Managing the performance of maintenance personnel

Managing the Performance of Maintenance Personnel

13

A. van Berkel
P. Janssen
H. Martin
H. van Tuijl

13.1 Introduction

In many organisations with own maintenance facilities, maintenance people are looked at as specialists going their own way. This perception or attitude may lead to a mental separation of the maintenance department from the rest of the organisation, resulting in low effectiveness of maintenance operations and low efficiency in capacity and material utilisation. Not surprisingly, management will be inclined to consider contracting out the entire maintenance function as a final solution to the problem.

In this paper, we will describe the application of a recently developed performance management technique (Pritchard, 1990 [1]) to enhance the performance of maintenance personnel, which also proved to be very beneficial to improve the co-operation between the maintenance department and production departments. Human motivation is the point of departure of the technique mentioned. So, the emphasis will be on those elements of total maintenance performance that can be controlled by maintenance personnel. By total maintenance performance we mean the performance of the combined human-technological maintenance system. This performance can be defined as "The efficient application of resources to control and reconcile actual system behaviour to the effective attainment of business requirements" (Geraerds, 1991 [2]). Maintenance performance is defined as a contribution to total system performance. In a similar way, the performance of the human part of the maintenance system is seen as contributing to the performance of the maintenance system as a whole and can be defined as "The efficient and effective use by the human subsystem of its resources to achieve maintenance goals" (by analogy to Pritchard, 1992 [3]). So, performance can be defined from different perspectives. This paper will deal with two of those perspectives, viz. the perspective of maintenance personnel performance, aiming at the conditions under which people will be prepared and motivated to perform, and the procedural perspective of maintenance performance, aimed at evaluating and improving total system performance. More in particular, the relationship between these two perspectives will be elaborated.

We will start with the level of maintenance personnel performance. A short introduction into this performance management technique and the underlying principles will be presented. Next, the technique will be illustrated with a case study of an actual group of maintenance personnel. The performance management system developed by this group will be described in detail. Then, we continue with a critical review of this system from the performance perspective of the total maintenance function. Finally, some issues will be discussed, viz. the relationship between the two perspectives mentioned, their contribution to a better integration of the maintenance department and some suggestions for future research.

13.2 Performance management

The literature on motivation (Locke and Latham, 1984 [4], 1990 [5]) provides a number of clear answers to the question of how employees can be stimulated to strive for the achievement of organisational goals. The most important condition for this, trivial as it may look at first sight, is that employees set goals themselves. Naturally, these goals will have to relate to the organisation's goals. Once goals have been realised, a second mechanism comes into play: employees become interested in the degree to which they are able to achieve the goals they have set for themselves. In other words, they start to look for feedback. To be effective, goals and feedback must meet a number of requirements. The most important ones are:

- both goals and feedback must be accepted by the employees concerned;
- goals must be specific, difficult but practicable;
- feedback must be specific, relate to controllable factors and to all important areas of responsibility.

Actually, accepted goals and feedback are the main components of self-control loops. In order to contribute to organisational goals, employees have to define which aspects or dimensions of total system performance can be influenced by them, and they have to set goals for themselves on each one of those dimensions. Discrepancies between accepted goals and accepted feedback, indicating that actual performance stays behind the targets which have been set in an earlier stage, will result in two possible consequences. On the one hand, group members will increase efforts directed towards goal accomplishment. On the other hand, group members will search for more adequate strategies that, in contrast with those applied until then, are expected to result in goal accomplishment. A practical application of the principles described above is ProMES.

13.3 ProMES: a system for the development of self-control loops

ProMES stands for 'Productivity Measurement and Enhancement System'. The system developed by Pritchard and his co-workers (1988 [6], 1989 [7]) is actually a procedure for designing performance management systems, or self-control loops. A basic premise is that for each individual situation a performance management system has to be developed from scratch. In other words, systems developed by means of ProMES are tailor made systems. In addition, it is essential that both the organisational unit that will use the system and the management which is responsible for that particular unit are involved in developing the system. In essence, the system is developed in four stages, covering successively areas of responsibility ('products'), performance indicators, effectiveness curves ('contingencies') and a feedback report. The system is developed by a design team, consisting of (representatives of) the members of the unit for which it is developed, the unit's supervisor, and a facilitator. The design team develops the system following a 'discussion until consensus' procedure. At the end of stages two and three, the system is reviewed by the design team and the management in a joint meeting. When approved, the system is implemented and the unit will receive regular feedback reports, which are used as the basis for thorough discussions directed towards continuous improvement.

ProMES is characterised by two essential elements: participation and consensus. Participation by those for whom the system is intended is necessary for several reasons. First of all, these are the people who are most familiar with their work and therefore may be expected to have in depth knowledge of it, which is required in various stages of the development process. Secondly, if the system is to function properly, the co-operation of the unit members whose performances are to be measured is a prerequisite. This co-operation can only be achieved if those who are involved feel that they have produced their own system. Something which requires the participation of a "critical mass" of individuals from the group(s) for whom the system is being created.

The second essential factor for success is to achieve consensus along the hierarchical line. This consensus is required not only because of formal considerations. Most importantly, it will result in an increased commitment, both by the group and management, to discuss matters in terms of a common framework of concepts and measures developed together. In addition, management becomes involved in the actual problems a group may encounter in their daily work routine. Some problems have been solved already during the course of system development, i.e. during negotiations on 'responsibility-controllability' issues: the group will accept responsibility for certain areas if it is provided with the necessary "instruments".

13.4 The case study: experiences in an actual situation

Before going into the details of the four development stages in this case study, some context information will be provided about the company and the maintenance group that used the ProMES procedure to develop its own self-control loop.

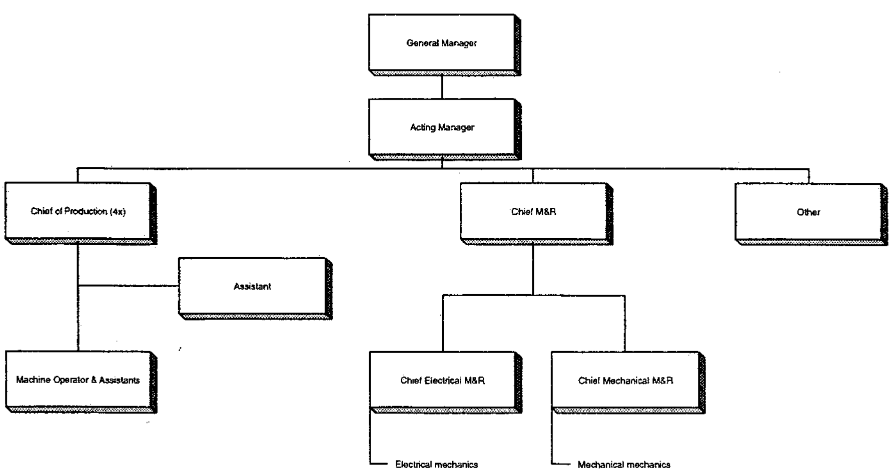

Figure 13.1. The Vandra organisation chart of the production department

Vandra, the company used in this case study, produces corrugated fibreboard. The company employs about 200 people and is very profitable, achieving a steady increase in annual sales and in Return-On-Investment. The organisational structure of Vandra is basically built on four main departments : Sales, Production, Administration, and Personnel & Organisation (see figure 16.1). The corrugated fibreboard produced by the factory is used to manufacture boxes and other packing materials. About 120 people work in the Production Department in two shifts. Production comprises of the sub-departments named Corrugated Board Machine, Manufacturing, Special Packing, Logistics & Shipping, and Maintenance & Repair (M&R). The technical systems (i.e. the production equipment) used in the production process are relatively new and commonly used in this type of industry.

Despite its highly successful performance Vandra changed its strategic business orientation in the late eighties. Until then Vandra operated in a way that is typical for this type of business. The company focused primarily on selling large numbers of packings. Due to fierce competition between different manufacturers profit margins on single packings were fairly small. However, by turning out large volumes the company had been able to maintain good profits. A couple of years ago its view on the business changed. Vandra decided that it would be much more profitable to focus on small orders, very short delivery times and a flexible way of meeting customer demands, getting better prices in return. For the company it was obvious that a complete turnaround of the organisation was necessary in order to realise the intended changes. Until then Vandra was rather traditionally organised with large numbers of hierarchical layers, strong formal boundaries between different departments. Both factors resulted into a complex communication structure. In order to make the transition, it was considered necessary to change to a fairly flat organisation, where responsibilities are delegated downwards as far as possible to people on the shop floor, and with a more direct and straightforward communication between management and the shop floor.

The introduction of ProMES played an important part in the process of change. In an early stage of the project, production groups developed their own ProMES performance management systems and learned how to use these systems to manage and improve their own performance. They became much more self motivated, knowledgeable and self-reliant. As a result, they also became much more demanding with regard to the way in which other departments, the maintenance department included, affected their performance as a production group. At some point in time it became evident that the maintenance department would also have to change in order to keep the momentum of the larger project going.

13.4.1 The maintenance and repair department (M&R)

The M&R department, which employs twelve technicians is responsible for the monthly preventive maintenance and all other maintenance operations with the exception of small and some daily routine maintenance which is carried out by machine operators. A substantial part of the workload can be attributed to repair activities caused by provisional repairs. All maintenance activities can be carried out by two types of skills. The M&R department utilises mechanical and electrical specialists for maintenance jobs.

In each production shift, one technician is available to resolve failures which lead to machine downtime, loss of product quality or a significant decrease in production speed. His task is to minimise machine downtime. Currently, maintenance practices have resulted in a situation where about thirty percent of all repairs are carried out only provisionally, because the production department is urging maintenance people to achieve high utilisation rates of the available equipment or simply because essential spare parts are not available when needed. Both the time spent on repairs and the machine downtime are recorded by the "breakdown" technician.

The rest of the technicians carry out planned maintenance with respect to the production equipment and the buildings, single handed or in small teams. They also develop, prepare, plan and carry out modifications to machinery, mostly on request of machine operators. A separate administrative information system is used for job allocation, to determine priorities and to check on progress. Finally, the M&R department is responsible for installing new machinery, mostly in co-operation with technicians sent by the suppliers. Often, a substantial number of technicians is involved in these projects, which take place during holidays or weekends.

With regard to the performance and the way in which the M&R department operated scepticism was prevalent, both within the M&R department as well as in the production department. Members of the M&R department complained that they were not involved at an early stage in plans to buy and install new machinery, that workers in production used machinery incorrectly, that they were pressed much too often to immediately comply with

demands from production, etc.. People in production stated that technicians from the M&R department reacted slowly to their needs and demands, took too much time to repair failures, often did poor jobs etc. As far as maintenance management is concerned there were no elaborated systems to monitor the technical performance of the machinery. Some data were registered but this was not used for systematic analysis. There was only a limited insight in the amount of work to be done by the M&R department. Work was not planned on a routine basis. Finally, the M&R department was internally divided. Each person did his own job according to his own standards without bothering too much on its potential influence on the performance of the M&R department as a whole.
All this factors contributed to the decision made by the production manager to initiate development of ProMES in the M&R department.

13.4.2 Developing ProMES in the M&R department

In March 1992 the development of ProMES was started in the M&R department. At that time, the production department was already quite familiar with ProMES, because the ProMES system had been introduced in the Manufacturing and the Shipping Department in an earlier stage. At first, effort was spent to get rid of the old stereotypical grievances and prejudices between the production and maintenance people. The measurement system was developed and implemented, following the "standard" framework of the ProMES method (Pritchard, 1990 [1]). In two introduction meetings, the facilitator and the production manager explained the system to the technicians. Though the group was aware of severe criticism with respect to their performance they were reluctant or had mixed feelings at least to engage ProMES. It took quite some pressure from the production manager to convince them to give it at least a try. He made clear that the performance of the M&R department at that time was indeed insufficient and that something had to be done. Furthermore, the production manager had to assure them that the system would not be used to evaluate individual performance of members of the M&R department. On these conditions the technicians agreed to give it a try. Interestingly, once this decision was made all technicians expressed their wish to participate in the process; nobody wanted to be left out obviously. They agreed in a weekly meeting of one hour. The facilitators accepted this commitment as a starting point of the process, knowing that apart from developing ProMES there was a lot more to be done with regard to the internal organisation of the department and the way in which the department co-operated with other departments within the company. The design team consisted of all technicians, their supervisor and the facilitator. Development was done in weekly meetings of one hour.

Stage 1: Determining areas of responsibility ('products')

Determining areas of responsibility means that the organisational unit or group seeks clarification on the contents and purpose of their work: what are the essential contributions the group is expected to make for the organisation. In this case study, these questions had to be answered from the perspective of being a part of the organisation's maintenance function. Using brainstorming as a technique, the design team generated about twenty ideas which later on were clustered into four products:

Product 1: Solving Machine Breakdown

Product 2: Carrying Out Planned Repairs

Product 3: Carrying Out Maintenance

Product 4: Coping with Safety Demands

Two other potential products were suggested, viz. spare parts management and installing new equipment. Although both types of activities were considered important and should be monitored, they were not taken up in the list of products.

Although the detailed description of the products was a first, good step in simplifying the discussion on identifying the indicators, the design team chose to make agreements with other departments on the organisation of the activities of the M&R department as a next step in the development. This was necessary to clarify the means the technicians have to improve their products. One of the most frequent criticisms that were put forward during group sessions was: "We cannot do anything about that, but others, viz. ..., and ... can!". E.g., in order to get clarity about what a technician is supposed to do when a breakdown should be resolved urgently, an extensive discussion with shift supervisors was required. It became clear that technicians and machine operators actually shared the responsibility to minimise machine downtime. Solving a failure should be a joint activity. So detailed agreements were made on the availability of a technician, the way a technician is alerted in case a failure occurs, activities machine operators have to carry out during repair, and how priorities have to be determined in case multiple breakdowns occur simultaneously. Making these agreements not only helped the technicians to develop and accept their measurement and feedback system, it also clarified what means are actually available and accepted by others to improve maintenance products.

Stage 2: Determining performance indicators

Performance indicators are milestones which accurately reflect the degree to which the group succeeds in fulfilling its responsibilities. In determining indicators the group follows the same procedure as in stage 1. At least one indicator is developed for each product, but more than one is allowed if the product consists of a number of clearly differentiated aspects. In order to trigger ideas on potentially useful indicators, the group was asked to tell how it would convince a sceptical outsider that they performed well on each of the products. For most products the group came up with several ideas for indicators.

These ideas were then discussed until consensus was achieved. In the end, seven indicators were accepted as adequately covering the main aspects of the four products. These indicators are listed below.

Product 1: Solving Machine Breakdowns

Indicator 1.1: Percentage of breakdowns which lead to a machine downtime shorter than or equal to 15 minutes.

The technicians of the M&R department are expected to solve machine breakdowns within 15 minutes. Being unsuccessful usually means that another machine will be set up to continue with the production run, provided a compatible machine is idle. A technician is expected to reduce downtime by applying proper technical problem analysis and solving skills.

Indicator 1.2: Percentage of repeated breakdowns. A repeating breakdown is a breakdown that occurs again within five days.

Note that only breakdowns where a technician was called for assistance are recorded.

In case the technician does not solve the problem properly, it is possible that the same breakdown occurs again shortly after the repair. This indicator aims to measure the technical quality of repairs. As mentioned before, in some cases the technician decides to solve a problem provisionally due to time pressure or a lack of spare parts. In case of time pressure the shift supervisor decides to stop the machine or asks for a provisional repair. Although the technician only has a minor influence on a dissentient decision by the shift supervisor, it is his task to provide a provisional solution which will last until next opportunity for maintenance (usually within five days).

Product 2: Carrying Out Planned Repairs

Indicator 2.1: Number of customer complaints on planned repairs.

All customers are situated within the company (so called internal clients). The service minded technician is responsible for technically correct repair and calibration of machinery.

Indicator 2.2: Percentage of tardy planned repairs

Each maintenance work order is given a priority rating from one to four (high to low). The M&R department tries to stay within timely limits set by priority rating, which range from 48 hours to two weeks. In case of priority four (lowest priority) a latest date of completion is agreed upon with the internal client, depending on work load and available personnel. It is the task of the technicians to meet the deadlines set by the priority system to the best of their ability.

Product 3: Carrying Out Maintenance

Indicator 3.1: Number of preventable failures causing machine downtime.

A preventable failure is a failure that should (or could) have been prevented by carrying out preventive maintenance. Operator induced failures are excluded. This indicator is not monitored for those machines which have no preventive maintenance.

Indicator 3.2: The number of man-hours spent on monthly maintenance

Another task of the M&R department is to minimise costs of preventive maintenance. Because of the priorities set by management, man-hours spent on preventive maintenance depend on the availability of technicians. Therefore, technicians themselves are not responsible for the number of hours spent on maintenance, but are compensated in the measurement system. If more than 250 hours are spent, there is a negative adjustment is made. If less than 250 hours are spent a positive adjustment is made.

Product 4: Sustaining Safety Requirements

Indicator 4.1: Number of accidents and near-accidents. Technicians are obliged to report accidents and near accidents.

Technicians are obliged to report accidents and near accidents. Both accidents during maintenance execution performed by technicians and accidents due to poor repair are taken into account. The purpose of the measurement is to oblige technicians to spend time on safety demands.

After development of the indicators, the system was presented to the management for approval. With some minor corrections products and indicators were accepted. The design team and the production manager decided to test the measurement system first before developing the contingencies (stage 3).

At this stage, hardly any historical performance data was available. Therefore, it would be very difficult to determine performance ranges, which are a prerequisite for developing contingencies. A second reason for testing the measurement system in such an early stage was that existing measurement procedures were not reliable. In addition, several new procedures had to be developed and implemented. By making a break in the development process, the design team could further develop, test and improve the measurement system itself. After six months of pilot testing, the group was satisfied with the new and improved procedures and the performance data which had been collected. In the meantime, a personal computer with a performance database system developed by the supervisor was installed at the shop floor.

Stage 3: Determining effectiveness curves ('contingencies')

The essence of stage 3 in the development process comes down to develop a conversion table, which can be used to transform the different measurement values into one universal performance scale (effectiveness). This is done in such a way that the relative importance of performances for different indicators is taken into account and that some slack is added for aspects such as "diminishing returns" of very high performances compared with somewhat lower performances. A detailed description of the procedure for developing "contingencies" can be found in the original publications (Pritchard, 1990 [1]; Pritchard et al., 1988 [6], 1989 [7]). In general terms, the procedure of developing "contingencies" entails the following steps.

First, each indicator's maximum and minimum performance level is determined. Next, the maximum values are ranked and the most important maximum gets a value of 100 on the dimension "effectiveness". The other maximum values are then expressed as percentages of this maximum of 100, corresponding to their relative importance. Subsequently, a similar procedure is followed for the minima. In addition to maximum and minimum values, so called "zero effectiveness performance levels" are determined for each indicator. "Zero effectiveness" represents the performance level characterised as "not good, not bad" (in a way, an expected, neutral level). Now, the overall shape of the contingency of each indicator can be drawn. Finally, the last step can be taken, i.e. the determination of the effectiveness of the performance levels between the minimum and zero, and between zero and the maximum. An example is shown in figure 13.2.

The design team of the M&R department did not have a difficult time in developing its contingencies. By evaluating the collected data, the design team determined levels of worst (minimum) and best (maximum) performances per indicator. Next, the expected (zero) performance level was determined for each indicator in a group discussion until consensus was achieved. Finally, the relative importance of maxima, minima and intermediate points was determined, again by means of group discussion. In Table 13.1, the performance levels

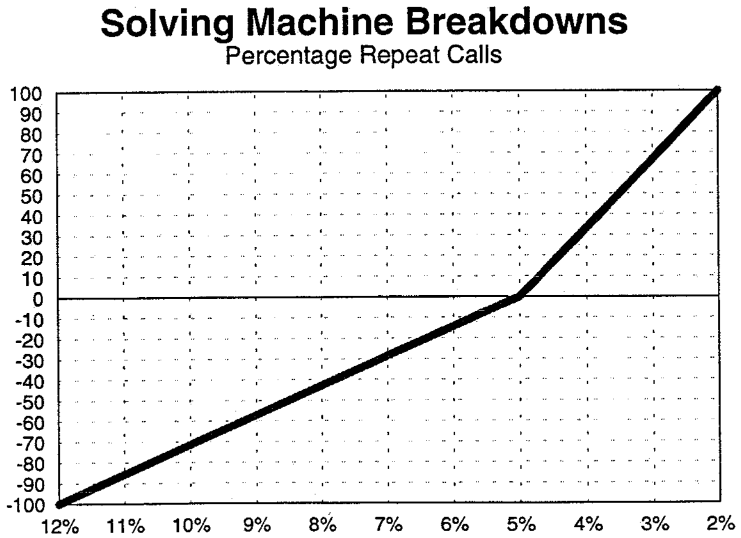

Figure 13.2. An example the perceived effectiveness versus the level of performance.

corresponding to the maximum, minimum and zero performance levels are shown for each indicator together with the respective effectiveness values.

The contingencies were discussed with and approved by the management.

Indicator	Minimum Performance	Effectivenes s Scores	Normal Performance	Maximum Performance	Effectivenes s Scores
% Breakdowns with more than 15 min. downtime	70%	-60	80%	86%	60
% Repeat calls	12%	-100	5%	2%	100
Number of customer complaints	9	-100	4	0	100
% Delayed deliveries	10%	-50	6%	2%	50
Number of technical breakdowns	85	-150	50	30	100
Number of working hours	500	-150	250	125	75
Number of accidents	1	-100	0	0	0

Table 13.1 The contingencies used by the Vandra M&R department.

Stage 4: Determining contents, layout, and usage of the feedback report; putting the system to work

As soon as data becomes available on all the indicators, a first feedback report can be produced, containing the indicator data as well as the corresponding effectiveness scores (these can be easily looked up from the contingencies). When all indicator scores are converted into universal effectiveness scores, they can be totalled to derive an overall effectiveness score (see Table 13.2 for an example of a feedback report).

Yet, another important question concerns the issue of the length of the feedback period (e.g. one week, two weeks, a month; the length of this period depends largely on the nature of the work (cycle time)), what persons will have access to the feedback information, and the way in which the feedback report will be used (constructive problem solving instead of looking for someone to blame).

In the M&R department, data gathering and feedback started from February 1994. Technicians together with their supervisor discuss feedback reports monthly. Changes in overall performance level and changes on individual indicators are discussed. Plausible causes of these changes are determined and strategies aiming at performance improvement are developed. Also, agreements on the implementation of new strategies made at earlier meetings are evaluated.

Feedback report for M&R Department - Technicians

Indicator	Result	Effectiveness-scores
Solving Machine Breakdowns		
% Breakdowns with downtime < 15 min.	75.2%	-21
%Repeat Calls	8.5%	-50
Carrying Out Planned Repairs		
Number of Customer Complaints	6	-40
% Delayed Deliveries	6.0%	0
Carry Out Maintenance		
Number of Technical Breakdowns	72	-94
Number of Working-Hours	68	109
Coping with Safety Demands		
Number of Accidents	0	0
	Total:	**-96**

Table 16.2. An example of a feedback report used by Vandra

13.5 Comments on the M&R-ProMES from a maintenance function control perspective

From a maintenance function control perspective (in short, the control perspective) all activities concerning maintenance are regarded as processes, i.e. sets of activities carried out in some logical way. The logic of maintenance activities is the core subject in this perspective. Humans responsible for performing these activities are generally known to have a significant role in the success of the maintenance function. However, organisational structures, inter-human co-ordination and motivational aspects are typically neglected, or at best, regarded as given.

The basis of the ProMES approach is measuring performance of (maintenance) personnel and to confront them with their own results in order to achieve a positive leverage in performance. Performance measurement is also a well known element in the control perspective, i.e. defined as the maintenance evaluation function in the EUT maintenance model (Geraerds,

[2]). He defines maintenance as: All activities needed to keep or to bring back technical systems in the condition which is considered necessary to fulfil its function. Hence, the objective of performance measurement of maintenance is to improve maintenance practices and procedures.

Clearly, assessing (current) maintenance activities requires a thorough knowledge in maintenance theory as well as the practical situational settings. The available knowledge and experience in this field will be used to comment the Vandra maintenance indicators. But, first it is necessary to clarify some important aspects which will be relevant to all Vandra maintenance performance indices.

13.5.1 The goal of the maintenance function

The goal of a maintenance function is to reduce the consequences of failures that occur when technical systems are used. Consequences of failures may have a negative impact on the organisation in several ways, including on the personnel that operates the technical systems. Three major categories of failure consequences can be distinguished:

1) maintenance effort
2) loss of production
3) secondary or environmental damage

ad 1) In order to repair technical systems after failures have occurred or to prevent failures maintenance resources are required. In general, different types of scarce maintenance capacities (internal and external skills), spare parts (consumables and repairables) are used.

ad 2) The occurrence of failures and/or the execution of maintenance activities triggered by the maintenance concept may limit the utilisation of technical systems. In some cases, during failure and the execution of maintenance activities unrecoverable loss of production or reduced use is a potential consequence.

ad 3) Sometimes failures may result in threatening the (living) environment, which can be not only costly, but also unethical and therefore unacceptable in most cultures.

Maintenance effort must be effective in reducing downtime or loss of use and other secondary damage, and efficient in terms of the required maintenance effort. From a control perspective, performance measurement should be linked to these categories in one way or another.
If we compare the products the M&R department group specified, no direct relationship with the consequences of failures can be recognised. One would expect an analysis revealing all relevant failure consequences bound to the technical systems in use at Vandra. The products of the maintenance function (the M&R department and the operators responsible for some basic maintenance tasks) are the exact negation of each failure consequence in the list. E.g. if downtime is considered to be an item on this list, then the uptime would be a maintenance "product". Clearly, if maintenance "products" are determined this way, the clients of the M&R department, i.e. the production departments, would understand the meaning of these products, which would help the M&R department in communicating its improvements in later stages to its clients. An additional benefit of determining products this way is that it is very clear in what direction improvements should be aimed (e.g. maximising uptime).
Other products which don't relate directly to failure consequences usually assume certain situational circumstances, which may change over time risking invalidation of such a product. The direction of improvement may also become ambiguous.
Besides the effectiveness of maintenance, its efficiency will be also of major concern. Any effort or expense in maintenance must be balanced against its effectiveness. Special efficiency oriented performance indicators are needed to cover all types of maintenance efforts and expenses.

13.5.2 Determining performance indicators

Given the list of products, a more detailed analysis is needed to determine how each product can be measured and what restrictions are to be taken into account. E.g. it may be rather obvious to measure downtime in, lets say, minutes per technical system per month. But situational circumstances may complicate matters. E.g. if in case technical systems are tightly coupled in a production flow line, downtime of each individual technical system adds to the total downtime of the production flow line. In this situation, the downtime of the flowline is more important than the individual downtimes of each technical system in the flowline.

Redundancy in available technical systems may also restrict simple downtime measurement. In this situation downtime is only important if all redundant technical systems are also down. These simple examples illustrate the analytical effort which is needed to determine what and how parameters are measured. In reality, performance indicators can be quite complex and highly situation specific.

In maintenance management literature, frequently suggestions are made with respect to performance indicators deemed to be important (e.g. see Hibi [8]). In most cases, implicitly, certain organisational settings are assumed. Not surprisingly, given the sheer unlimited number of organisational settings of a maintenance function, the number of possible performance indicators is expected to be virtually infinite as well.

13.5.3 Using performance indicators

From control perspective, norms are required to trigger an improvement analysis. The need to investigate the causes of unsatisfactory performance arises only in the event that performance doesn't conform to its pre-set norm. Improvement analysis are triggered by exception rather than on a continues reviewing basis advocated by ProMES (see also Mann Jr. [9], Dwight [10]).

In general, an improvement analysis can be complicated and time consuming, because of the huge diversity of aspects that may be related to a certain performance aspect. In addition, thorough knowledge of the cause-effect relationships and the current organisational and procedural settings is a prerequisite. In the area of maintenance, knowledge of the functional areas listed in the EUT maintenance model is important. In particular, the current maintenance concepts of the technical systems are essential, since the decisions made concerning what maintenance packages are carried out and the way in which they are initiated is not only used as primary input for the operational planning and control of maintenance activities, but also as a basis for structuring planning and control procedures, spare parts and rotable management, contracting policies etc.

13.5.4 Discussion of the Vandra maintenance "products"

As far as the other specified products are concerned, apart from the 'Safety demands product', it is unclear whether carrying out more planned repairs or more maintenance in general or vice versa would be desirable from the company perspective.

In an ideal situation, all consequences of failures would be listed first. The products of a maintenance function would be measured in terms of these (negative) failure consequences. A maintenance concept of the technical systems (basically a formal representation of what and when maintenance should be carried out) would provide the basis for the design of maintenance planning and control procedures fit for the situational context. Then, derived products can be specified, based on the current maintenance planning and control structure.

13.5.5 Discussion of the Vandra performance indicators

The products which have been determined in the Vandra case are prone to ambiguity. All listed products cover some lower level aspects of the maintenance function, but in general they are ambiguous with respect to in what direction improvement is aimed at and the completeness of all performance aspects has not been demonstrated.

Perhaps, this situation can be explained by the approach the ProMES team has chosen in order to determine the products and indicators. Instead of starting with an analysis of possible failure consequences, the brainstorming technique has been used. Viewed from a control perspective, the list of performance indicators makes a more or less "coincidental" impression. All indicators undeniably have some relevance to what can be perceived as the performance of the M&R department. However, no precise and detailed information is available in order to assess the validity of the proposed set of indicators. The assessment of the completeness is limited, since only the proposed indicators can be commented.

Product 1: Solving Machine Breakdowns

The current maintenance concept determines the amount and type of maintenance activities that are carried out. 'Solving machine breakdowns' refers to the technical effectiveness of the M&R technicians and should be 100% for all of the technical systems they carry maintenance responsibility for, in case of breakdown. If a performance of 100% is not achievable immediate action is necessary, either by replacement of failed components, taking technical courses, contracting out, etc.. More importantly, the application of preventive maintenance may counteract the need for breakdown maintenance. A maintenance concept for the technical systems at Vandra would clarify what maintenance activities are effective and efficient. In some cases breakdown maintenance (= Failure Based Maintenance) is the only effective, if not the most efficient option, as opposed to preventive maintenance (= Condition Based Maintenance and Used Based Maintenance). The (desired) technical competence of the maintenance technicians is taken into account in the framework for designing maintenance concepts described by Gits [11].

Indicator 1.1: Percentage of breakdowns which lead to a machine downtime shorter than or equal to 15 minutes.

This indicator measures the effectiveness of the maintenance function. However, the total downtime is not measured, which is certainly desirable to get a complete picture of the availability of technical systems. For certain types of technical systems the 15 minute downtime criterion is important because the production operator decides to switch a production run to another (redundant) technical system in case a breakdown is not resolved within 15 minutes. In that situation one would expect that the percentage of breakdowns per machine which took longer than 15 minutes to resolve is more meaningful.

In addition, some differentiation in technical system may be needed, since not all of the production process is laid out in an unbuffered flow line, or can make use of redundancy. In general, this type of indicator would be useful to spot potential "problem" systems causing more severe failure consequences than others.

In order to summarise the negative effect of breakdown induced "production switches", it may be sufficient to just count the number of these switches per subset of technical systems besides the total availability of an individual technical system (uptime/(uptime+downtime)) per measurement interval.

Indicator 1.2: Percentage of repeated breakdowns. A repeating breakdown is a breakdown that repeats itself within five days.

This indicator is a measure for the effectiveness in relation to efficiency of the maintenance function. The primary objection against this indicator is the confusion it may cause by the terminology used in its definition. By definition failures may occur repeatedly after repair (e.g. as is the case if failure based maintenance rules are applied), which may be perfectly acceptable. Interviews revealed the true intentions of this indicator, which is measuring the effectiveness of provisional repairs. Provisional repairs are by definition less technical effective than "normal" full repair and usually much less efficient from a maintenance function perspective. However, seen from a higher aggregate level in which production and maintenance function overall performance is valued, provisional repairs may be justified. E.g. in the Vandra situation a technical system breakdown occurs on a technical system which currently produces an important customer order may justify a provisional repair. Depending on the point of view, provisional repairs can be regarded as being negative or positive. Therefore, it seems advisable to use this indicator only on company level, or if the cause for provisional repair is justified because of limitations in maintenance function itself (e.g. missing spare parts) the number of provisional repairs per cause would be valid.

Product 2: Carrying Out Planned Repairs.

Indicator 2.1: The number of client complaints on planned maintenance.

It is unclear what phenomenon is measured here, since complaints are not categorised to type or cause. This indicator cannot be used as performance indicator from a maintenance function perspective because maintenance effectiveness and efficiency are not directly addressed or maybe not even addressed at all. Interviewing showed that this indicator should be regarded as a measure of the clients dissatisfaction with maintenance, which can be subjectively biased. In other words, the clients believe or suggested believe of maintenance performance is measured.

Indicator 2.2: Percentage of tardy planned maintenance

This indicator indirectly measures the effectiveness of the maintenance planning and control function. The planning and control function matches maintenance capacity and spare parts to the maintenance requirements specified in the maintenance concept and the requirements of the production departments. In case maintenance demand exceeds maintenance resources the priority system determines what maintenance activities will be delayed. In many maintenance situations the priority of a maintenance activity is determined by the urgency, i.e. the latest acceptable moment that a maintenance activity has to be carried out. This indicator will be important in more complex planning and control situations and/or if available maintenance resources are very limited. In the Vandra case the planning and control function has to deal with regular planned and high urgency breakdown maintenance and the more complex provisional repair system. Certainly, in this situation simple optimisation is not possible, but instead careful monitoring the performance to gradually learn and improve maintenance planning and control procedures and practices via performance measurement is recommended.

Product 3: Carrying out (preventive) maintenance

Indicator 3.1: Number of technical failures causing with machine downtime.

This indicator aims to measure for the effectiveness of the maintenance function. Again, the negative effect of (the number of) failures will have to be assessed in view of what maintenance rules have been prescribed in the maintenance concepts of the technical systems in use. This indicator can be helpful to evaluate maintenance concepts and the performance of current planning and control procedures and practices.

Indicator 3.2 : The number of working hours spent on monthly maintenance.

This indicator intends to measure maintenance effectiveness of a certain category of maintenance activities. Monthly maintenance refers to a category of maintenance packages that is carried out each month. Apparently, other maintenance packages with cyclic intervals of initiation are not important or do not exist. The reason for paying attention to this category of work is that usually planning schedules this work as low priority work (sometimes imposed by higher management levels on the short term). Potential tardiness in this category of work can occur easily. In fact, this category intends to measure tardiness, just as indicator 2.2, for a specific category of work.

It is unclear why working hours instead the job codes themselves are used, since actual working hours may fluctuate for several other reasons.

Product 4: Coping with safety demands

This is the only product that directly relates to the list of negative consequences.

Indicator 4.1: Number of accidents respectively the number of near-accidents.

Clearly, this indicator can be helpful if more information is available to the technicians to analyse the potential causes of (near-)accidents. The technical competence and discipline of the maintenance activities carried out by the maintenance crew, the timeliness of certain safety critical activities, etc.

13.6 Preliminary results

It took two years to develop ProMES in the Maintenance and Repair Department. In about fifty hours of discussion a measurement system was developed, new agreements were made and measurement procedures installed. After that a period of monthly feedback meetings started. There are three kinds of effects of developing and implementing ProMES.
Firstly, group productivity improved both during development and during feedback. On one side the demand for maintenance increased due to increasing customer quality demands and an extending technical system. On the other hand, M&R department decreased working hours in overtime and their total number of working hours. An other indication for improvement is found in figure 13.3, where the total ProMES Effectiveness scores of the first four months are compared.

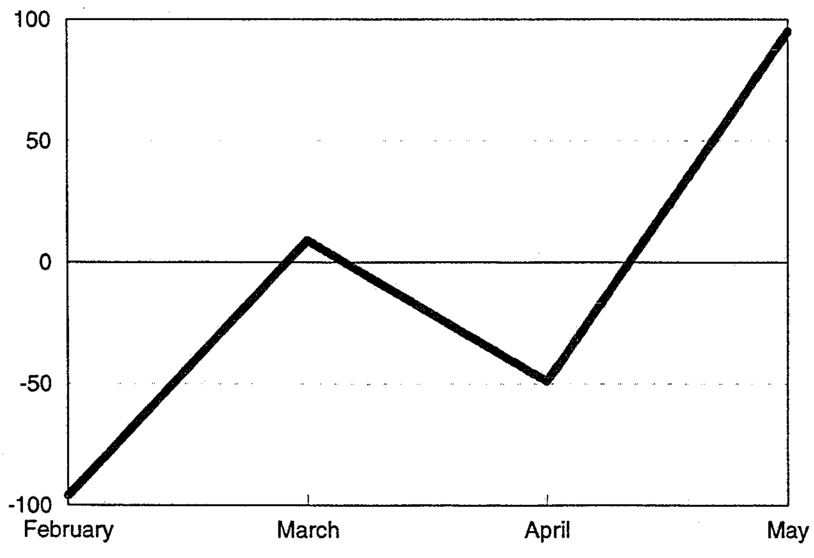

Figure 13.3 Vandra ProMES effectiveness scores for the initial four months

Secondly, the behaviour of the technicians changed. Before development a technician was an individualist, who sometimes had to work in co-operation with colleagues or machine operators. Afterwards, most technicians realised that improving performance should be a joint effort, because working alone did not mean that there was no interdependence. E.g. by discussing work methods and by making agreements on how to handle problems with machine operators, the technicians formed a group where they could learn from each other. Last but not least, some procedures and practices within the maintenance function itself were revised. For example, checklists were made for machine operators carrying out daily maintenance. The storehouse was cleared of old spare parts, and the administration system for these spare parts was improved.

13.7 Discussion

Experience in Vandra and in other companies where the ProMES system has been introduced shows that not only the preparedness and self-reliance of maintenance groups improve, also their attitude towards their "clients" and vice versa improves as well. To make ProMES truly effective special attention must be paid to the way in which group products are determined and as a consequence what performance indicators can be considered valid. A valid product in maintenance is the availability of technical systems. Because failures and their consequences not only reduce availability, but may imply a wide spectrum of other negative effects, it is in general more appropriate to define the reduction in potential failure consequences as the primary product category of the maintenance function.
Apart from these basic considerations, the process of determining a complete set of valid performance indicators, is theoretically unsolved. Yet, thorough knowledge of applicable maintenance procedures can be valuable in the process of determining valid performance indicators (see comments on Vandra indicators). Unfortunately, one cannot automatically assume that in practice maintenance technicians will possess the latest (theoretical) knowledge in fundamentals of maintenance and maintenance management. An expert in this particular area could solve this matter. But, to maximise motivation with maintenance technicians, as the primary beneficiaries in our case, it is essential they perform the decision process themselves.

Perhaps, expert knowledge in maintenance could help to shorten lengthy ProMES indicator development times by providing crucial knowledge to the technicians on the right moment without making decisions for the technicians. This would mean that a maintenance expert is standby, monitoring ProMES group discussions. More field experiments are needed to explore this option.
From a ProMES perspective the Vandra case was a success, because the attitude of maintenance technicians has changed positively and the M&R department became "accepted" in the Vandra company. Apparently, ProMES can achieve these "conditioning" objectives in a relative short period of time.

The questions raised above are fundamental in their nature and require long term collaborative research in both fields: maintenance and ProMES. A framework specifically geared towards a systematic analysis of a maintenance situation to arrive at a complete set of valid maintenance products and performance indicators, whilst strengthening the workers motivation, represents the greatest challenge in this area of research.

13.8 References

[1] Pritchard, R.D., "Measuring and improving organizational productivity", New York, Praeger, 1990.

[2] Geraerds, W.M.J., "The EUT Maintenance Model". IFRIM Report 90/6. Eindhoven University of Technology, 1990 (see also chapter 1 in these conference proceedings)

[3] Pritchard, R.D., "Organizational productivity". In: Dunnette, M.D. & L.M. Hough (eds.). Handbook of Industrial and Organizational Psychology, second edition, Vol. 3. Palo Alto, California: Consulting Psychologists Press, 1992.

[4] Locke, E.A. & G.P.Latham, "Goal setting: a motivational technique that works" Englewood Cliffs, NJ: Prentice Hall, 1984.

[5] Locke, E.A. & G.P. Latham, "A theory of goal setting and task performance". Englewood Cliffs, NJ: Prentice Hall, 1990.

[6] Pritchard, R.D., S.D. Jones, P.L. Roth, K.K. Stuebing, and S.E. Ekeberg, "The effects of feedback, goal setting and incentives on organizational productivity". Journal of Applied Psychology, Monograph Series, 73, 1988, 337-358.

[7] Pritchard, R.D., S.D. Jones, P.L. Roth, K.K. Stuebing, and S.E. Ekeberg, "The evaluation of an integrated approach to measuring organizational productivity". Personnel Psychology, 42,1989, 69-115.

[8] Hibi, S., "How to measure maintenance performance", Asian Productivity Organization, 1977, 1980, 192p

[9] Mann, L. jr., "Maintenance Performance Indexes", chapter 12 in these conference proceedings.

[10] Dwight, R., "Concepts for Measuring Maintenance Performance", chapter 10 in these conference proceedings.

[11] Gits, C.W., "Design of Maintenance concepts", Int. Journal of Production Economics, Vol. 24, p 217 -226, 1992