UNIVERSITÀ DEGLI STUDI DI TRIESTE

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INDUSTRIAL PLANTS II

Chapter two ï part 6

Maintenance of Industrial Plants

Computerised Maintenance Management System

CMMS

DOUBLE DEGREE MASTER IN

ñPRODUCTION ENGINEERING AND MANAGEMENTò

CAMPUS OF PORDENONE

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CMMS (Computerized Maintenance Management System)

Briefs history

Before CMMS, obtaining centralized, dynamic visibility and automated management was impractical because maintenance information was buried in paper files, and later, scattered across spreadsheets.

The earliest versions of CMMS appeared in the 1960s and were typically used by large enterprises. Technicians used punch cards and IBM mainframes to inform computerized records and track maintenance tasks. In the 1970s, punch cards gave way to checklists fed into CMMS systems by technicians at the end of their shifts.

CMMS gained greater prevalence with smaller and mid-sized businesses in the 1980s and 90s as computers became smaller, more affordable, more distributed ð and more connected. In the 1990s, CMMS began to share information across local area networks or LANs.

The 2000s saw the emergence of intranets and web-based connectivity that expanded CMMS capabilities to a range of mobile devices, field applications and operational sites.

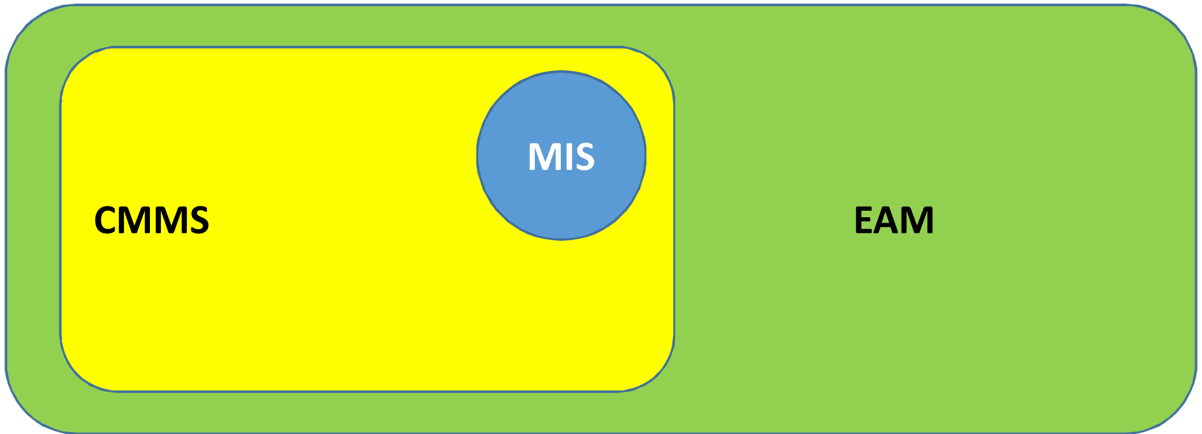
The latest generation of CMMS is cloud-based and highly mobile. It offers greater functionality with faster implementation, easier maintenance and greater data security.

CMMS (Computerized Maintenance Management System)

Structure

CMMS (Computerized Maintenance Management System) is the term used to identify a software application that supports the maintenance management information system often integrated with the **Enterprise Asset Management (EAM)** focuses on the entire lifecycle of an asset from design and installation through ongoing maintenance through to retirement or replacement.

The main objective of a **maintenance information system (MIS)** is the centralization and standardization of data flows that allow you to have an information set necessary to create a schedule of optimal maintenance actions. The MIS is not a simple information management system, but an organization tool capable of bringing effectiveness and efficiency to the maintenance system. Also referred as **CMMIS (computerized maintenance management information system)**



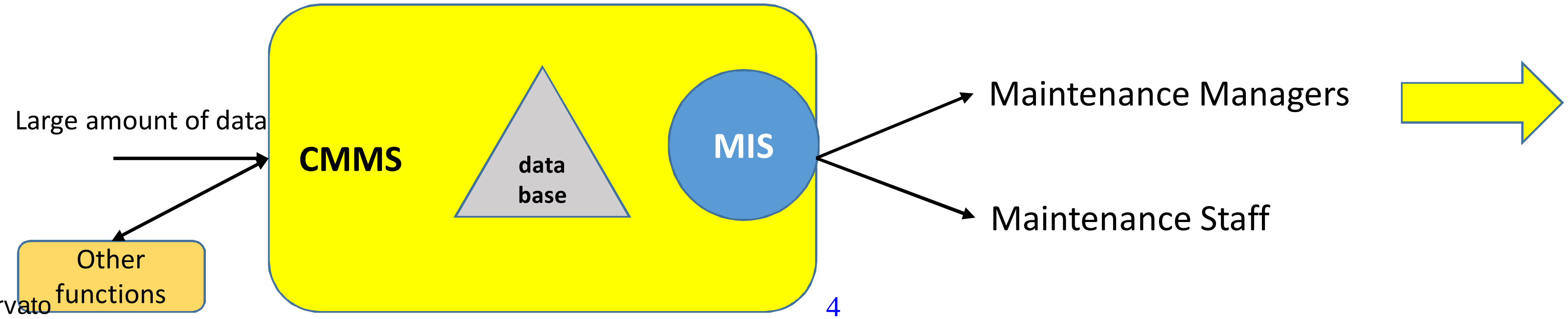
CMMS (Computerized Maintenance Management System)

Structure

The **large amount of data** to be analyzed, managed and modified for the management of a MIS has seen the creation of software packages capable of managing and reproducing this system efficiently (**CMMS**). These allow the collection and management of the large amount of data from maintenance interventions by interacting with neighboring functions such as the production department, personnel and warehouse management, with external companies. The core of a CMMS is its **database.**

The information contained in a MIS can be provided to two classes of users :

- the **maintenance manager**, who manages all phases and analyzes all information relating to maintenance activities;
- the **maintenance staff**, who only observes the information related to the activities that must be performed and reports failures that have arisen on the system's components.



CMMS (Computerized Maintenance Management System)

Structure

The **maintenance manager** can interact with the MIS getting info from the database:

- **asset setup**: the information of all the machines, plants, equipment is entered the system and can be viewed and modified, included the maintenance policy, the type of intervention and the pertinent parameters.
- **intervention planning**: they are defined according to the parameters of each machine, the cost of maintenance and stocks. In the case of preventive maintenance, the time interval between two interventions is displayed. The time value can be entered by the user, or can be calculated by the system. An operation can be translated, which involves a machine downtime, from a high period to a low demand period.
- **activity**: the work orders of all the planned interventions with a shorter date are launched and the interventions defined in the setup phase on a daily basis are displayed. The maintenance manager can decide the **order of execution** of the interventions by varying their **priority**. If an intervention is completed, the engineer in the maintenance activity closes the works by entering their execution time and all the other pertinent data;

CMMS (Computerized Maintenance Management System)

Structure

The **maintenance manager** can interact with the MIS getting info from the database:

- **Functional tree**: the database is designed in such a way as to be able to insert the functional tree of each machine in the system. The machinery is broken down into the individual parts that make it up and a maintenance policy is defined for each of them
- **Breakdowns**: they are reported by the maintenance staff to the manager who assesses their criticality and issues the work order by deciding the execution priority;
- **Warehouse**: the quantities of components are evaluated in order to determine whether to order them for future use in maintenance operations, together with all the pertinent performances evaluation parameters;
- **Human resources**: the quantity of human resources and their professional skills that can be used in maintenance activities are identified in real time;
- **Budget**: the forecasts of the cost of maintenance items are defined and the other **Key Performance Indicators** showing the trends towards the targets;
- **Historical data**: information relating to any maintenance work performed is provided.
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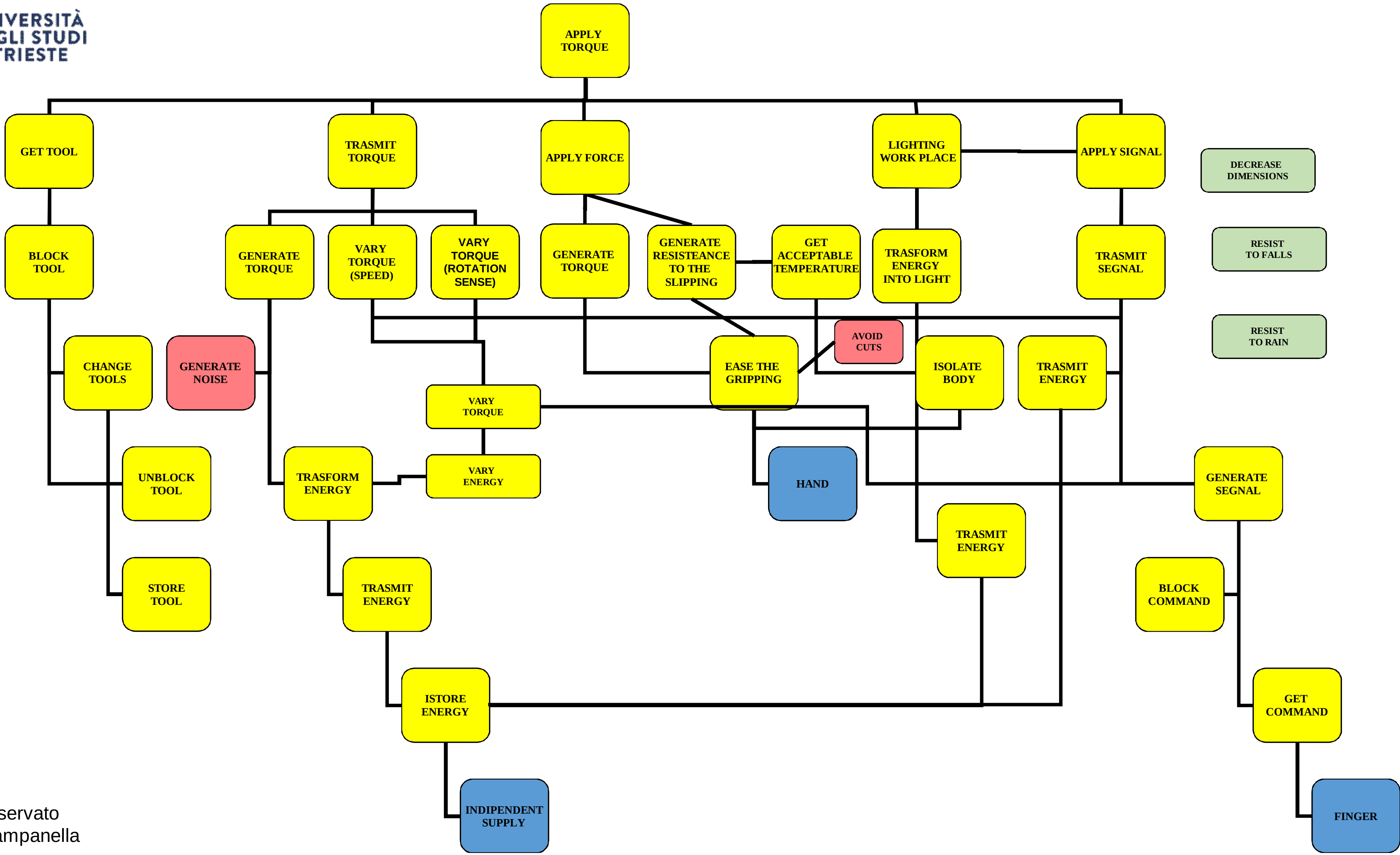
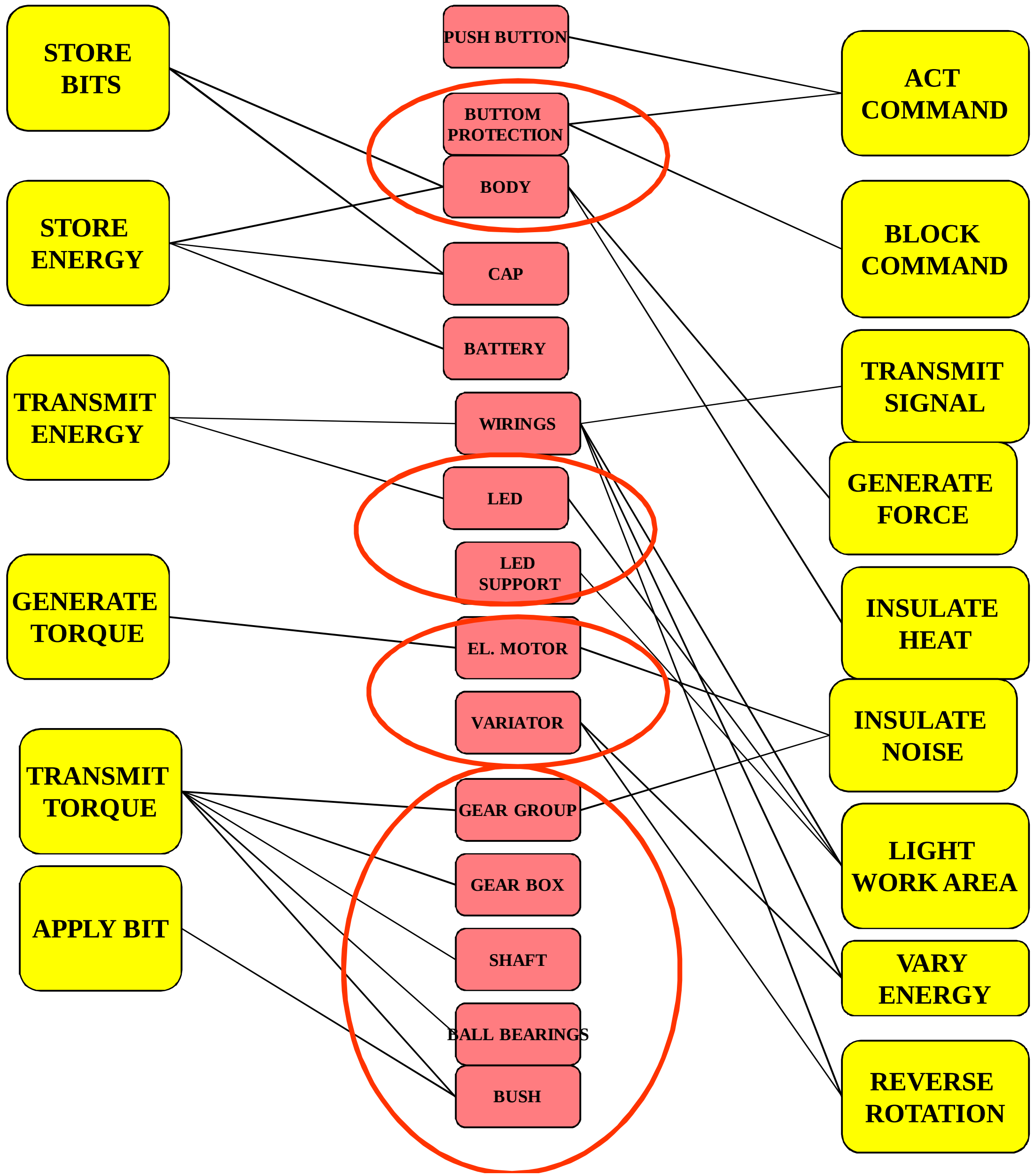


Materiale riservato
Raffaele Campanella

4 ï CONCEPT COMBINATION TABLE

Generate energy	Store energy	Transmit energy	Vary energy	Transfom electric energy into mechanical one	Transmit mechanical energy
Batteries ●	Batteries ●	wirings ●	current variator	DC el. motor ●	gears ●
Fuel cells	Batteries	pipes	tension variator ●	AC el motor 1 ph	direct coupling
photovoltaic cells	Batteries		valve	AC el motor 3 ph	
Air compressor	tank			turbine	


STORE BITS
STORE ENERGY
TRANSMIT ENERGY
GENERATE TORQUE
TRANSMIT TORQUE
APPLY BIT
PUSH BUTTON
BUTTOM PROTECTION
BODY
CAP
BATTERY
WIRINGS
LED
LED SUPPORT
EL. MOTOR
VARIATOR
GEAR GROUP
GEAR BOX
SHAFT
BALL BEARINGS
BUSH
ACT COMMAND
BLOCK COMMAND
TRANSMIT SIGNAL
GENERATE FORCE
INSULATE HEAT
INSULATE NOISE
LIGHT WORK AREA
VARY ENERGY
REVERSE ROTATION

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CMMS (Computerized Maintenance Management System)

Implementation

The **introduction and implementation of the CMMS system** in a company involve several steps:

- **Set Up the Right Culture**: There are a number of **guiding principles** (like Lean Production) you need to put in place before implementing, to make sure the organization can support it. Eg. enforce work **requests documentation**, perform proper **root cause analysis** on failures, and identity and **rank equipment by criticality**. These tasks executed on a consistent basis will create an accountability-focused platform thatōs essential when working with a **CMMS**.
- Once established these guiding principles, as in any organizational change, **support needs to come from the top down**. In order to fully integrate a CMMS into your organization, dedicated time and resources are required and overall management has to be committed to providing or allowing these resources. Make sure your **management and staff teams are aware** that it can take some time to see these returns but, at the end, itōs a tool that will, with the right resources and inputs, lead to smarter, more efficient and less costly maintenance.
- Above all, itōs important to **assign a CMMS champion**. This is someone who will work very closely with your CMMS vendor to build a realistic implementation plan that takes your organizationōs structure and goals into account.

CMMS (Computerized Maintenance Management System)

Implementation

- **Detailed Project Plan:** build a project plan with the help of your CMMS vendor. This plan should be as detailed as possible and can span from six months to a year and beyond.
- **analysis of the production system** in order to build or complete the asset database
- **analysis of the functional structures** of the machinery and the localization of the components. Each machine has been divided into three levels:
    - **groups,**
    - **components**
    - **elements or items**,

  which are the elementary parts on which the study focuses to determine maintenance policies;
- **analysis of critical issues** aimed at determining the consequences of the occurrence of a failure from an economic and safety point of view of a component. Historical data were used to determine the risks and repair costs in case of future component failure
- **choice of the maintenance strategy** to be implemented;
- **definition of the reliability models** of preventive maintenance items;
- **definition of the parameters** of the families of preventive maintenance components.

PREVENTIVE MAINTENANCE

AT CONSTANT AGE

Letôs suppose that:

N_c(t) = number of failures in the interval (0, t);

N_p(t) = number of preventive maintenance interventions in the interval (0, t);

C_c = cost of a corrective maintenance intervention (emergency intervention) ú/intervention, which takes into account both the replacement cost and the ones provokes by the the unit stop;

C_p = cost of a preventive maintenance intervention with replacement of the unit in the event of failure) ú/intervention;

T = Preventive Maintenance Time Cycle).T [1, ▯▯ ▯▯]

▯▯ ▯▯ = Maximum Preventive Maintenance Time Cycle, where the unit is operating without failure

▯* = Optimal Period of Preventive Maintenance optimizing the pertinent Maintenance cost

▯▯▯ ▯(▯) = Expected Cost Maintenance Per Period

▯▯▯ ▯* (▯) = optimal Expected Cost Maintenance Per Period

▯(▯) = Function of Density of Probability of failure

▯(▯) = Unreliability at time T(Cumulative probability of failure ▯(▯))

▯(▯) = Reliability at T time (1 ī ▯(▯))

▯ (▯)= Expected time of maintenance cycle if we do corrective maintenance due to a failure within 0 and T

▯ ▯▯▯ (▯) = Mean time between maintenance

PREVENTIVE MAINTENANCE

AT CONSTANT AGE

□□∗ □(□) + □□ ∗ □(□)

□□□ □(□) = ----------------------------

□ □□□ (□)

□

□ □□□ (□) = □(□) ∗ □ + Ú□∗ □(□)□t

0

PREVENTIVE MAINTENANCE

AT CONSTANT DATE

First of all, we need to define a function that determines the **expected cost for each maintenance interval T**:

$$EC(T) = [C_p + C_f * H(T)] / T$$

That is, the expected cost for period T can be determined as the cost of preventive maintenance, added to the cost of corrective maintenance for the **number of failures that occurred in the interval (0, T].**
Once the cost function has been described, the following step is to determine the expected number of failures in the cyclic maintenance period T as follows:

$$H(T) = \sum_{i=0}^{T-1} [1 + H(T - i - 1)] * \int_{i}^{i+1} f(t)\, dt$$

CMMS (Computerized Maintenance Management System)

Implementation

The determination of the two characteristic parameters of the Weibull distributions (β and α) if a set of data is available. For its application two equations of two unknowns must be solved:

$$\left[\frac{\sum_{n+1}^{N} t_T^{\beta} \cdot \ln t_T}{\sum_{n+1}^{N} t_T^{\beta}} - \frac{1}{\beta}\right] - \frac{1}{n}\sum_{1}^{n} \ln t_i = 0$$

$$\alpha = \sum_{n+1}^{N} \frac{t_T^{\beta}}{n}$$

where:

N = total number of samples available (observed);

n = number of breakages occurred on the N samples;

t_i = failure times of the samples with i = 1, é .., n;

t_T = observation period;

β = shape parameter of the Weibull distribution;

α = scale parameter of the Weibull distribution.

CMMS (Computerized Maintenance Management System)

Implementation

Example

The table riports an example done on actual components, with the Weibull paramentrs calculated as shown, the intervention times and the estimated monetary values

Family	Weibull parameters		Intervention times (h)		Cost of item (€)
	β	η	Preventive	Corrective	
Idle roller bearings	12,51	406,0	1	2	12,95
Motor roller bearings	31,81	384,6	1	2	141,85
Process roller bearings	11,43	432,0	8	12	24,58
Feeding hoses	3,28	222,8	1	3	10,00
Vacuum valves	7,73	7,52	1	2	–
Cutter roller bearings	12,04	403,1	1	2,2	36,40

CMMS (Computerized Maintenance Management System)

Implementation

Based on the parameters entered, the system assesses the costs of the two possible types of intervention: preventive and corrective. The total cost value is mainly influenced by the downtime (table), which affects the gross industrial margin of the machinery.

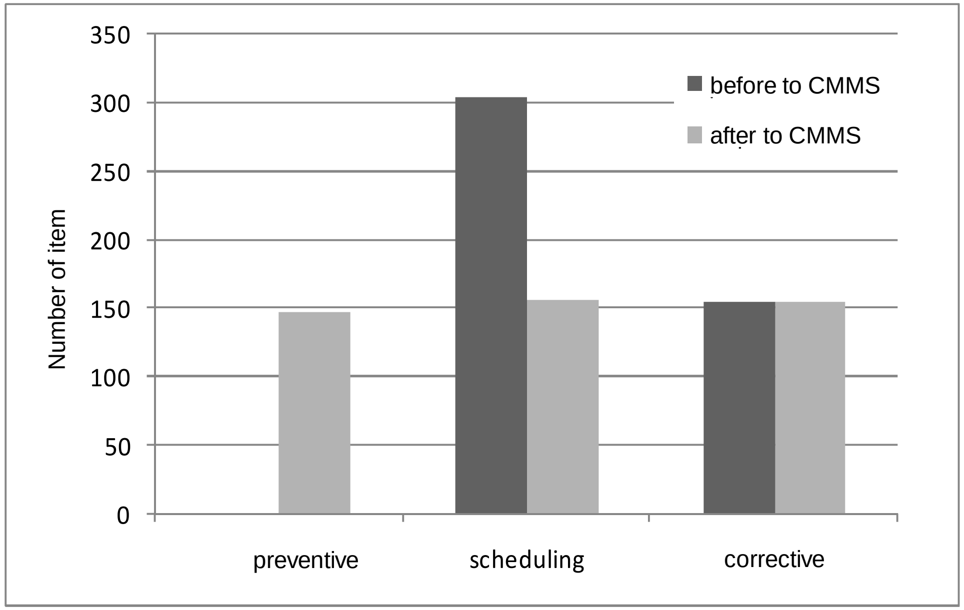
Machine	Item	Interventon costs (€)	
		Preventive	Corrective
Metalliizer1	Cusc. rulli folli	682,58	1340,58
Metalliizer2	Cusc. rulli folli	460,58	896,58
Metalliizer1	Cusc. rulli mot.	799,85	1457,85
Metalliizer2	Cusc. rulli mot.	577,85	1013,85
Metalliizer1	Cusc. rulli pro.	5288,58	7920,58
Metalliizer2	Cusc. rulli pro.	3512,58	5256,58
Metalliizer1	Tubi alim.	640,86	1920,86
Metalliizer2	Tubi alim.	418,86	1254,86
Metalliizer1	Valvole vuoto	658,00	1316,00
Metalliizer2	Valvole vuoto	418,00	836,00
Cutter 1	Cuscinetti rulli	217,20	452,40
Cutter 2	Cuscinetti rulli	152,40	291,60

Unit costs of the interventions

CMMS (Computerized Maintenance Management System)

Implementation

With the implementation of the system and the launch of the new CMMS program, the structure of the maintenance strategy is extremely changed. The introduction of the preventive maintenance policy has allowed a better balance between the three types of maintenance (figure)



Item maintenance classes

CMMS (Computerized Maintenance Management System)

Benefits

Å **Asset visibility:** Centralized information in the CMMS database enables maintenance managers and teams to almost instantly call up when an asset was purchased, when maintenance was performed, frequency of breakdowns, parts used, efficiency ratings and more.

Å **Workflow visibility:** Dashboards and visualizations can be tuned to technician and other roles to assess status and progress virtually in real time. Maintenance teams can rapidly discover where an asset is, what it needs, who should work on it and when.

Å **Automation: Automating manual tasks** such as ordering parts, replenishing inventory, scheduling shifts, compiling information for audits and other administrative duties helps save time, reduce errors, improve productivity and focus teams on maintenance ð not administrative ð tasks.

Å **Streamlined processes: Work orders** can be viewed and tracked by all parties involved. Details can be shared across mobile devices to coordinate work in the field with operational centers. Material and resource distribution and utilization can be prioritized and optimized.

Å **Managing field workforces:** Managing **internal and external field workforces** can be complex and costly. CMMS and EAM capabilities can unify and cost-effectively deploy internal teams and external partnerships. The latest EAM solutions offer advances in connectivity, mobility, augmented reality and blockchain to transform operations in the field.

CMMS (Computerized Maintenance Management System)

Benefits

Å**Preventive maintenance:** CMMS data enables maintenance operations to move from a reactive to a proactive approach, and so to an advanced **asset management strategy** can be developed. Data derived from daily activities as well as sensors, meters and other IoT instruments can deliver insights into processes and assets, inform preventive measures and trigger alerts before assets fail or underperform.

Å**Consistency and knowledge transfer:** Documentation, repair manuals and media capturing maintenance procedures can be stored in CMMS and associated with corresponding assets. Capturing and maintaining this **knowledge creates value** for the company. It also preserves that knowledge can definitely leave the company in case of resignation.

Å**Compliance management:** Compliance **audits** can interfere to maintenance operations and asset-intensive businesses as a whole. CMMS data makes an audit exponentially easier by generating responses and reports tailored to an auditôs demands.

Å**Health, safety and environment:** In line with compliance management, CMMS and EAM offer central reporting for safety, health and environmental concerns. The objectives are to reduce risk and maintain a safe operating environment. CMMS and EAM can provide investigations to analyze recurring incidents or defects, incident and corrective action traceability, and process change management.