Data for better maintenance plans and investments policy

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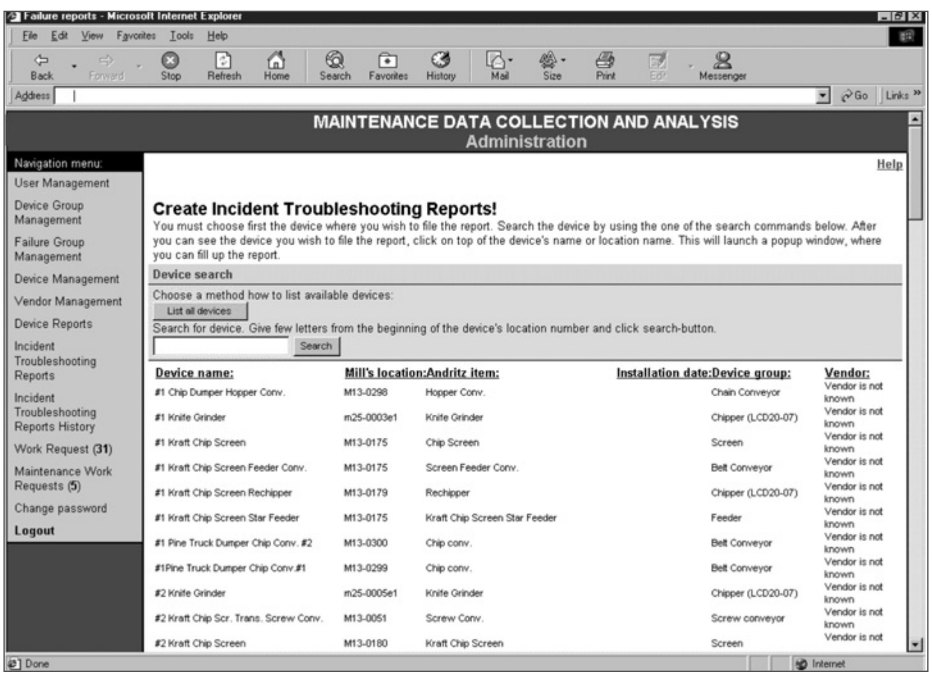
ABSTRACT: This paper describes a new Internet-based maintenance data collection application and its use for improved maintenance planning at a woodyard. It presents some data collection results and demonstrates how the availability performance measures based on the collected data are calculated. The developed data collection application met the user requirements. The device-based data structure makes further analysis, reporting, and use of the data possible. The database, from which a mill can recall maintenance and failure data, supports maintenance information exchange and helps to solve recurring problems. Detailed analysis of availability performance helps locate bottlenecks in a production line and insures accurate direction of corrective measures. The information boosts the efforts to increase production line efficiency and supports decision-making for new investments.

Application: Mills can use this information to improve their existing data collection systems and process efficiency. It also helps to set requirements for new systems.

Operations managers in the capital-intensive pulp and paper industry are under pressure to achieve a high return from assets employed. Cash flow and return on assets are indicators of a company's performance. This translates into a requirement for maximum uptime of the machinery. The fight to eliminate production losses from downtime, slowdowns, and rejects and to increase manufacturing efficiency requires a combination of contributions from the maintenance department, operations, and engineering [1].

Overall equipment efficiency (OEE) is a measure applied in the pulp and paper industry that combines the effects of availability, speed, and prime quality production [1, 2, 3]. New maintenance concepts, such as total productive maintenance (TPM), rely on collected maintenance data [4]. Remarkable savings have been observed when a systematic reliability program has been implemented, even without major investment [5].

Computerized maintenance management systems (CMMS) typically help maintenance organizations manage work orders, material and resource control, and purchasing. Advanced systems may also provide a cost and repair history. However, the causes and consequences of the production stops are seldom identified and recorded. Often, when data is recorded, it is in a form that is difficult to use. The development of a systematic decision-making process requires better-recorded information.

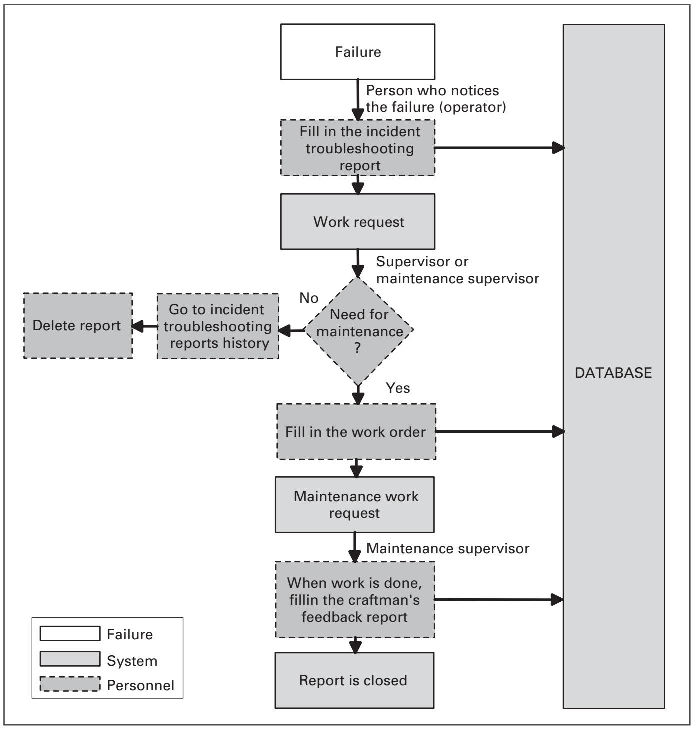


1. The user interface of the maintenance data collection software.

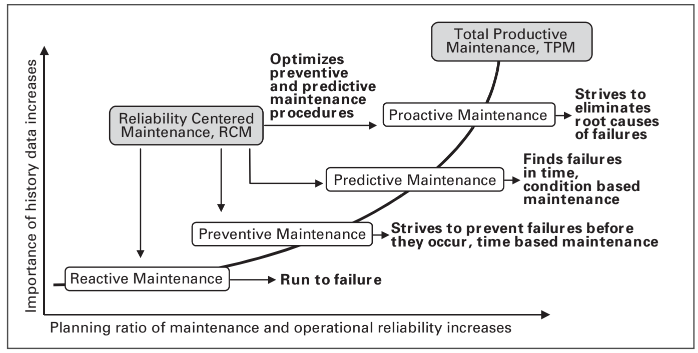
This paper describes a new Internet-based maintenance data collection application that was tested and implemented at a woodyard of a U.S. paper mill. The data recording and classification software produces device-based structured data–a prerequisite for analysis and use. The application offers pulp and paper mills, and machinery manufacturers a better tool for improving equipment reliability and the efficiency of production systems. Detailed analysis of availability performance helps identify bottlenecks in a production line, so corrective measures can be directed at the right objects.

Maintenance data collection application

The data collection application uses Internet-based software (**Fig. 1**) designed for failure and maintenance data collection at a woodyard. The application includes data analyzing and reporting properties and established data collection procedures. The data collection software produces device-based



2. The data collection procedure.



3. Maintenance history in relation to the maintenance management development [4, 9].

structured data. We derived the basic idea of the classification system from previous experience [6]. We used specific knowledge provided by the machinery manufacturer to develop the categories and item lists for woodyard equipment. Thus, the data collection application meets the unique requirements of the woodyard without further tailoring.

Maintenance data is collected through the incident troubleshooting report and saved to the database. A failure is characterized with the data entered in the different fields. The information contained in an incident troubleshooting report includes the following data items:

- device name and tag number (mill's location)
- failure discovery
- environmental conditions
- effect on the production
- failure group
- failure indication
- failure cause
- device failure location

Mill personnel can supplement mandatory data with optional data, such as downtime. If a maintenance action is necessary, the supervisor creates a work order.

Information regarding completed work is added in the craftsman's feedback report. This includes the duration of the work and actions performed. The following questions also can be answered:

- problems and delays encountered
- comments on delays
- what could be done to prevent reoccurrence

Most of the fields in the reports are pull-down menus with alternatives. The classification fields and ready-made lists make the data recording easier and faster, and reduce errors. As the device-based failure data builds in the database, the user can learn from previous experience. The knowledge will aid in future problem resolution.

Data collection procedure

Successful maintenance data management requires a user-friendly interface and established data collection and evaluation procedures. As manual data input is required, the mill needs to institute a routine procedure. The goal is to motivate all employees to record disturbances as well as failures–even minor ones. **Figure 2** illustrates the procedure which supports data collection application.

Every employee who notices a failure is encouraged to fill in the incident troubleshooting report. This involves operations personnel directly in the reliability improvement efforts. The data collection application is also a means for creating work orders. It helps supervisors keep track of the activities at the mill.

Data collection in a commercial maintenance management system

The typical commercial CMMS focuses on handling spare part data, work orders, maintenance resources, costs, and other related items. It seldom contains the failure data collection, classification, and analysis properties needed for availability performance management [4, 6]. This data collection application supplements the CMMS by providing tailored data collection for a woodyard.

The CMMS and maintenance data collection application function as individual systems, but they can be connected to each other via a site server. When connected, the data collection application reduces duplication of work as the manufacturer's device lists and product structures can be directly used. The ability to derive data from different sources, and combine it to create more sophisticated reports, enables the machinery manufacturer to provide better services.

Device-based information on maintenance history

A successful maintenance program incorporates planning and follow-up processes, including systematic feedback [7, 8]. The more advanced and comprehensive maintenance programs become, the greater the significance of the collected maintenance data (**Fig. 3**).

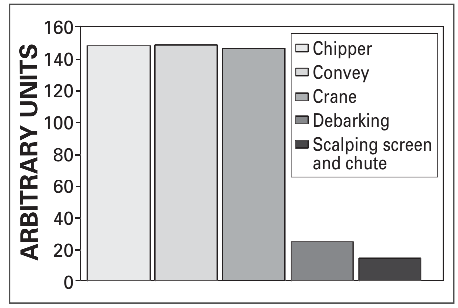
Meaningful data analysis requires accurate, quantitative information about equipment failures and maintenance actions.

Device Troubleshooting Reports

Device: Portal Crane
Mill's location: xxx-yyyy
Machinery manufacturer's item: xxx Portal Crane

	Failure Discovery	Environmental Conditions	Effect on the Production	Failure Group	Failure Indication	Failure Cause	Action	By	Out of Production
Motor Building Elevator									
09/18/2001 09:12:45 am (#173)	Observation	Normal	Stop Only the Equipment	Electric	Does Not Operate Correctly	Material Defect	Not Finished		36 hrs
Cable reel Grapple									
04/20/2001 06:47:52 pm (#141)	Alarm from the Process Computer	Normal	Stop the Whole Process	Electric	Won't Start/Stop		Not Finished		4 hrs
11/15/2001 04:33:46 pm (#186)	Observation	Dirty Equipment	Stop the Whole Process	Mechanical	Does Not Operate Correctly	Normal Wearing	Not Finished		17,5 hrs
06/05/2001 09:51:57 am (#162)	Observation	Dirty/Dusty Air	Stop Only the Equipment	Electric	Does Not Operate Correctly	Process Fault	Not Finished		5 hrs
Other parts									
04/20/2001 06:55:35 pm (#142)	Alarm from the Process Computer	Normal	Reduced Production Rate	Hydraulic	Alarm	Maintenance or Repair Error	Not Finished		1,5 hrs
Crane									
04/05/2001 08:24:01 pm (#132)	Observation	Normal	Stop Part of the Process	Mechanical	Shutdown List	Normal Wearing	Not Finished		8 hrs
11/29/2001 10:33:43 am (#189)	Observation	Normal	Stop the Whole Process	Mechanical	Won't Start/Stop	Material Defect	Not Finished		15,5 hrs
04/05/2001 00:35:37 am (#131)	Alarm from the Process Computer	Dirty/Dusty Air	Stop the Whole Process	Electric	Does Not Operate Correctly	Factory Defect	Not Finished		1 hr

4. An example of the device troubleshooting report for a portal crane (based on hypothetical data).



5. An example of the Top 5 list of woodyard equipment.

The device troubleshooting report automatically derived from the data entered into the system is device-specific, and includes the name of the device, location in the mill, and the device failure location. **Figure 4** shows an example.

As presented in Fig. 4, the portal crane has failed eight times during the data collection period. Most of the failures have hampered production as they have stopped the entire woodyard process. In this case, failure causes vary, but the failures seem to be concentrated on two parts of the crane. By going through the incident troubleshooting reports in detail, it is possible to understand the failure mechanisms and the cause-consequence relationships better. As more data becomes available, typical failure causes and device failure locations can be identified, and the mill personnel can then decide on a reliability improvement program.

The data added to the craftsman's feedback report reflects the function of the whole maintenance organization, including spares handling and document management. The information helps to identify the main sources of delays. On the other hand, properly completed feedback reports also contain valuable information concerning the repair work. The systematic collection of improvement proposals from the shop floor is also a cornerstone of TPM [8, 10].

Downtime analysis

A downtime analysis is one of the first steps when identifying problem areas and bottlenecks. Often a Pareto diagram is used for this purpose. A Pareto analysis is commonly known as the "80/20 rule" with the idea that 80% of the problems result from only 20% of the causes. In the data collection application, "Top 5" lists encompass the same principle. **Figure 5** shows an example of a downtime graph.

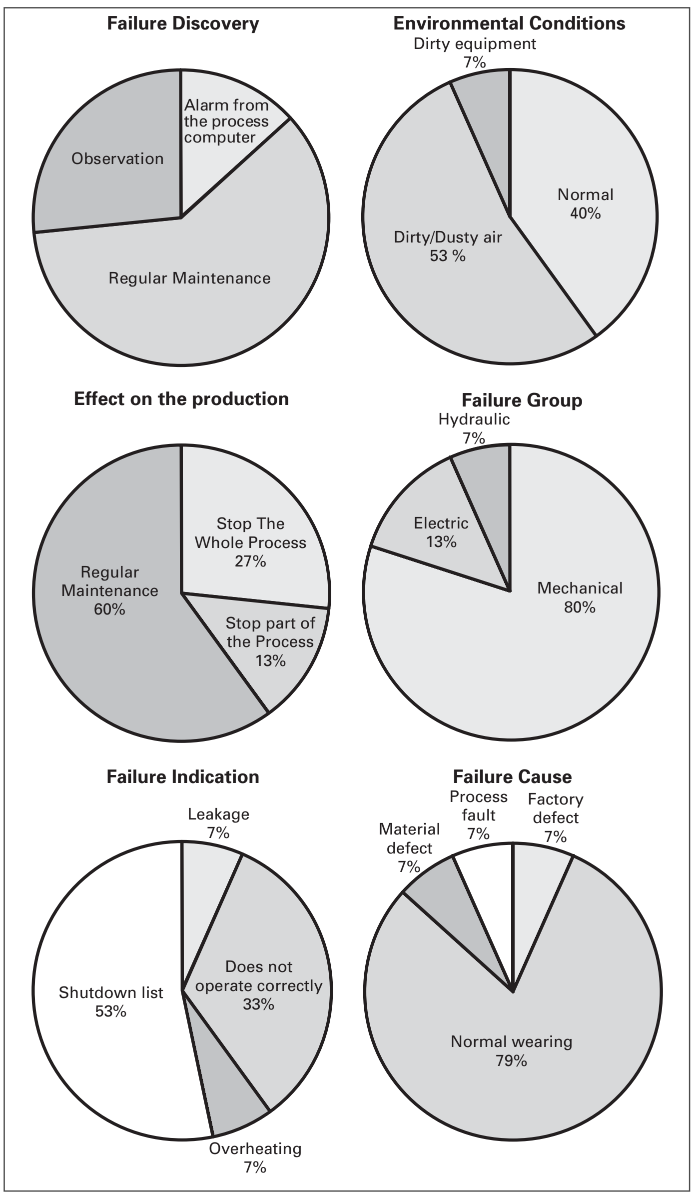
Systematic analysis of the failure group, cause, discovery, indication, effect on the production, and environmental conditions helps to improve the production systems, and enables a rapid response to any problems that arise. The reports enable the user to follow the distribution of typical failure groups (**Fig. 6**).

Downtime analysis can be supported by plotting the cumulative number of the failures as a function of time. This will provide an indication of failure due to equipment [11].

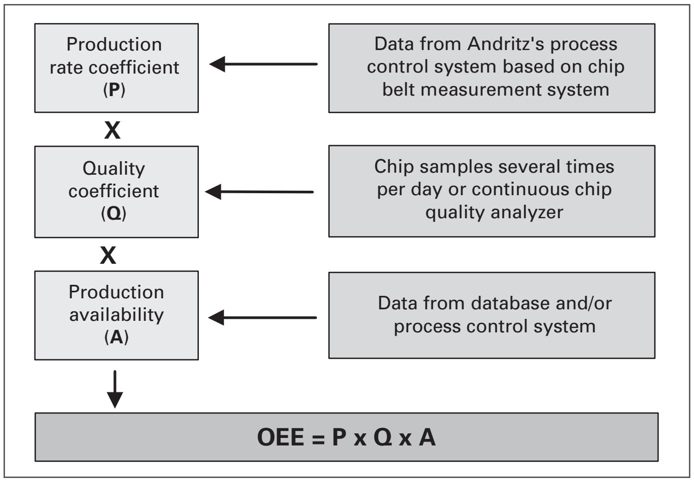
Calculation of availability performance measures

Failure data is needed when calculating availability performance. The data contained in the database allows the calculation of availability performance, which is needed for OEE control.

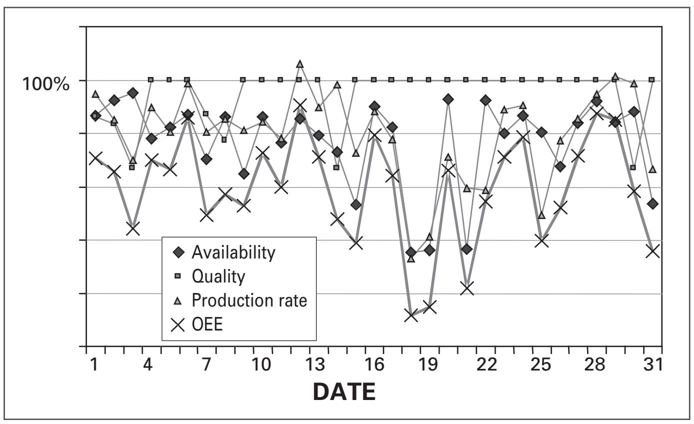
You can calculate availability performance at any level of the process hierarchy, to one piece of equipment or to the whole process. Availability combines the effects of failure and repair



6. Failure reports for typical chippers in a woodyard.



7. A schematic representation of the OEE control at a woodyard.



8. An example of the OEE summary sheet.

and the effects of downtime caused by preventive maintenance. In principle, availability performance is calculated by dividing the real operation time by planned operation time, as follows:

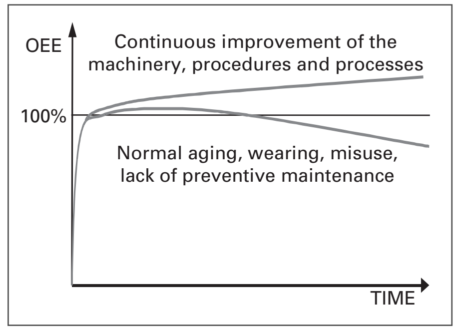
$$A_{device\ or\ production\ line} = \frac{\sum t_{\max\ production\ time} - \sum t_{downtime}}{\sum t_{\max\ production\ time}}$$

Often the most economical way to increase the production is to improve the process efficiency by small investments in the trouble areas instead of replacing the whole piece of machinery. This policy necessitates detailed information on the device's (or subsystem's) maintenance history. The maintenance history data is also needed if a feasibility or life cycle cost analysis is to be carried out [12].

Overall equipment efficiency

Process line specific OEE is one of the most important measurements when analyzing maintenance and operating data. It is also the key concept of TPM [8]. OEE is a single measure that combines production rate, quality and availability. When the data collected from the maintenance data collection application, CMMS, automation system, and other sources is combined, OEE can be continuously monitored. **Figure 7** summarizes the basic principle behind the proposed OEE control.

A careful study on the variation of the contributing factors is necessary in order to find the areas that require improvement.



9. Impact of the lifetime support on the production efficiency.

Figure 8 shows an example of an OEE summary. In this example, the main problems have been availability and production rate. More detailed information is obtained from the downtime analysis and device troubleshooting reports.

The proposed OEE control is based on measurable quantities. It enables the mill's personnel to follow up quantitatively on the progress of the improvement program.

OEE aims at maximum use of the current design capacity. OEE control is a good overall efficiency measure as it collects and combines all relevant factors. The "part optimization" or "trade-off," e.g. production rate vs. product quality, may not yield the best solution. The system may, however, contain upgrade potential. Debottlenecking, process optimization, or upgrading the equipment with the latest technology may increase capacity. **Figure 9** shows the impact of systematic and continuous improvement.

In the long run, the pulp and paper mill will profit from the remote process and condition monitoring, reports, and improvement proposals. The OEE level of the existing machinery also remains high throughout the life cycle.

Internet-based collaboration

As an Internet application, the data collection assures easy communication within a company and provides a link to the machinery manufacturer when troubleshooting or special assistance is needed. A machinery manufacturer can recall the customer's database, attached documents, and deliver design data or repair recommendations. The data collection feeds to a remote server, in which availability performance and OEE calculations take place. The collected information, together with process and equipment audits, creates the basis for continuous improvement of the woodyard operation. The data exchange offers a means for deeper collaboration.

For benchmarking, and for effective use of remote service and support options offered by the machinery manufacturer, consistent data collection principles are a prerequisite. All mills using this system are guided to do so in the same way.

CONCLUSIONS

Successful maintenance data management requires user-friendly software, consistent data collection, and consistent evaluation procedures. The maintenance data collection application presented in this paper proved to meet the user requirements. The application provided a means for collecting reliable and structured device-based failure and maintenance data. The mill used the data to improve its maintenance plans and to react quickly to problems that arose. The information increased the availability performance or OEE level. The data collection application was also a crucial part of efforts aimed at increasing the current capacity without major capital investment. By systematic analysis of the improvement potential and by good collaboration between the woodyard personnel and machinery manufacturer, this became possible. **TJ**

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INSIGHTS FROM THE AUTHORS

In our preliminary research for this study, we found that the process industry has only sporadically collected and used failure and maintenance data. In our opinion, there seemed to be a big potential for improving production efficiency if this data is properly collected, analyzed, and systematically used to support decision-making.

Our recent research was a continuation of the previous work in which we established a mill-wide data collection system. In this research, we use the Internet to link the mill data collection application to the manufacturer information sources. We further developed the analysis of the data and visualization of the results in order to support versatile use of the data.

The most difficult aspect of the research was the implementation of the data collection system at the mill. The benefit of the data collection is not evident before the database contains enough event information and this requires time and patience. A lot of discussions, training, and motivating were needed before mill personnel really started to fill in the data.

The most interesting experience was that the failure and maintenance data recorded at a mill in the United States was immediately available in Finland and could also be responded to directly. The quick and easy communication opens tremendous new possibilities for collaboration.

We still have much work ahead of us in the data analysis, especially when combining the data from different sources. The use of automatically collected condition monitoring and control system data, together with manually collected data, will be an important field of research in the future, together with on-line diagnostics features.

— Helena Kortelainen

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