CHAPTER 2

Classifying plant maintenance[1] from a business perspective

2.1 DEFINITIONS

In business administration, plant maintenance is traditionally classified as part of production (Nolden 1996; Hartmann 1995). The following definitions are intended to illustrate the many diverse ways of evaluating plant maintenance, as well as the different objectives these entail.

2.1.1 Plant maintenance to DIN 31051

According to the German standard DIN 31051, plant maintenance comprises 'all measures for maintaining and restoring the target condition as well as determining and assessing the actual condition of the technical equipment in a system'. These measures are subdivided into

- Preventive maintenance

1 We wish to express our thanks to Ms Renate Sommer (Business Administrations Department, University of Applied Sciences Coburg) for advice on the business administration aspects of this chapter. In numerous discussions, Ms Sommer established the links between traditional business administration and applied plant maintenance.

- Inspection
- Repairs

Preventive maintenance comprises all measures for maintaining the target condition of the technical equipment in a system. In addition to the maintenance task itself, this includes creating maintenance plans which are used to carry out the PM tasks at regular intervals.

Inspection comprises measures for assessing the actual condition of the technical equipment in a system. This also includes creating a plan for determining the actual condition, with information on the inspection date, method and tasks, as well as on the use of technical equipment. An inspection is carried out on the basis of the plan; in other words, specific characteristics are determined quantitatively. These results are then evaluated and any necessary PM tasks deduced.

Repairs comprise measures for restoring the target condition of the technical equipment in a system. This process includes the actual order, order documentation, and analysis of the order content. During order planning, alternative solutions should be isolated and evaluated to enable the best possible solution to be found. Preparing to execute tasks comprises costing, scheduling, provision of personnel, funds and material, as well as creating maintenance task lists. After the tasks have been completed, a functional test, acceptance inspection, notification of completion, and evaluation (including documentation, cost monitoring, and indication of suggested improvements or preventive measures) are carried out.

2.1.2 System-oriented plant maintenance

Whereas DIN 31051 applies to the individual parts of a system and associated measures, system-oriented plant maintenance focuses on safeguarding the functioning of a production system as a whole. Plant maintenance in this sense belongs to system logistics, the primary goals of which are planning, creating and maintaining system availability. System availability is planned taking the maximality and minimality principles into consideration.

The maximality principle aims at achieving the maximum possible yield from a given resource (yield maximization). For further information on this principle, see Schierenbeck (1995). The PM budget, for example, is a given quantity and is intended to ensure the highest possible level of system availability. By contrast, the minimality principle aims at keeping the resource required to achieve a particular result as low as possible (expenditure or cost minimization). For example, a particular system is to be maintained twice a year at as low a cost as possible. To ensure an optimum relationship between PM costs and system availability, the extremum principle is used. This aims at achieving the most favourable relationship possible between yield and expenditure. Yield and expenditure are optimized when the maintenance costs, as well as costs incurred through loss of output, are reduced to a minimum.

Costs related to system logistics include:

- Procurement costs of the system
- Preventive maintenance costs
- Stockholding costs for spare parts
- Procurement costs for replacement equipment
- Costs incurred through loss of output
- Costs incurred for shutting down and scrapping the system

The goals of plant maintenance here are subordinate to those of system logistics. As a result, the aim of plant maintenance is, by means of corrective maintenance, to prevent loss of output and maximize system lifetime. Other tasks include influencing the storage of spare parts so that, when required, spare parts are available at the right time and place. Ideally, plant maintenance should also ensure that maintenance tasks are scheduled to coincide with normal breaks in production or system downtimes. In production, this requires close coordination between maintenance planning and production planning. The basic dilemma in plant maintenance is that, while preventive maintenance initially increases plant maintenance costs, it can help to prevent even higher costs being incurred as a result of breakdowns in production. This means that every company has to determine a plant maintenance strategy located between the following positions:

- Risk-based plant maintenance with low maintenance costs, but with a high risk of system breakdown and high repair or replacement costs;
- Preventive maintenance with high regular plant maintenance costs, but with a low risk of system breakdown.

2.1.3 Extended plant maintenance

In recent years, plant maintenance has been freed from its original, purely production-based context. In addition to its traditional task of safeguarding system availability, plant maintenance has come to include disposal of basic materials in accordance with ecological considerations and environmental legislation. Another new aspect is facility management. In plant maintenance, this area encompasses preventive maintenance, inspection and repairs for utility installations (for example, power supply, water supply and air conditioning). Plant maintenance has now become an important issue not only in production environments, but also in building management. (Consider, for example, the costs that can be incurred due to a defective air-conditioning system in a computer centre.) The following definition takes these recent trends into account, without neglecting DIN 31051:

> Plant maintenance comprises preventive maintenance, inspection, and repairs for operational facilities. In many cases, this also involves utility installations or

> disposal of materials. The purpose of plant maintenance is to ensure the availability of operational facilities at a minimal cost. (Index entry 'plant maintenance' in Sokianos (1998))

2.1.4 Malfunction and breakdown

Whereas inspection and preventive maintenance are carried out on a functioning system, repairs presuppose a malfunction or breakdown.

> A malfunction (or defect) is an unwanted interruption to or impairment of the correct functioning of a unit; this definition does not take the cause of the malfunction into account. A malfunction can take the form of a brief interruption. The terms 'malfunction' and 'breakdown' are often defined in such a way that a breakdown is caused by factors in the actual unit in question. In the event of a malfunction, a unit can continue to carry out its required function (a ventilator filled with dust or leaves is an example of a malfunction, not a breakdown). A breakdown always implies a malfunction, not vice versa. (Hubert Becker: Grundbegriffe. http://home.t-online.de/home/becker2/log3_1_1.htm)

The criteria according to which breakdowns can be classified include

- The life cycle of the system
- The particular form breakdowns take
- The logical sequence of breakdowns

In the life cycle of a system, there are three breakdown phases:

1. Early breakdown phase; for example, due to incorrect operation or material weaknesses
2. Random breakdown phase during consolidation; for example, due to vibration or fluctuations in pressure, temperature, load, or voltage
3. Late breakdown phase; for example, due to aging, wear and tear, or fatigue

Depending on the particular form they take, breakdowns are classified either as total or partial. For example, if one motor breaks down in a system comprising a total of three motors, this is considered a partial breakdown.

The logical sequence of breakdowns can be used to distinguish primary and secondary breakdowns, as well as breakdowns with a common cause. A primary breakdown is the breakdown of a unit due to a failure in the unit itself. In the case of a secondary breakdown, the unit either breaks down due to the failure of an upstream unit or has to be deactivated for safety reasons. A breakdown with a common cause involves several units breaking down simultaneously.

Documenting and analysing breakdowns is one important task of plant maintenance. In this context, the technical breakdown (failure) rate in VDI (Association of German Engineers) Guideline 2893 is particularly significant.

The technical downtime comprises all the downtimes attributable to technical malfunctions. According to VDI Guideline 3423, the target running time is the running time of a machine (according to capital investment planning, for example). The aging of a unit can be deduced from the characteristic of the technical breakdown rate; in other words, if the technical breakdown rate increases, scrapping a unit could, in certain circumstances, entail lower costs than maintaining it.

2.2 TRADITIONAL FORMS OF ORGANIZATION IN PLANT MAINTENANCE

2.2.1 Plant maintenance in line organization

Line organization is the oldest and most basic form of organization (Steinbuch 1997: 172ff). The characteristic features of line organization are:

- Centralization of tasks
- Simple subordination
- Full authority only

In line organization, each job is allocated only one manager, and each manager has several subordinate members of staff. This is a form of organization in which the manager plays an authoritarian role and each member of staff is answerable to only one level of authority. In other words, every PM technician is answerable to the PM manager. Line organization is the most common organizational form in small and medium-sized companies, in which all decisions are made by one person.

The advantages of this form of organization include unambiguous relationships between superiors and subordinates, uniform channels for communication and reporting, as well as clear demarcation of tasks, authority and responsibility. The responsibility of the manager for the decision process ensures that all process steps can be interpreted easily, and facilitates control and supervision of members of staff.

One of the disadvantages of line organization is the excessive load it puts on management. The emphasis on hierarchical thinking hinders cooperation between members of staff and also runs the risk of increasing bureaucracy. With line organization, a limited number of intermediate authorities results in a broad organizational plan and, therefore, large spans of control. A large number of intermediate authorities in line organization, however, results in long communication and reporting paths.

Figure 2.1 illustrates plant maintenance in line organization as a subarea of production. The PM manager is subordinate to the production manager here. Figure 2.2

illustrates plant maintenance as a separate area on a par with production. The PM manager here shares the same hierarchical level as the production manager, and both are subordinate to the corporate management.

2.2.2 Plant maintenance in the line-staff organization structure

To relieve the excessive load on management staff, which is a disadvantage of line organization, this organization structure assigns authority to staff units (Steinbuch 1997: 173ff). These staff units do not usually have competence to issue instructions; their tasks are, rather, in the areas of decision preparation, planning and support, as well as monitoring. A characteristic feature of the line-staff organizational structure is its separation of decision-making powers (for example, of the production manager) and the expert knowledge of the staff (for example, of the PM manager and his staff). Further characteristic features of this organizational form are:

- Centralization of tasks
- Simple subordination
- Full and partial authority

In addition to relieving management staff, the advantages of the line-staff organization structure include improved decision quality by incorporating specialists, the uniform

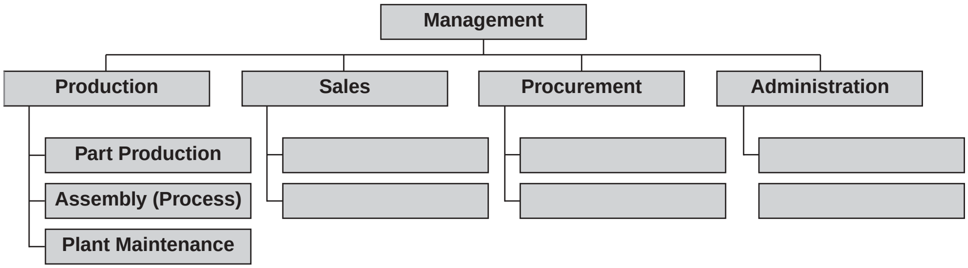

FIGURE 2.1 Plant maintenance in line organization as a subarea of production (© SAP AG)

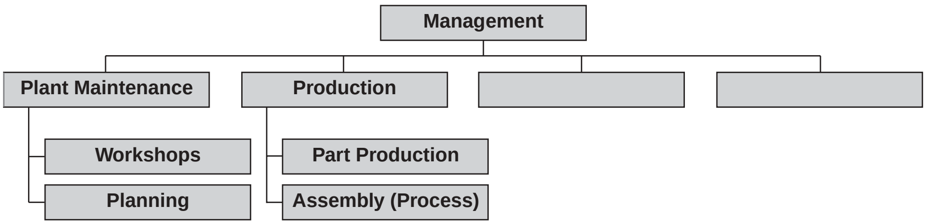

FIGURE 2.2 Plant maintenance in line organization as a separate area (© SAP AG)

line of command and communication channel, as well as the clear demarcation of responsibility.

The disadvantages of this organizational form include the potential for conflict between the line position and the staff unit assigned to it (for example, between the production manager and the PM manager), the danger of staff units becoming too large for the line position, as well as the possibility of the staff unit using its specialist knowledge manipulatively.

> As a rule, the staff units in plant maintenance are entrusted with long-term planning tasks, such as drawing up maintenance strategies for individual production plants, creating budgets, determining personnel capacity, elaborating maintenance task lists, and administering and maintaining the plant maintenance data. (Grobholz 1988: 84ff)

The planned PM tasks can actually be carried out either by the specialists of the PM staff unit, or by production staff. External processing (outsourcing) managed by the staff unit is also conceivable. Figure 2.3 represents plant maintenance as a staff unit assigned to the line position 'Production'.

2.2.3 Plant maintenance in matrix organization

With matrix organization, specific functions are not assigned to the business areas but are carried out centrally for the entire company (Steinbuch 1997: 185ff). Central departments are set up for this purpose and carry out their tasks for all business areas. At a second level, a horizontal functional organization is combined with this vertical organization of business areas, thereby creating a matrix. The characteristic features of matrix organization are:

- Centralization of objects
- Multiple subordination
- Full authority, or partial and full authority

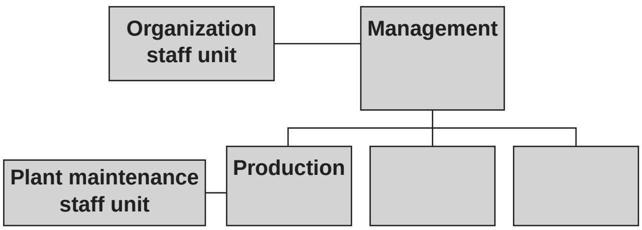

FIGURE 2.3 Plant maintenance in the line-staff organization structure (© SAP AG)

This organizational form is primarily used by large companies which have diverse product groups, a marketing orientation and high management potential.

Some of the advantages of matrix organization are that it safeguards corporate unity, generally confers the advantages of specialization, relieves the strain on management, and provides a large variety of response options.

The disadvantages of matrix organization, however, include the risk of conflict due to multiple subordination, the danger of entering into unsatisfactory compromises, the tendency towards greater bureaucracy, as well as high costs due to the large number of managers required.

Within matrix organization 'the PM unit that carries out the maintenance tasks is assigned to the (horizontal) central Maintenance division, as well as to the vertical division of the relevant product group' (Grobholz 1988: 35ff). In general, strategic PM planning is located in the central division, while the vertical divisions carry out PM planning for their product division and also perform the PM tasks. Figure 2.4 shows an example of the central Production and Plant Maintenance divisions for three product divisions.

2.2.4 Classification of external plant maintenance

Generally speaking, internal plant maintenance can be combined with external plant maintenance (outsourcing) in all of the three traditional forms of organization. In this case, the maintenance department is responsible for planning and monitoring the PM measures but not for carrying them out. Of course, it is also possible to transfer planning, control and execution of maintenance tasks entirely to the external provider.

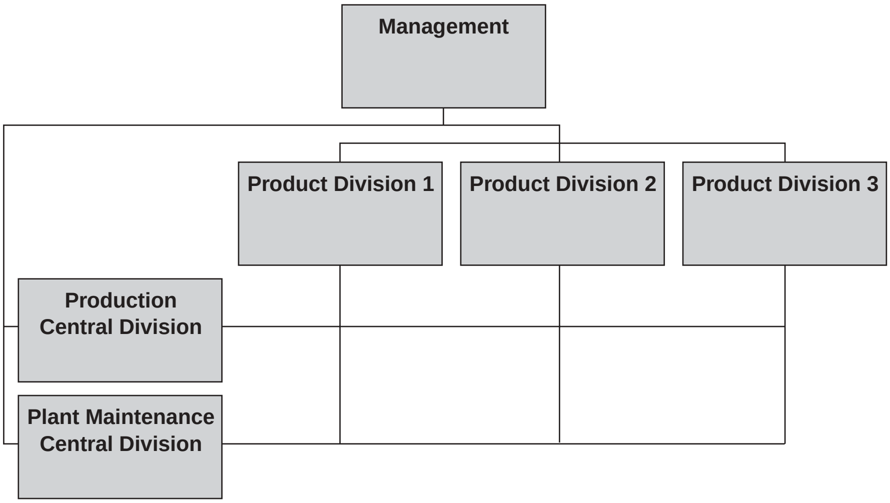

FIGURE 2.4 Plant maintenance in matrix organization (© SAP AG)

In all three organizational forms, external plant maintenance can result in leaner structures. Figure 2.5 illustrates the structure of integrated fixed-asset management and the inclusion of internal and external plant maintenance.

> If maintenance is placed at the core of this type of fixed-asset management, it is clear that choosing between internal and external maintenance has consequences not only for the area of maintenance, but for all of the remaining activities in fixed-asset management. Depending on the particular tasks carried out by fixed-asset management, these consequences can affect the planning, execution, and control of the various activities in fixed-asset management. (Grobholz 1988: 54)

The evaluation technique used in decision making can be applied as a basis for deciding for or against external plant maintenance. This technique centres on creating a value profile which comprises the variables criterion, weighting, degree of fulfilment, and evaluation. Specific criteria are assigned a weighting from 1–10, for example. In addition to this, the degree of fulfilment is specified; in other words, which maintenance provider fulfils which criterion, and to what extent. The external maintenance provider is then evaluated on the basis of the criteria, weighting, and degree of fulfilment. Multiplying the values in the ‘Weighting’ and ‘Degree of fulfilment’ columns yields values per line, the sum of which constitutes the final value. Comparing the final values for the various external maintenance providers with the final value for internal plant maintenance provides a basis for deciding whether external plant maintenance is a viable option and, if so, which external provider should be commissioned.

The following criteria can be used for decision making (Grobholz 1988: 66ff):

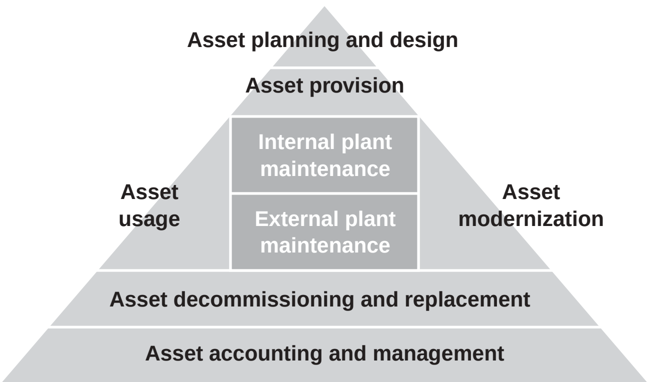

FIGURE 2.5 Integrated fixed-asset management (from Grobholz 1988: 55) (© SAP AG)

1 *Quality*
Deployment of well-trained specialists; use of precision tools; experience with similar cases; selection of repairs, spare parts, repairable spares and operating supplies appropriate to the specific demands involved; procedure in accordance with state-of-the-art technology.

2 *Time*
Time savings during execution of measures by means of deploying specialists in parallel; use of planned downtimes in production.

3 *Capacity*
Improved utilization of internal plant maintenance capacities; internal PM capacities relieved of routine tasks; short-term and cost-saving satisfaction of peak demand for PM activities.

4 *Elasticity*
External PM provider adapts to meet fluctuations in demand and changes in type of PM requirement.

5 *Planning*
Planning on the basis of data provided by system user (wear-and-tear profiles, lifetime statistics and operating efficiency analyses); determination of optimum PM strategy for the system user.

6 *Information processing*
Development and/or maintenance of specific software for IT-assisted plant maintenance; entry of existing PM data.

7 *Provision and storage*
Provision of spare parts, repair materials, repairable spares and repair operating supplies; knowledge of input/procurement market for spare parts, and so on.

8 *Finance*
Funds required remain constant due to long-term service contracts.

9 *Safety, environmental protection and industrial safety*
Elimination of risks to personnel, such as risk of internal specialists being unavailable due to illness or accident; warranty confirmations and good-will services; improved industrial safety and accident prevention by adopting tried-and-tested concepts; transfer of waste disposal issues.

10 *Human resources*
Reduction in staffing requirements; reduction in internal training measures.

11 *Organization*
Improved process structure in plant maintenance; centralization of decision-making authority.

12 *Costs*
Avoidance of overtime; elimination of reworking costs by means of warranty claims; falling fixed costs; cost-saving execution via plant-scale/quantity reductions.

EXAMPLE Your company operates an ice-cream production plant. You are planning external maintenance for the cooling systems in this plant, since these require highly specialized maintenance and sophisticated precision tools. You now have the task of creating a value profile for selecting the most suitable external maintenance provider.

You choose quality, time, elasticity, planning, corporate finance, safety/environmental protection/industrial safety, human resources, and costs as criteria with a high weighting. Since you consider support during PM planning and saving training costs to be less important, you assign these criteria a weighting of 5 on a scale of 1–10. You consider environmental protection to be very important for the cooling system, since you also intend to transfer disposal of the coolant to the external maintenance provider. You consider it equally important to conclude a long-term service contract with favourable conditions, and therefore assign these criteria a weighting of 10. You assign all the remaining criteria a weighting of 8. Table 2.1 illustrates the resulting value profile with entries for an external maintenance company X. In this way, you can evaluate the potential external maintenance providers, and decide on the company with the highest final value.

TABLE 2.1 Value profile for an external maintenance provider

Criterion	Weighting	Degree of fulfilment (from –2 to +2)	Evaluation of company X
Quality	8	+1	+8
Time	8	–1	–8
Elasticity	8	–1	–8
Planning	5	+1	+5
Finance	10	+2	+20
Environmental protection	10	+1	+10
Human resources	5	–1	–5
Costs	8	+1	+8
			Final val.: +30

2.3 PLANNING IN PLANT MAINTENANCE

2.3.1 Planning and control

Planning in plant maintenance comprises ‘all activities, tasks and actions, process flows, technical data, economic criteria and costs, which affect the labour productivity of the plant maintenance department and the adjoining enterprise areas or the enterprise as a whole’ (Grobholz 1988: 38).

Control in plant maintenance comprises order-related scheduling and capacity determination, as well as monitoring the execution of PM tasks. Whereas planning is intended for the medium or long term, control is always short-term in nature. Figure 2.6 shows how planning and control interact in the order processing cycle.

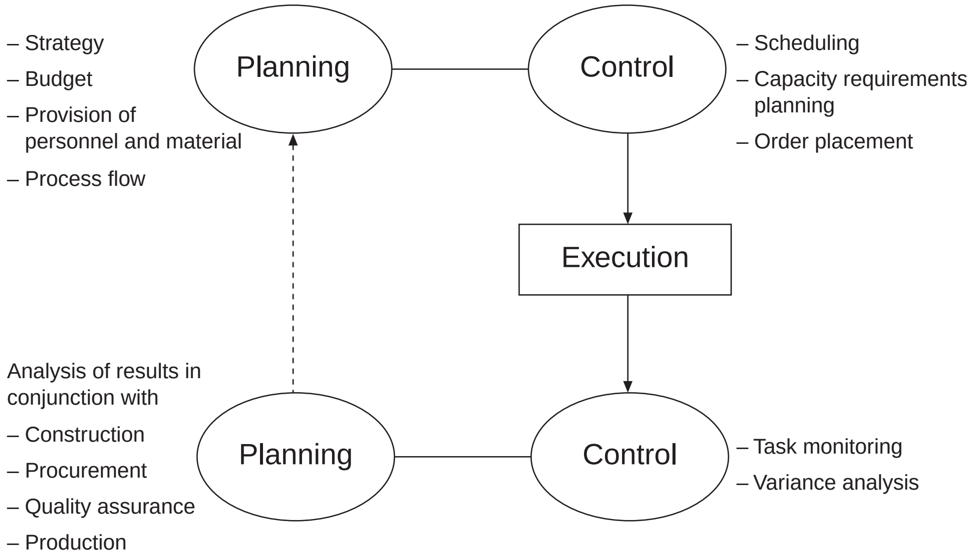

FIGURE 2.6 Planning and control (© SAP AG)

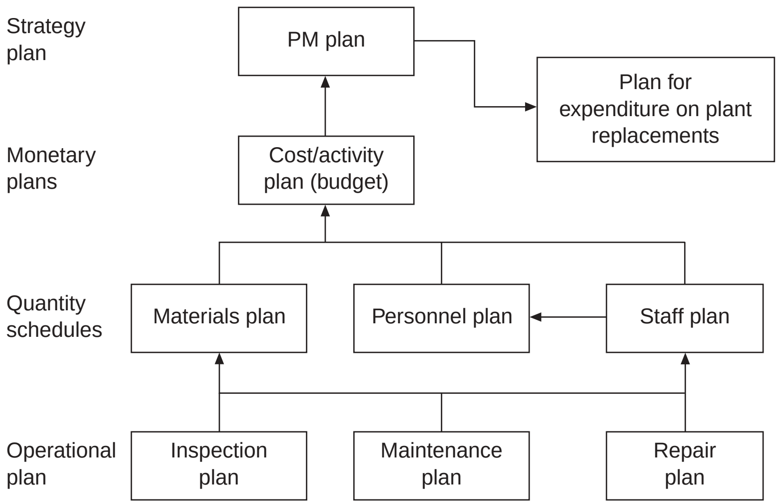

FIGURE 2.7 Strategy plans (from Grobholz 1988: 40) (© SAP AG)

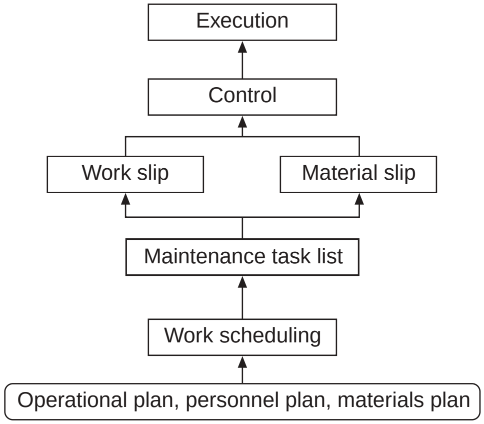

FIGURE 2.8 Work scheduling (from Grobholz 1988: 41) (© SAP AG)

2.3.2 Strategy plans and maintenance task lists

On the basis of Recommendation No. 10 of the Deutscher Komitee für Instandhaltung (DKIN: German Committee for Maintenance), a distinction is drawn in plant maintenance between strategic planning and work scheduling using maintenance task lists. Strategy plans are always created for the medium term or long term, and apply to a cycle or a period of time. By contrast, maintenance task lists are short-term in nature, and apply to a specific date.

> Strategic planning includes creating the operational plans (activities: preventive maintenance, inspection, repair), the quantity schedules (the personnel plan as well as the materials plan including the machine and equipment plan), the cost/performance plans, and the strategic overall plan. (Grobholz 1988: 40)

Figure 2.7 shows the strategy plans in context.

The maintenance task list is the instrument for controlling the PM tasks and is based on the operational plans. For example, a maintenance task list based on a repair plan contains detailed instructions on repair tasks as well as information concerning the execution date. After the repair tasks have been executed, the maintenance task list is returned to the preparation stage to allow an analysis to be carried out during planning. Figure 2.8 shows the work scheduling cycle in plant maintenance.

2.4 PLANT MAINTENANCE METHODS

2.4.1 Damage-based plant maintenance

The damage-based method of plant maintenance (in extreme cases, also known as the breakdown or 'run-to-failure' method) is characterized by the fact that no preventive maintenance is carried out. System components are installed with no PM outlay, worn out, and replaced completely in the event of a malfunction.

EXAMPLE

The service life of a seal is used up completely until a malfunction occurs. A damage-based plant maintenance task is then carried out to install a new seal. In this case, the damage-based plant maintenance method is worthwhile, since regularly inspecting and maintaining a seal would cost more than the seal itself. The situation is rather different, however, if the seal is classified as a system component presenting a danger to production or safety. In this case, the method would not only be foolish, but would also give rise to high downtime and follow-up costs.

The damage-based plant maintenance method is financially viable, therefore, only under the following conditions:

- If the system components involved cost considerably less to acquire than to maintain.
- If system components involved present no danger to either production or safety in the event of a breakdown, and can be repaired without significant outlay (for example, without shutting down the system).
- If the system components involved have a limited service life that it is neither feasible nor desirable to extend (no refurbishment).

The business process for this method begins with the notification that a malfunction has occurred. The second step involves specifying the nature of the malfunction. The PM planner responsible can either ask the notification creator for more details or investigate the malfunction himself. If the notification creator is a PM technician, he can also specify the nature of the malfunction himself in the second step. As soon as the details have been established, planning and control of the repair task can be carried out. The amount of time available for planning and control varies depending on the severity of the malfunction and its effects on production. If sufficient time is available, the PM planner can specify repairable spares, workflows, or the tools to be used. If little time is available, the PM planner provides a PM technician with a roughly specified work order.

In the event of serious malfunctions, this sequence can also be reversed. In this case, the repair is performed first, and official notification and specification of the malfunction are carried out only afterwards.

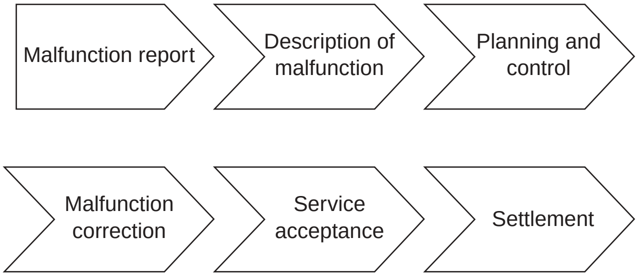

FIGURE 2.9 Business process for damage-based plant maintenance (© SAP AG)

After the malfunction has been corrected (repaired) by an internal or external PM technician, the PM planner (as the ordering party) signs off the service performed. In the concluding step, the order is settled by accounting. Figure 2.9 presents an overview of this business process.

2.4.2 Time-based plant maintenance

With time-based (or periodic) plant maintenance, preventive maintenance of a system component is carried out regularly after a specific period of use. One advantage of this method is that regular preventive maintenance increases the service life of a system component. In some cases, statutory or safety regulations require proof of regular preventive maintenance (for example, fire extinguishers and automobiles are subject to inspection at regular intervals). One disadvantage of time-based maintenance is that the service life of a system component always depends on its level of usage.

EXAMPLE A pump in an ice-cream production plant has to be replaced after every 10,000 litres at the latest. From a statistical point of view, this limit is reached every two months. As a result, a maintenance cycle of two months is specified by time-based plant maintenance. In March, this pump is replaced after 9000 litres; in May, after 4000 litres; and in July, after 9200 litres. In May, the utilization level was considerably lower than in the other months, which means that the pump only really needed to be replaced in June. However, time-based plant maintenance takes only the maintenance cycle of two months into account, and not the actual wear and tear. As a result of replacing a pump that was still functioning in May, the company incurred additional costs.

The business process for time-based plant maintenance begins with notification (generally output by a computer system) that the specified date has been reached. The specified date is the finish date of a particular maintenance cycle. Following notification, the planning and control of the maintenance task is carried out on the basis of a maintenance plan. Since the maintenance tasks are known in advance, this maintenance plan can also be output by a computer system. An internal or external PM technician carries out the maintenance on the specified date, and the PM planner signs off the service performed. As in damage-based maintenance, this step is followed by settlement. Figure 2.10 shows an overview of this business process.

2.4.3 Condition-based plant maintenance

Of the three traditional plant maintenance methods, condition-based plant maintenance is the one that enables the service life to be leveraged optimally and economically. In condition-based maintenance, a maintenance task is required only if a specific level of wear and tear has been reached (for example, if and only if the value for the pump has actually reached 9900 litres).

To enable condition-based plant maintenance to be carried out, the actual condition of the system component must be measured precisely by means of regular inspections. For example, the pump can be fitted with a meter that measures the flow in litres and is read regularly.

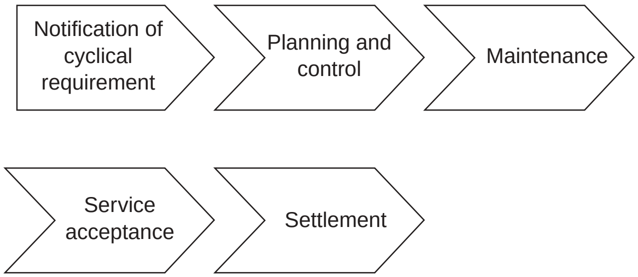

FIGURE 2.10 Business process for time-based maintenance (© SAP AG)

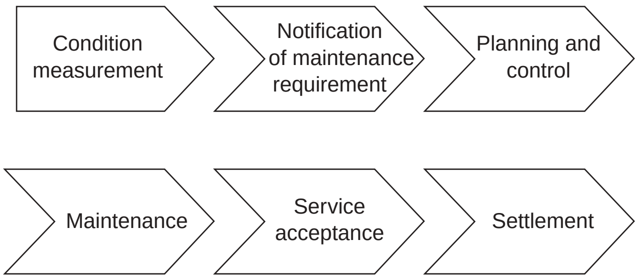

FIGURE 2.11 Business process for condition-based plant maintenance (© SAP AG)

The business process for this method begins with regular measurements of the condition. When this measurement determines that a specific value has been reached, notification of the maintenance requirement is issued. The PM planner plans and controls the maintenance tasks on the basis of a maintenance plan. As in the other business processes, maintenance is then carried out, signed off and settled. Figure 2.11 shows an overview of this business process.

A company can use all three of the above methods in parallel, or combine them as required. The particular method used often depends on the type and value of the material in question. Damage-based plant maintenance can be used as a method for parts subject to wear and tear, whereas time-based or condition-based plant maintenance can be used for system components with a long service life. It can also be expedient to combine time-based and condition-based plant maintenance.

EXAMPLE The pump should always be replaced after 10,000 litres, but only after a minimum usage time of two months. Or the pump should be replaced by an external company every two months; if the value of 9900 litres is reached, however, the pump can also be replaced within the two-month cycle.

2.5 BENCHMARKING IN PLANT MAINTENANCE BASED ON KEY PERFORMANCE INDICATORS

Benchmarking involves using specific criteria to define various subareas of plant maintenance, and then comparing these within one's own company or with other companies. To enable plant maintenance management to be improved, the particular demands that have to be satisfied are specified for the criteria. Two of these subareas are, for example, corporate management and asset management.

In the corporate management subarea, the following criteria must be evaluated as regards their level of maturity and the results achieved in comparison with the benchmarking partner (Biedermann 1998: 34):

1. Written version of the plant maintenance philosophy
2. Target-based formulation of continuous improvement
3. Cross-departmental teams with target achievement monitoring
4. Cross-departmental controlling with PM contribution as regards
   - Quality (key performance indicators)
   - Productivity (key performance indicators)
   - Utilization of system capacity (key performance indicators)
   - Safety (internal area) and environment (external area)

5. Standardization (standards, guidelines, instructions)
6. Staff commitment and delegation
7. Risk profile for organization (division) of work between system operator and maintenance provider
8. Catalogue of criteria for transferring tasks to production
9. Analytical evaluation of the optimum level of decentralization
10. Strategic orientation in assigning external services
11. Controlling functions

In the asset management subarea, the following criteria must be evaluated as regards their level of maturity and the results achieved in comparison with the benchmarking partner (Biedermann 1998: 35):

1. Documentation of critical systems/assemblies and description of relevant maintenance strategy
2. Systematic process of weak-point elimination
   - Technical assessments
   - Business assessments
3. Assessments with regard to occupational and operational safety, as well as environmental protection, with associated documentation
4. Classification of systems with regard to their significance and place in the production process, with associated documentation (key performance indicators)
5. Definition of targets in the areas of reliability and availability
6. Use of methods and tools or techniques to increase actual production time
7. Routine evaluation for reliability engineering
8. Use of information technologies for supporting reliability management
9. Visualization by means of reports, graphics and diagrams as means of organizing information in accordance with demands
10. Inclusion of plant maintenance concepts in the drafting and construction of new systems
11. Use of methods to compare the economic efficiency of asset investment as regards plant maintenance or replacement

In this context, some of the PM key performance indicators in VDI Guideline 2893 are significant. You can use key performance indicators 1–4, for example, to analyse PM costs. Key performance indicator 1 is the PM cost rate; in other words, the total costs (costs for personnel, labour, materials and external services) for PM tasks to DIN 31051 divided by the indexed acquisition value, the asset value in the year of procurement multiplied by the price index (index figures of the Federal Statistical Office Germany) for the year in question.

Key performance indicators 2–4 provide a further breakdown of the total cost. Key performance indicator 2 is the PM cost portion for personnel; in other words, the labour and salary costs for PM personnel, including the total cost divided by the total PM costs in accordance with key performance indicator 1.

Key performance indicator 3 is the PM cost portion for materials; in other words, the costs for material used for plant maintenance (spare parts, operating supplies and consumables) divided by the total PM costs in accordance with key performance indicator 1.

Key performance indicator 4 is the PM portion for external services; in other words, the costs for PM tasks carried out by external companies divided by the total PM costs in accordance with key performance indicator 1. It is advisable here to list separately the labour and material costs for the external service in accordance with key performance indicators 2 and 3.

The PM personnel cost rate (key performance indicator 17) and PM material cost rate (key performance indicator 18) can also be calculated in accordance with key performance indicator 1. With the PM personnel cost rate, the personnel costs in accordance with key performance indicator 2 are divided by the indexed acquisition value in accordance with key performance indicator 1. With the plant maintenance material cost rate, the material costs in accordance with key performance indicator 3 are divided by the acquisition value in accordance with key performance indicator 1. (For further PM key performance indicators, refer to VDI Guideline 2893. On PM key performance indicators, see Gamweger 1998: 101–112.)

2.6 MODERN PLANT MAINTENANCE MANAGEMENT

2.6.1 Total Productive Maintenance (TPM)

The TPM concept was developed in Japan in the 1970s, but only became more widespread during the 1990s. The main characteristic of TPM is that the tasks formerly planned and carried out by central PM departments are transferred gradually to the machinist.

> In contrast to traditional plant maintenance, which is regarded as an auxiliary plant or service function of production, TPM pursues considerably more extensive objectives, since all members of staff are included in the improvement process. (Matyas 1999: 31)

Training the operating personnel is an important prerequisite here for overcoming the traditional organizational separation of machine operation and machine maintenance. According to Matyas, the objective of TPM is ‘autonomous operator maintenance’.

This is evident, for example, in the Japan Technology Group's mission statement for TPM:

> Total Productive Maintenance means that operators are empowered to maintain continuous production on totally efficient lines. (Japan Technology Group, Nippon Lever BV, Japan. http://www.bekkoame.or.jp/~axeichi/n_lever)

Within the scope of TPM, the actual PM department analyses the PM tasks carried out by the operating personnel. The PM department also carries out strategic planning, administration of maintenance task lists and maintenance plans, as well as cost control.

2.6.2 Reliability Centred Maintenance (RCM)

RCM, also known as Reliability Based Maintenance (RBM), is concerned specifically with system breakdowns, the associated follow-up costs, and how to avoid them. The aim of this method is to use a risk analysis and risk evaluation (as a separate method, Risk Based Maintenance) to decide whether preventive PM tasks could incur higher costs than a system breakdown and its consequences.

> The question of whether preventive measures are expedient arises especially where redundant (bypass) or multiply redundant systems are used. This is because the bypass is intended to take effect if the component breaks down. What is the use of prevention where a safeguard is already installed? This should be taken into consideration particularly in the case of systems with a high level of redundancy determined by technology or legal stipulations (for example, in systems involving nuclear technology). (Stender 1999: 43)

The most important prerequisites for RCM are calculation and evaluation of a system breakdown.

2.6.3 Life Cycle Costing

Life Cycle Costing is a tool used in cost management for a product or a system.

> Life Cycle Costing is not a separate method; it is based on a number of well-known methods from capital budgeting (for example, system evaluation methods, cost forecasting procedures, and methods for taking risk and inflation into account). (Günther 1997: 900)

When a system is procured, for example, Life Cycle Costing facilitates the decision between alternative products offered by rival providers. This method is used to compare not only the procurement and initial costs, but also (and more importantly) the operating and follow-up costs in the life cycle of a system. The operating and follow-up costs essentially contain the costs for preventive maintenance and plant maintenance, as well as the operating and disposal costs. Even after a system has been procured, Life Cycle Costing contributes to optimizing costs and performance throughout the life cycle of the system:

> In contrast to capital budgeting, Life Cycle Costing does not end when the analysis of life cycle revenues and costs is complete. To achieve its goal as regards design, Life Cycle Costing employs a continuous process for optimizing the design of the particular product or system throughout its entire life cycle (. . .). (Günther 1997: 912)

Life Cycle Costing is particularly worthwhile for systems involving high capital investment and with a long service life, as well as where the follow-up costs accrued by the system are high in comparison to the initial costs. Life Cycle Costing is, therefore, an important method for classifying and planning the scope of plant maintenance strategically.

2.6.4 Decentralized Equipment and Process Responsibility (DAPV)

DAPV was developed by the Fraunhofer Institute for Production Engineering and Automation (Germany). The method focuses primarily on the organizational structure of the PM department; in other words, on creating decentralized structures and transferring responsibility to work groups and teams.

> With a centralized form of organization, personnel and organization in the four elements of planning, control, execution, and monitoring are separate. In fact, it can even be said that the greater the separation of these elements with regard to persons and departments, the higher the level of centralization. By contrast, the characteristic feature of a decentralized organization is that these four elements or tasks are performed by a group or team (and possibly even by only one person). (Stender 1999: 51)

Former members of the PM department can be integrated in the production team that performs plant maintenance tasks. The team calls in external maintenance providers only in the event of more extensive and complex plant maintenance tasks. These providers come either from an internal 'plant maintenance service centre' or from an external company.

> The obvious thing to do, then, is to eliminate function-oriented departments, such as production (quantity), plant maintenance (system), logistics (time), and quality, in order to establish process-oriented departments (fractals), in which part

> tasks of the original logistics, plant, maintenance and quality functions are carried out, as well as production. The former logistics, plant maintenance, and quality departments are retained in cases where specific tasks requiring a high level of function-specific know-how have to be carried out. If they are retained, however, these departments give up personnel, since the overall scope of their tasks is reduced. In addition to this, the role of persons responsible changes, since they are now only engaged by the production fractals as service providers within a clearly defined customer/vendor relationship. (Stender 1999: 56)

As with TPM, the organizational role of the PM department within the company is changed, while the actual PM tasks are now carried out as a role in a production team.

2.6.5 Other trends

System engineers as service providers

In addition to the PM management concepts outlined above, a number of other trends for modernizing traditional plant maintenance are currently developing. Some manufacturing companies are now carrying out not only traditional system engineering, but also production optimization and system maintenance.

> This means that erstwhile producers are increasingly becoming providers of holistic product solutions extending from system planning and construction through to system support during operation. This establishes a control loop that also sets important new trends for maintenance. The total asset history costs of a machine or system from construction through to system operation are now relevant for system engineers. This means that they not only have to take the costs of the first phase of the product life cycle into consideration, but also have to allow for the subsequent costs of ensuring the availability of their system. This involves giving particular consideration to influences on system behaviour arising from the construction of assemblies and operational methods, the use of basic materials, and the quality of internally produced as well as externally purchased parts. (Proksch 1999: 14)

Remote diagnosis and virtual service groups

Virtual service groups are specialist teams for High Intelligence Maintenance (HIM), which work together on projects and are organized via virtual markets.

> Virtual service groups will be created, in which companies (particularly PM service providers and component suppliers, but also system manufacturers) cooperate to provide services. The global options for accessing system data enable highly qualified specialist plant maintenance teams to be assembled internationally as and when required. This is especially useful in the case of more complex

> malfunctions, system optimizations, modifications, or other large-scale measures. (Slender and Proksch 1999: 14)

This scenario offers following remote diagnosis options:

- Process supervision and weak-point analysis
- Process management and control
- Business reengineering, process optimization
- Remote programming and control of machines
- Remote control and fault correction for control software
- Teleservice with sensors, video/audio monitoring (on teleservice, see Stoll 1999))

Internet technologies can be used to create a virtual marketplace (or portal) operated by providers of software for PM planning and control systems, for example. In this portal, providers of PM services, suppliers of spare parts, and systems engineers can advertise their products and services under the heading 'Sell'; companies seeking to purchase plant maintenance services in the short-term or mid-term can advertise under 'Buy'. This marketplace can be used not only to level out supply and demand, however, but also to exchange information (for example, on benchmarking results, key performance indicators, and PM strategies, as well as experience with modern PM management concepts or technical innovations). Some of the above options for remote diagnosis could also be implemented directly via a marketplace of this type.

Facility management

Building maintenance is a subarea of facility or building management. The greater the level of automation via building control systems, the more important it is to integrate the PM processes smoothly. If computers are used to support plant maintenance operations, an interface must exist between the maintenance planning and control system (MPC) and the building control system so that a malfunction report is generated automatically in the MPC as soon as the building control system detects a malfunction.

Graphical user interfaces for MPC

Traditional MPC systems can be made easier for PM planners or technicians to operate by means of intuitive user interfaces. Malfunctions in a system can be localized more easily if the MPC system is equipped with a user interface supporting CAD drawings, three-dimensional images, construction plans, or process and instrumentation diagrams. Drawings or images of this kind can be made available throughout the company on the internet/intranet and accessed via a browser. This means that users do not require a technical key for the system component affected in order to enter data and trigger events in an MPC system (for example, to initiate a malfunction report).

Solution databases

Analysis procedures, such as 'Safety through organizational learning' (SOL), are centered on the concept of learning from experience. (On SOL, see Geipel-Kern (1999).) Breakdowns, malfunctions, accidents and near-accidents are evaluated systematically to enable processes to be improved and similar malfunctions to be corrected more quickly. Tried-and-tested solutions can be stored in solution/task databases. By means of Case-Based Reasoning systems (CBR), the system can link the description of a particular problem to descriptions of similar problems. These descriptions are connected, in turn, to a tried-and-tested solution that has already been used successfully and linked to the descriptions of problems via SOL, for example. This enables company-internal knowledge relating to plant maintenance processes to be stored in a knowledge base. Some system engineers or manufacturers of spare parts supply product-specific knowledge bases with their products. The PM technician (as customer) can then call up the manufacturer's knowledge base directly or via the internet should problems arise.

Simulation programs

Simulation programs can be used, for example, to show how the breakdown of a subsystem will affect the system as a whole.

> In the simulation system itself, the behaviour of the system is mapped via events, which are triggered at the appropriate times by means of the determined characteristics. These cause changes in the system condition, which trigger further events (discrete event simulation). This not only enables the behaviour of real systems/system components to be described, but also allows supplementary levels of analysis to be integrated in the simulation model in parallel with the actual process flows. (Feldmann 1999: 54)

When used as part of a preliminary economic evaluation of the simulated malfunction, this procedure enables the costs for PM personnel to be calculated directly according to the duration of the malfunction and the hourly rate, for example.