policy can be improved gradually, which in turn improves company profitability, when more knowledge, experience and data from plant's different activities are collected and analysed followed by a reliable feedback & training.

Experience concerning identification of damage initiation, its root causes and damage development mechanisms of a component, such as rolling element bearing, can be updated after each planned or unplanned replacement. This can be approached through confronting the new analysis results of the machine history, including vibration measurements, and the on renewal analysis, e.g. of the bearing. Thus, failure mode, effect and criticality analysis, FMECA-database can be started and improved continuously to create an Updated Record of Failure Mode, Effect and Criticality Analysis, URoFMECA. These data provide convincing evidence for a machine manufacturer to perform the required modification in the next machine generation and the basis to perform cost-effective selections, modifications and improvements. The combination of the relevant data from operation, production, maintenance, quality and accountancy would help to achieve more reliable monitoring and assessment
of plant financial (cost and profit) factors, machine/process capability indices, availability, quality rate, process performance efficiency and the cost-effective investment/improvement.

In general, the database of a vibration monitoring program including information of many years' experience is important to improve that monitoring system itself. Such improvements can not be carried out reliably without considering data regarding operating and environmental conditions, quality, etc. The same thing can be said about the improvements in other working areas. Thus, when using vibration-based maintenance (VBM) policy, numerate records from operation and specially machine load, speed, temperature, lubricant and temperature, and the past vibration measurements, can be utilised to distinguish the reasons behind increments in the significant vibration levels. These data can also be used to highlight other reasons behind damage initiation and development, such as repair/replacement quality, operator’s misuse, faulty design in the machine, harsh operating or environment conditions, replaced component quality or the usual deterioration. The assessment of the probability of failure of a component during the lead-time and when product quality is still acceptable can be done reliably basing on such wide database. In the life of a rolling element bearing we can find three different phases, which are; no damage, damage initiated and development and imminent failure phase, where the second phase represents about 65% of bearing total usable life, Al-Najjar (1997). Therefore, when replacing a bearing as soon as its vibration level exceeds the normal means we are losing more than 50% of the bearing effective life, which is the case in general (Ibid). Such replacements are usually performed to avoid failures due to the high uncertainty in the assessment of damage severity, component residual life, probability of failure at that moment and vibration level and determination of the most cost-effective replacement moment. But, more accurate identification of the vibration levels and moments of damage initiation and replacement help to extend bearing effective operating life appreciably, Al-Najjar (1999). We have observed that it is often difficult to tell for certain that the second phase has began, especially when the number of vibration measurements is very small, without using the CUSUM chart, Al-Najjar (1997).

4 TOTAL QUALITY MAINTENANCE (TQMain)
One of the essential forces driving total quality management (TQM) and total productive maintenance (TPM) is the improvement cycle (Deming cycle), i.e. Plan - Do - Check - Act. Practically, this cycle has been used in a way that one should act as soon as failure is occurred. But, it can also be interpreted so that action is started at an earlier stage, i.e. as soon as a significant deviation in the equipment/process condition is observed. Vast majority of the failures of mechanical components are preceded by some detectable indications of condition change. Vibration spectral analysis provides a basis for identification of damage causes, damage development mechanisms and failure modes for most types of faults in rotating and reciprocating machines. In this paper, the failure is defined as a termination of a component’s ability, to perform its required function, which can be defined on basis of the machine function, capability, production rate, production cost, product quality, or personnel/machine safety. TQMain is a means to maintain and improve continuously the technical and economic effectiveness of the production process and its elements, i.e. it is not just a tool to serve or repair failed machines rather than a means to maintain the quality of all the elements involved in the production process. Thus, its role is defined as: A means for monitoring and controlling deviations in a process, working conditions, product quality and production cost, and for detecting damage causes and their developing mechanisms and potential failures in order to interfere (when it is possible) to “stop” or reduce machine deterioration rate before the production process and product characteristics are intolerably affected and to perform the required action to restore the machine/process or a particular part of it to as good as new. All these should be performed at a continuously reducing cost per unit of good quality product.

TQMain promotes that the data required should be gathered in a common database without the duplication that usually occurs when each department collects its own data. It also promotes the integration of the databases of relevant working areas that can be selected based on their significance and impact on mapping, analysis and enhancement of the production process and company business.
Integrating data from relevant working areas has many benefits. For example, the integration of the data collected from production and VBM policy provides good opportunities for monitoring, measuring and improving reliability, availability and productivity of the producing machines. Integrating the data from VBM database with those from the databases for production and quality control establishes the basis for monitoring, measuring and improving the quality rate and causes behind quality deviations in addition to the latter characteristics. The integration of the data from VBM policy and quality control provides a possibility for monitoring, measuring and improving the quality system, because VBM policy works in this context as a quality assurance tool see above. A reliable redesign and modification of manufacturing equipment can also be achieved.

When using OEE as a measure of the progress achieved by a particular improvement, there is a major question to be addressed, which is whether that progress was cost-effective? TQMain would answer whether it would be cheaper to have buffer stores to permit the required actions or to duplicate the machines as the production method might need if production had to be kept up. When the cost accountancy program is integrated with the common database, TQMain offers particular criteria and tools to assess the cost-effectiveness of the technical improvements. Many possible optimisations and analysis are currently abandoned because people simply do not have the time to co-ordinate data from several sources and hunt for missing data only to find ambiguities affecting the values of model parameters.

4.1 Production process from the point of view of Total Quality Maintenance

One of today’s biggest business challenges is to ensure equipment performance & availability whilst achieving minimum cost. More attention should be given on broadening the perspective of maintenance through integrating it with the production program and into a complete market-oriented system, and on the importance of utilising a feedback system in improving, e.g. productivity, quality, reliability, designs. Furthermore, for any production process or enterprise to survive the harsh international competition, specific competitive advantages should be created, maintained and improved continuously. These competitive advantages are:

1. High quality production
2. Competitive price
3. Delivery on time
4. Environmental friendly production process and product
5. Society acceptance

The basic elements constituting a production process may be summarised in: producing machines, tools, procedures and methods, maintenance policy, operational conditions, competence of the operating and maintenance staff, quality system, raw material and managerial functions. Deviations in the quality of any of the essential manufacturing input elements have major effect in the competitive advantage and product technical specifications (product quality). In this study the condition of the production process is defined by the state of the basic elements constituting it. In general, it is not usual that old and deteriorated equipment/processes can manufacture quality products in high effectiveness at a competitive price to be delivered on time and being environmental friendly process in the sense demanded by the society. Deterioration in equipment can be started, or developed, by means of external causes, such as misuse, bad raw material, unsuitable lubricant, inefficient maintenance, external shock and harsh operational conditions. For example, these factors constitute about 70% of the total reasons behind failures in rolling element bearings, Bloch and Geitner (1994). Therefore to prevent or reduce their effect, relevant parameters should be monitored actively.

In order to provide more accurate real-time mapping and analysis of the condition of a production process, both the product characteristics and the condition of the relevant elements involved in the production process should be monitored and assessed. This is also necessary to prolong the lead-time required for preparing and performing maintenance actions to restore the condition of a component, equipment or process to be able to function according to the specifications. Technical, statistical and economic analyses are effective tools to identify and assess the deviations in the condition of the
production process, product quality, working environment and production costs. Vibration spectrum analysis is a powerful tool for monitoring rotating and reciprocating machines. It is also partly suitable for monitoring the working environment and personnel competence in specific areas. Vibration frequencies can be utilised to monitor the machine condition and product quality and to identify and localise a wide range of the causes behind the deviations and consequently which elements in the production process that these causes are related to. The best output of the production process that fulfils the competitive advantages can be distinguished and achieved through selecting the suitable combination of the process elements, which cannot be achieved without using an easily accessible and special database.

4.2 Features, Applicability and Benefits of TQMain

The features characterising TQMain and distinguishing it from other maintenance techniques, such as preventive (PM), condition-based (CBM), reliability-centred (RCM) and total productive maintenance (TPM) can be summarised in the following:

1. It covers a wider range of a production process compared with the traditional maintenance concept, which deals with just machinery.
2. It is based on a new CBM concept. It is planned and performed based on the needs arise due to the deviations in the quality of the elements involved in the production process.
3. It handles production and maintenance technical and financial problems by integrating tools and methods belong to both deterministic and probabilistic approaches.
4. It advocates the use of a common database that should be updated by real-time measurements of the essential information parameters, for real-time monitoring and assessment of the machine condition and production process technical and economic effectiveness, product quality and working environment. Thus, within TQMain, it is possible to select and improve the most informative CM system and the most cost-effective maintenance policy effectively.
5. Consequently, it provides a holistic view of the state of the production process (including all the elements involved), maintenance technical & financial impact on company business
6. It is based on making intensive use of the real-time data acquisition and analysis to detect at an early stage the causes behind quality and cost factors deviations and machinery malfunctions, and following damage/defect development to prolong the component mean effective life and to improve company’s profitability and competitiveness.
7. It provides tools and methods for proactive-predictive maintenance, i.e. to detect and eliminate the cause behind damage initiation. If it is not possible due to the technological limitation, detect the deviation at an early stage and predict its development to reduce (or eliminate) the risk of failure.
8. It emphasis on the systematic maintenance work combining technical, organisational and economic knowledge and experience, where all the theories, tools and methods required are, more or less, developed and verified. This systematic maintenance work starts by detecting the deviation/damage at an early stage, identifying damage initiation causes and developing mechanisms and predict the situation in the close future technically and financially.
9. It provides the basis for cost-effective continuous improvement of the whole production process and in particular vibration/condition-based maintenance policy after each renewal through confronting database history, including vibration measurements, with the replaced components, i.e. continuous cyclic improvement.

TQMain has been applied partly in many case studies (about ten case studies). The results of these applications have shown a big beneficial potential and possibility of applying it as a whole concept, which is now under planning together with one of the biggest companies in Sweden. The extensive use of data feedback is considered essential to accomplish cost-effective continuous improvements and to assure the achievement of the competitive advantages demanded. It would enable the user, on demand and at all levels to get reliable information for:
1. Detecting the deviations in the state of a component, machine or process, production cost, product quality and working environment at an early stage in order to control the situation when possible by “stopping” or reducing the rate of the development.

2. Selecting the most cost-effective maintenance policy and the most cost-effective condition monitoring level, such as vibration level, at which to replace components.

3. The acceptable deterioration rate to “guarantee” no sudden failure during the lead-time, i.e. the time between detecting a potential failure and action to repair it.

4. Detecting potential failures (damage under development) in machine element and follow up their development, and predicting the level of the condition monitoring parameter, such vibration level, during the close future.

5. Assessing the condition-dependent failure rate of the component during the lead-time, the probability of failure, the remaining useful working lives (residual life) of the components/equipment under consideration, and the most cost effective opportunity for performing maintenance action.

6. Identification of failure mechanisms, failure causes and failure modes with increasing diagnosis and prognosis precision by relating the past measurements to the damage subsequently found and safe lead-time achieved.

Total quality maintenance consists of four essential working phases (modules). In order to achieve high quality result, these modules should be applied in the same rank order shown in Fig.2. Theories, tools and methods are specially developed or adapted for the application of all these modules. The modules are for:

1. Identification
2. Description
3. Selection
4. Cost-effective continuous improvement, which includes per definition Cost-effective application, see also Fig.2

In the first phase the major focus is to collect relevant data for mapping and analysis the situation to identify significant components, their failures, damage basic causes and the mechanisms for developing the damage. The output of this phase is utilised to describe the possible changes in the state of the component/equipment under consideration when the damage is initiated and is underdevelopment until failure. In other words, the deterioration process can then be described properly. When the latter is done, the most informative CM parameter(s) and consequently systems for detecting changes in equipment condition and follow up their development can be identified effectively. CM systems are to detect deviations in the quality of the production elements at an early stage. CM technology is one of the information sources that can be utilised for mapping and analysing the condition of a component, equipment and process. But, the management work required for planning and performing relevant and cost-effective maintenance actions necessary for maintaining the quality of one or more of the elements involved in the production process is very important. Usually, we identify many maintenance techniques, i.e. strategies, policies, methodologies and philosophies that are technically applicable for maintaining the component, equipment in question. TQMain provides tools, methods and technical and economic criteria required to select the most cost-effective maintenance techniques and the most informative CM parameter. Cost-effective continuous improvement cannot be approached without a reliable feedback links, such as the common database, and a reliable policy for performing continuous cost-effective improvement. Cost-effective improvement means that every improvement should be judged in conjunction with its cost-effectiveness and not just how technically advanced it is. TQMain phases are discussed in details in the following chapters that are subdivided in four parts. An additional part discusses the integration of maintenance with plant activities for identification and elimination of profit losses. TQMain provides all the tools and the methods required to perform these steps. These tools and methods are usually verified in several case studies and usually based on the common concept of TQMain.
5 ECONOMIC IMPACT ON COMPANY PROFIT WHEN USING VBM

The case study was conducted at StoraEnso (a paper mill company in Hyltebruk area in the southern part of Sweden). The data collected was delimited to only stoppages of mechanical components, which were (or could be) monitored by vibration signals. The study was conducted at PM2, one of the company’s four machines. It was selected due to its valuable database especially during study period (1997-2000). A special data sheet was designed for collecting manually technical and economic information parameters from the company databases. The data sheet was adapted to suit the company terminology and context. Technical data included parameters, such as operating time, production rate, time and frequency of stoppages in which mechanical tasks, e.g. bearing replacements, were performed as a result of using VBM, failures, short stoppages, quantity of bad quality products caused by maintenance problems. Economic data such as fixed and variable operating costs, profit margin, net profit, working capital, direct maintenance cost.
Direct maintenance cost, which was almost constant during the study period with an average of about 13 MSEK. Total maintenance investment in PM2 was increasing for the years 1997-1999 with a little bit decrease in year 2000, on average it was about 0.455 MSEK per year. Total production losses (potential savings or maintenance potential income) consists of the summation of lost profit and unutilised costs calculated for unavailability due to unplanned and planned stoppage times, short stoppages, bad quality products caused by maintenance problems, and tied up capital due to extra spare parts. On average the total potential saving was about 30 MSEK, and it was increasing for the total losses elements. Losses due to short stoppages represent the highest value, then the planned stoppages, and quality problems, after that come the failures, finally the tied capital due to extra spare parts inventory, which was calculated with respect to year 1997. On average the minimum savings was estimated to be about 4 MSEK, which was increasing especially during the years 1999 and 2000. The last factor is maintenance profit, which represents the difference between the minimum savings and maintenance investments. On average it was about 3.58 MSEK, see Figs. 3 and 4.

Twelve maintenance-performance measures were developed and used. The first and second performance measures are the direct maintenance cost (mechanical), and total investments in maintenance. The third, fourth and fifth are the ratio of the direct mechanical maintenance costs to operation cost, running time and accepted product, which showed approximately the same trend (almost constant) during 1997-2000. The sixth measure is the total losses (in profit and resources) per each accepted ton produced. It shows that on average about 168 SEK were lost for each ton of paper produced, and, also, the trend of losses is increasing. The seventh measure is the minimum savings divided by the accepted tons of paper produced. The eighth measure is the ratio of maintenance investments to potential savings. It was appreciably small and varied between 1-2.2%. The ninth measure is the ratio of minimum savings to maintenance investments on average it was about 9.2 which was high and within the range achieved internationally, i.e. 5-10. The tenth measure is the ratio of lost profit to actual profit. We noticed that on average a value of a bout 3.5% of the actual generated profit could have been gained for lost production during failures and short stoppages. Note that the quantities that are not produced during the planned stoppage time are not included. The eleventh measure is the restricted overall process effectiveness (ROPE). ROPE is equivalent to OEE but restricted to only when the machine is subjected to mechanical faults that can be maintained by VBM. Finally, the last measure, which represents the value of ROPE, divided by the direct mechanical maintenance costs, Al-Najjar and Alsyouf (2004).

6 CONCLUSIONS
In general, using TQMain would enable the user, on demand and at all levels from the executive manager to the operator, to get reliable information about:

1. The deviations in the process to control the situation at an early stage.
2. Cost-effective vibration-level to replace components suffering deterioration.
3. Acceptable deterioration rate to avoid sudden failure during the lead-time.
4. Potential failures and prediction of remaining useful working life.
5. Probability of failure during the lead-time.
6. Failure mechanisms, causes & modes to ease and enhance their identification tools.
7. Cost-effectiveness of using the CM system.

The implementation of TQMain can be carried out easily if the integration is achieved gradually and expanded after each successful extension. Better (and relevant) data coverage and quality, which is easily accessible, increase the possibility of achieving Just in Time Maintenance concept. This together with vibration measurements help to detect damage initiation and following its development, effective diagnosis and prognosis, effective control of the condition of machinery and less production losses. The variation in the machine load and speeds influences the amplitudes of rolling element bearing defect frequencies and such changes should be considered when interpreting vibration spectra. This will improve the effectiveness and accuracy of fault diagnosis and prediction of the time to maintenance action. Using TQMain concept, makes it possible to detect causes and their development mechanisms that are behind deviation in the machine condition and product quality at an early stage. The quality and reliability of product and equipment, respectively, will then be maintained and a higher overall equipment effectiveness at a low cost can be approached consequently. Vibration spectral analysis can be used as a tool for quality assurance, which enables the user to detect quality deviations at an earlier stage than when using traditional quality control diagrams in order to eliminate the causes and prevent the machine from manufacturing defective items. The quality problem causes that were identified technically were confirmed by both vibration signal analysis and quality data analysis. Using the suggested LCC model means that cost factors will be used as monitoring parameters to provide the required information for decision-making and to insure cost-effective actions and enhances never ending improvement efforts. Comparing the minimum savings with the investments done for improving maintenance policy reveals how cost effective the investment in maintenance was and whether it was relevant or not.

References


Bibliography

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He is Professor of Terotechnology at Växjö University. He obtained his Ph.D. in production management, Lund University, Sweden. Al-Najjar main research area is Terotechnology. It is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs. It covers maintenance management, optimisation, CM, CBM and its impact on the plant business. He is the head of the division of Terotechnology, School of Technology and Design, Växjö University. He has many years of experience of teaching and research mainly in industrial asset management, cost-effectiveness, CBM, problem shooting using vibration spectral analysis, modelling and optimisation. He is author of about 90 papers published in international journals and conferences in CBM and its impact on production, quality, performance effectiveness, cost-effectiveness, data gathering and databases and human resources. He is a member of the Scientific board/Swedish Maintenance Society, International Network for Industrial Diagnostics, European Research Network on Strategic Engineering Asset Management and IFRIM (International Foundation on research in Maintenance). He developed the concept of Total Quality maintenance and applied it in many case studies, which is taught to the personnel of Siemens and Alstom Power as industrial training courses. He was the 2003 Eminent Speaker to the Maintenance Engineering Society of Australia and will be for 2008. In 2000 he received award for Excellence of Journal of Quality in Maintenance Engineering, the Most Outstanding Award from Literati Club, MCB University Press. Further, he received Tore Danielssons fond Award together, 2002, which was motivated by his outstanding research results and their usefulness for the Swedish industry and to establishing a research team in Terotechnology