Maintenance Management

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Agenda

- Maintenance
- Organization of Maintenance
- Design of maintenance
- Total Productive Maintenance
- Examples
- Case studies
  - Improvements in a pharmaceutical industry
  - GrAMS – Granted Availability Management System
  - Telemaintenace Intelligent System
  - Bridge Management System in Ferrovie dello Stato (IT)
- Maintenance of historic structures
- Risk map and Cova
- Rome: door to East

Background: A brave new world ?*

- Technological progress and social changes have been characterized at least the last 40 years:
  - Quantity and quality of information: low cost communication
  - Globalization: low cost transports
  - Consumptions increasing
  - Quality life increasing
  - Competition…

- New exigencies in Industry…:
  - Rationalization needs
  - Management needs
  - Cost savings
  - Green perspective
  - Customers perspective…

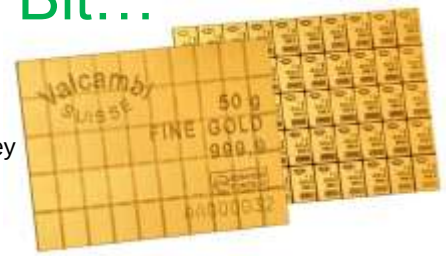
- … and new political institutions:
  - New political subjects
  - New economic agreements…

Innovation

Services

Networks

Bit…

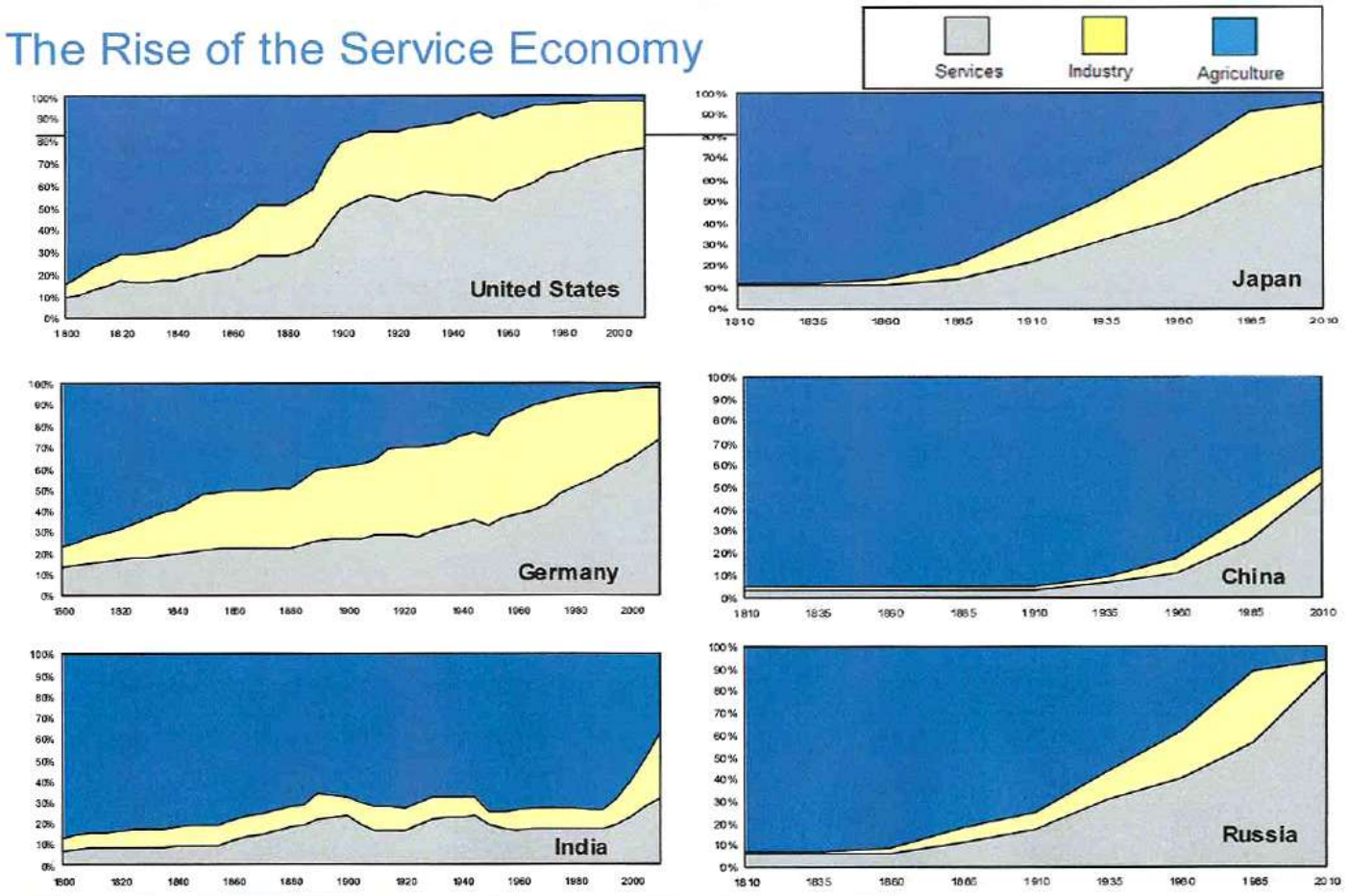


**A brave new world* by Aldous Huxley

Background: dematerialized products

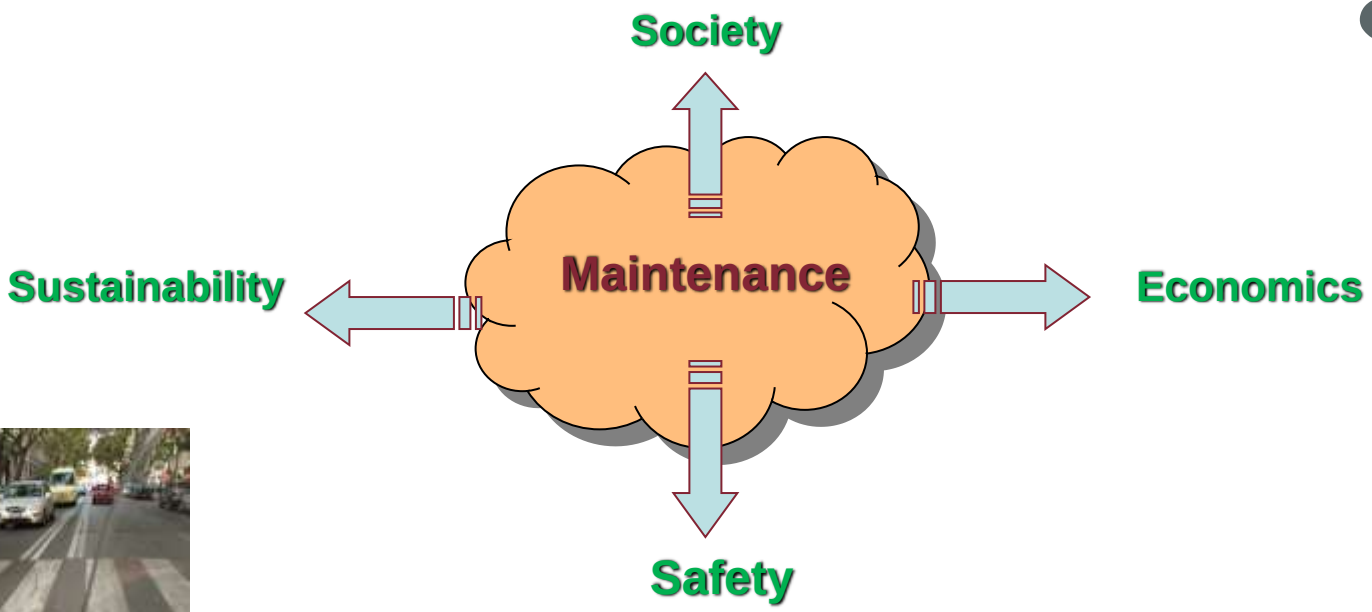
- Some examples:
  - Fleet management
  - Surgical instruments pay per use
  - Computers pay per use
  - Software on demand
  - Pay as you drive
  - Private labeling in the department stores
  - Pay as you fly
  - Pay as you work
  - Pay as you need
  - …

Background: dematerialized products



Maintenance and its evolution

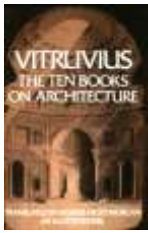
- Maintenance is in the middle of a strategic crossroad:



Maintenance and its evolution: some definitions

- It 's the business function that has as its purpose the efficient maintenance of machinery and equipment (**Resolution OECD**, **1963**).

- Combination of all technical, administrative and **management actions** during the life cycle of an item intended to retain it in, or restore it to, a state it can perform the required function (**EN 13306**, **2001**).



Today:

Maintenance has gone from **support service** to support production and for the repair or removal of decay in buildings, systems and structures…

…to…

… **all that is directed to the preservation of systems**, also complex, both with regard to their consistency and to their **efficiency**.

Background: Maintenance

- Maintenance refers to one of the three main life phases of every industrial good:
  - Construction
  - Use
  - Preservation, i.e. the maintenance of its functionality and efficiency.

- Such a potential value is further increasing at present as the national systems are characterized by limited expansion.

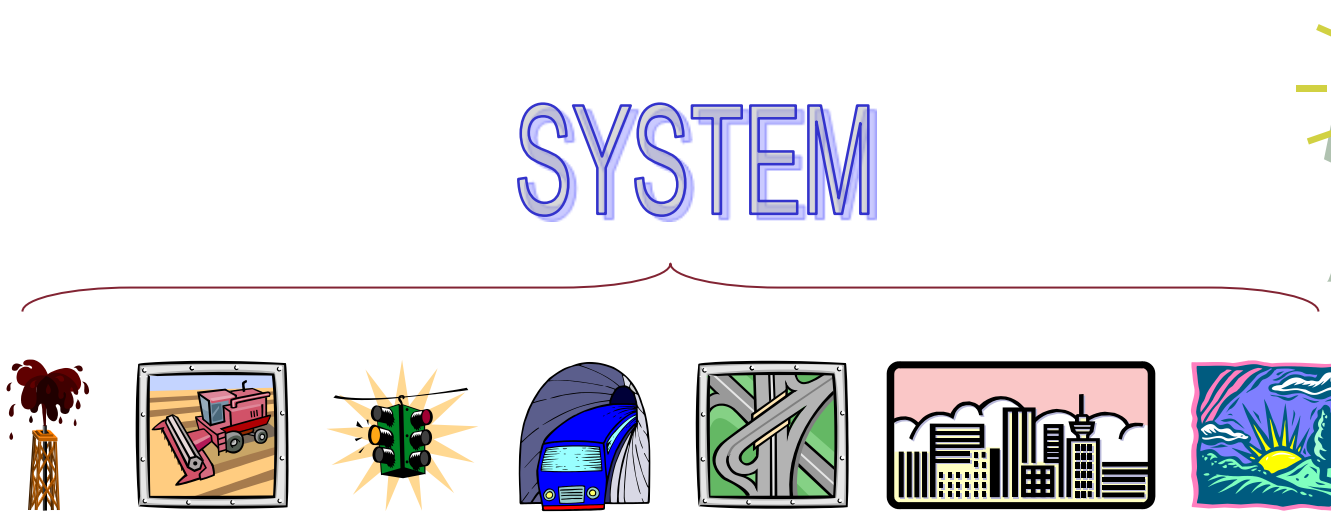
- We live in a “built“ world, in which the preservation of the means of production and infrastructure is particularly important.

Background: Maintenance services

- Maintenance services are characterized by:
  - a high added value and
  - a low specific investment
  - they derive from permanent/periodic needs
- The number of maintenance companies grew, due to outsourcing tendencies acting in large industries.
- New contract types spread up too:
  - Granted results contracts (in Italy “global service” type)
  - Multi-services contracts referring to well defined topographic areas (facility management).

Background: From Maintenance to Facility Management

- Systems engineering is the cultural and technical basis that gives to Maintenance the dignity of an autonomous and independent discipline.



Background: From Maintenance to Facility Management

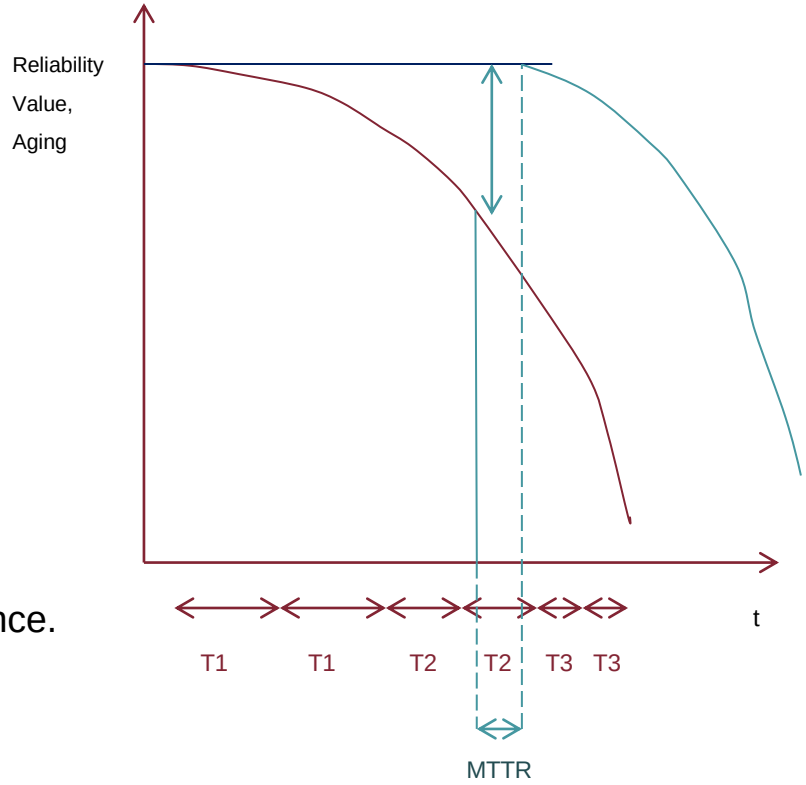
- Maintenance of technical systems increasingly tends to extend its boundaries and to become management and remote management of technical systems, thanks to the adoption of technologies and procedures more and more sophisticated.

Maintenance and its evolution: Italian peculiarities

- Ordinary maintenance. It is:
  - preventive (before the fault)
  - periodic (constant or variable)
  - does not increase the value of the item
  - maintains constant the degree of aging of the item
  - the user is responsible for the ordinary maintenance

- Extraordinary maintenance:

- it is an after failure/accident maintenance
- it increases the value of the good
- it restores the operation of the item
- it is not periodic
- the owner is responsible for the extraordinary maintenance.

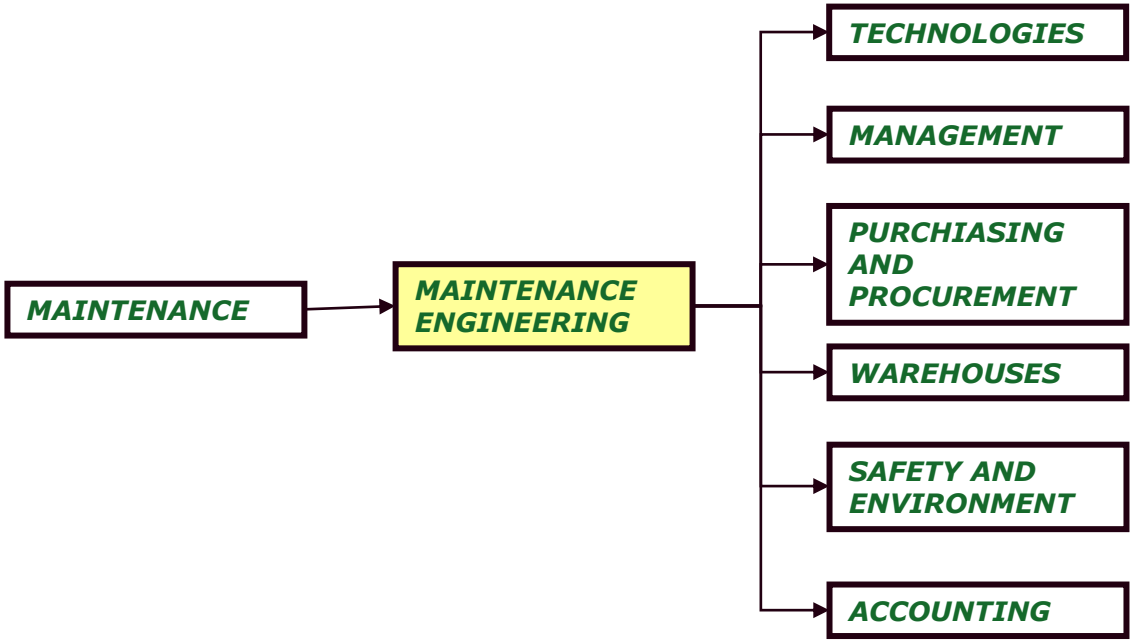


Organization of Maintenance

- The "classical" functional location of Maintenance is as follows:
  - Management
    - Production
    - Logistics

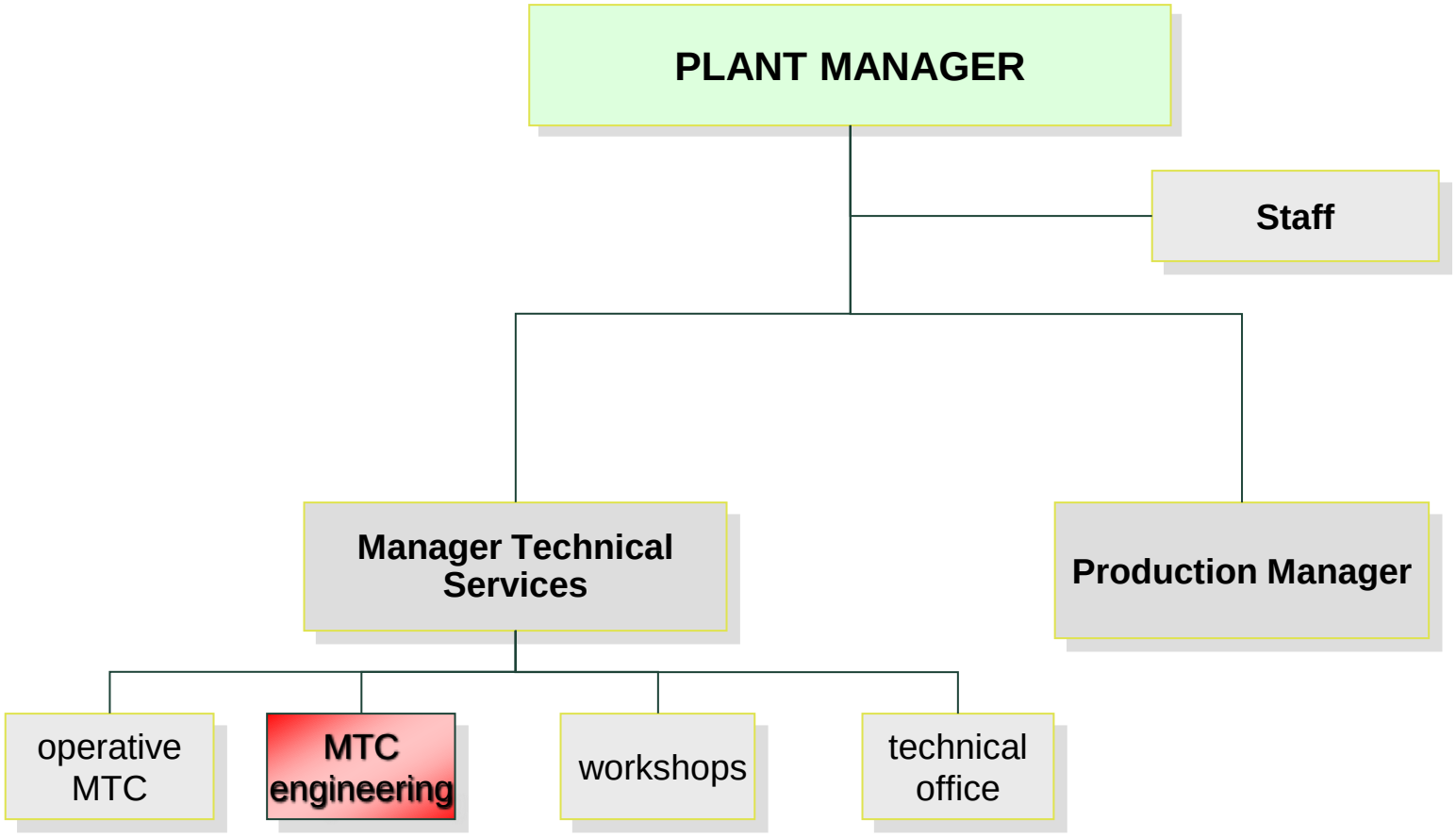
Maintenance

- Main activities within the maintenance division are as in the following:



Organization of Maintenance

- An example of organization of maintenance:



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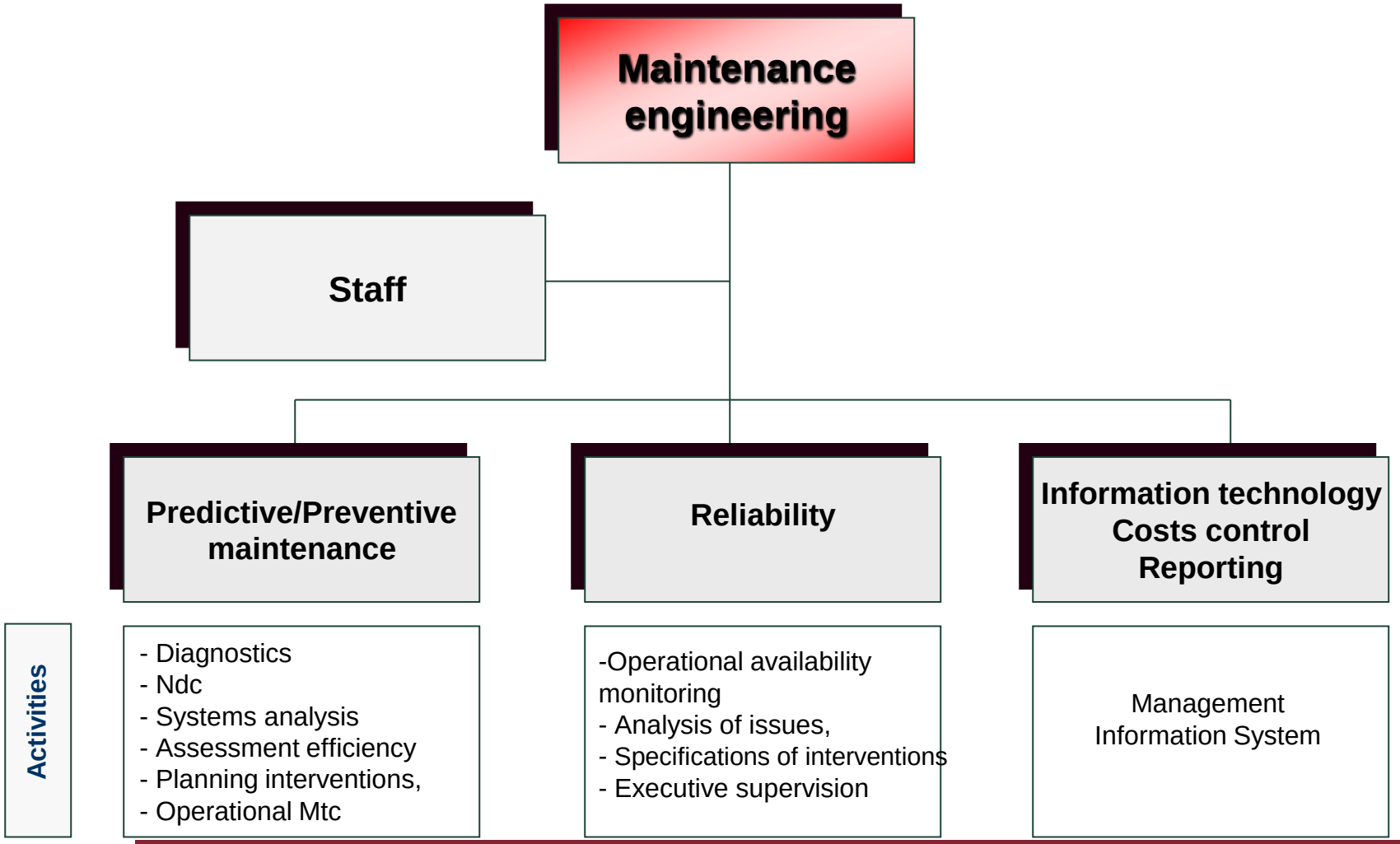
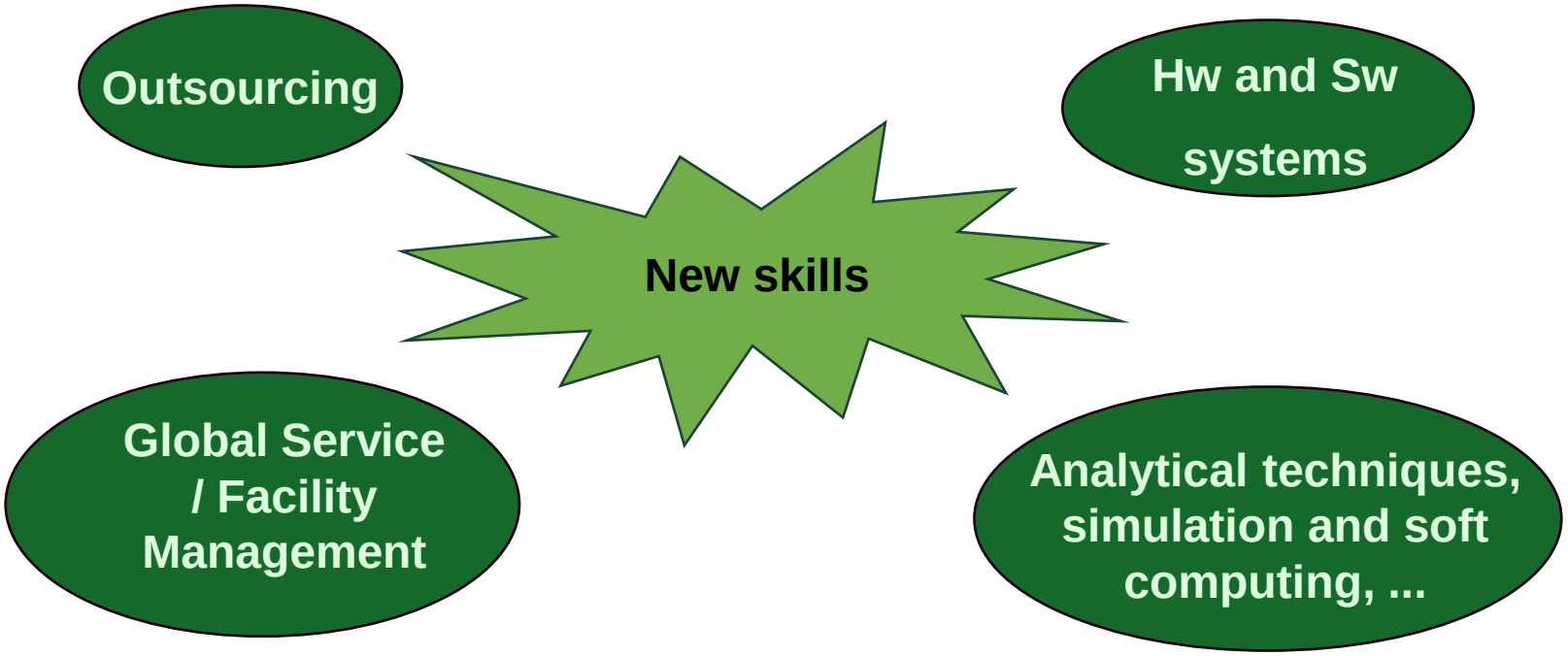


Organization of Maintenance

- Roles, Responsibilities and Objectives
  - The evolution of maintenance has an impact on skills:



Organization of Maintenance

- Roles, Responsibilities and Objectives
  - The evolution of maintenance has an impact on skills:

European Maintenance Engineer (Level A)

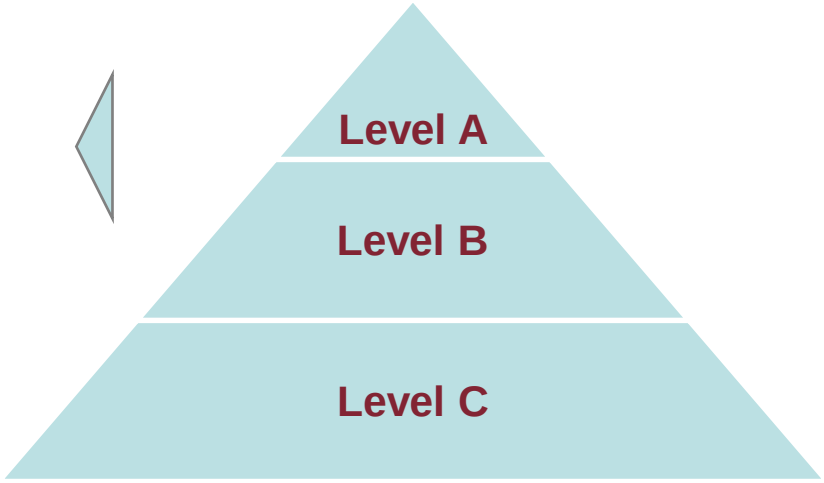
"person with approved engineering background and sufficient theoretical knowledge to perform and co-ordinate maintenance"

European Maintenance Technician (Level B)

"person with at least two years of practical experience in maintenance and sufficient theoretical knowledge to independently perform and co-ordinate maintenance projects (responsible for medium term decisions)"

European Maintenance Specialist (Level C)

"craft person with at least two years of practical experience in maintenance and sufficient theoretical knowledge to independently perform and co-ordinate maintenance activities (responsible for short term decisions and communication)"



[EN 15628 "Qualification of Maintenance Personnel "]

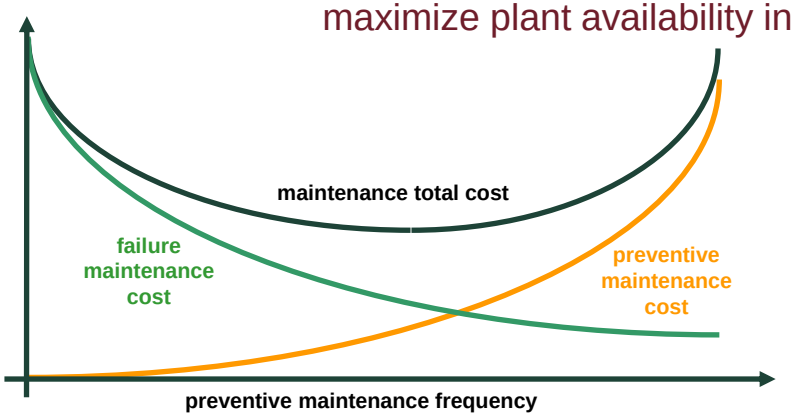
Design of Maintenance

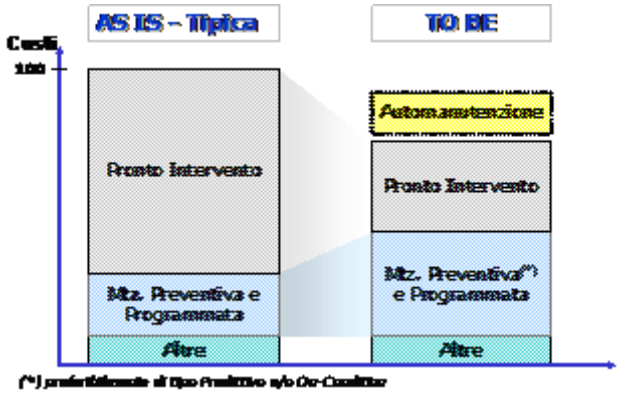
- Design of Maintenance involves elements of uncertainty in addition to the more usual and structural design of material objects.

- You need:
  - methods of analysis (qualitative and quantitative);
  - analytical techniques;
  - simulation techniques;
  - soft-computing techniques.

- In general:

"Design the maintenance means determining the mix of maintenance policies that maximize plant availability in a context of global costs containment"

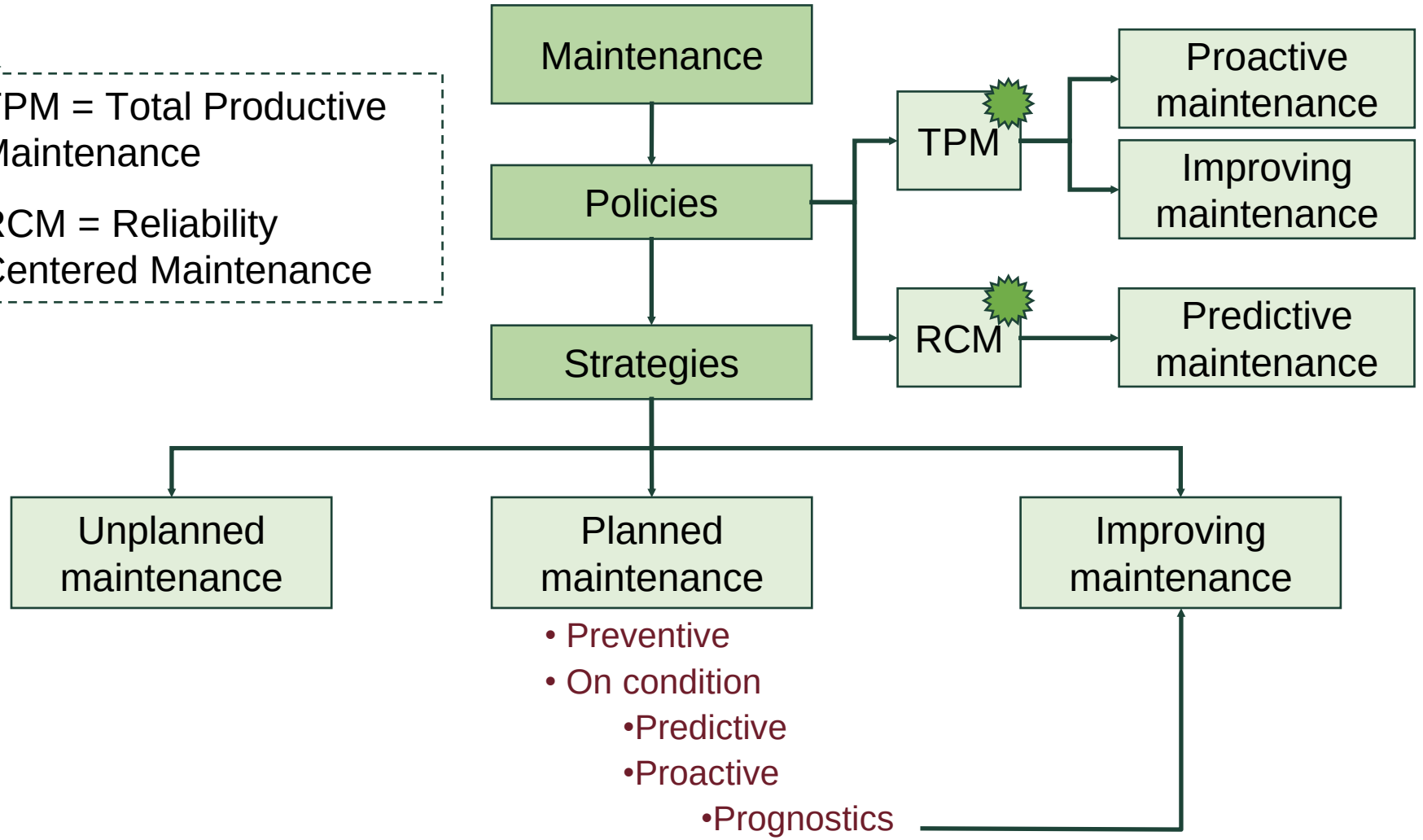




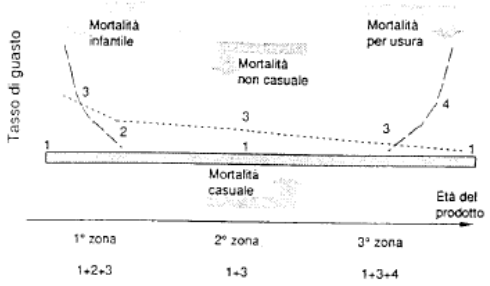
Design of Maintenance

TPM = Total Productive Maintenance

RCM = Reliability Centered Maintenance



Design of Maintenance



1 guasti "intrinseci" dovuti al dimensionamento del prodotto in rapporto allo spettro di sollecitazioni
2 guasti causati da errori di progetto e/o di processo
3 guasti causati da errori di processo
4 guasti causati dalle ripetute applicazioni di sollecitazioni

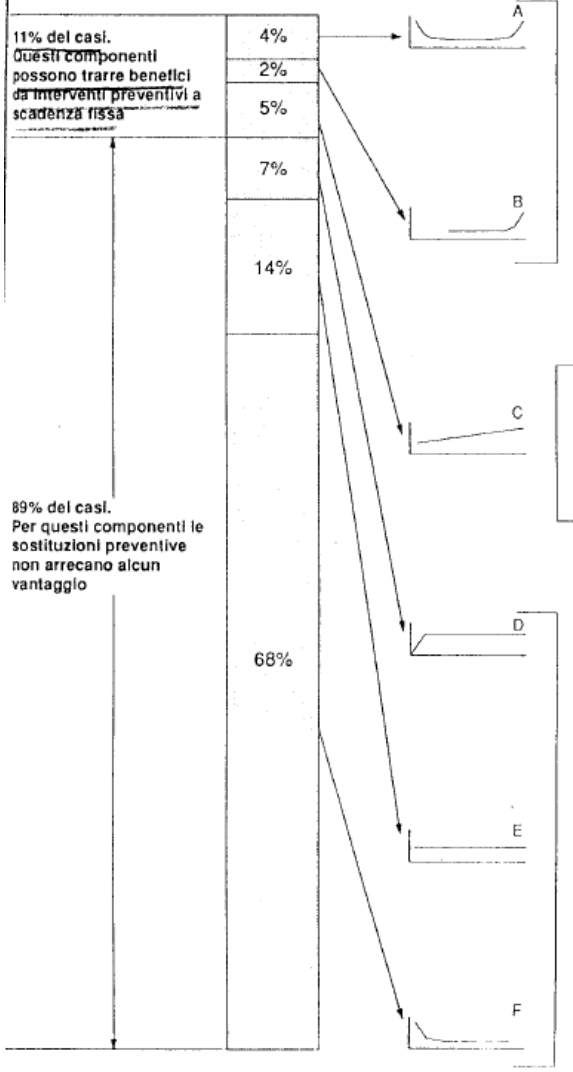
	% delle cause
Progettazione/sviluppo prodotto	20 - 40
Componenti (qualità)	40 - 65
Manodopera (capacità, attenzione)	15 - 20

1° zona
- inadeguatezza delle specifiche e delle procedure di prova
- instabilità del processo produttivo (parametri, macchinari, attrezzature o utensili)
- instabilità/inadeguatezza dei materiali
- movimentazione e/o imballo inadeguati
- sovrasollecitazione di componenti/parti
- errori nell'installazione/avviamento
- utilizzo improprio/procedure erronee
- ambiente operativo diverso da quello considerato in fase di progettazione
- personale operativo inadeguato/impreparato
- non completamento del collaudo

2° zona
- dimensionamento insufficiente
- erroneo utilizzo/sovrasollecitazione
- ambiente operativo improprio
- guasti intermittenti
- instabilità/inadeguatezza del processo produttivo e/o dei materiali
- altre possibili cause non conosciute

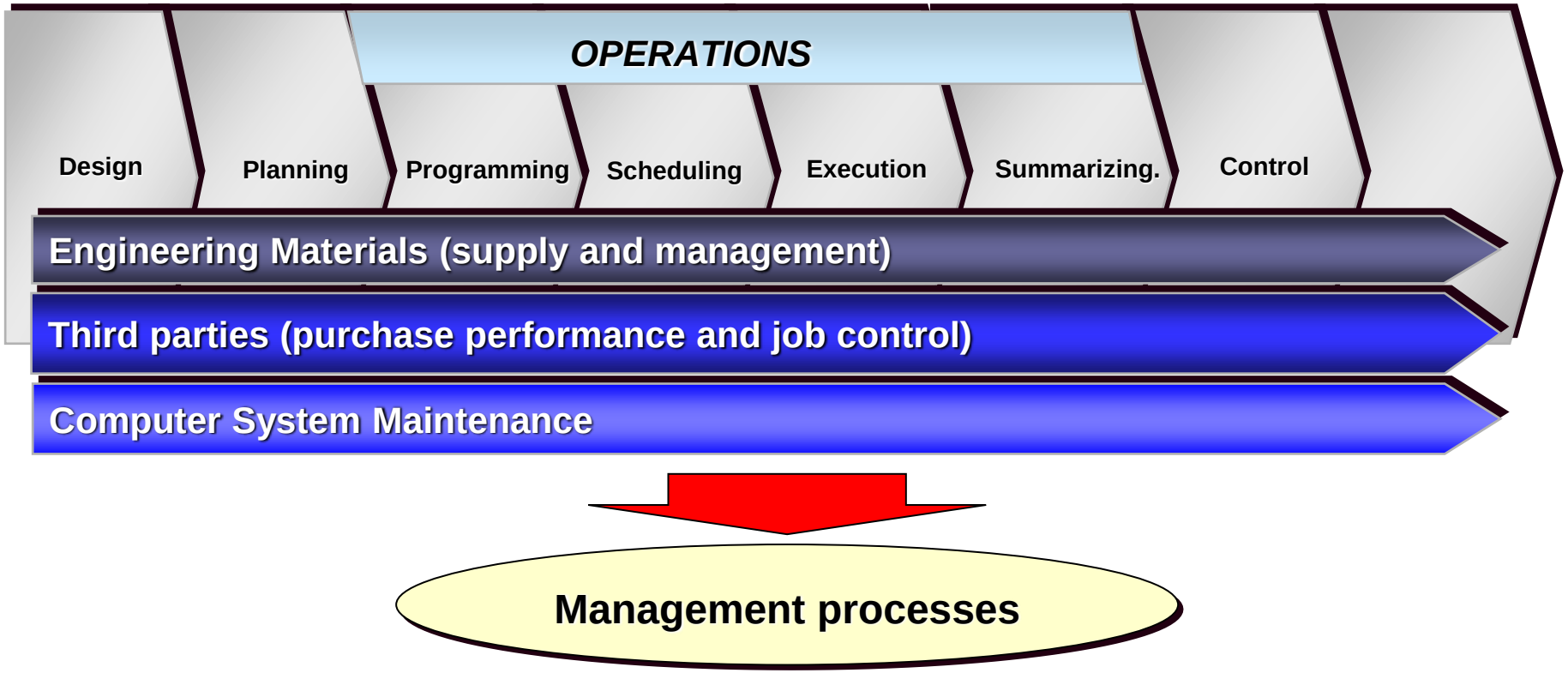
3° zona
- invecchiamento dei materiali
- fatica/corrosione/abrasione/...
- inadeguatezza della manutenzione preventiva
- dimensionamento insufficiente
- instabilità/inadeguatezza del processo produttivo e/o dei materiali
- altre possibili cause non conosciute

Fig. 15 - Andamento del tasso di guasto di componenti di aeroplani rilevato dalla United Airlines



Design of Maintenance

- Maintenance is managed by **processes**, taking as a basis the maintenance **budget**, and using as a guide the **maintenance indexes** (general, effectiveness, efficiency and governing the organization):



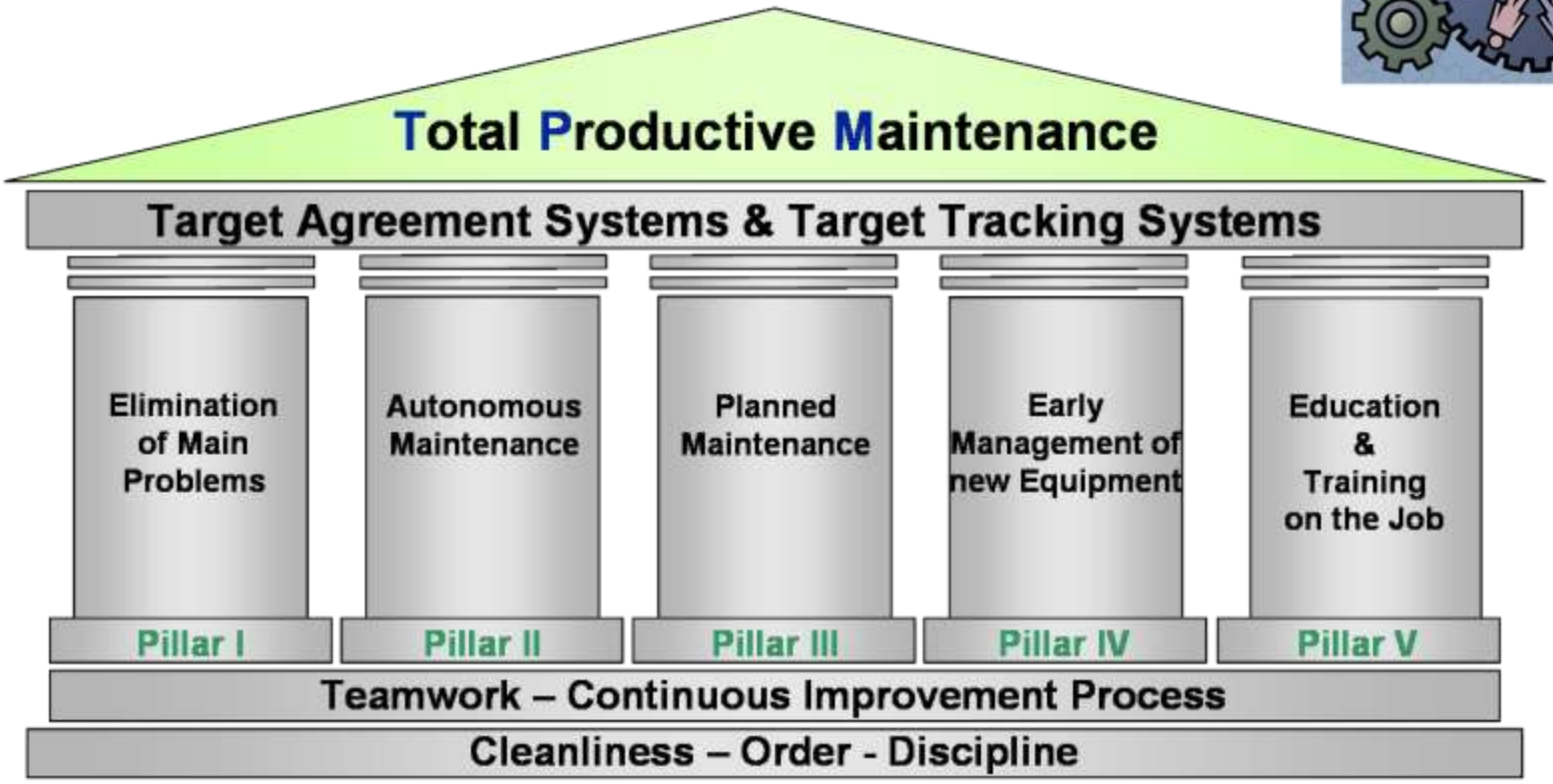
Total Productive Maintenance

- Total Productive Maintenance (TPM) is a comprehensive, pervasive and synergic approach to production problems, with the aim of improving performance through the commitment of all employees and the use of small groups of assets.

- TPM approach aims to reduce the so-called "six big losses“:
  - loss of time
    - troubleshooting and preventive maintenance
    - set-up and adjustments
  - speed losses
    - minor stops (reversals, cleaning, ...)
    - speed reduction
  - defects
    - losses in yield, in particular at start-ups
    - losses due to non-compliance

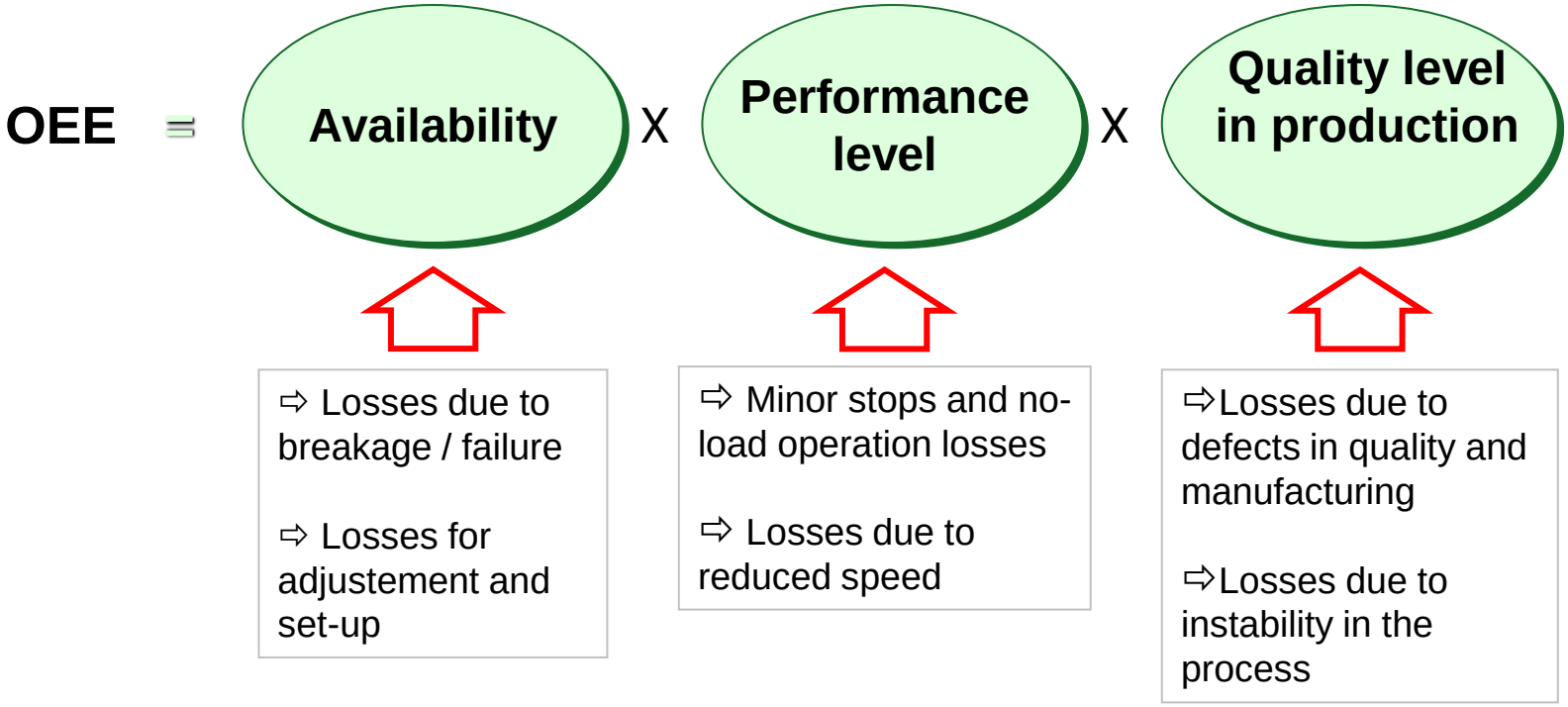
Total Productive Maintenance

The 5 Pillars of TPM-Concept



Examples

OEE - *Overall Equipment Effectiveness*



Examples

What is the contribution to profit due to an increase of 1% of A, P o Q (OEE)?

Total Time (220 x 24h)	=	5280 h
Maximum capacity of production	=	25 t/h
Profit margin	=	300 E/t

OEE (A x P x Q) Present	= 0,9 x 0,9 x 0,9 = 0,729
Improvement of OEE	= 0,91 x 0,9 x 0,9 = 0,737

Profit improvement:

(0,737–0,729)x5280x25x300 = ***316.800 E***

Examples

PIANO DI MANUTENZIONE E AUTOMANUTENZIONE

	Turni anno
Stabilimento :	**Giorni anno**
Impianto :	**Settimane anno**
Macchina : ***Pompa E5701/1***	**Mesi anno**
Codice Primo Livello	Foglio nr. di

COMPONENTE CRITICO					ISPEZIONI - PREVENZIONI										AZIONI CORRET.	
Cod	2° Livello	Cod	3° Livello	Q.ta	N	Descrizione	Op.	Fr.	T min.	Stato Macc MF	Stato Macc ML	O	M	P	Segnali Deboli	Note
1	**Struttura portante basamento pompa motore**	1	Basamento cemento rivestito con vernice anticorrosiva, con tirafondi di acciao rivestiti	1		ESAME VISIVO DELLO STATO DEL BASAMENTO E DELLA SUA STABILITA'	1	6M	1		X	X				
						VERNICIATURA DEL BASAMENTO DEI BULLONI CON ANTIRUGGINE	2	1A	120	X			X			FERMATA D'AGOSTO
2	**Pompa**	1	Supporto pompa	1		VERNICIATURA ESTERNA ED ESAME VISIVO	3		480	X			X			ALLA REVISIONE
		2	Chiocciola	1		CONTROLLO ANELLO DI USURA GIOCHI GIRANTE ANELLO-USURA	3		*	X			X			ALLA REVISIONE
		3	Girante	1		ESAME VISIVO EQUILIBRATURA ED EVENTUALE CONTROLLO CON LIQUIDI PENETRANTI	3		*	X			X			ALLA REVISIONE
		4	Corpo pompa	1		ESAME VISIVO	3		*	X			X			ALLA REVISIONE
		5	Asse pompa con camicia di tenuta	1		ESAME VISIVO DELLE SUPERFICI, CONTROLLO DELL'ACCOPPIAMENTO E DI LINEARITA'	3		*	X			x			ALLA REVISIONE
		6	Cuscinetti	1		SOSTITUZIONE	3		*	X			X			ALLA REVISIONE
		7	Tenuta flussata a lavaggio permanente e raffreddamento	1		SOSTITUZIONE CON TENUTA RIGENERATA O NUOVA	3		*	X			X			ALLA REVISIONE
		8	Tenute olio	1		SOSTITUZIONE ANELLO	3		*	X			X			ALLA REVISIONE
3	**Motore elettrico**	1	Motore elettrico	1		RILEVAZIONE RUMORI ANOMALI NELLA SOSTITUZIONE DELLA POMPA	4		5	X			X			ALLA REVISIONE
						CONTROLLO RUMORE CON SPM PER CUSCINETTI MOTORE	5	6M	10		X		X			
4	**Giunto di collegamento**	1	Giunto Eupex con 6 tasselli	1		CONTROLLO DI ALLINEAMENTO MONTAGGIO CON STRUMENTAZIONE IDONEA	6		5		X		X			AL RIMONTAGGIO
						CONTROLLO DI VIBRAZIONI POMPA	7	1S	5		X		X			
5	**Impianto elettrico**	1	Pulsantiera accensione	1		ESAME VISIVO DEI COLLEGAMENTI	8	1G	5		X	X				
		2	Cabina elettrica con cassetto	1		CONTROLLO GENERALE	9		20	X			EL			FERMATA AGOSTO
		3	Cavo motore-colonnina	1		CONTROLLO INTEGRITA'	8	1G	*		X	X				

Case study: improvements in a pharmaceutical industry

- Improvement of maintenance and increase of productivity in a chemicals-pharmaceuticals company in Latina.

Blister machine

Cases machine

Tray machine

Shrinkwrapper

Boxes machine

Case study: improvements in a pharmaceutical industry

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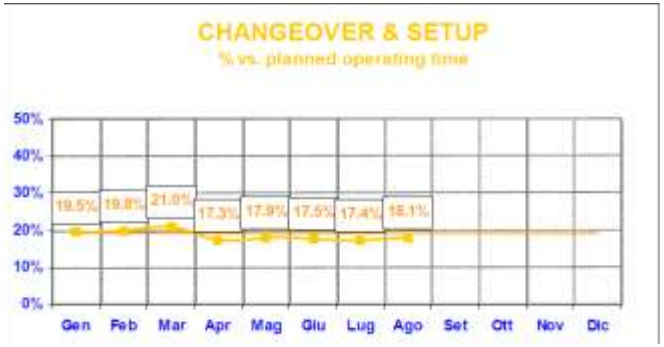
Monitoring system for PRS data (Production Reporting System)



Case study: improvements in a pharmaceutical industry

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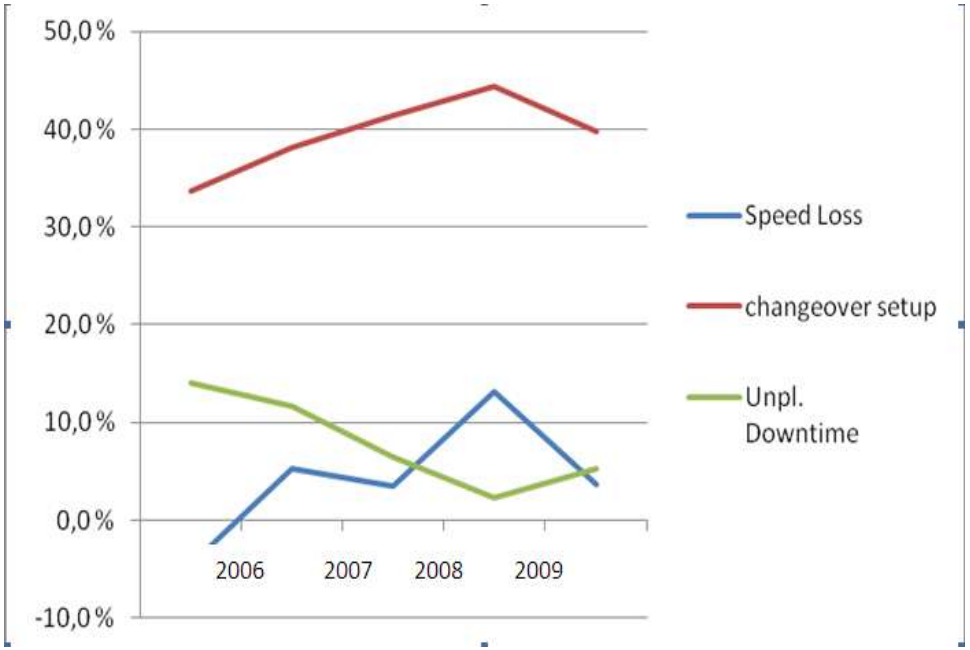

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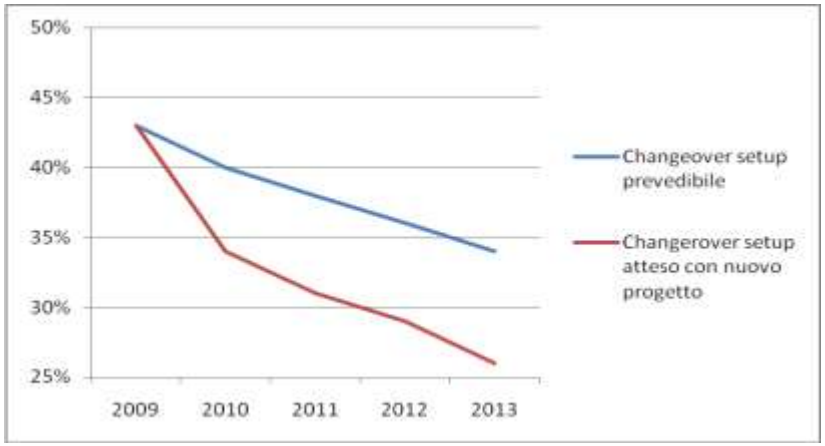
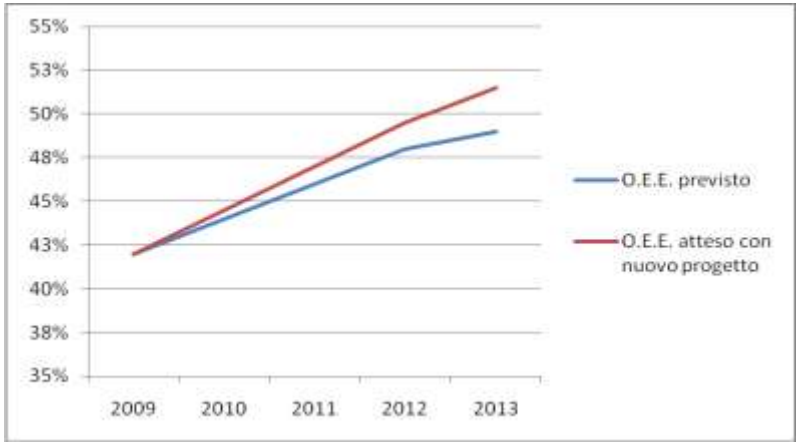




Granted Avalilability Management System - GrAMS

- The management of technical plants is a complex activity in terms of productivity and safety, particularly when the plants are distributed in a large area.

- ‘‘Intelligent’’ maintenance–management systems for the distant monitoring and evaluation by a remote control center can be developed.

- The so-called GrAMS (Granted Availability Management System) methodology/technology is conceived to give to organizations involved in technical–industrial plants management the possibility to reach a ‘‘well-known availability’’ and ‘‘zero-failures’’ management.

Granted Avalilability Management System - GrAMS

- GrAMS system consists of two main elements:
  - a plant result management model, and
  - a tele-maintenance intelligent system for
    - the forecast of the reliability and safety level of each plant, and for the
    - planning and scheduling of maintenance operations.

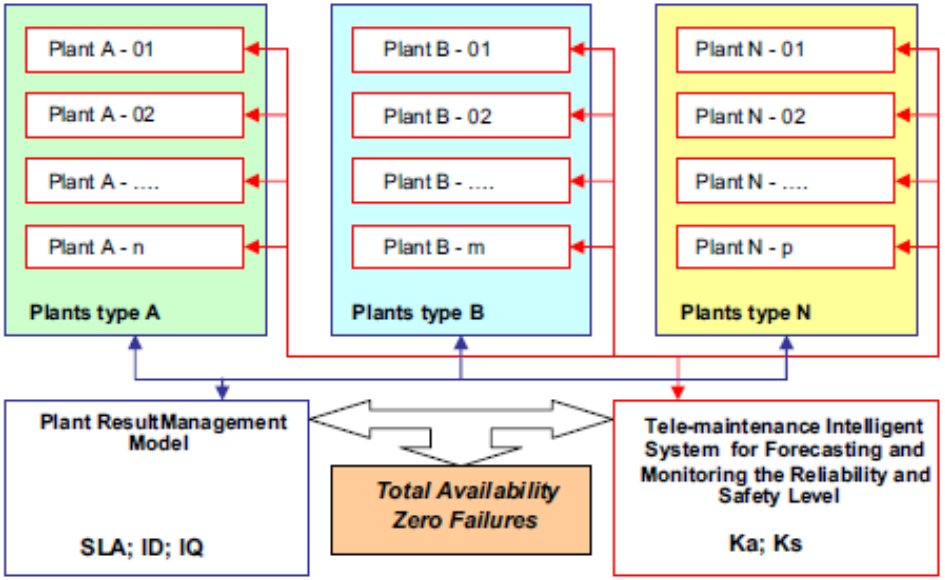
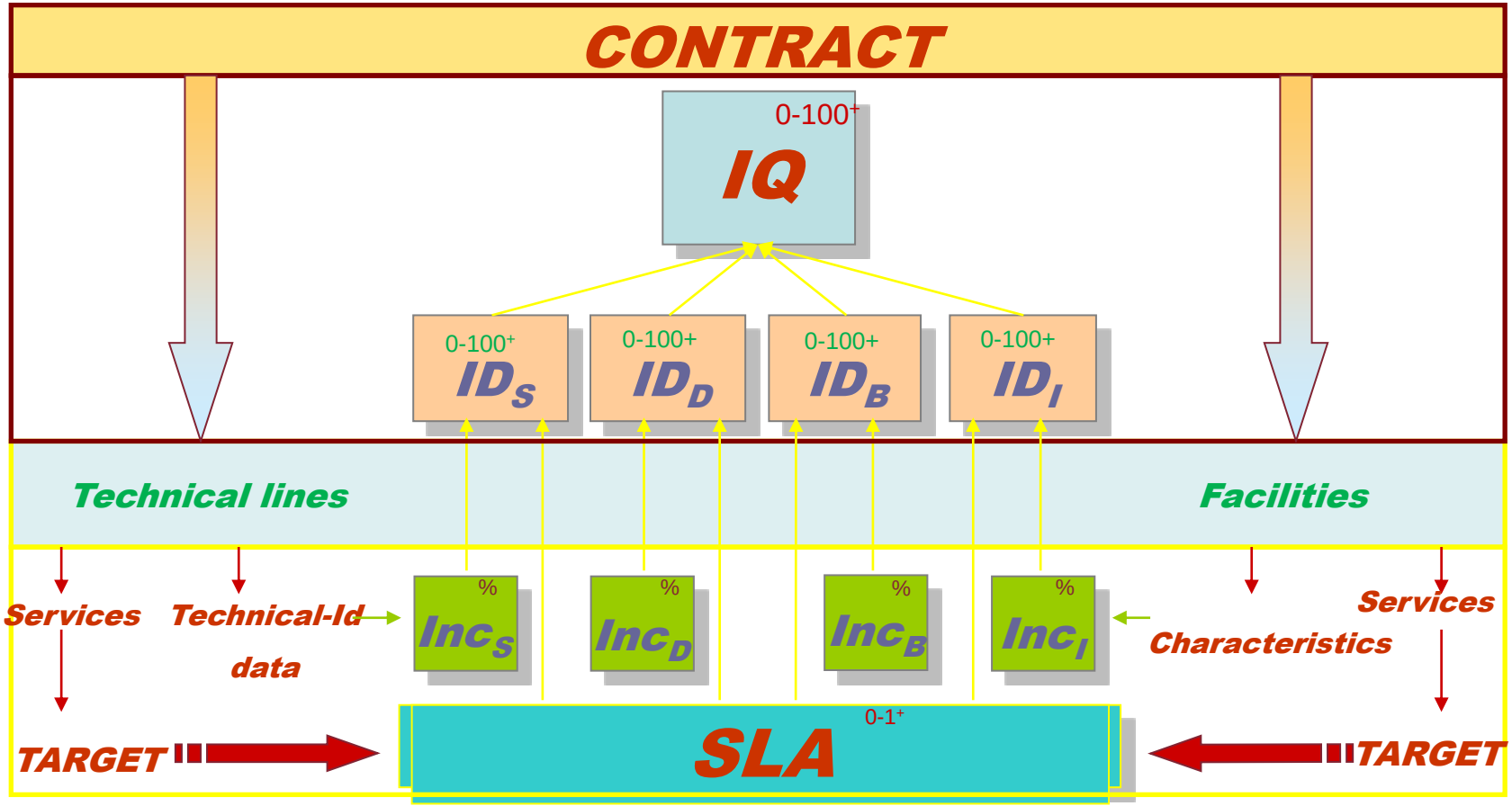


Fig. 1. General diagram of the GrAMS.

GrAMS: the plant result management model

- The model restores for each contract a global quality index (IQ), through a series of phases.



GrAMS: the plant result management model

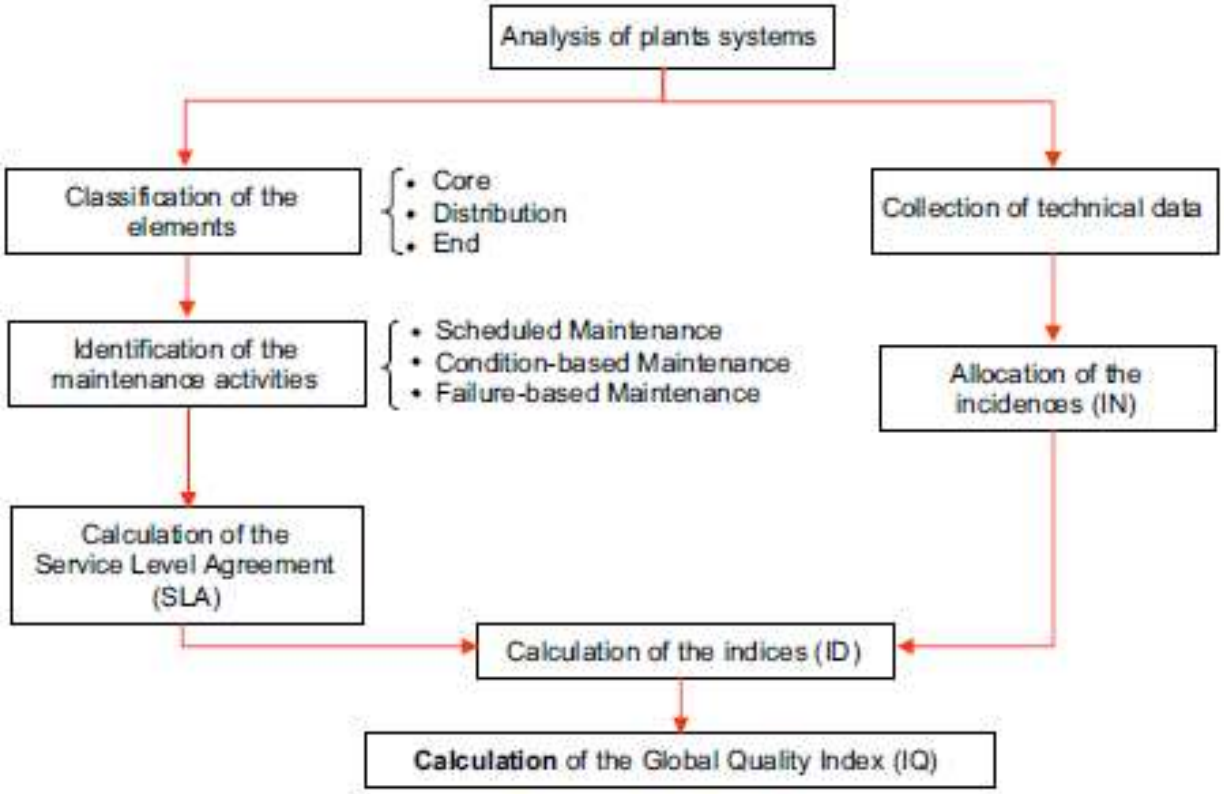


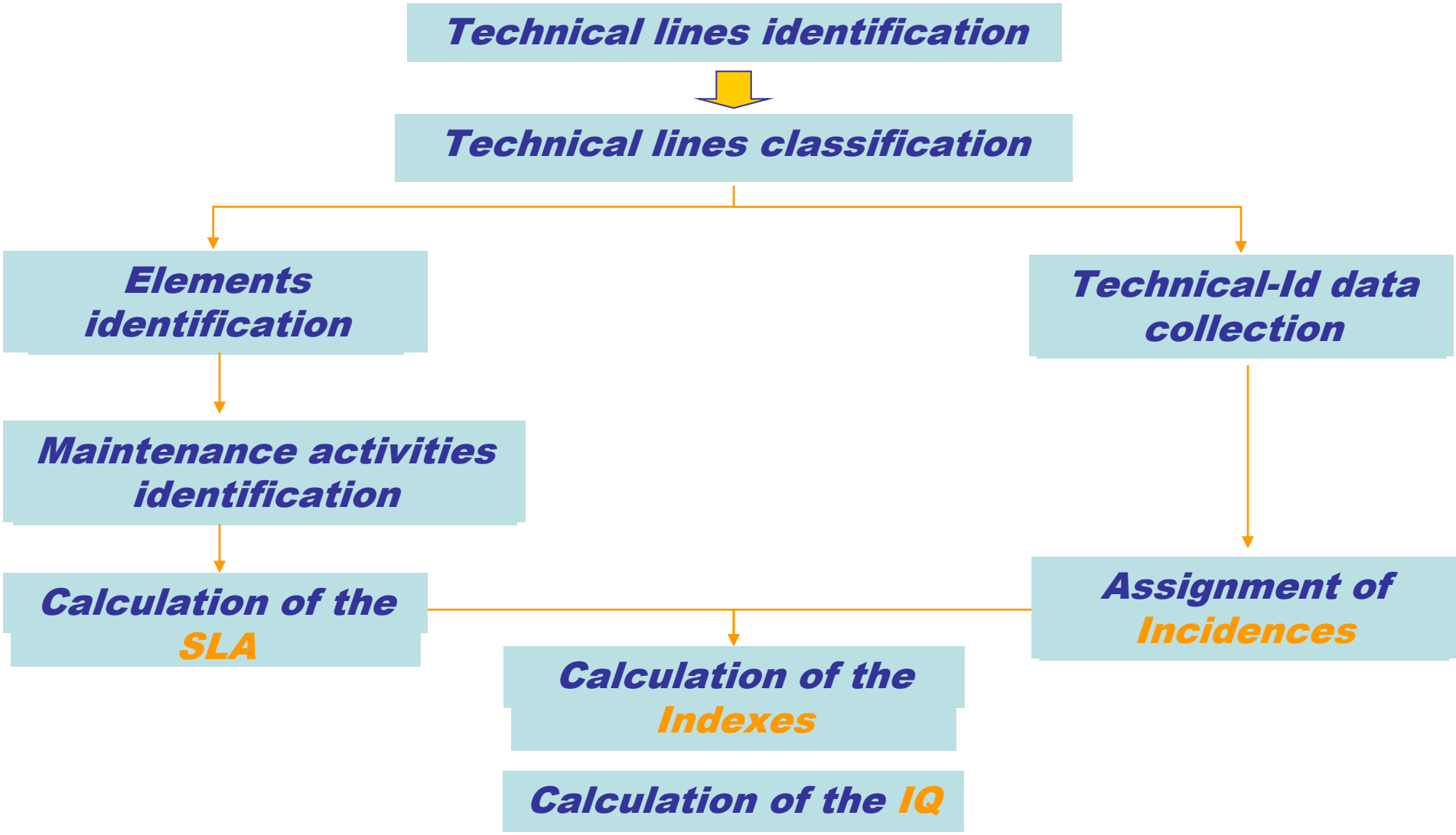
Fig. 2. Functional chart of the Plant Result Management Model

GrAMS: the plant result management model

- Three types of indices were identified basing on the state of the art:
  - **SLA**: the result, referring to a stated time interval, of the performance of the services supplied relevant to a specific technological line.
  - **Incidences** or indicators of incidence (of well-being, image, availability and safety): degree to which a technological line influences the characteristics perceived by the people in the buildings.
  - **Performance indexes** (of well-being, image, availability and safety): measure of the characteristics perceived by the people in the buildings and of the infrastructures.

Indices/Indicators	Reference	Range	Measuring method
Service Level Agreement	Technological Line	0-1	Calculated for each technological line as a measure of the variance between the value of the guaranteed result and the measured value of the result.
Indicators % (IN)	Technological Line and performance factor (e.g. Well-being, image, etc)	0-100 %	Assigned for each type of Technological Line and each type of performance factor based on the type of line and on several technical-identity characteristics of the line.
Performance Indices (ID)	Contract and performance indicator	0-100	Calculated for each performance factor as weighted average of the SLA of each line, assuming the % indicators as weight factors.
Quality Indices (IQ)	Contract	0-100	Calculated for the contract as weighted average of the partial indices.

GrAMS: an application



GrAMS: an application

Technical lines identification

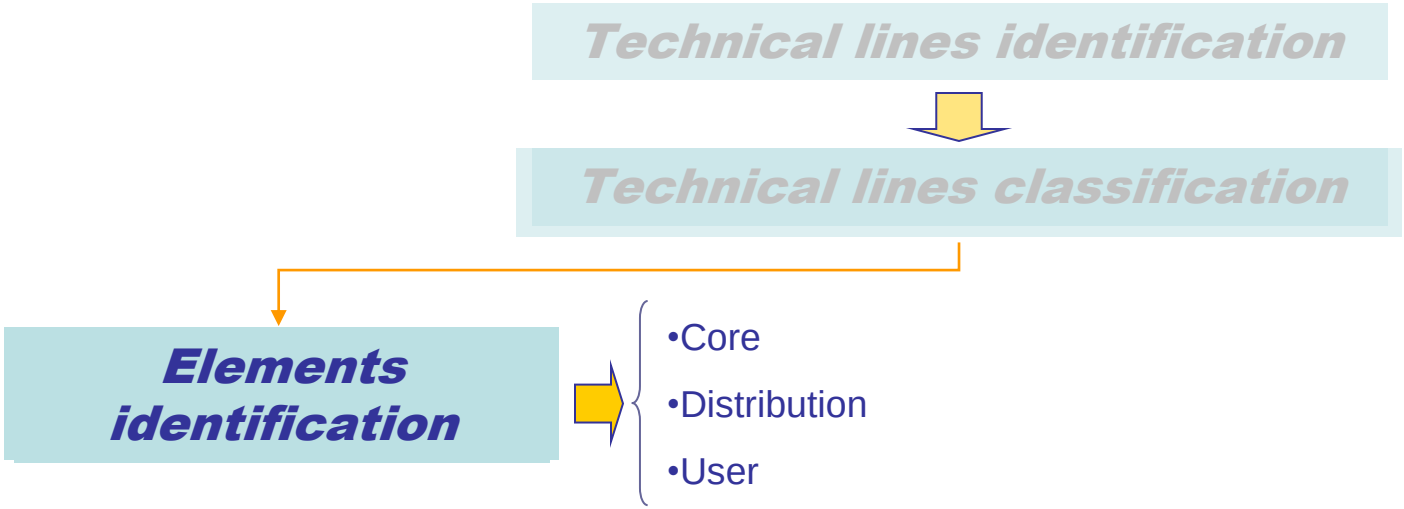
Technical lines

LT 01	L.T. Produzione caldo
LT 02	L.T. Telefonia e Trasmissione Dati
LT 03	L.T. Sollevamento + carrelli soll.
LT 04	L.T. Produzione freddo
LT 05	L.T. Distribuzione elettrica
LT 06	L.T. Distribuzione Acqua
LT 07	L.T. Trattamento Acque Civili e Ind.li
LT 08	L.T. Antincendio
LT 09	L.T.Cogenerazione
LT 10	L.T. Produzione aria compressa
LT 11	L.T. Rete emergenza
LT 12	L.T. Supervisione
LT 13	L.T. Mensa e spaccio
LT 14	L.T. Fabbricati

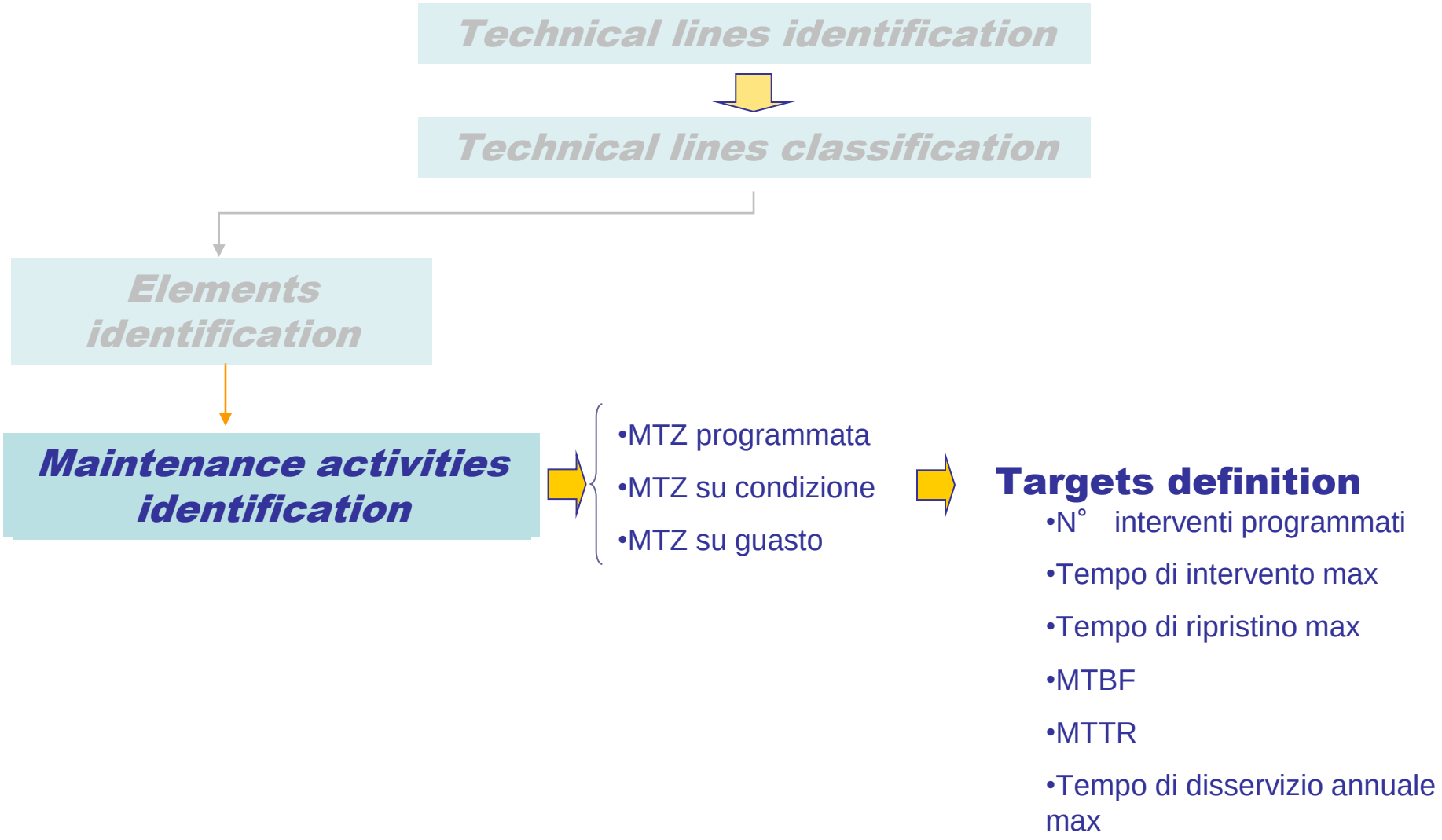
Facilities

FM 01	F.M. Vigilanza
FM 03	F.M. Verde/Giardinaggio
FM 04	F.M. Posta interna
FM 05	F.M. Segnaletica stradale
FM 06	F.M. Smaltimento Rifiuti
FM 07	F.M. Agenzia viaggi
FM 08	F.M. Gestione automobili
FM 09	F.M. Magazzini
FM 10	F.M. Pulizie
FM 11	F.M. PDL
FM 12	F.M. Laboratori metrologici

GrAMS: an application



GrAMS: an application



GrAMS: an application

$$SLA = 1 - \left[\frac{A(Mtz\,Programmata) + B(MtzGuasto) + C(MtzCondizione) + D(MtzGlobale)}{A + B + C + D} \right]$$

$$\{MtzGuasto\} = \frac{B1\{V02\} + B2\{V03\} + B3\{V04\} + B4\{V05\}}{B1 + B2 + B3 + B4}$$

$$\{V02\} = \left[\frac{E\{V02_{Core}\} + F\{V02_{Distr.}\} + G\{V02_{Finale}\}}{E + F + G} \right]$$

$$\{V03\} = \left[\frac{E\{V03_{Core}\} + F\{V03_{Distr.}\} + G\{V03_{Finale}\}}{E + F + G} \right]$$

$$\{V04\} = \left[\frac{E\{V04_{Core}\} + F\{V04_{Distr.}\} + G\{V04_{Finale}\}}{E + F + G} \right]$$

$$\{V05\} = \left[\frac{E\{V05_{Core}\} + F\{V05_{Distr.}\} + G\{V05_{Finale}\}}{E + F + G} \right]$$

Calculation of the SLA

$$1 - \frac{(n°\,interventi\_su\_guasto\_conTint > T\,int\_max) - (n°\,interv\_su\_guasto\_effettuati)}{(n°\,interv\_su\_guasto\_effettuati)}$$

GrAMS: an application

$$SLA = 1 - \left[\frac{A(Mtz\,\mathrm{Pr}ogrammata) + B(MtzGuasto) + C(MtzCondizione) + D(MtzGlobale)}{A + B + C + D} \right]$$

Formulas for the calculation of the evaluation indices

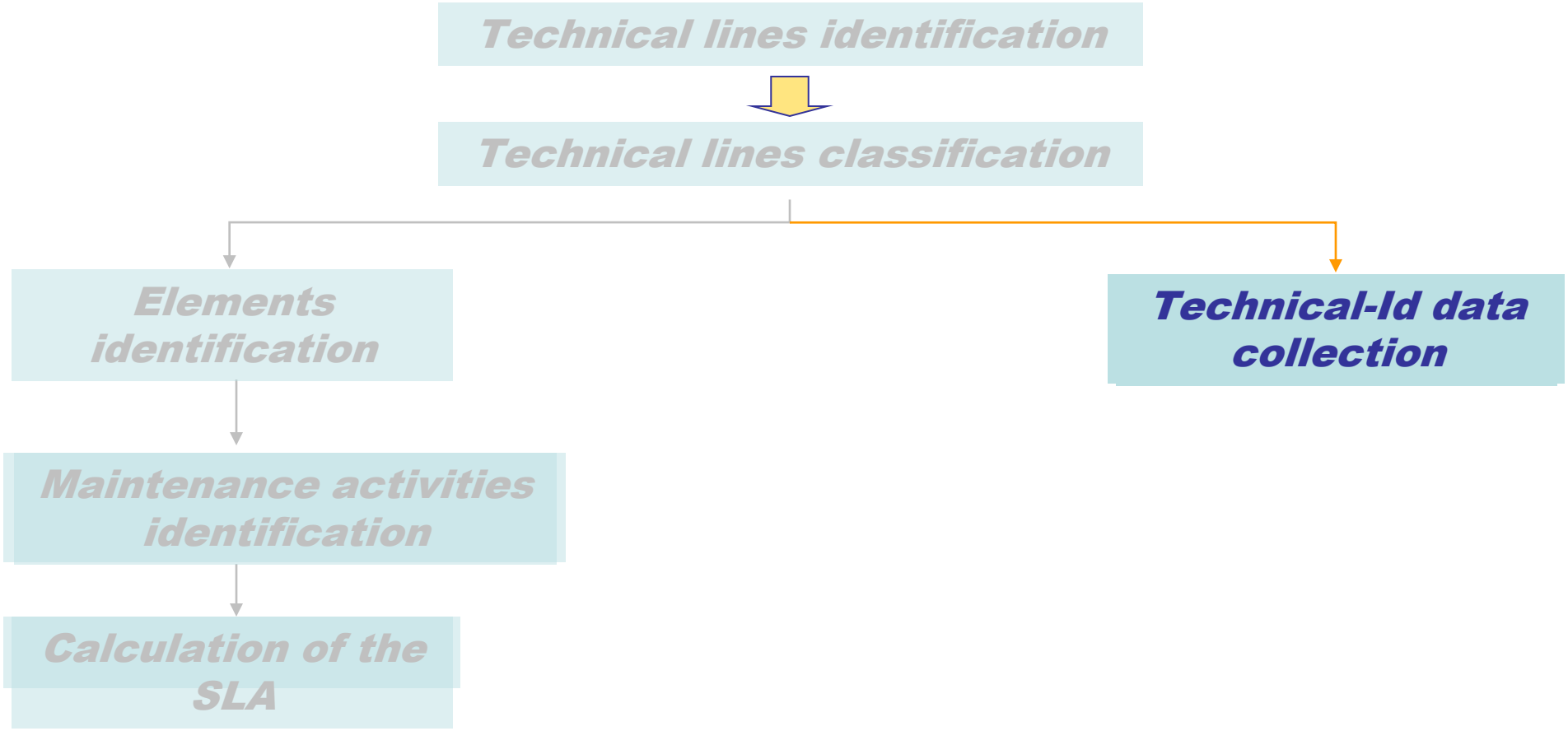
Maintenance strategies	Evaluations	Id.
Scheduled Maintenance {ScheduledMtc}	1−(RM01/RG01)	V 01
Corrective Maintenance (failure-based) {FailureMtc}	1−((RM02a−Rm02b)/(RM02b))	V 02
	1−((RM03−RM02b)/(RM02b))	V 03
	(RG04−RM04)/(RG04)	V 04
	(RM05−RG05)/(RG05)	V 05
Condition-based Maintenance {ConditionBasedMtc}	1−((RM06b−RM06a)/(RM06b))	V 06
Globals {Global}	(RM07−RG07)/(RG07)	V 07

Guaranteed and monitored results

Maintenance strategies	Guaranteed results		Monitored results	
Scheduled maintenance	Number of scheduled maintenance operations (maintenance plan)	RG 01	Number of scheduled maintenance operations (executed)	RM 01
Corrective maintenance (failure-based)	Maximum administrative delay time (ADT)	RG 02	Number of operations exceeding maximum ADT	RM 02a
			Number of executed operations	RM 02b
	Maximum mean down time (MDT)	RG 03	Number of operations exceeding maximum MDT	RM 03
			Number of executed operations	RM 02b
	Mean time between failure (MTBF) guaranteed	RG 04	MTBF measured	RM 04
	Mean time to repair (MTTR) guaranteed	RG 05	MTTR measured	RM 05
Condition-based maintenance	Mean up time (MUT) guaranteed	RG 06	MUT measured	RM 06a
			Number of executed operations	RM 06b
Globals	Maximum guaranteed annual down time	RG 07	Total annual down time	RM 07

Calculation of the SLA

GrAMS: an application



GrAMS: an application

COMMESSA		B	I	D	S
LT 01	L.T. Produzione caldo				
LT 02	L.T. Telefonia e Trasmissione Dati				
LT 03	L.T. Sollevamento + carrelli soll.				
LT 04	L.T. Produzione freddo				
LT 05	L.T. Distribuzione elettrica				
LT 06	L.T. Distribuzione Acqua				
LT 07	L.T. Trattamento Acque Civili e Ind.li				
LT 08	L.T. Antincendio				
LT 09	L.T.Cogenerazione				
LT 10	L.T. Produzione aria compressa				
LT 11	L.T. Rete emergenza				
LT 12	L.T. Supervisione				
LT 13	L.T. Mensa e spaccio				
LT 14	L.T. Fabbricati				
LT 15	L.T. PDL				
LT 16	L.T. Laborato				
FM 01	F.M. Vigilanza				
FM 03	F.M. Verde/Giardinaggio				
FM 04	F.M. Posta interna				
FM 05	F.M. Segnaletica stradale				
FM 06	F.M. Smaltimento Rifiuti				
FM 07	F.M. Agenzia viaggi				
FM 08	F.M. Gestione automobili				
FM 09	F.M. Magazzini				
FM 10	F.M. Pulizie				
FM 11	F.M. PDL				
FM 12	F.M. Laboratori metrologici				
		100%	100%	100%	100%

Assignment of Incidences

GrAMS: an application

Safety index

$$ID_S = \frac{\sum_i SLA_i * INs_i}{\sum_i INs_i} * 100$$

Availability index

$$ID_D = \frac{\sum_i SLA_i * INd_i}{\sum_i INd_i} * 100$$

Well being index

$$ID_B = \frac{\sum_i SLA_i * INb_i}{\sum_i INb_i} * 100$$

Image index

$$ID_I = \frac{\sum_i SLA_i * INi_i}{\sum_i INi_i} * 100$$

Calculation of the Indexes

GrAMS: an application

$$IQ = \frac{ID_S + ID_D + ID_I + ID_B}{4}$$

Calculation of the IQ

GrAMS: the plant result management model

Table 3: Example of the model application

		QUALITY INDEX (IQ)			
		88			
		Performance Indices (ID)			
		Well-being	Image	Availability	Safety
		87	91	91	82
Technological Lines	SLA	INDICATORS %			
		Well-being	Image	Availability	Safety
LT 01	Heat Production	70%	35%	30%	25%
LT 02	Lifting/Elevators	15%	40%	25%	35%
LT 03	Electrical Distribution	15%	25%	45%	30%

The tele-maintenance intelligent system

- The main objectives of the tele-maintenance intelligent system are:
  - forecasting and monitoring plant reliability/availability [Ka];
  - forecasting and monitoring the plant safety level [Ks];
  - management optimization (effectiveness and efficiency of the maintenance process).

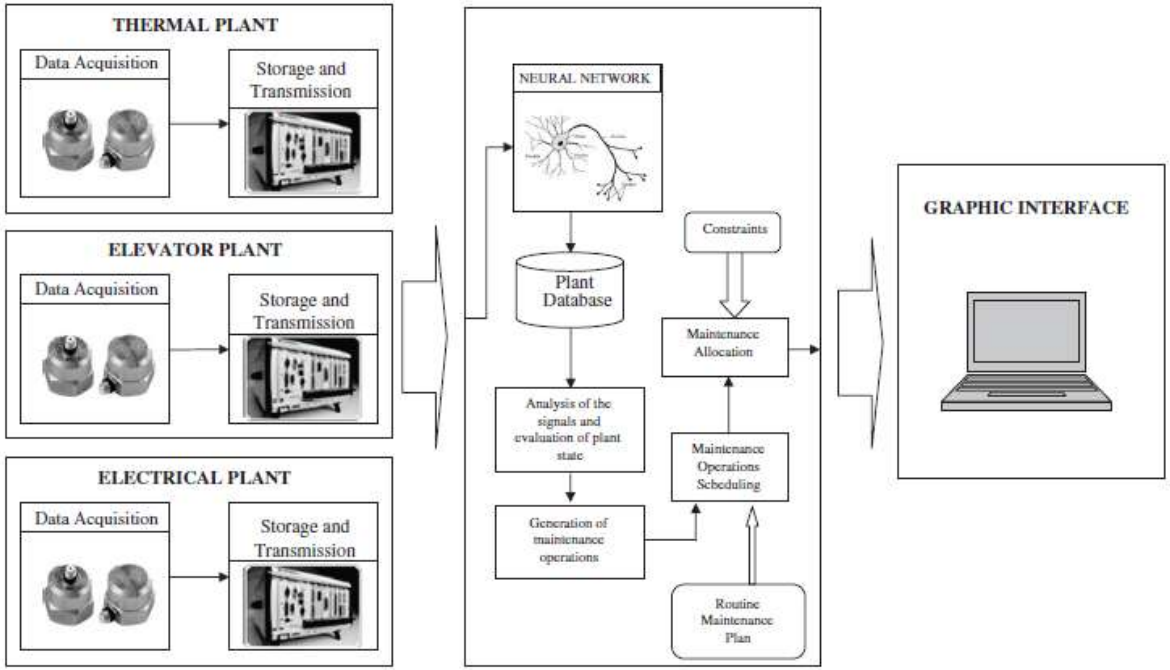


Fig. 3. General diagram of the Tele-Maintenance Intelligent System.

The tele-maintenance intelligent system

- All the information detected on each plant is sent to the control center by a signal transmission and conversion sub-system.
- The control center uses dedicated software to record the information in the individual plant identification file and schedules the maintenance operations taking into account the plant safety level and the plant reliability forecast.
- If it becomes necessary, for safety reasons, the system could signal the plant to shut down.
- The sub-system for processing some of the data collected from the plant uses software tools based on neural networks capable of forecasting the evolution of events.

The tele-maintenance intelligent system

- Neural networks tool, compared to other techniques (i.e. data mining, decisions tree, etc.), is useful to obtain information about weak signals (from the monitored parts) thanks to the training routine.

- The tele-maintenance intelligent system is developed according to the following steps:
  - identification of the technical characteristics of the plants and choice of the parameters to monitor (FMECA);
  - design of the parameter recording system;
  - definition of the sensors type and characteristics;
  - design of the neural network and the diagnostic system;
  - design of the signal transmission system.

The tele-maintenance intelligent system

- The following critical parameters were chosen for the elevator:
  - resistance of the contacts of the landing door locking device;
  - adjustment motor-winch unit brake;
  - clutch pulley–rope sliding;
  - car load; and
  - motor-winch unit vibrations.

- Other signals were identified, and used without further processing:
  - extra-stroke switches [on/off];
  - frame contact [on/off];
  - overspeed governor contact [on/off];
  - overspeed governor tightener contact [on/off];
  - pit stop contact [on/off];
  - car parking [position in the hoistway];
  - traffic [no. of runs]…

The tele-maintenance intelligent system

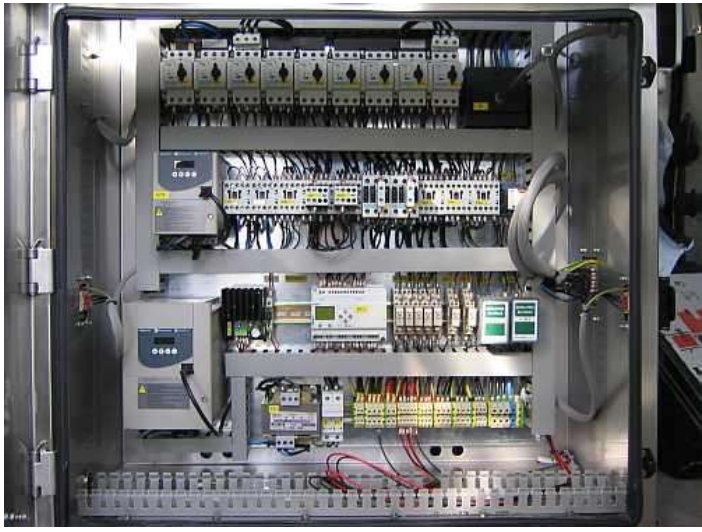
- As a result of the FMECA analysis carried out on a thermal plant the following critical parameters were chosen:
  - measurement of fume pressure in the flue outlet;
  - measurement of the fume temperature in the flue outlet;
  - measurement of the pressure in the delivery hydraulic circuit; and
  - measurement of the temperature in the delivery hydraulic circuit.

- Furthermore, other signals were identified, originating from the diagnostics and used without further processing, such as, for example:
  - thermal blowdown valve [on/off];
  - shutdown pressure switch [on/off];
  - shutdown thermostat switch [on/off];
  - fuel interception valves [on/off]…

The tele-maintenance intelligent system

- The FMECA analysis on the electrical plant led to the following critical parametrs:
  - measure of the ground resistance;
  - temperature in the electrical distribution panel;
  - voltage in the electrical distribution panel; and
  - dispersion of current in the circuit.

- Furthermore, other signals were identified such as:
  - operation of the differential safety switch [on/off];
  - Volt values [minimum, medium, maximum];
  - Ampere values [minimum, medium, maximum];
  - Watt values [minimum, medium, maximum]...



The tele-maintenance intelligent system

- The following steps were involved in the design of the neural network:
  - definition of the inputs and outputs for each type of plant;
  - data collection and allocation of target values;
  - definition of the neural network architecture;
  - training of the neural network;
  - analysis of the training results; and
  - testing of the neural network.

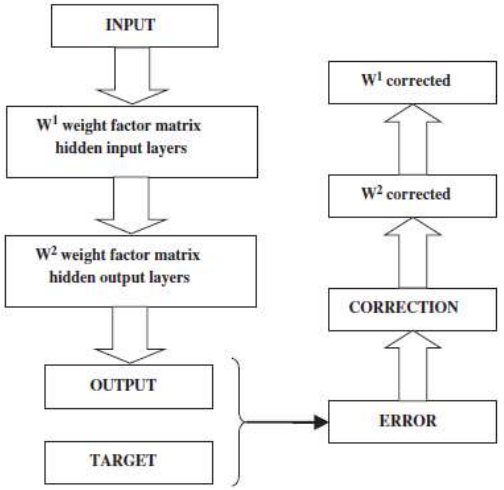


Fig. 7. Diagram of the error back propagated supervised training.

- All the input values were normalized and the neural network outputs were introduced (they can have a value between 0 and 1):
  - Ks—plant safety index;
  - Ka—plant reliability/availability index.

The tele-maintenance intelligent system

Ks range

Ks	Safety	Actions
0	Plant is safe	None
0.25	Plant is safe but to be kept under control	Check the parameters during the scheduled routine maintenance visits
0.5	Plant is safe but to be kept under strict control	Schedule specific controls during routine maintenance visits
0.75	Plant requires attention	Schedule specific action to check the safety conditions and, if necessary, restore them
1	Risk unacceptable	Shut sown the plant and emergency action required

Ka	Reliability/availability	Actions
0	Plant is reliable and available	None
0.25	Plant is reliable and available but to be kept under control	Check the parameters during the scheduled routine maintenance visits
0.5	Plant is reliable and available but to be kept under strict control	Schedule specific controls during routine maintenance visits
0.75	Incipient failure	Schedule specific action to check the safety conditions in order to restore the reliability and availability level
1	Failure	Failure condition imminent; emergency action required on the plant to avoid shutting down the plant and reducing the plant availability time

The tele-maintenance intelligent system

- The experimental data acquisition campaign was designed in order to collect input data and allocating the Ka and Ks target values by simulating all the possible operating conditions of the plants and the possible safety, reliability and availability conditions.

- Using particular criteria for allocating Ka and Ks target values it was possible to train the neural network to make it capable of forecasting (during normal on-line operation of the plant) unacceptable failure and risk conditions when the neural network outputs Ka and Ks tend to 1.

- The neural network chosen has a specific structure and main characteristics for each plant type:
  - Number of layers
  - Number of hidden layers
  - Number of neurons in each layers
  - Transfer functions between layers
  - Weights synapses matrix dimension
  - Bias matrix dimension
  - Error calculation and training/verification algorythm

The tele-maintenance intelligent system

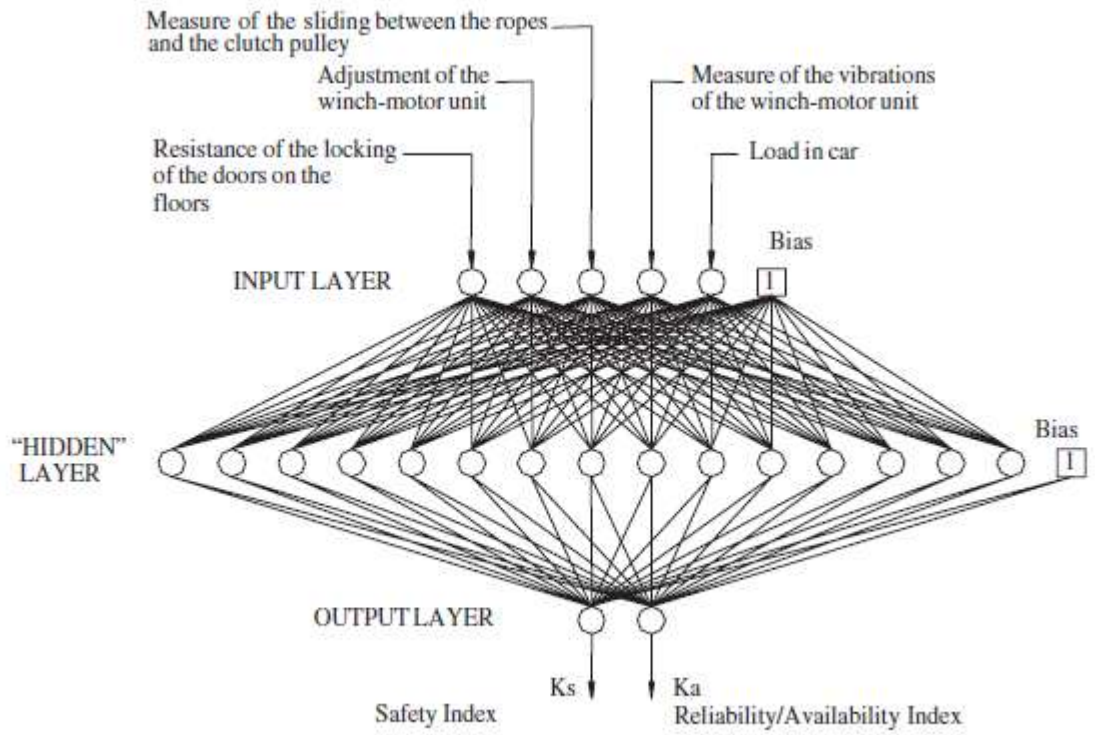


Fig. 4. Architecture of the neural network used for the elevator plants.

The tele-maintenance intelligent system

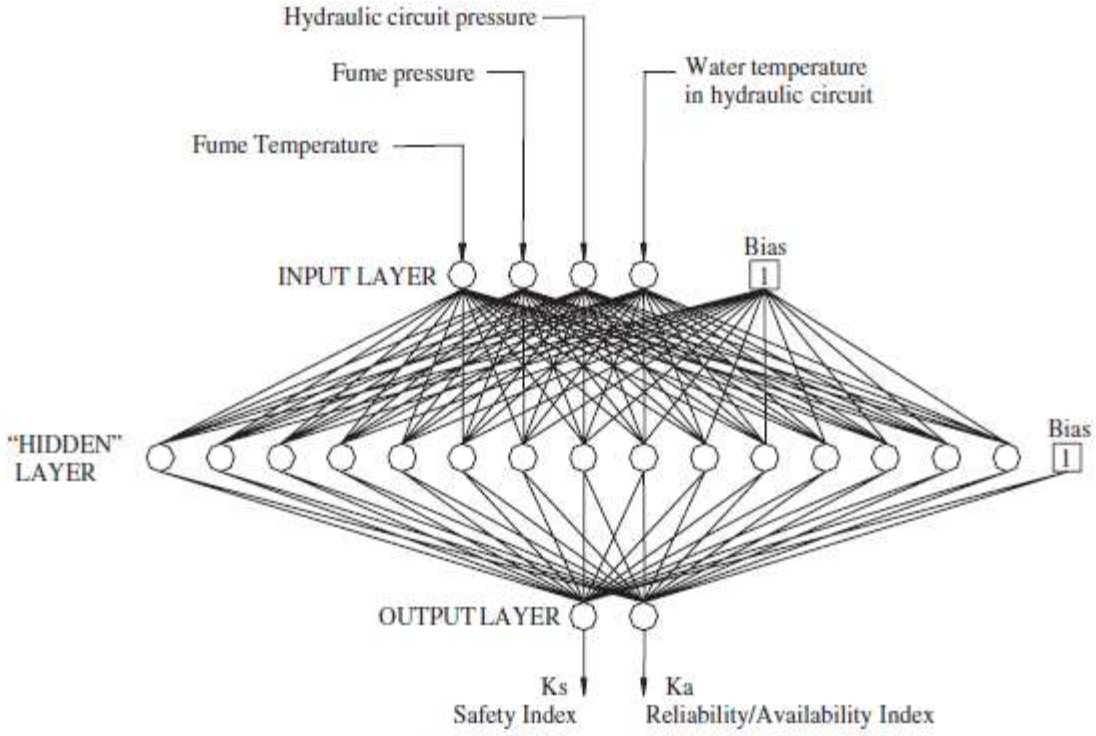


Fig. 5. Architecture of the neural network used for the thermal plants.

The tele-maintenance intelligent system

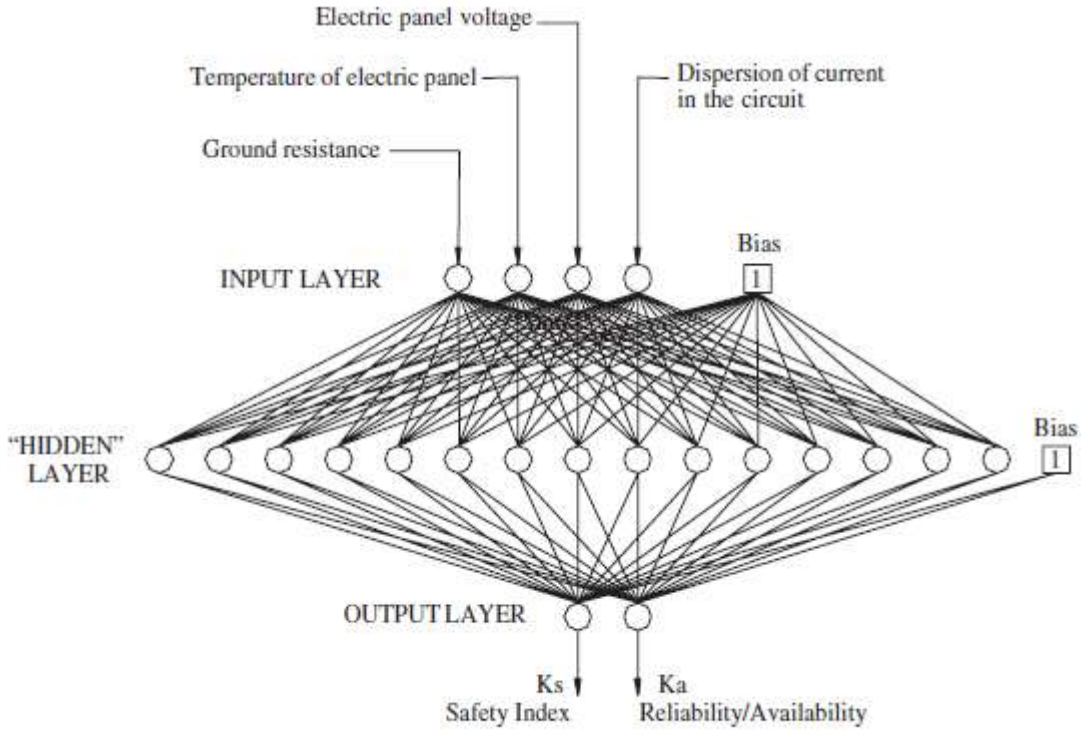
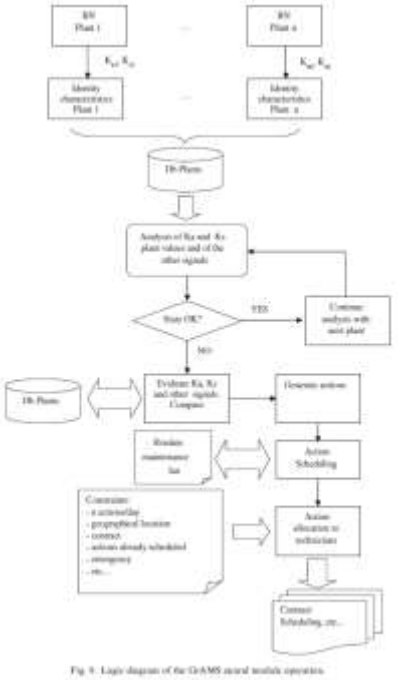


Fig. 6. Architecture of the neural network used for the electrical plants.

The tele-maintenance intelligent system

- The system executes the detailed ‘‘scheduling’’ of the actions and allocates them to the technicians taking into account the rules established by the user such as, for example:
  - number of actions to be carried out each day by each technician;
  - geographical location of the plants on which the actions are required;
  - other constraints of a contractual nature;
  - actions already scheduled through previous processing;
  - actions scheduled in the routine maintenance plan; and
  - emergency situations (i.e.: hospitals, hotels, etc.).



- The criterion for selection of the actions takes moreover into account:
  - the estimated Ka and Ks values
  - the history of the actions previously carried out on the plant and
  - the state of the other monitored signals using statistical and probabilistic methods.

The tele-maintenance intelligent system

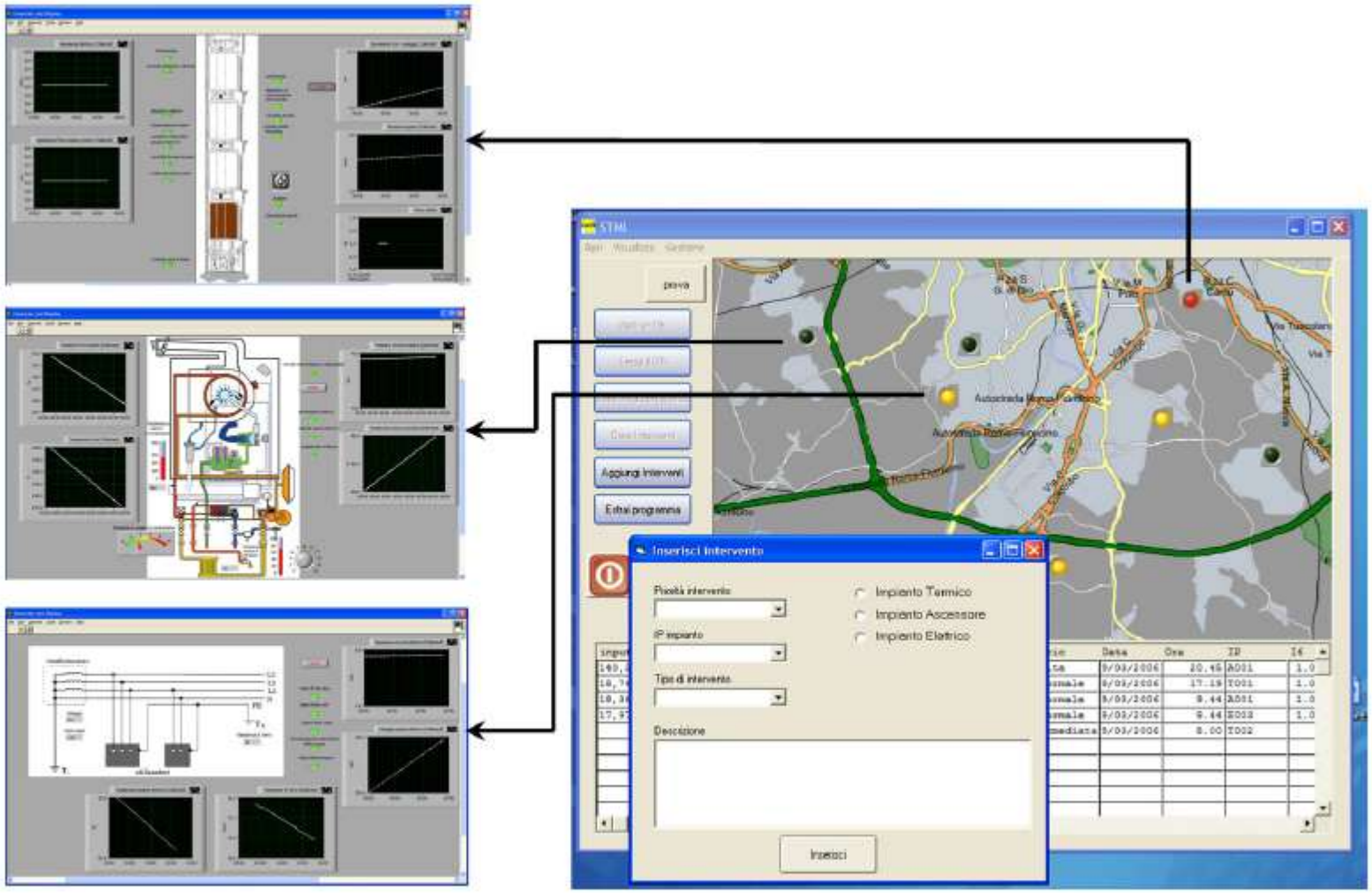
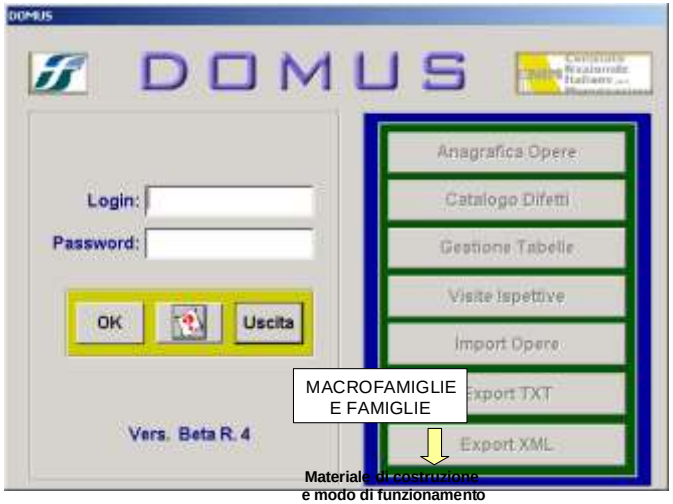


Fig. 10. A view of the software management tool.

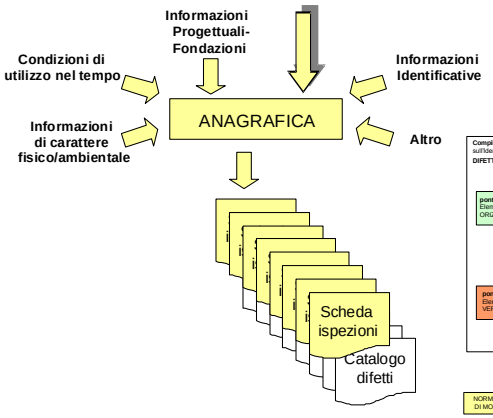
DOMUS – Diagnostica Opere di Manutenzione Unificata Standard

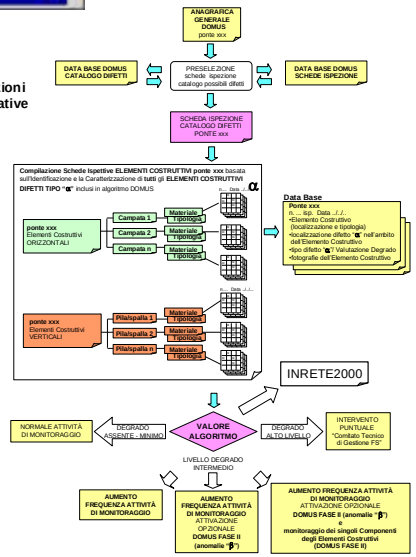
DOMUS – Diagnostica Opere di Manutenzione Unificata Standard



MACROFAMIGLIE E FAMIGLIE

Materiale di costruzione e modo di funzionamento





MATERIALI

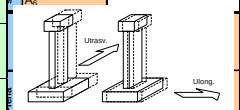
			Acciaio	Travi di acciaio incorporate	Sistema composto Acciaio/cls	Cls e Cls armato	Cls precompresso	Murature	varie
TRAVATA	Parete Reticolare		A_1^F		S_1^F	C_1^F			V_1^F
	Parete Piena	Sezione Piena	A_2^F	I_2^F	S_2^F	C_2^F	P_2^F		V_2^F
		Sezione scatolare	A_3^F		S_3^F	C_3^F	P_3^F		V_3^F
ARCO	Parete Reticolare		A_4^F			C_4^F			V_4^F
	Parete Piena	Sezione Piena	A_5^F	I_5^F		C_5^F		M_5^F	V_5^F
		Sezione scatolare	A_6^F			C_6^F		M_6^F	V_6^F
PONTE	Parete Reticolare					C_7^F			V_7^F
	Parete Piena	Sezione Piena	A_8^F		S_8^F	C_8^F	P_8^F		V_8^F
		Sezione scatolare				C_9^F	P_9^F		V_9^F
SOTTOSTRUTTURE						C_{10}^F		M_{10}^F	V_{10}^F
	Sezione Rettangolare					C_{11}^F			V_{11}^F

DIFETTI NELLE SOTTOSTRUTTURE

S1 — **MOVIMENTI NEL PIANO ORIZZONTALE**

Definizione: movimenti della fondazione su un piano orizzontale.

Modalità isnettive: ispezione visiva e misurazione con metro. Poiché, il difetto è difficilmente rilevabile se ne può individuare la presenza attraverso: apertura e rigonfiamenti del terreno limitrofo alle fondazioni, spostamenti relativi anomali nei giunti, deformazioni dei binari.



Descrizione sintetica: spostamenti laterali sia nella direzione longitudinale che trasversale all'impalcato, generati sia da spinte del terreno sia da cedimenti nelle strutture di fondazione

Procedure e strumenti: Lo strumento da utilizzare è il metro da impiegare per rilevare spostamenti relativi ad esempio nei giunti. Sulla base di queste misure è necessario quantificare lo spostamento orizzontale della fondazione rispetto alla configurazione originaria. Fotografare e misurare lo spostamento laterale.

B	2		
K_2	CRITERIO VALUTAZIONE INTENSITA': Valutazione dello spostamento nel piano orizzontale delle strutture di fondazione	$K_2 = 0,5$	< 2cm
		$K_2 = 1,0$	da 2 a 5 cm
		$K_2 = 1,5$	da 5 a 10 cm
		$K_2 = 2.0$	> 10 cm
K_3	CRITERIO VALUTAZIONE ESTENSIONE: Localizzazione del difetto	$K_3 = 1,0$	Il difetto non richiede una valutazione dell'estensione. Al coefficiente K3 deve essere assenato valore 1 se il difetto è presente.

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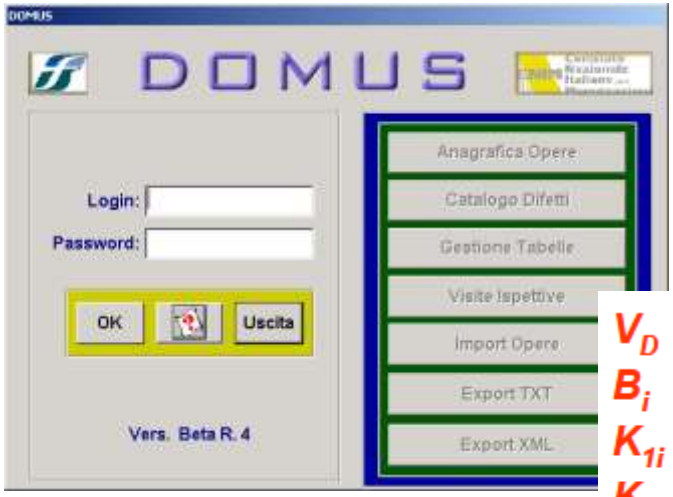


$$S = R_c = \frac{R}{R_r} \times 100 = \frac{\sum V_D}{\sum V_{D,ref}} \times 100$$

V_D valore del danno

B_i valore di base associato ad un determinato danno "i", assume valori da 1 a 4;

K_{1i} fattore di importanza del singolo elemento sull'impianto strutturale;

K_{2i} fattore per l'intensità e grado del danno di tipo "i".

K_{3i} fattore di estensione del danno.

K_{4i} fattore di urgenza.

$$S = R_c = \frac{R}{R_r} \times 100 = \frac{\sum V_D}{\sum V_{D,ref}} \times 100$$

- **PERUS D** — Somma su tutti i danni definiti per tutti gli elementi definiti
- **ZNIDARIC** — Somma su tutti i danni possibili per tutti gli elementi possibili
- **PERUS M** — Somma su tutti i danni definiti per tutti gli elementi definiti in una famiglia
- **DOMUS 1** — Somma su tutti i danni rilevati per tutti gli elementi possibili
- **DOMUS 2** $\sum\sqrt{(\max[V_{\alpha,\gamma}])^2}$ — Somma il valore efficace di tutti i danni possibili

Case study: the management of a railway infrastructure DOMUS Project

- The number of bridge structure entering the last period of their service life is increasing in Europe (Italy)

This process generates

- Large demand by European Regional (Italian) Public Administration of tools and techniques useful for bridge decision support

- Different Italian Agencies that manage a bridge network are interested in developing automatic procedure for inspections and bridge safety assessment

Case study: the management of a railway infrastructure
DOMUS Project

Prevalent Material

Structural Scheme of the Main Span

Bridge Inventory – Definition of Bridges Groups

STRUCTURAL SYSTEMS			MATERIALS: Steel	Concrete covered steel beam	Mixed Steel / Concrete	Reinforced concrete	Pre-stressed concrete	Masonry	variation
DECKS	Truss Beams		A_1		S_1	C_1			V_1
	Beams	Open Section	A_2	I_2	S_2	C_2	P_2		V_2
		Sezione scatolare	A_3		S_3	C_3	P_3		V_3
ARCHS	Truss Beam		A_4			C_4			V_4
	Beams	Open Section	A_5	I_5		C_5		M_5	V_5
		Sezione scatolare	A_6			C_6		M_6	V_6
SUSPENDED AND STAYED BEAMS	Truss Beam		A_7		S_7	C_7			V_7
	Beams	Open Section	A_8		S_8	C_8	P_8		V_8
		Closed section	A_9		S_9	C_9	P_9		V_9
TUBES	Circular Section		A_{10}			C_{10}		M_{10}	V_{10}
	Rettangular Section					C_{11}			V_{11}

Case study: the management of a railway infrastructure
DOMUS Project

Priority Ranking Procedure

Priority Ranking Index

$$I = R_c = \frac{R}{R_r} \times 100 = \frac{\sum_c V_D}{\sum_c \max|V_D|} \times 100$$

where

$$V_D = \sum_{i=1..d} B_i \times K_{1i} \times K_{2i} \times K_{3i} \times K_{4i}$$

Modified version of: Wicke 87, Bergmeister 97, Znidirac and Perus 98

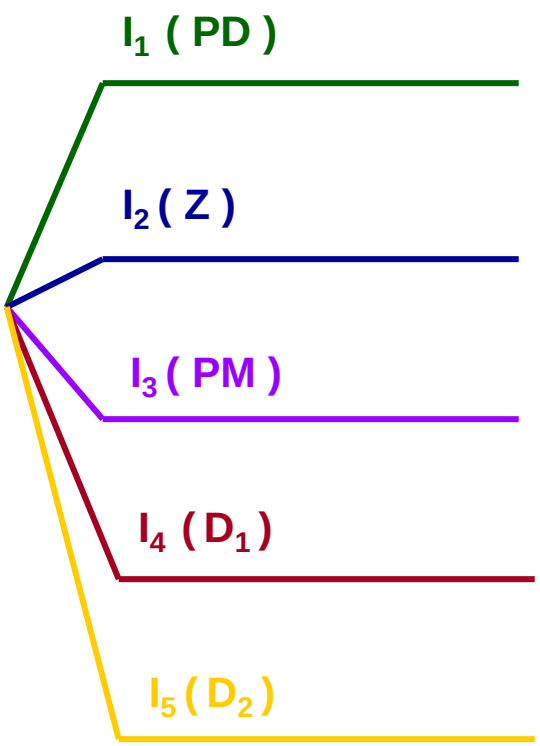
- V_D **damage or defect level for the type component *c* (average or maximum)**
- B_i **potential effect of the damage type "i", (range value 1 to 4);**
- K_{1i} **component's effect (range value 0.5-1-1.5-2);**
- K_{2i} **intensity of the damage type "i". (range value 0.5-1-1.5-2);**
- K_{3i} **extent and expected propagation of the damage type "i" (range value 0.5-1-1.5-2);**
- K_{4i} **urgency and needs of intervention . (range value 1 to 5);**

Case study: the management of a railway infrastructure
DOMUS Project

Priority Ranking Procedure – Evaluation R_r

Evaluation of the reference value R_r

Different measures for *I*



Add all defined damages for all defined components

Add all defined damages for all components belonging a bridge group

Add all damages for all components belonging a bridge group

Add all inspected damages for all defined components

Add the rms value of all defined damages for all defined components

Case study: the management of a railway infrastructure
DOMUS Project

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DOMUS Project

Case study: the management of a railway infrastructure
DOMUS Project

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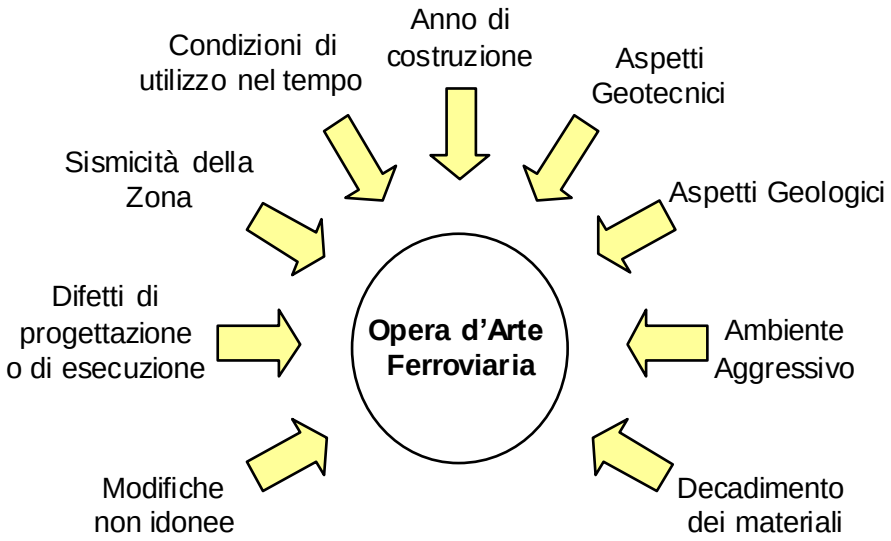
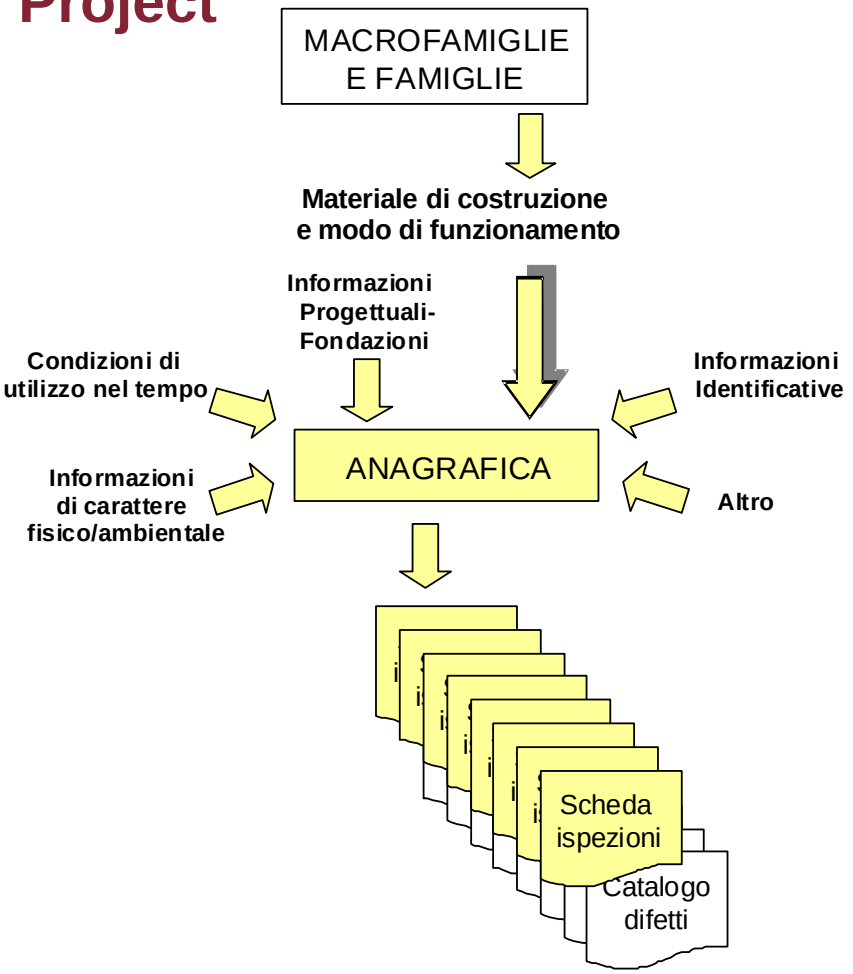
Case study: the management of a railway infrastructure
DOMUS Project





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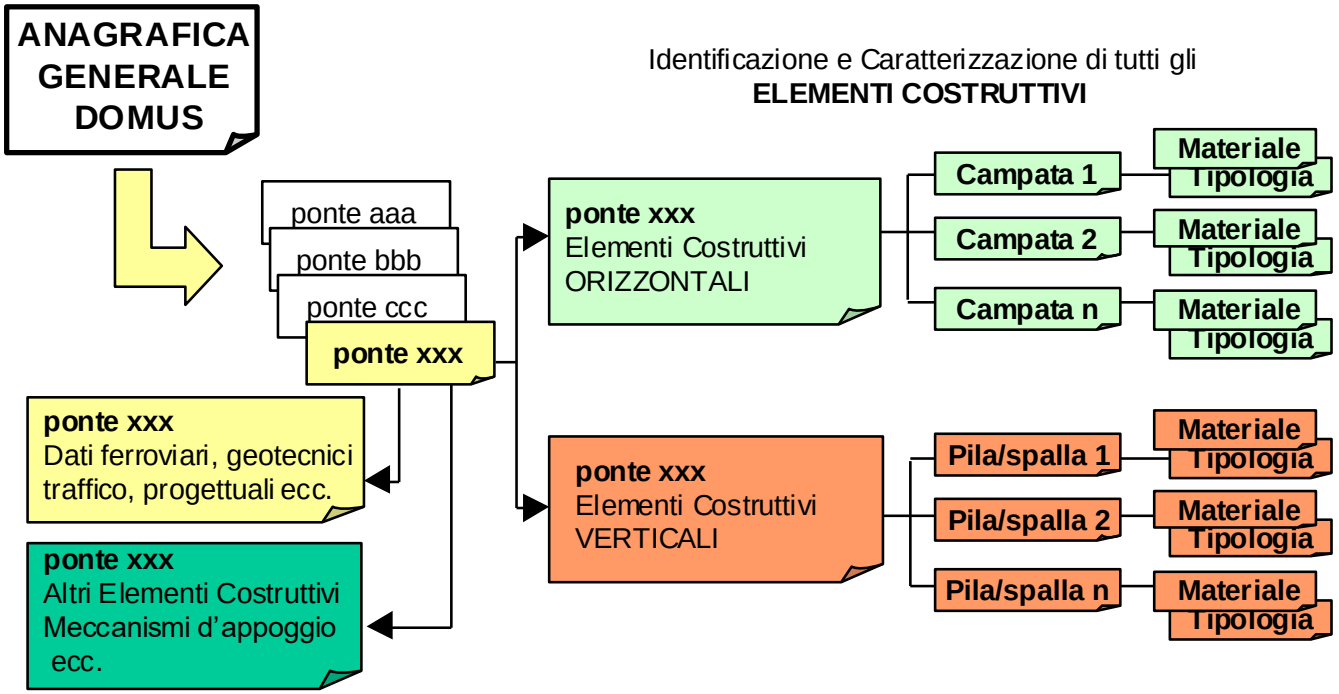

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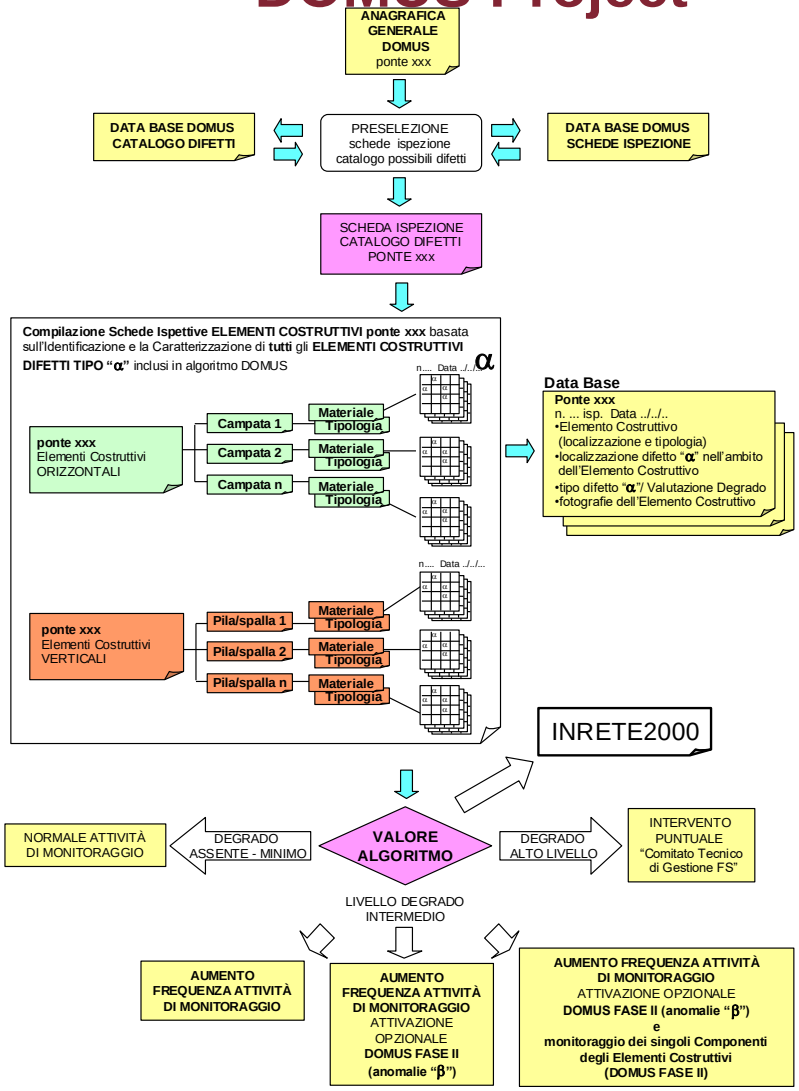

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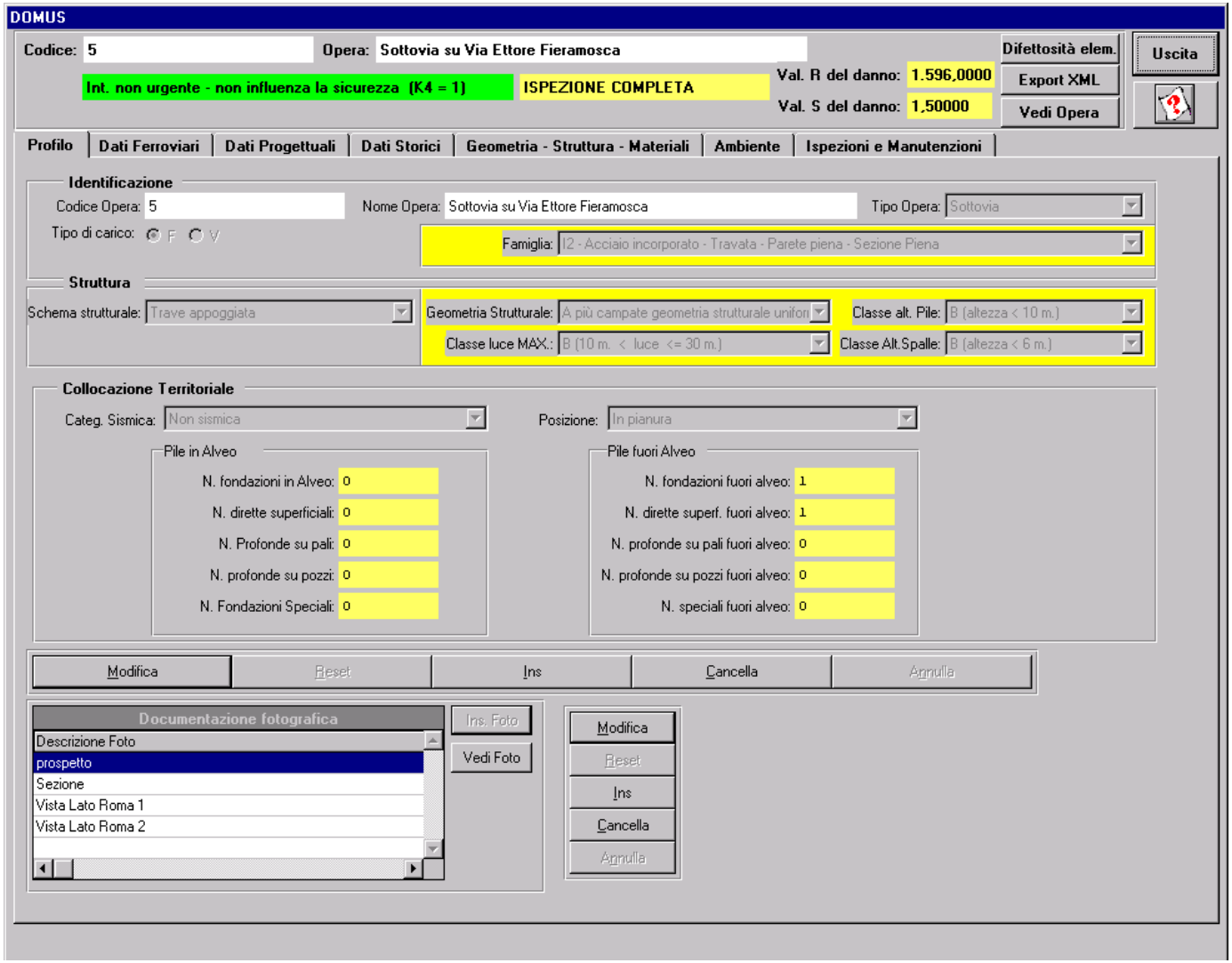

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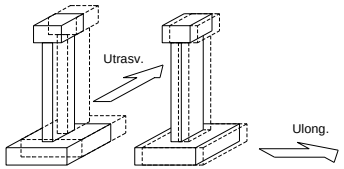
DIFETTI NELLE SOTTOSTRUTTURE			
S1	**MOVIMENTI NEL PIANO ORIZZONTALE**		
Definizione: movimenti della fondazione su un piano orizzontale.			
Modalità ispettive: ispezione visiva e misurazione con metro. Poiché, il difetto è difficilmente rilevabile se ne può individuare la presenza attraverso: apertura o rigonfiamenti del terreno limitrofo alle fondazioni, spostamenti relativi anomali nei giunti, deformazioni dei binari.			
Descrizione sintetica: spostamenti laterali sia nella direzione longitudinale che trasversale all'impalcato, generati sia da spinte del terreno sia da cedimenti nelle strutture di fondazione			
B	**2**	**Procedure e strumenti:** Lo strumento da utilizzare è il metro da impiegare per rilevare spostamenti relativi ad esempio nei giunti. Sulla base di queste misure è necessario quantificare lo spostamento orizzontale della fondazione rispetto alla configurazione originaria. Fotografare e misurare lo spostamento laterale.	
K_2	**CRITERIO VALUTAZIONE INTENSITA':** Valutazione dello spostamento nel piano orizzontale delle strutture di fondazione	**K_2 = 0,5**	< 2cm
		K_2 = 1,0	da 2 a 5 cm
		K_2 = 1,5	da 5 a 10 cm
		K_2 = 2,0	> 10 cm
K_3	**CRITERIO VALUTAZIONE ESTENSIONE:** Localizzazione del difetto	**K_3 = 1,0**	Il difetto non richiede una valutazione dell'estensione. Al coefficiente K3 deve essere assegnato valore 1 se il difetto è presente.

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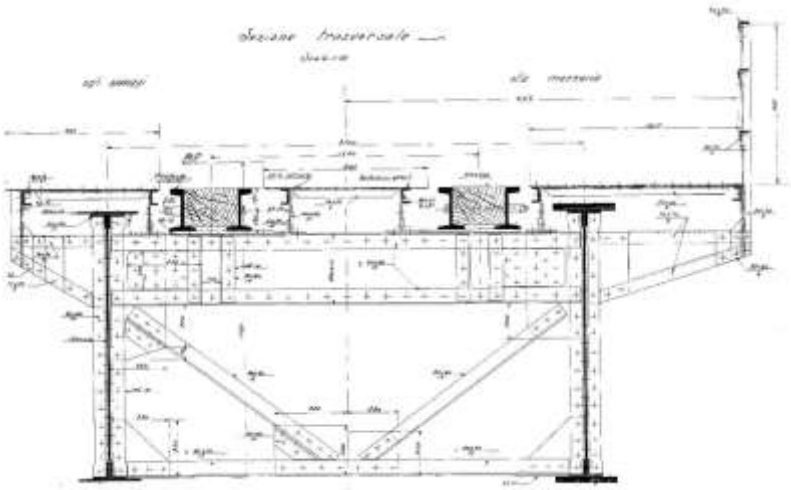
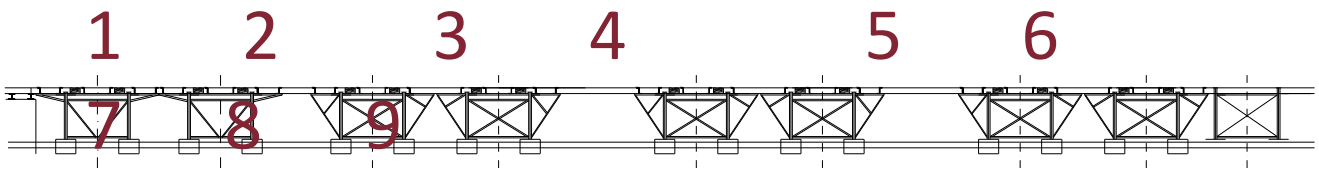
DOMUS Project



SEZIONE TRASV. SCHEMATICA VIADOTTO

COPPIE DI TRAVI



Case study: the management of a railway infrastructure DOMUS Project

CODICE OPERA	DATA RILEVAMENTO	N. ISPEZIONE	FOGLIO N.	3A
NUMERO SPALLA			IMPORTANZA ELEMENTO K_1	

Spalla n° ...

	M_S	S	D	M_D
Campo A				
Campo B				

NOTE:

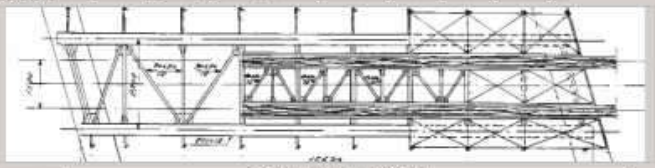
SCHEDA 2B : DIFETTI IMPALCATI A TRAVATA IN ACCIAIO – Ponti a parete piena **2B**

CODICE OPERA	DATA 13.11.2001	N. ISPEZIONE 1	FOGLIO N. 3	TRAVI MAESTRE
CAMPATA Unica	Coppia di travi 1 e 2		IMPORTANZA ELEMENTO K_1	

campo 1 2 3 4 5 6 7 8 9

Trave 2 - 4

Trave 1 - 3



Coppia 1 – 2

TRAVI MAESTRE

Campo	COPPIA 1				COPPIA 2			
	1	2	3	4	1	2	3	4
	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3	F C K_1 K_2 K_3
1	A1 1.0 1.0 1.0	• A1 1.0 1.0 1.0	• A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
2	• A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
3	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
4	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
5	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
6	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
7	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
8	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0	A1 1.0 0.5 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0
9	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0	A1 1.0 1.0 1.0
	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0	A2 0.5 0.5 1.0

NOTE: Le coppie di travi 1 e 2 sono datate 1924 e sono diverse dalle coppie 3 ÷ 8

Maintenance of historic structures: background

- Why speaking of maintenance in Rome:
  - The first builders?
    - The first stone temple is the Gobekli Tepe (rounded hill) one, in Turkey (9600 bC)
    - The first stone towers are the so called ziggurat in the area of Mesopotamia (Sumerian, Babylonian and Assyrian) (4000 bC)
    - The first stone temple un Europe is the Stonhenge, in UK (3000-1600 bC)
    - The first pyramids and stones are probably in Egypt (2500 bC)
    - The first one-stone monument is the Sphinx from Egypt (2500 bC)
    - The first one-stone obelisks (monoliths) are from Egypt (2300 bC) and they are now in Rome (less in London, Paris, etc.)
  - The first engineering handbook?
    - De Architectura, by Marco Vitruvio Pollione (15 bC)

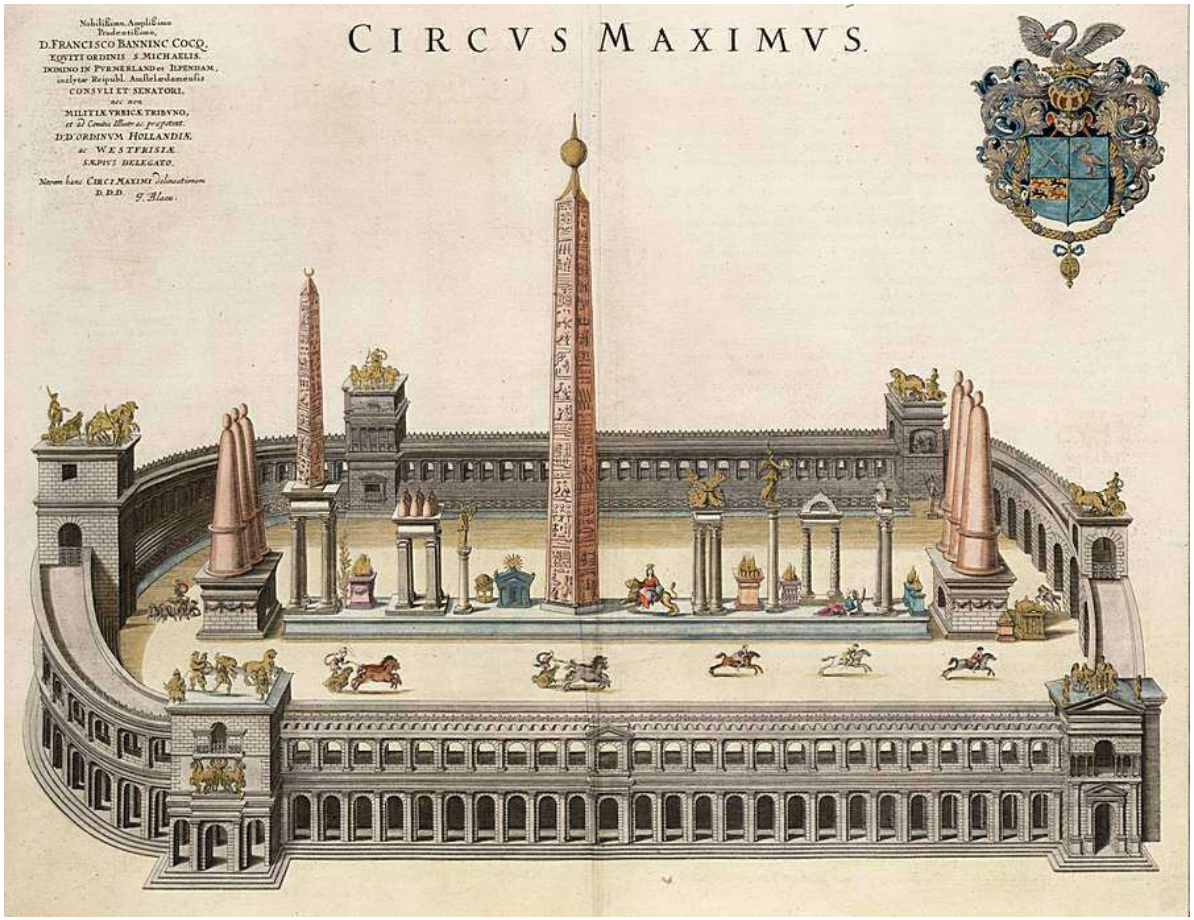
  - The first engineer?
    - Leonardo Da Vinci (‘500)

  - The most visited historic building?
    - The Flavius amphitheatre or Amphiteatrum (Colosseo) (80 AD): 91 Geuro/year

Quamdiu stabit Colyseus stabit et Roma;
cum cadet Colyseus cadet et Roma;
cum cadet Roma cadet et mundus

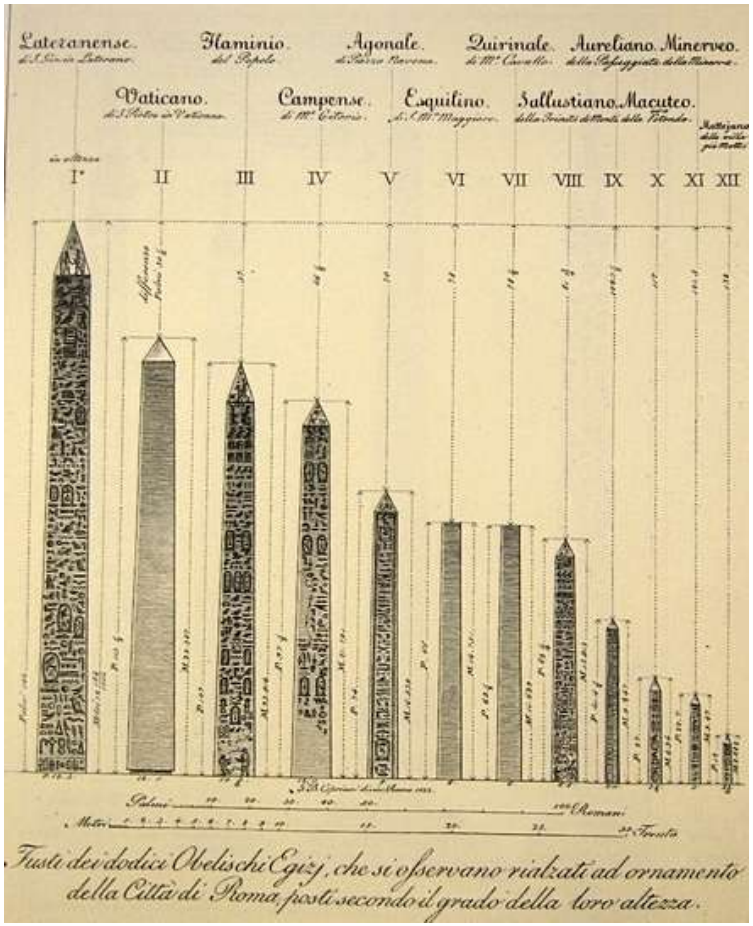
As long as the Coloseum, Rome also exist;
when the Coloseum falls, Rome will fall;
when Rome falls, the world will fall.

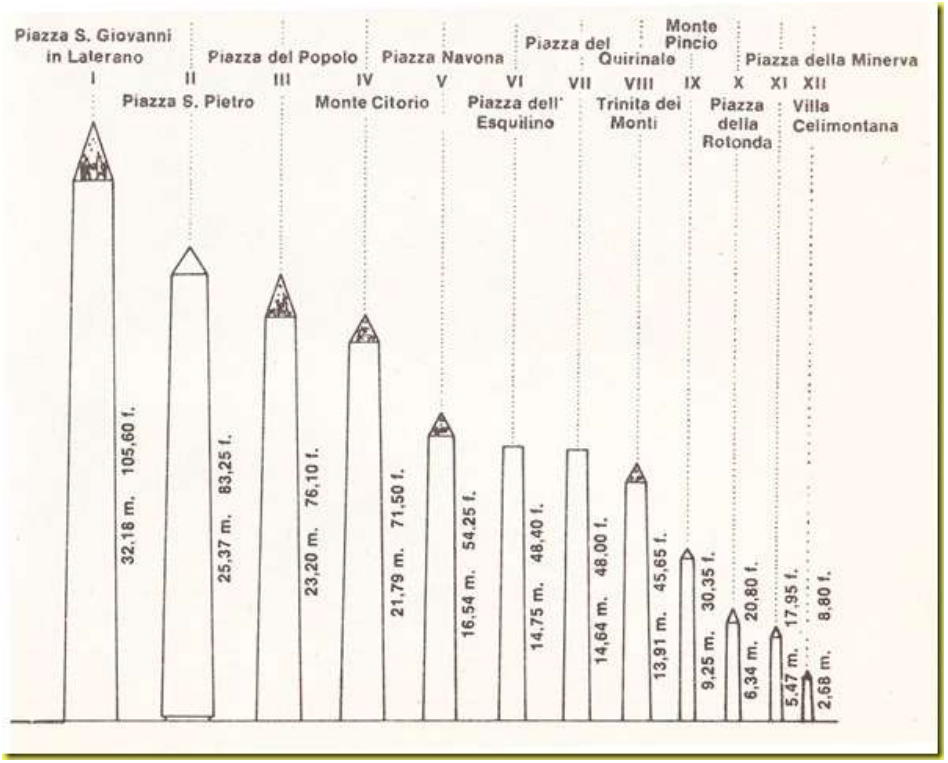
Historic structures in Rome: the monoliths



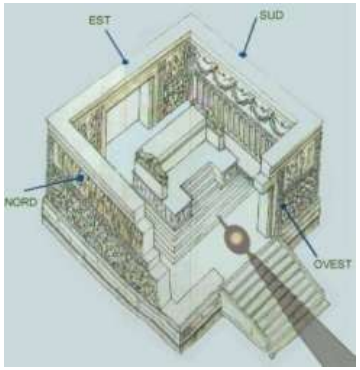
Historic structures in Rome: the monoliths

Historic structures in Rome: the monoliths





Historic structures in Rome: the monoliths



Historic structures in Rome: the monoliths

SAPIENTIS AEGYPTI
INSCVLTAS OBELISCO FIGURAS
AB ELEPHANTO
BELLVARVM FORTISSIMA
GESTARI QVISQVE HIC VIDES
DOCVMENTVM INTELLIGE
ROBVSTAE MENTIS ESSE
SOLIDAM SAPIENTIAM SVSTINERE

Whoever sees here that the symbols of the Egyptian sage, inscribed on the obelisk, are carried by the elephant, the strongest of the beasts: understand that it is a proof of a robust mind to sustain solid wisdom.

Rome and Maintenance of historic structures

- The public spending for the maintenance of historic/artistic structures is (2012)
  - 53 Meuro
  - 0,003% of GNP (1500 Geuro)
  - X% of the value of the historic/artistic structures
  - For Industry: maintenance is at least the 4% of the value of the goods
  - For Health sector: maintenance goes from 8% to 19% of the value of the goods.

- What is the value of the Italian monuments (X)?
  - The brand value of some of the most famous Italian monuments is estimated at nearly **400 billion euro* (but 2/3 of the archaeological sites are not surveyed)**.
  - It is a value that does not affect the tangible heritage but it is linked to the image and visibility of the brand.

- Then the public spending for maintenance of Italian maintenance should be at least:
  - 16 billion euro
  - 300 times of the present spending.

Risk Map

- The "**Risk Map**" is the geographic information system of scientific and administrative support to the government agencies responsible for protecting the territorial and cultural heritage.

- For the construction of the risk model was adopted a statistical approach, based on which the individual assets are valued as a "unit" of a "statistical population" of which the aim is to assess the level of vulnerability and risk.

- The Risk factors have been divided into:
  - **Individual Vulnerability** (**V**), ie a function that indicates the level of exposure of a given item to the aggression of environmental and territorial factors

- - **Territorial Hazard** (**P**), ie a function that indicates the level of potential aggressiveness of a given geographical area, independently of the presence or not of historic structures.

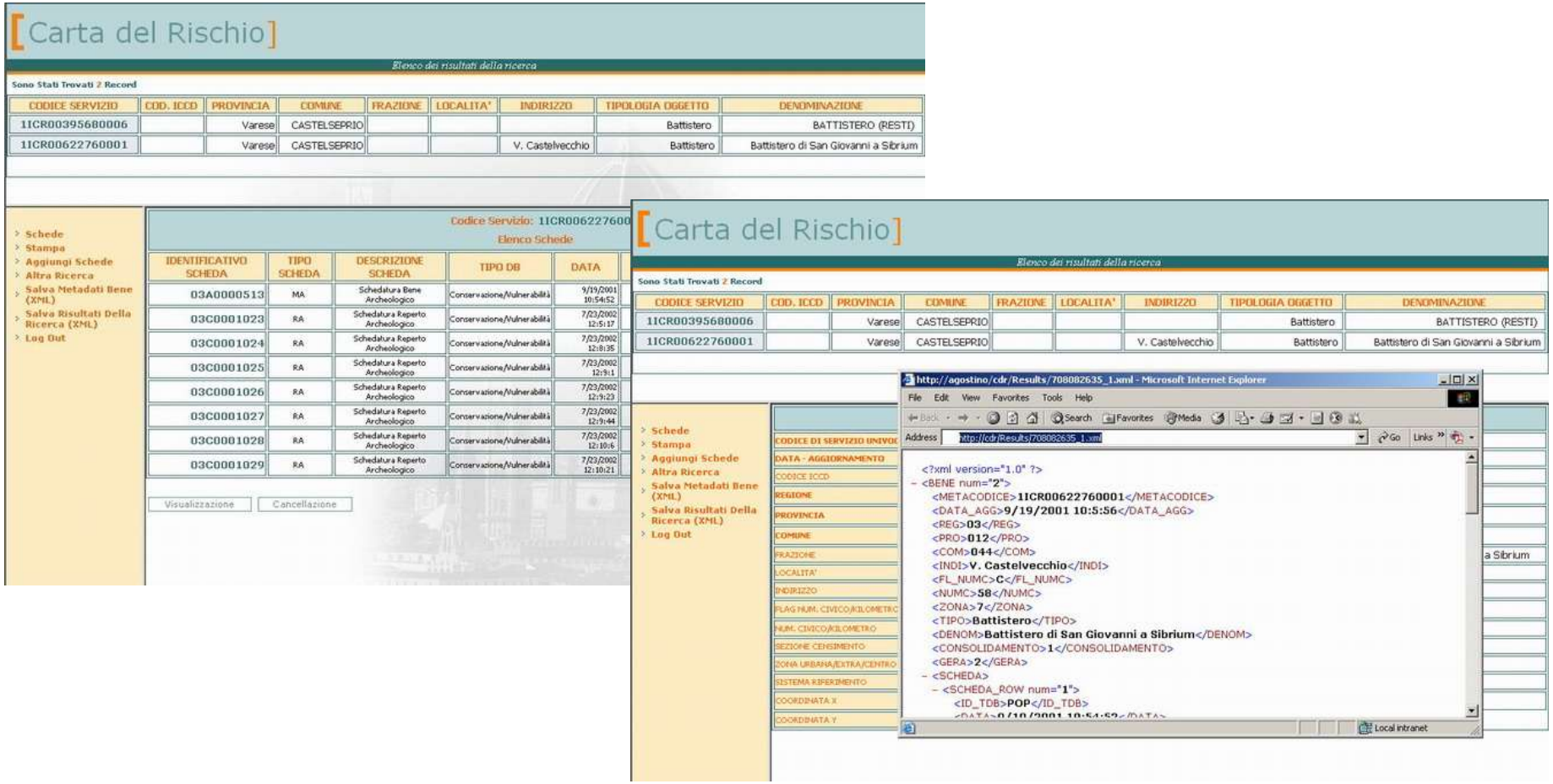
- The **ISO 31000** (2009) (“Principles and Guidelines on Implementation of risk management”)/ISO Guide 73:2002 (“Risk Management - Vocabulary”) definition of risk is the **'effect of uncertainty on objectives**'.

Risk Map

- The search fields available are all self-explanatory and search clauses are linked by a relationship type logic AND.

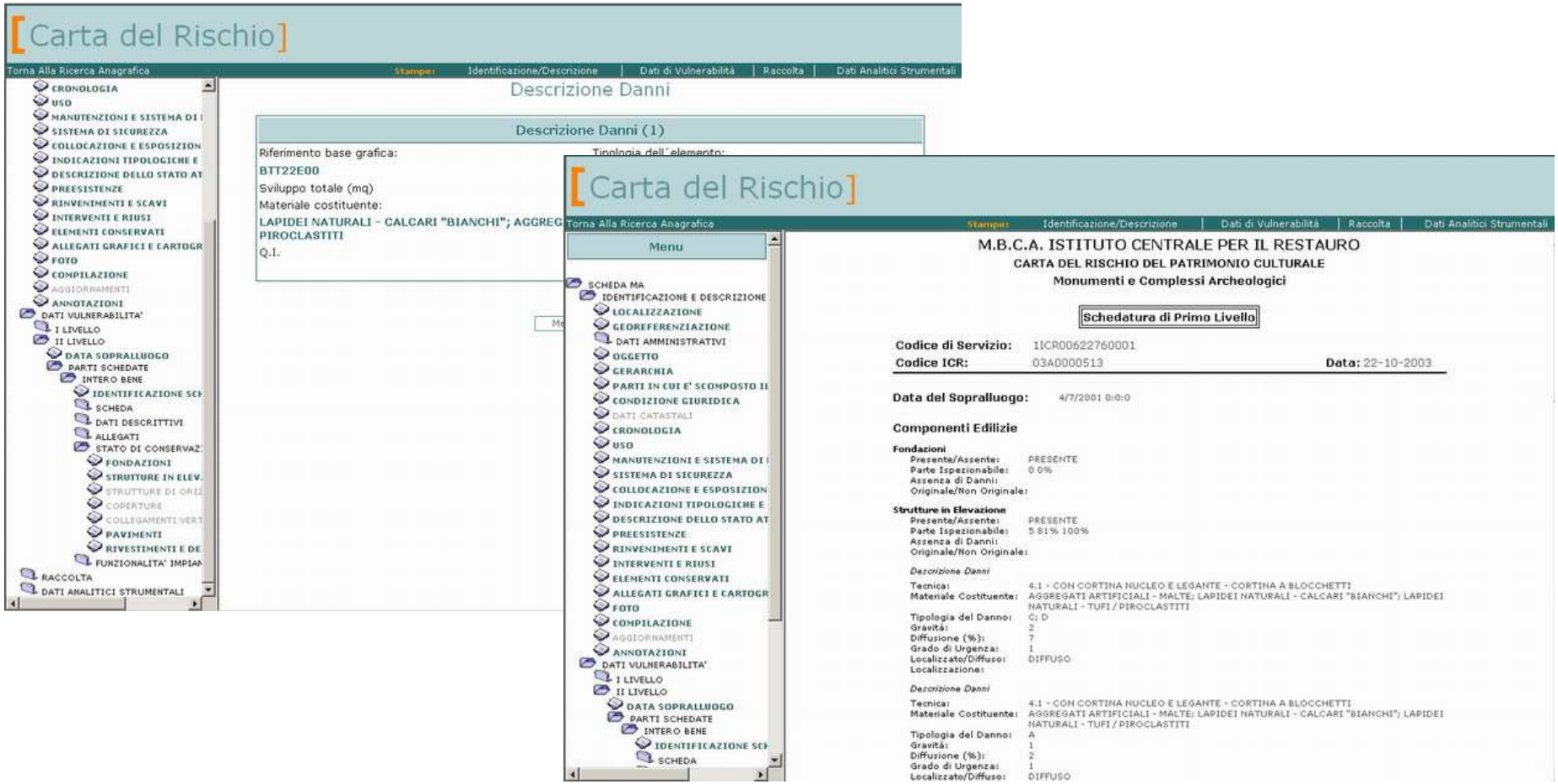
Risk Map

- Clicking on the voice *Schede* (*cards*) on the side menu you get the list of all cards associated with the item selected. Such cards can also be selected in turn by clicking on the card identification code.



Risk Map

- Through the side menu you can navigate completely card information that are in a hierarchical/tree structure.



COVA, Crowd funding for cOnserving and VAlorizing minor monuments

- COVA, is the project by Sapienza University which aims to enhance the minor assets of Italian cultural heritage through virtual models and augmented reality applications.

- The idea is designed to:
  - create digital reconstructions of monuments to monitor the state of conservation
  - to return the enjoyment of works otherwise inaccessible to the general public.

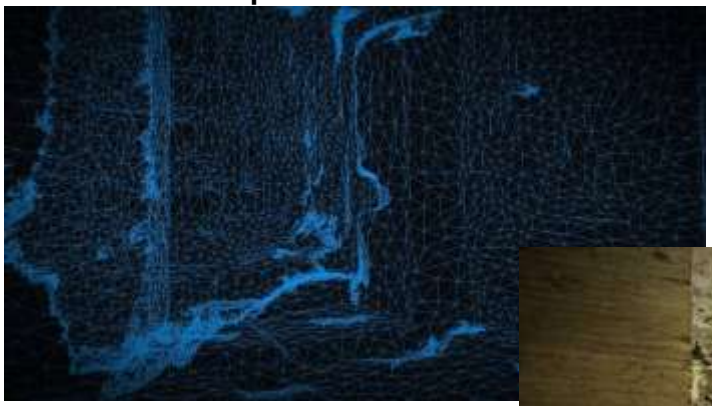
- The vital parameters for the preservation of monuments, obtained from wireless sensor networks, are received on tablets and other computing platforms, so to plan actions for protecting the sites and manage emergencies in real time.

- The digital model allows a remote user both a visit in 3d sites in its present state of preservation, and a journey into their history reconstructed.

COVA, Crowd funding for cOnserving and VAlorizing minor monuments

- COVA site visits are enhanced by augmented reality apps that extend and enrich the sensory perception of the visitors with tourist information and culture.

- COVA technology is designed for those monuments that are not part of the main tourist circuits and are often relegated to the margins of cultural consumption.



Inside Rome: Rome door to East

- Eastern wind always caressed Rome and it blowed over the Tiber valley well before that within the seven hills was founded a city named Rome (4/21/753 bC).
- Magic and esoteric rituals always lived there, with the ancient babylonic and egyptian cultures.
- The “Devil”? It existed there well before that the Pope established.
- *Rome? She was a young, lonely and romantic girl, gentle as a sea flower, but so strong to strike the will of Aenea with whom, together with other Troyans, she escaped from the annihilation of Troy.*
  Rome could use the art of magic, of love and of the other more deep and sacre human feelings.
  (Stesicoro, VI sec. b.C.).

Inside Rome: Rome door to East