Maintenance management for energy rationalization in modern buildings

José Paulo Saraiva Cabral *

* General manager of Navaltik Management Lda; author of the books “Maintenance Organization and Management, from concepts to practice” in its 6th edition, and “Practical Guide to Maintenance Management of Buildings” due in April 2009, both edited by Lidel in Portuguese language; he has presented a number of papers, participated in many seminars on maintenance matters and is currently an invited lecturer of the APIRAC training courses on IAQ. Currently dedicates to consultant services on industrial, building and ship maintenance organization.

Abstract

This article reviews some key maintenance concepts and methodologies that have been standardized by the CEN (European Committee for Standardization) in recent years and provides guidelines to organize effective computer based maintenance management in buildings, satisfying modern EU requirements in what concerns maintenance, energy and internal air quality, and proposes a number of KPIs aimed at ensuring proper implementation of the CMMS, savings in energy, overall improvement in management and a driving motor for continuous improvement of the technical management of buildings.

Legal requirements for the maintenance of buildings

EU Directive 2002/91/CE dated December 16, establishes that EU members should implement an energy efficiency certification system that imposes specific requirements over the maintenance management function of buildings. The technical requirements of this Directive are set out in Portuguese Law by Decree-Law no. 79/2006, dated April, 4, the so-called RSECE (Regulations for Energy and Air-Conditioning Systems in Buildings).

With regard to maintenance these regulations basically stipulate:

- Maintenance management should follow established good practices;
- Technical management to rely on a qualified / certified engineer (TRF);
- Maintenance plan to cover all energy systems and cope for internal air quality (IAQ), requiring detailed written procedures (maintenance schedules), specification of frequencies and allocation to qualified / certified technical intervention personnel (TIM).
- Maintenance plan to include periodic energy and IAQ audits
- Maintenance history records detailing the names of the people who carried out the work
- Energy consumption monitoring and analysis
- Specification of relevant HVAC equipment running parameters
- A number of small details usually included in the “established good practices” concept.

Therefore, building management has to deal with a number of important legal requirements that will improve management quality. However, these do not exclude the whole maintenance issue; they rather provide a solid stand point to go further, to reduce costs and increase profits, to improve human comfort, safety and environment preservation.

We should recognize the merits of these regulations and implement them positively looking at their real future potential.

Facts and figures on maintenance

Literature on Maintenance has established some guidance figures over the theme of proactive (planned) maintenance versus reactive (corrective) maintenance.

- Well maintained equipment lasts 30 to 40 % more than poorly maintained equipment.
- Studies have shown that effective preventive maintenance once implemented will reduce energy consumption by 5 to 11%.
- Maintenance costs distribute approximately 50 % to manpower effort and 50 % to spares and materials.
- An efficient store should provide a service level (percent of the times that a part requested is available) above 95 %.
- In reactive maintenance up to 20 % of spare parts may be waste
- Preventive maintenance reduces dramatically downtime and improves equipment efficiency; studies have shown that equipment efficiency losses are always greater than downtime losses.
- Reactive maintenance work costs 2 to 4 times more than planned work.
- In a well organized maintenance the proactive / reactive work ratio should be 80 % or more.
- In many cases when contractor maintenance is cheaper than in house it is because contractor planning, scheduling and materials usage is more cost efficient.
- Converting a traditional reactive maintenance type organization into a best practice organization can take 3 to 5 years.
- Exploring only 50 % of the resources of a typical CMMS is common to many organizations using these systems.

Further to these cost based figures that we can broadly manipulate around our case there are many other issues that are more relevant:

- Environment preservation
- People safety
- Good social image and sustainability
- Satisfying legal requirements.

Slackness in any one of these may impair the standing or, in extreme cases, condemn by itself the whole enterprise.

And the good thing is that with a sound set of meaningful and consistent maintenance key performance indicators you can check if some of the above arguments belong to the specialist’s wishful thinking approach or if they are actual handy targets that you can set and evaluate for yourself.

Maintenance concepts

The maintenance discipline has in the last 4 or 5 years been furnished with a series of standards and management approaches that are referred in the bibliography. Among other things these standards aim at putting people speaking the same language and figures expressing the same parameters.

The most relevant ones are:

- Maintenance terminology, EN 13306 [8]
- Maintenance Key Performance Indicators EN 15341 [9]
- Instructions for the preparation of maintenance contracts, EN 13269 [7]

Lets us review some important key concepts.

Maintenance plan is a *structured set of tasks that include activities, procedures, resources and the time scale required to carry out maintenance*.

Availability is the *ability of an item to be in a state to perform a required function under given conditions at a given instant of time or during a given time interval, assuming that the required external resources are provided*. In the management context, it is an “a posteriori” indicator given by the ratio between the time that the item actually performed the required function and the required time.

Failure is the *termination of the ability of an item to perform a required function*. *Failure is an event, as distinguished from fault, which is a state.* The limitation of this definition is that it does not clearly define the level of ability after which the item is considered as not being performing. We suggest that you complement the standard definition in your particular context with a precision of the type “… considering that the item is not able to perform the required function when: a) it is totally unable to operate, or b) requires an immediate unplanned stoppage, or c) requires an unplanned repair within a time frame of less than 2 hours.

Fault is the *state of an item characterized by the inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources*.

Operating state is the *state when an item is performing a required function.*

Required time is the *time interval during which the user requires the item to be in a condition to perform a required function*.

Maintenance time is the *time interval during which maintenance is carried out on an item either manually or automatically, including technical and logistic delays*.

Downtime due to failure is the *time interval during which an item is in downstate due to a failure.* It is also referred as the *time to restoration* (IEC 60050-191).

All concepts appear to be quite clear but, sometimes in day to day life, this is not the case. You should have at hand the referred EN standards and consolidate the meanings of each concept in your case.

Maintenance objectives and performance indicators

We start the approach to maintenance management asking the questions:

- What do we want? What are the objectives?
- How do we target them? How do we control them?

Assume that you have elected the following set of objectives for a building:

1. Maintenance management in accordance with the established good practices of this discipline.
2. Accomplishment of legal regulations resulting from EU Directive 2002/91/CE
3. Energy control and optimization
4. Effective preventive maintenance leading to minimum number of failures and quick repairs when they occur
5. Effort on improvement maintenance
6. Optimized maintenance costs
7. Optimized operation costs
8. Good image

Accepting that *you only manage what you measure* let us set out the targets in terms of performance indicators.

According to EN 15341 [9], *indicator is a measured feature of a given phenomenon established by a formula that evaluates its evolution*.

What indicators should we select to target and control the above objectives?

<u>Objective 1 – maintenance according to the good practices</u>

If you introduce some established maintenance indicators and are able to consistently provide reliable information that means with great probability that you have a sound maintenance management system. And remember that the crucial issue in working with indicators is not their computation; it is rather the collection of the necessary information to compute them; the management system should make it for you.

<u>Objective 2 – Accomplishment of legal regulation</u>s

Regulations stipulate that you need to have an appropriate maintenance management system; that you establish a proper preventive maintenance plan for all HVAC equipments and IAQ issues, schedule energy and IAQ audits, use qualified / certified personnel and accomplish a number of administrative requirements easily covered by the system.

In what concerns energy management it sets out the necessity to compute the *Energy Efficiency Indicator* (EEI) which evaluates yearly performance against specified minimum objectives and requires improvement action should the set out limits be exceeded.

$$\text{IEE} = \frac{\text{Total energy consumption in one year}}{\text{Net plant area of the building}} \qquad \text{Kgep/Year.m2}$$

Where:

- Total energy (electricity + natural gas + fuel, etc.) expressed in the common unit Kgep (Equivalent kilogram of petroleum) consumed along one complete year
- Net plant area = total interior plant area measured to the inner sides of the walls

Therefore, your maintenance management system should cope for all maintenance activities and also be able to support the computation of the EEI indicator and to support eventual improvement actions should they be required.

IEE computation is further described under the title “Monitoring Energy Consumption”.

<u>Objective 3. Energy control and optimization</u>

Gathering information about energy consumption is essential to compute the EEI so you are bound to do it. You should also evaluate EEI evolution along the years and learn much about the behaviour of your building. In the short term you will be confronted with a lot of possible improvements in individual equipments and systems and will probably be introducing particular indicators and targets in this context.

<u>Objective 4. Effective preventive maintenance = minimum failures</u>

Maintenance effectiveness indicators are well served by standardized maintenance indicators as defined in reference [9] (identified as in the source):

$$T17 = \frac{\text{Total operating time}}{\text{Number of failures}} \quad \text{Hours}$$

$$T21 = \frac{\text{Total restoration time}}{\text{Number of failures}} \quad \text{Hours}$$

Where:

- Operating time = time interval during which an item is performing its required function;
- Restoration time = time interval during which an item is in downstate due to a failure (including administrative and logistic delays)
- Number of failures, see under Maintenance Concepts title.

T 17 expresses average operating time between failures, that is, gives an idea of frequency; T 21, the average time to complete repairs.

Note that in all indicators numerator and denominator refer to the same maintenance item (the building as a whole, a system, etc.) and to the same time period.

Remember that the crucial matter for the computation of indicators is the reliability of the source information; without this there is no meaningful indicator, at most we can “pretend” that we are managing!

<u>Objective 5. Effort on improvements</u>

Let us assume that the necessity of improvements had been diagnosed and we wanted some metrics to express effort in this area. Improvement maintenance is frequently identified as an ever present objective in buildings (introduction of energy saving equipment, improving accesses for maintenance, monitoring equipment and the like). A suitable indicator for this could also be selected from reference [9]:

$$E19 = \frac{\text{Cost of improvement maintenance}}{\text{Total maintenance cost}} \times 100\ \%$$

Where:

- Maintenance cost = wages + social taxes + extra time of personnel + external personnel + materials and spares + contractors + departmental costs (energy, machine tools, depreciation, etc.). It excludes downtime costs.
- Cost of improvement maintenance is the part of the maintenance costs dedicated to the *improvement* type of work

Objective 6. Optimized maintenance costs

An indicator suited for maintenance costs that furthermore provides good resources for comparisons between buildings and has good evolution features is also inspired in reference [9]:

$$E3 = \frac{\text{Total maintenance cost}}{\text{Net plant area of the building}} \quad €\ /\ m2$$

Where:

- Total maintenance cost, as in E19
- Net area, as in EEI.

Objective 7. Optimized operating costs

Operating costs fall in the domain of the operational management so let them establish their own indicators. But take a good note of those indicators as they are bound to be closely linked to your own, as the major cost issues in a building are clearly connected with maintenance and energy issues.

Objective 8. Good Image

It is also in the domain of operational management. They make their own indicators and you should try to use or create one or more indicators for maintenance that somehow express what *they* want.

This set of indicators constitute a *balanced score card* or a “*tableau de bord*” that expresses analytically the overall management objectives for the building, enabling comparisons with other cases and scope for projections and bench marking exercises.

These indicators carry mutual relationships that can be evaluated along time pointing out problem areas or domains requiring action. For example, a focus on improvement maintenance is bound to lead to an increase in the maintenance cost indicator but also induce the lowering of the energy efficiency indicator. You should be able to *feel* these relationships.

If your management system is capable of providing the above indicators and to manipulate the maintenance concepts behind them, that is, failures, maintenance times, work types, availability, maintenance effort, and the like, that means that it is a capable maintenance management system.

Computerized maintenance management system

A maintenance management system today is made up of specialized software, the so called CMMS, plus an appropriate organization incorporated along the definitions stage of the software implementation. It provides basically the following resources:

- Equipments / maintenance items: coding and registration complete with technical particulars + maintenance plan + relationship with applicable materials and parts; quick tracking of equipments; links to technical documentation.
- Materials: coding and organization of all materials likely to be required for maintenance, both those intended for warehousing and those to be acquired from supplier when required; good tracking capabilities and relationship with equipments / items where used; intrinsic resistance to the growing of the materials population.
- Work orders: planning, scheduling and detail management of all types of maintenance activities; reporting of work done, dates and maintenance times, unavailability; man-hour effort; materials usage; contractor services. Costs. Automatic renewal of systematic work orders based on either calendar time or running units. Automatic build up of maintenance history of each item.
- Analysis: computation of relevant maintenance parameters and maintenance performance indicators (KPIs). In fact, it should be a very powerful reporting tool on maintenance issues.

It is indeed a much more complex software tool than it appears at first sight. A few recommendations concerning the choice:

- By all means discard developing such tools indoors. It would be painful, discouraging and most probably endless.
- Partial tools based on Excel or adaptation of administrative management ERPs are not recommended since in the short term show their limitations.
- Look for simplicity. Contrary to the user of an administrative type of software that spends most of his time around the software the maintenance guy should only dedicate his spare time to it.
- Take the opportunity to improve your skills by learning with an experienced and specialist maintenance management tool rather than requiring that the software work like you have always done.

Maintenance management organization

Definitions in a CMMS require that you take into account the established maintenance concepts. Organizing it for a building is very similar to what it would be for a ship or an industrial plant. If you design an organization that is suited to provide maintenance KPIs (key performance indicators) plus indicators for energy and fluids utilization you are sure to have organized it properly for a building.

Let us tackle some of the most critical issues.

<u>Plant item organization</u>

Coding and coordinating maintenance items are an important issue. Suggested good practice is exemplified in Figure 1.

Unit	Funcional coordination		Identity	
Cost Center	Major Group	System	Tag ID	Description
03	09	63	BB-0012	
Building III	Energy & Fluids	Sanitary Supply	Sanitary supply pump no. 1	

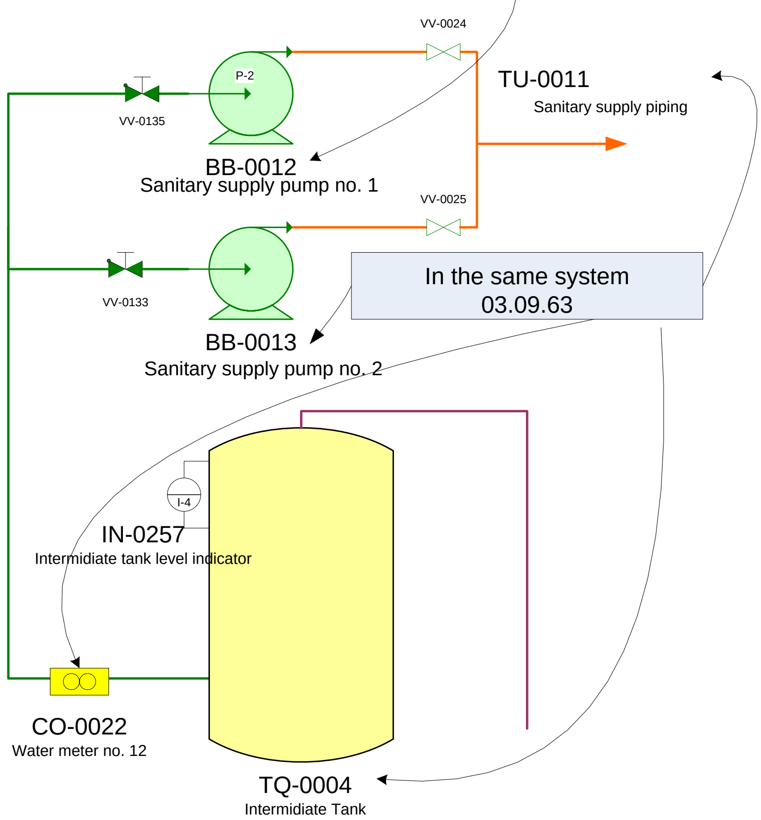


Fig. 1 – Coordination and coding of a maintenance item in a building

Where:

- Cost centre, designates the overall plant entity as seen by the finance department. It may be identified, in ways such as:
    - 03 - Building III, or
    - 234 – Bank XYZ main office
        - 234.001 Main Office Lisboa
        - 234.002 Byres Road Branch
        - 234.003 Kilmarnock Branch, etc.

  Coding 03 or 234.001, 234.002, etc. should conform to established practice; cost centres identification should be the same throughout the organization.

- Functional coordination – major group + system: expresses the system in which the maintenance item is, the function it is contributing to.
- Item identification number, BB-0012, where BB stands for the item type, in a broad sense – pump, valve, piping, tank, heat exchanger, chillier, etc. – and 0012 is a sequential number.

Technical datasheets for the maintenance items

Each item needs to have its main particulars recorded in accordance with a previously designed datasheet. That design is normally associated to the item type each one having its particular set of characteristics.

Work type classification

Maintenance work types should be classified according to the type of maintenance, whether planned, unplanned, systematic or non systematic.

Suggested classification for buildings:

Systematic maintenance

- Type A – Systematic work. Typically include predetermined schedules recommended by the manufacturers and/or established by the organization based on experience
- Type Q – Quality / certification. Administrative type of work connected with compulsory inspections, certificates, audits and the like (energy / IAQ audits, calibrations, lifts, fire extinguishers, etc.)

Condition based maintenance

- Type B – On condition work. Includes the interventions that are to be carried out when there are symptoms of the approach of a mal-functioning condition or an imminent failure (slack driving belt, singing roller bearing, low efficiency, leak, etc.).
- Type M – Improvement. Planned intervention aimed at improving some feature (fitting energy saving device, control instrument, improving maintenance access, etc.)

Corrective maintenance

- Type C – Repair. An unplanned intervention required as a result of a failure. Its necessity results usually from a Work Request.

Having the work types thus classified one is able to evaluate effort and costs in each one of these types, compute particular indicators and means of analysis.

Work types A, Q, B and M are the planned ones, those that the manager can control and mix so as to avoid the undesirable C type which induce unexpected unavailability and cost 3 to 4 times more.

The manager should target the planned work types and strive to reduce the C type to a reasonable minimum. Terry Wireman [10] suggests that 20 % effort in type C work is a realistic target; Japanese engineers in industry strive for the nice round figure of zero-failures. You decide your target!

Managing maintenance with a CMMS

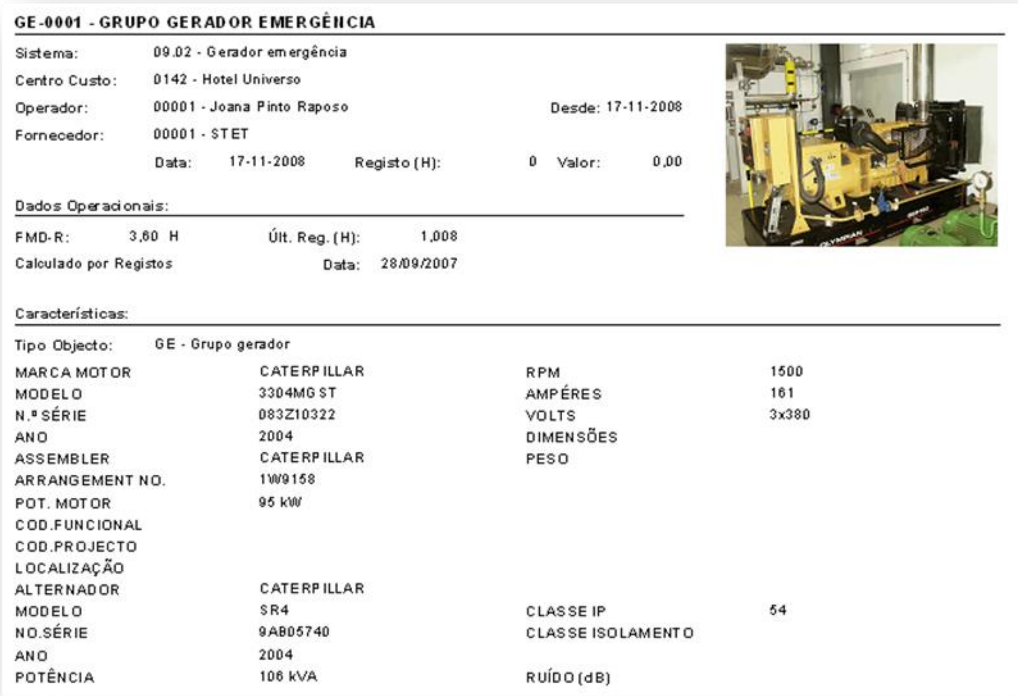
Once we have introduced the main organization definitions in our CMMS as described in the previous paragraph we can proceed to our management function.

Asset coding and registration

In accordance with the rules set up along the definitions process:

- Item coding + description
- Functional and cost centre coordination
- Fill technical particulars datasheet + additional linked documentation
- Input operational data: required time and forecast of running time

An item datasheet may contain technical information as illustrated in Fig. 2.



GE-0001 - GRUPO GERADOR EMERGÊNCIA

Sistema: 09.02 - Gerador emergência

Centro Custo: 0142 - Hotel Universo

Operador: 00001 - Joana Pinto Raposo Desde: 17-11-2008

Fornecedor: 00001 - STET

Data: 17-11-2008 Registo (H): 0 Valor: 0,00

Dados Operacionais:

FMD-R: 3,60 H Últ. Reg. (H): 1,008

Calculado por Registos Data: 28/09/2007

Características:

Tipo Objecto: GE - Grupo gerador

MARCA MOTOR	CATERPILLAR	RPM	1500
MODELO	3304MG ST	AMPÉRES	161
N.º SÉRIE	083Z10322	VOLTS	3x380
ANO	2004	DIMENSÕES	
ASSEMBLER	CATERPILLAR	PESO	
ARRANGEMENT NO.	1W9158		
POT. MOTOR	95 kW		
COD.FUNCIONAL			
COD.PROJECTO			
LOCALIZAÇÃO			
ALTERNADOR	CATERPILLAR		
MODELO	SR4	CLASSE IP	54
NO.SÉRIE	9AB05740	CLASSE ISOLAMENTO	
ANO	2004		
POTÊNCIA	106 kVA	RUÍDO (dB)	

Fig. 2 – Example of a maintenance item datasheet

Some rules to observe:

Buildings datasheets require the following information to be included:

- Owner + contact coordinates
- Renter + contact coordinates
- Certified manager (TRF) + contact coordinates
- Public identification of the building (Constituency registration, number, etc.)

- Construction details: Year built constructor, engineering, etc.
- Type of activities carried out
- Net area and air conditioned area (m2) + installed HVAC power
- Average number of users

As built drawings and specifications are to be kept up to date with eventual alterations made to the original design. In fact, technical documentation should be treated as a maintenance object with a maintenance history kept up to date.

Monitoring and measuring devices (MMD): technical datasheets, further to the equipment particulars, should include metrological information for calibration purposes (range, resolution, division, admissible error, calibration standard, etc.).

<u>Maintenance planning and preventive WO preparation</u>

Maintenance planning and work schedule descriptions should follow the established good practices that can be summarized as follows:

MANUAL: the first block should include a reference to the equipment manual if applicable, page numbers, etc,

SAFETY PRECAUTIONS: a second block with a telegraphic note to safety precautions to be observed to carry out the work – disconnect electrical supply, use protection equipment: gloves + protection glasses; outline work area with caution signalling; oil and filters to be disposed in proper container, etc..

TASKS: These should be telegraphic and synthetic still comprehensive so as to provide a complete check list of what should be done: it does not offend the experienced engineer and helps the less experienced one.

TEST ON COMPLETION: a very wise note to close the work description as it avoids many problems and maintenance recalls.

RESOURCE PLANNING, TIME AND COST ESTIMATES: maintenance times (TM), man-hour effort estimates (MH) and material requirements planning should be included in each preventive schedule. This is essential to plan the activities properly and ultimately will dispense a lot of reporting if planning is so reliable that you can assume that it can work also as the work report (as it is the case with vehicle maintenance where you stipulate that changing the distribution chain takes always 2.6 MH and requires a chain Part Number X, and so the price is Y).

A very effective maintenance schedule is the so called “*Walk around routine*” whereby the engineer walks around a particular site (e.g. the pump room) and inspects everything critically with wide open eyes, hands and ears, so as to take immediate action, prepare a Work Request or a Work Order to whatever item he may find as deserving it: dirt, abnormal noise, leaks, connection slackness amongst other things, are frequently detected and corrected before they originate problems.

<u>Work order management</u>

Work Order management is the front line of maintenance management. The very first rule to observe is to ensure that any *maintenance effort is supported by a WO* duly coordinated in the *type of maintenance work* as defined, and that its cost is allocated to the equipment.

The flow of maintenance work is outlined in Fig. 3 next page. Starting with the case of a preventive WO, the processes and events are as follows:

1. *Planned maintenance schedules (PMS)* – Preventive work by nature is a planned one. It assumes the existence of a pre-prepared maintenance schedule (PMS) for the equipment.
2. *Scheduled WO* – scheduling a WO involves incorporating the contents of a PMS into the WO specifying the actual calendar date or the running record when that work is due. The software triggers out with antecedence the date at which the WO should be performed.
3. *Work calendar* – The WO calendar shows for the whole set of maintenance items the planned WOs with their due dates. When the WOs are controlled by running records, due dates are automatically estimated. The WO schedule can then be looked at under a number of criteria chosen by the User: work due next week, all pending WO, all work to be carried out in system A, etc. The manager looks at the due work established blindly by the software application and takes the appropriate decisions as to the actual dates to carry out each WO.
4. *Running records* – Running records are a necessary input when the work order scheduling is based in running records rather than in calendar time. A compressor whose maintenance is set for each 1000 hours requires that a regular procedure for recording running readings be in place.
5. *Analysis of maintenance calendar* – The maintenance manager analyses the maintenance calendar to take decisions as to when he should actually perform the work. Such analysis will cover the following:

   Human resources (MH): do we have the personnel necessary to carry out the job? He should analyze the work load comparing the overall programmed MHs with the actual availability of MH for the period: let AL be the available MH load and PL the programmed MH load. The ideal situation is to have PL = AL, meaning that all available resources will be used in the programmed work; if PL > AL he cannot carry out all the work and he can postpone some WOs, contract external services or plan overtime; if PL < AL that means that there are more human resources than those required by the maintenance calendar; he may then anticipate some work planned for later or take the initiative to carry out some of those tasks for which there is never an opportunity.

   Materials: are all the planned materials available for the period? Should check item by item what is available.

   Other: do we have all the other planned resources available for the scheduled dates? Do we have the 5 t crane for day X to support the work? Contractor Y? Etc.. Last but not least, do we have the necessary financial resources to cover the requirements?

The golden rule is to issue the WO <u>only when all the human and logistic resources are available</u>.

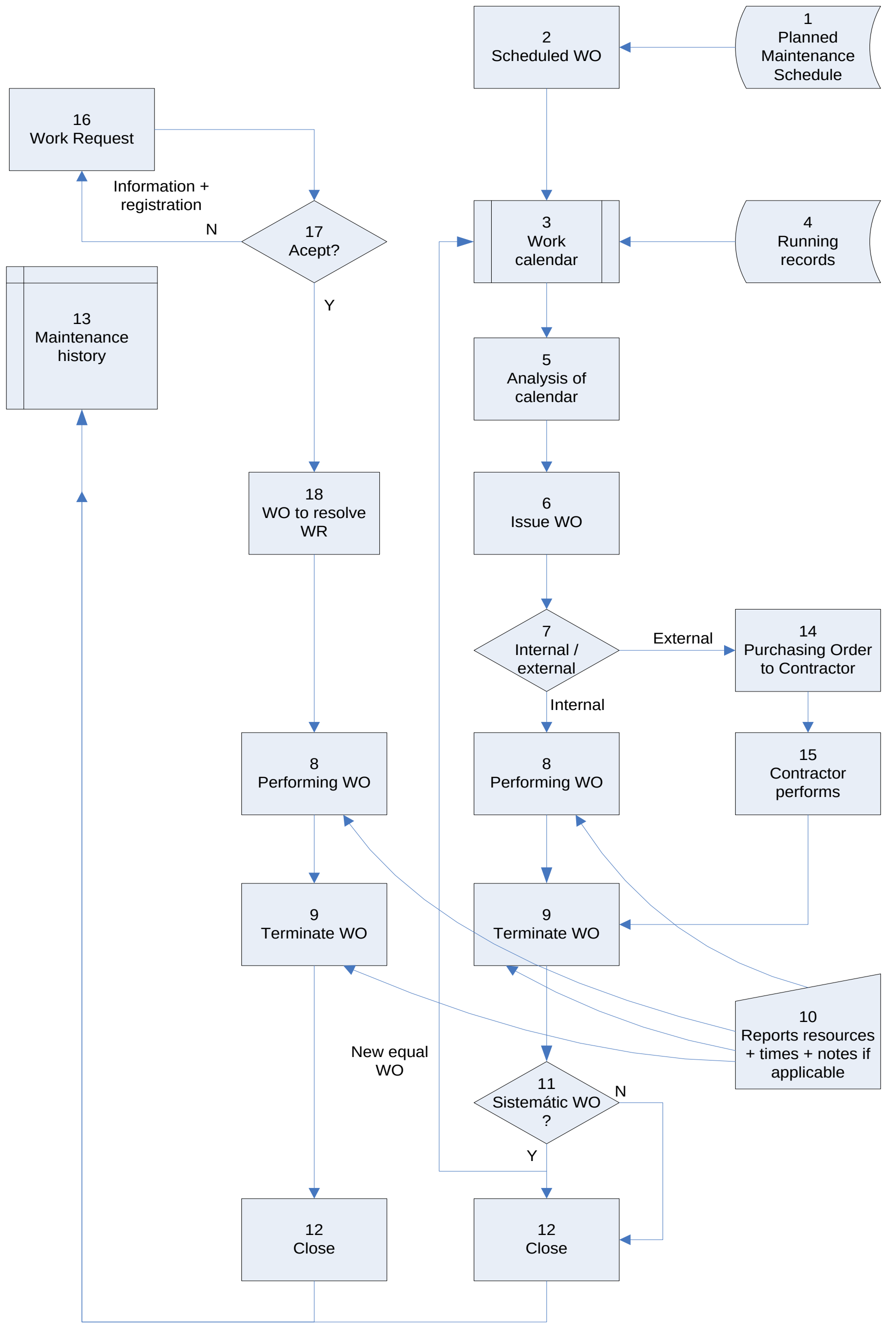


Fig. 3 – Work Orders flow diagram

6. *Issue WO* – Issuing a WO means deciding to carry out that WO in a given date. An issued WO has its performance date decided acquiring the status of *work in progress*, the responsibility of its performance having been transferred from the Manager to the person in charge of the intervention area (e.g. the foreman). Issuing a WO should be done only when the conditions to carry it out are ensured. Any eventual bottlenecks should occur at the

planning stage (before issuance) and NEVER in the intervention area. The main role of the maintenance manager is to send to the intervention area a well balanced set of maintenance WOs whose performance in the defined dates is feasible.

7. *Internal / external?* If the work is to be carried out by the internal maintenance resources the WO should be allocated to an internal maintenance performer (e.g. a department + trade); if it is to be performed by a contractor it should be allocated to that contractor. This is a decision to be taken at the issuance stage: the manager may retain whatever is planned or can decide otherwise if conditions so require. If performance is to be external proceed to step 14.

8. *Performing the WO* – The issued WO is under the responsibility of the intervention area. The work initiates and the WO is prepared to receive reporting of MHs and any other resources involved in its performance as described in step 10.

9. *WO termination* – Terminating a WO means that the planned work has been fully accomplished including testing. The WO assumes the terminated status and it is necessary to record the appropriate data:

   End: date and time. NB: when the WO is controlled by running records it is also necessary to record the running record at termination (as in the case of a car that ends the 60,000 km with the meter at 60,896 km).

   Times and delays: as applicable: TW waiting time, when there is a work request; TM maintenance time; PDI performance time period; TR repair time; TIM down time related to maintenance; TIA down time due to failure. The CMMS normally helps to compute these times but the manager should confirm such computations.

   Notes: other relevant elements should be reported. These can include a technical evaluation of the equipment condition, a diagnosis as to the symptom and cause of a failure, association of a document such as a datasheet of measures before and after the repair, a certificate, photo and the like.

10. *Resources reporting* – While the WO is in the status in progress or terminated the resources involved in its performance should be recorded:

    Man-hours: recorded for each worker involved (the worker should be individually identified)

    Materials: recorded along. Note that a material is only considered as such in the management system if it is duly coded and registered in the system materials master file.

    Other resources: record contracted services, non-registered materials, etc.

11. *Systematic?* – If the WO is of the systematic type at termination the system makes a new identical WO for T time later, T being the periodicity of that WO. This new WO shall be automatically incorporated in the work schedule

described in step 3. If the WO is not systematic it is simply transferred to the maintenance history duly coordinated in the equipment to which it refers.

12. *Closing* – Closing a WO is an administrative task that once accomplished renders the WO unable to receive any further reporting elements such as man-hours, parts, costs. The closed WO is a work report that can no longer be changed.
13. *Maintenance history* – The CMMS condenses and organizes in chronological order for each equipment all the maintenance information resulting from the WOs.
14. *Contracting outside* – When a WO is to be performed by a Contractor a specific administrative purchase process is carried out.
15. *Performance by a Contractor* – The technical reporting of a WO by a third party contractor should be agreed upon beforehand. Desirably it should include all relevant technical data as if it were performed in house. In many cases the contractor can be asked to fill in the reporting elements of the WO.

A non-programmed WO, such as a repair, follows an identical path but initiates on the performance stage, i.e. step 8. Before that there may have been steps 16 to 18:

16. *Work request* – A work request is a document that requests a maintenance department to carry out a particular job. A WR should be documented in writting and contain: identification of the requester, date and time the work is necessary, urgency level, description of the request and relevant information. The date and time necessary - in most cases, the current time - set the departure point to start counting the waiting time which occurs until the attending WO initiates, that is, the start time of the earliest MH record on the WO.
17. *Acceptance of WR?* – Decision as to the validity of the WR: if the WR lies within the scope of intervention of the department to which it was directed an attending WO is prepared and the WR assumes automatically the status *being attended*; if the WR lies outside the scope of intervention of the department it assumes the status *rejected* and a reason for such rejection should normally be given. Repairing the chair of Mrs. Smith may be outside the scope of the maintenance department so she could get a message to her WR such as: “Rejected: please ask John Allen” and the maintenance department would have thus discarded its involvement in the matter.
18. *WO to resolve WR* – the attending WO is like any other one and so is its contents. In most cases it is not a planned job so the WO assumes the form of a work report.

Monitoring energy consumption

Energy analysis is carried out for one year periods with monthly records.

Energy consumption readings are normally taken at the end of each month, although this frequency can be increased for specific purposes.

The consumption in the month is obtained by subtracting the readings at the end and at the beginning of the month: if the readings are taken exactly on the first day and on the last day of the month at the same time, the difference is the actual consumption of the month, otherwise, if you have, for example, a reading on the 27th March and another on the 30th April, to calculate the actual consumption of April you should have to subtract an estimate of the consumption between the 27th March and the 1st April. This approach is fairly accurate but the most practical method is to ensure that you take a reading on the last day of each month approximately at the same time. If you introduce some inaccuracies in the monthly evaluations it may happen that at the end of the year you get a yearly consumption that is not exactly the sum of the consumption of the months. Normally this would be no problem and confirm the old saying that an engineer can conclude soundly that 2 + 2 = 3.9999.

CO-0001 - E. ELEC. (HP) HORAS PONTA "HOTEL UNIVERSO"

Data	Registo	Unid.	Operador
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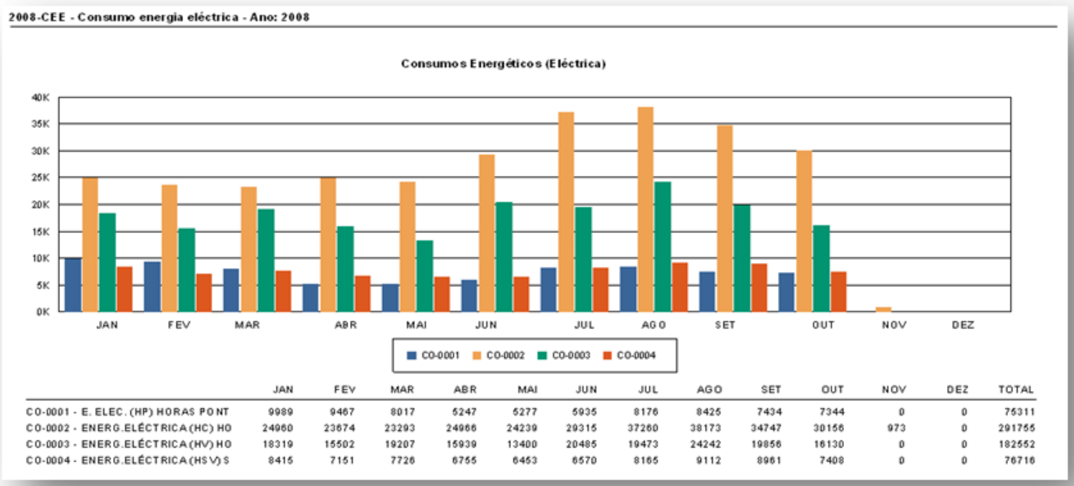
31-10-2007	18.021,00	KWH	09152 - Carlos Fernandes
30-11-2007	27.495,00	KWH	09152 - Carlos Fernandes
31-12-2007	37.820,00	KWH	09152 - Carlos Fernandes
31-01-2008	47.802,00	KWH	09001 - Maria Helena Tomaz
29-02-2008	57.336,00	KWH	09001 - Maria Helena Tomaz
31-03-2008	65.439,00	KWH	09001 - Maria Helena Tomaz
30-04-2008	70.692,00	KWH	09001 - Maria Helena Tomaz
31-05-2008	75.943,00	KWH	09001 - Maria Helena Tomaz
30-06-2008	81.818,00	KWH	09001 - Maria Helena Tomaz
31-07-2008	89.985,00	KWH	09001 - Maria Helena Tomaz
31-08-2008	98.434,00	KWH	09001 - Maria Helena Tomaz
30-09-2008	105.879,00	KWH	09001 - Maria Helena Tomaz
30-09-2008	105.879,00	KWH	09001 - Maria Helena Tomaz
31-10-2008	113.223,00	KWH	09001 - Maria Helena Tomaz

Fig.4 - Energy consumption readings

The calculated monthly consumptions can then be set out in an evolution chart as shown in Fig. 5 obtained from a hotel application detailing the various types of energy involved.



	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ	TOTAL
CO-0001 - E. ELEC. (HP) HORAS PONT	9989	9467	8017	5247	5277	5935	8176	8425	7434	7344	0	0	75311
CO-0002 - ENERG.ELÉCTRICA (HC) HO	24960	23674	23293	24966	24239	29315	37260	38173	34747	30156	973	0	291755
CO-0003 - ENERG.ELÉCTRICA (HV) HO	18319	15502	19207	15939	13400	20485	19473	24242	19856	16130	0	0	182552
CO-0004 - ENERG.ELÉCTRICA (HSV) S	8415	7151	7726	6755	6453	6570	8165	9112	8961	7408	0	0	76716

Fig. 5 - Monthly energy consumptions ***(courtesy Navaltik Management, ManWinWin Sunshine)***

The various types of energy can then be converted into the common unit “Kgep” (Equivalent petroleum kilogram) and summed to obtain the aggregate energy consumption. You may use the following conversion table:

Energy type	Reading units	To “Kgep” multiply:
Electricity	kW.h	0,290
Natural gas	m3	0,82
Propane	Kg	1,14
Thick fuel	Metric tonnes (t)	969
Thin fuel	Metric tonnes (t)	984
Gasoil	Litres (l)	0,84
Kerosene	Litres (l)	0,79

The resulting evolution graph of the EEI (monthly consumption divided by the net building area) can then look like in Figure 6. It shows the tendency towards the end of the year. Note that by definition the actual EEI will be the one you get at the end of the year.

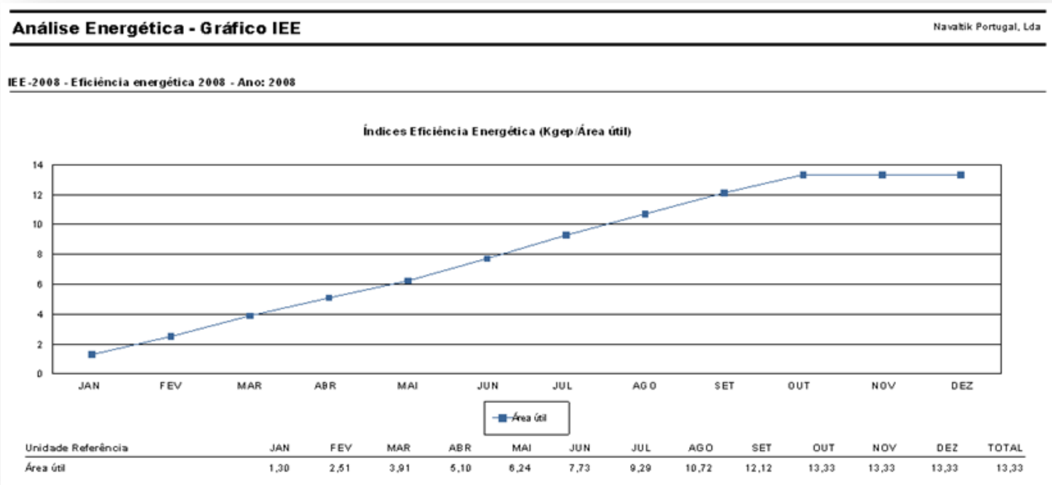


Fig.6 - Monthly evolution of EEI ***(courtesy by Navaltik Management, ManWinWin Sunshine)***

Continuous improvement

Continuous improvement is the focus of modern management, a key concept in ISO 9000 and other quality standards and an ever present reference in corporate orientation guidelines.

If you have established a sound maintenance management system in your building and have elected a set of meaningful management indicators (not necessarily many) you are set to learn a lot about your plant, detect problems, weaknesses and set realistic objectives and targets.

If furthermore you have a number of similar plants to manage, or good relationships with your neighbour with an identical case, you shall be able to make very useful comparisons and bench marking exercises.

It is interesting to note that the best organized industrial groups having plants spread over many locations in order to ensure that they have good maintenance management standards in those plants they just specify that each plant should provide the same set of key indicators: if the plant is able to do so, the first conclusion is that the maintenance management standard is satisfactory. Then, comparisons and bench marking come afterwards.

Energy consumption in buildings is a major issue so specific indicators in this area are most relevant. But they need to be linked with the other maintenance indicators as the energy performance of the equipments is closely connected with the quality of their maintenance; you should be able to *feel* and identify such relationships and tackle improvement with fully opened eyes.

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