Simulation-Based Framework for Maintenance Optimization

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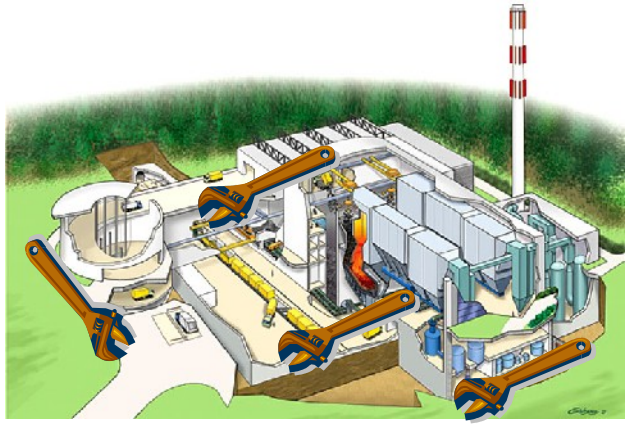
Introduction

Maintenance activities influence the entire production process, from product quality to on-time delivery:

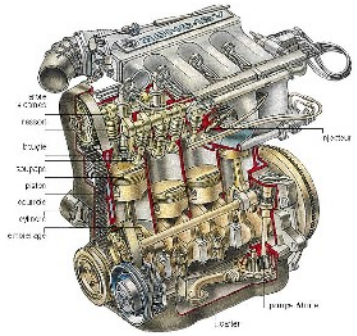


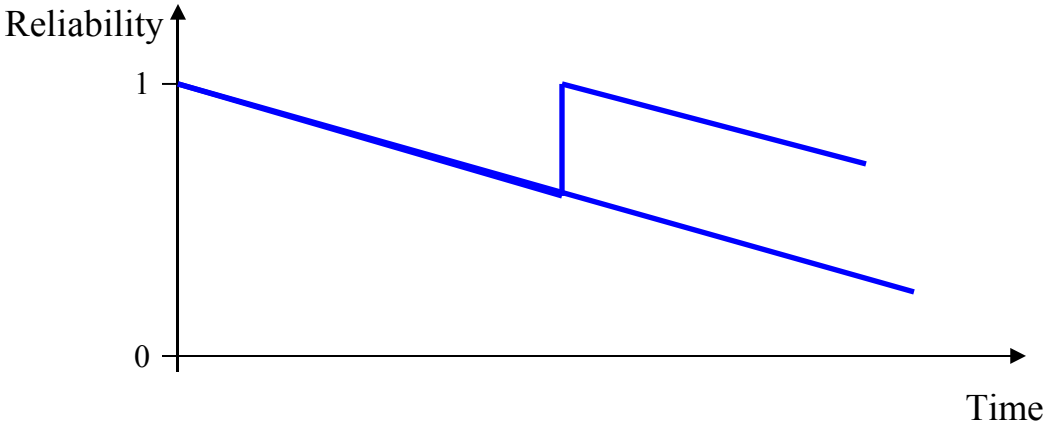
Poor maintenance procedures:

expensive cost

Maintenance → Strategic asset and a profit centre

Aim of the Framework





But :

- When to carry out maintenance activities ?
- How to do it ?
- On which component of the system ?

… To maximize the equipments availability and minimize maintenance average costs.

<u>Aim of the framework:</u>

To give a help to the manager who wants to implement optimal maintenance strategies to its production machines, thanks to a tool, easy to use.

Maintenance Strategies

Definition

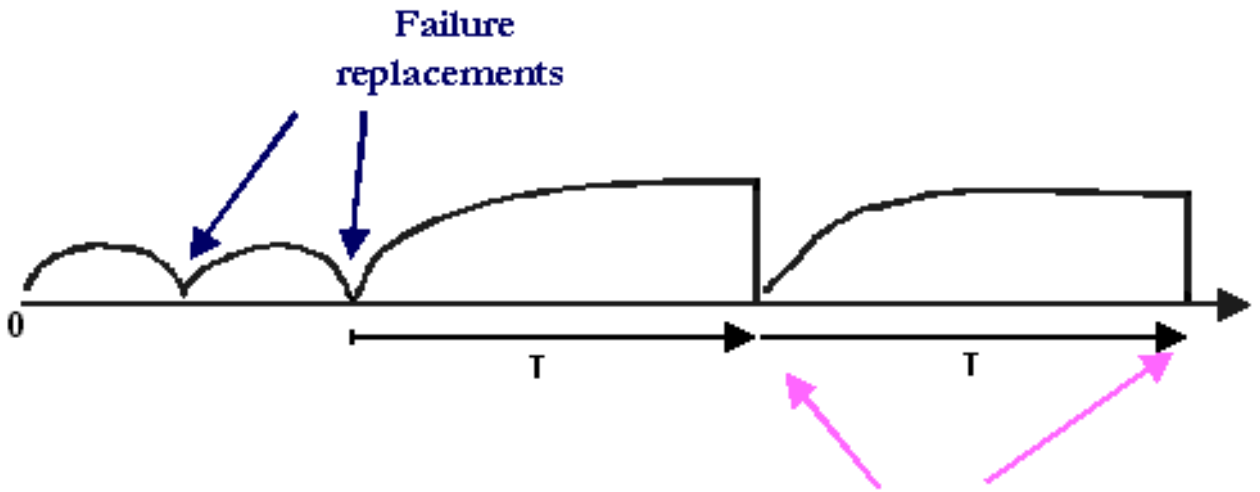
Decision rule which establishes the sequence of maintenance actions to be undertaken according to the degradation level of the system.

Various strategies depending on:

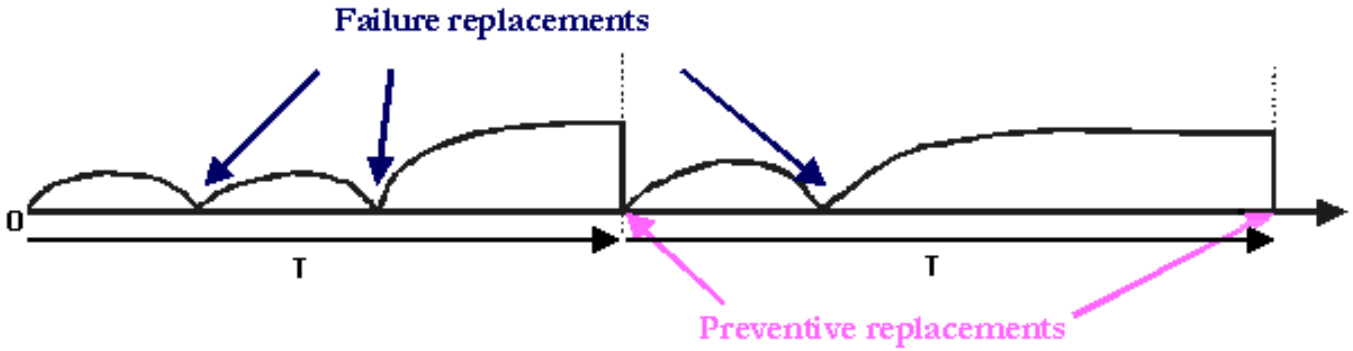
- the nature and the action sequel that they suggest
- the selected performance criteria
- if the system is considered as a sole entity or as constitued of many components
- if the state is know at all time or after inspection

Examples

Age Replacement Policy (ARP):



Block Replacement Policy (BRP):



Why not using analytic models to evaluate maintenance strategies ?

✓ Difficult to develop maintenance strategies models and very complex to solve them

✓ With simulation, not need to develop analytical models if you want to take into account :

- the production
- human resources
- material resources
- complex maintenance strategies (opportunist, replacement by used components)

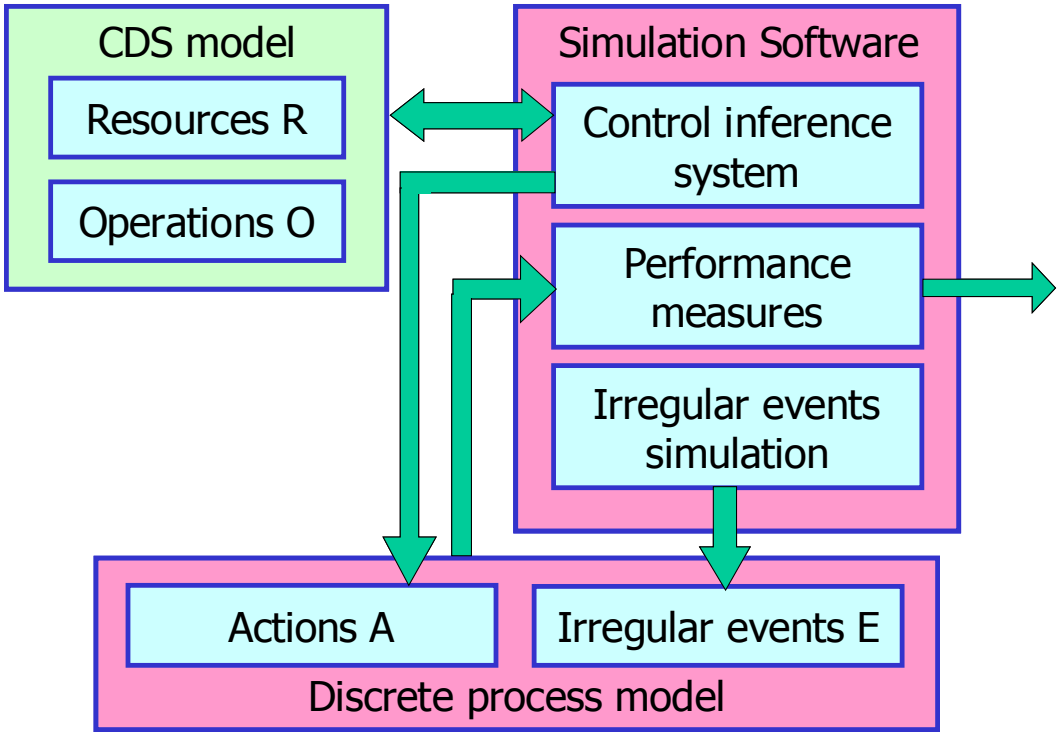
Maintenance Activities Simulation

Goal:

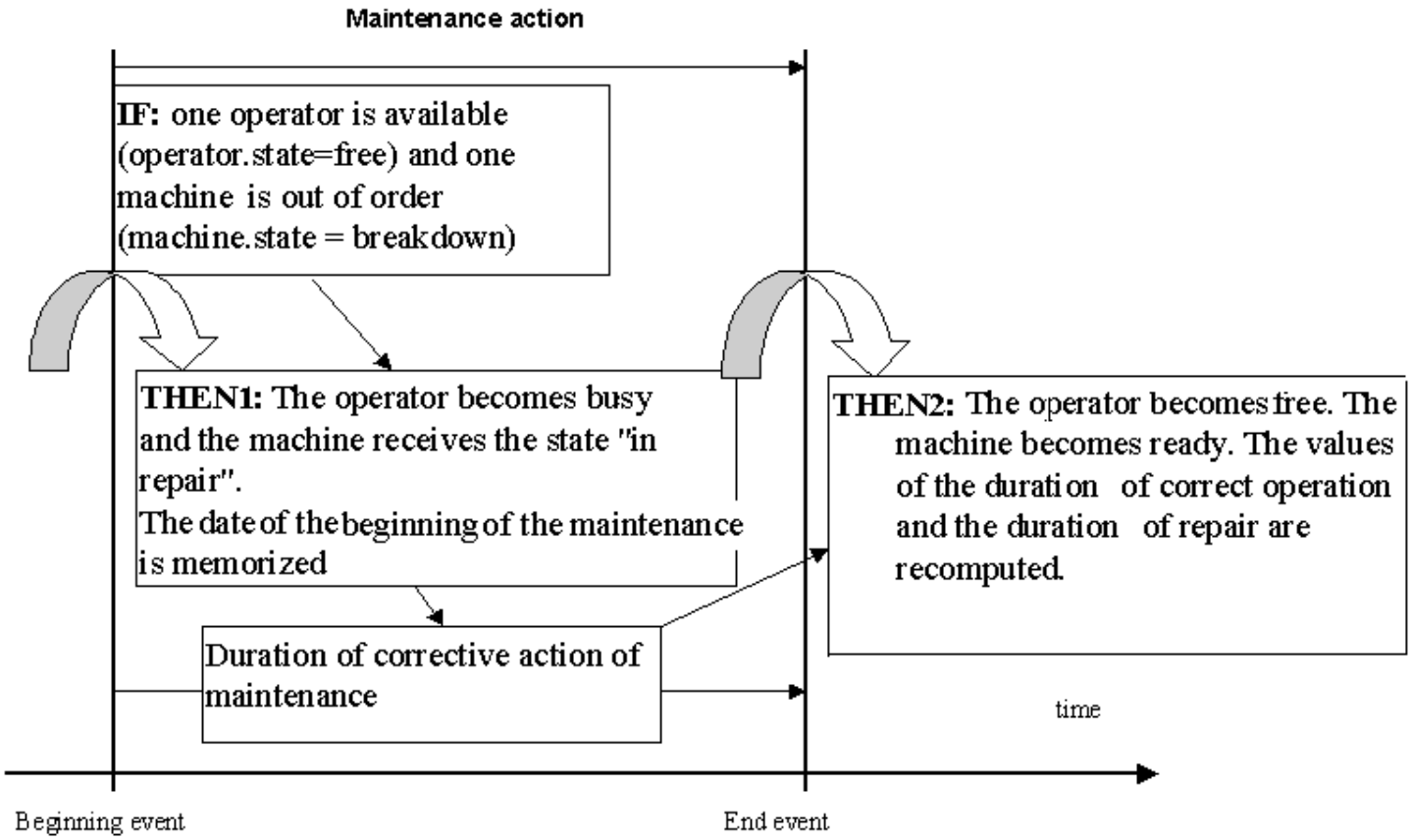
To evaluate the behavior of the system with respect to the integrated maintenance strategies, thanks to various indicators of performance, mainly:

- The system reliability
- The maintenance cost
- The system availability

The RAO Simulator

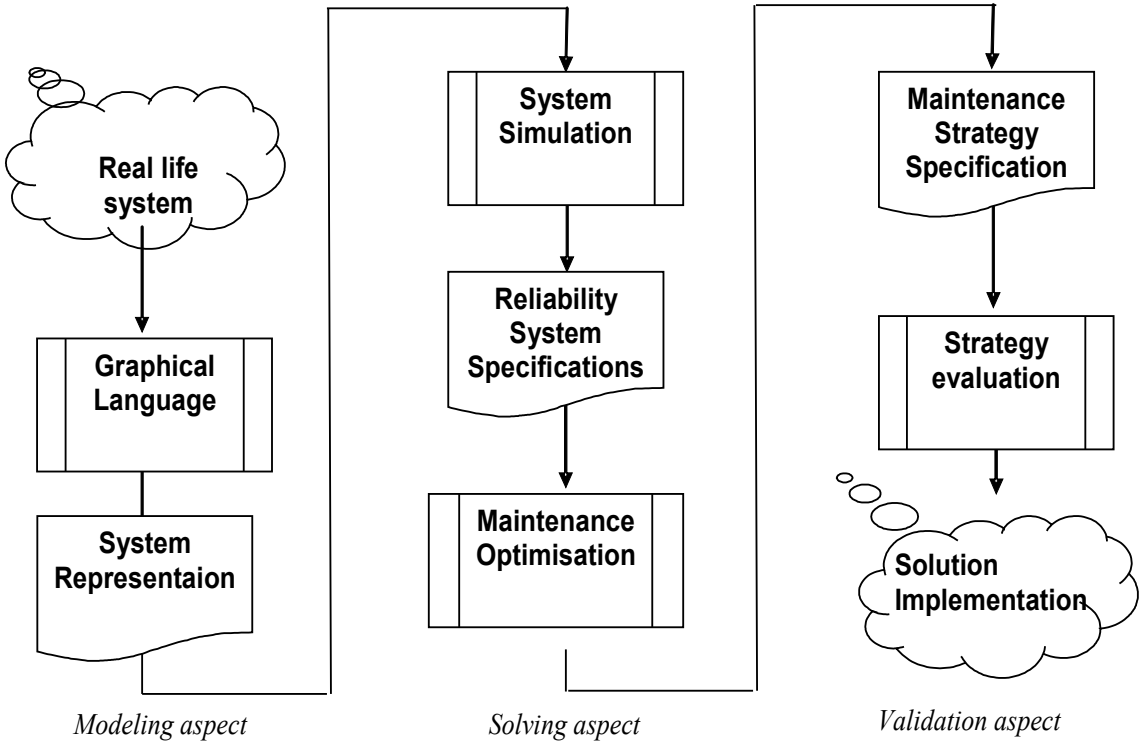


Example of maintenance strategy modeling with RAO



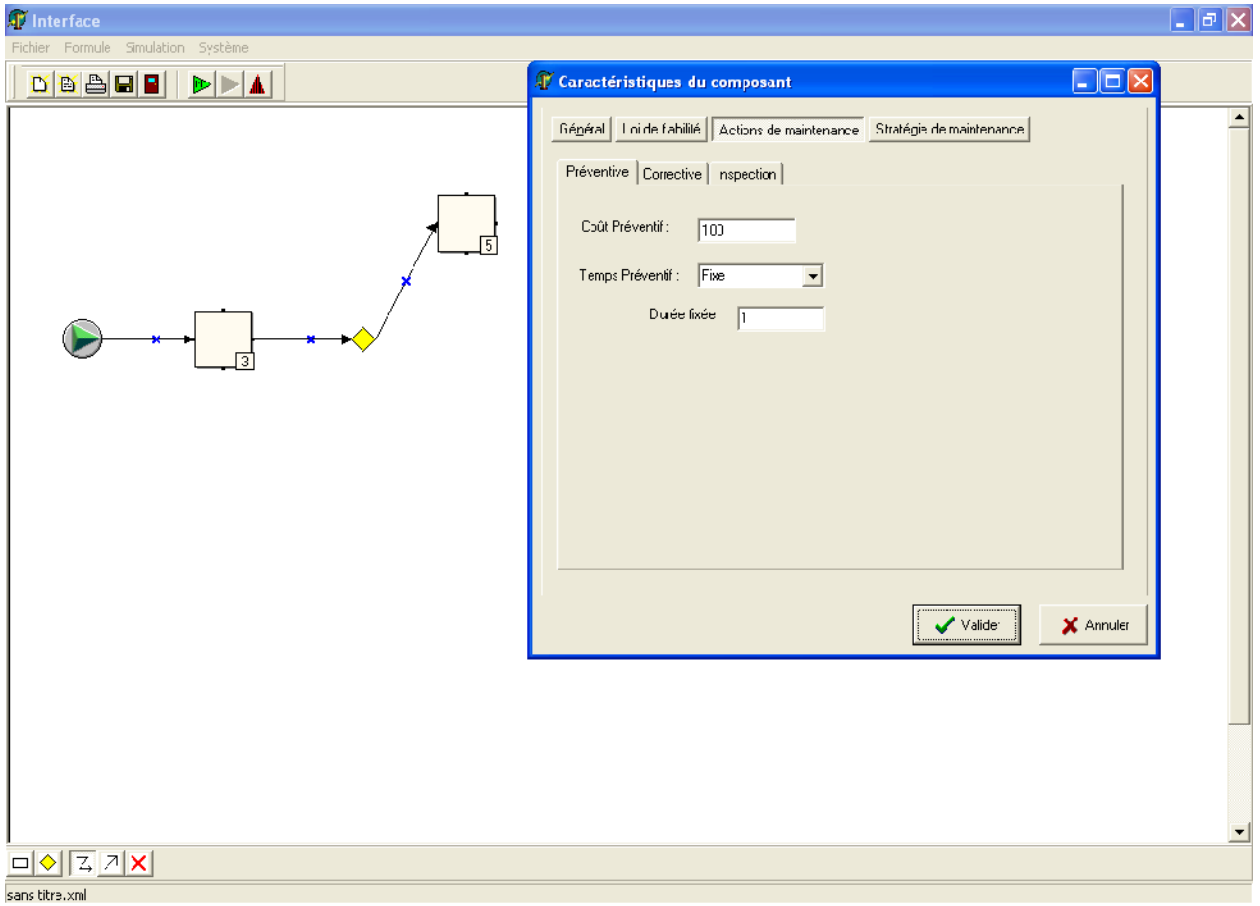
Framework Presentation

Simulation-Based Approch



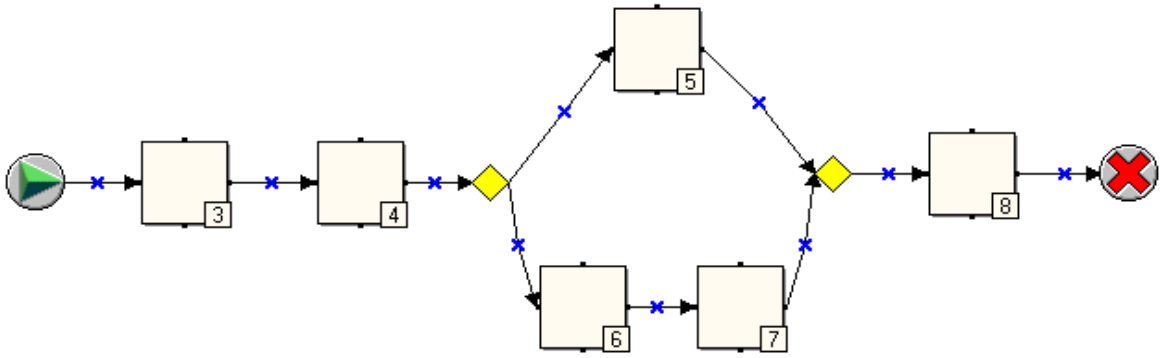
User-Friendly Interface for Maintenance Activities Modeling

Interface allowing to graphically model the components of a system and to define their parameters:



Maintenance Activities Modeling

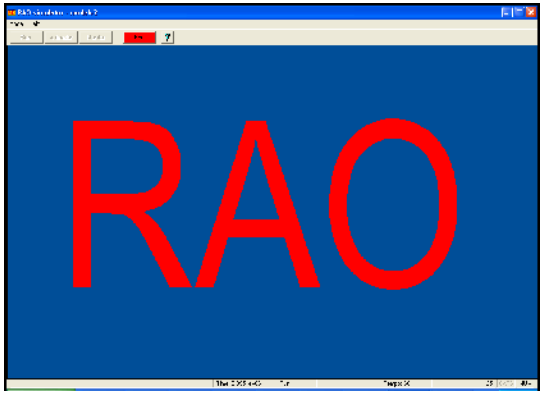
- System = set of components connected to each other in series or parallel



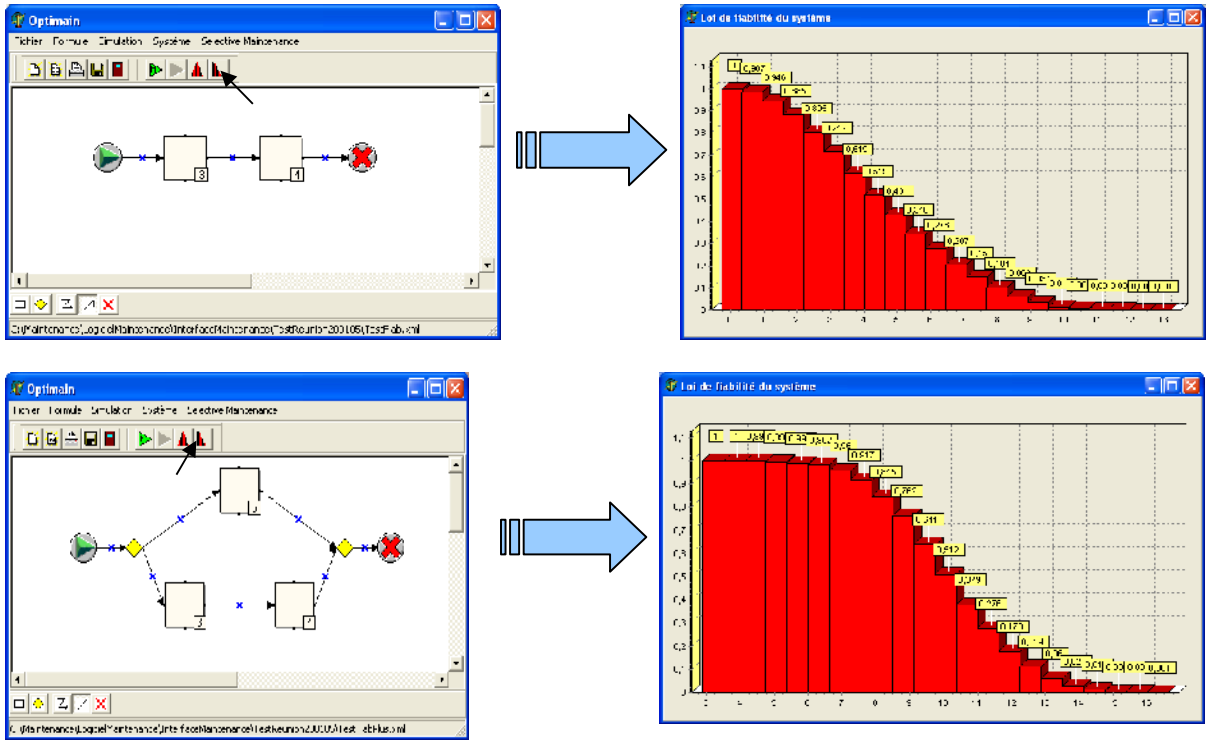
- Components characteristics :
  - Reliability function
  - Cost and time of the maintenance activities
  - Maintenance actions quality
  - Mode of detection of the component's failure

Maintenance Activities Simulation

The simulation of the dynamics of the system is then possible thanks to the RAO simulator. All the necessary models are generated automatically by the framework, so that the user should not write any code for the simulation.

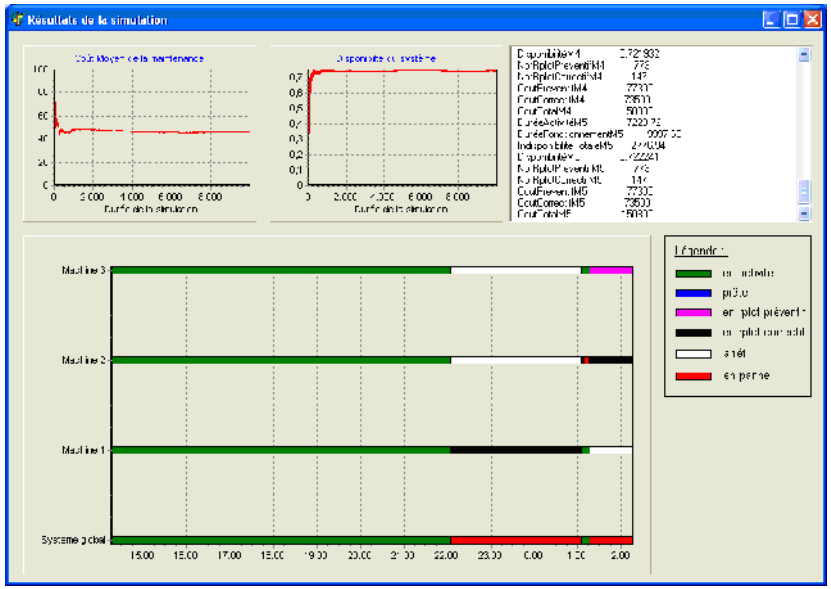


Reliability distribution of multi-component systems



	Original System	Modified System
T=3	0,74087	0,99994
T=6	0,29470	0,98395
T=9	0,04660	0,70584

Dynamic behaviour of the system

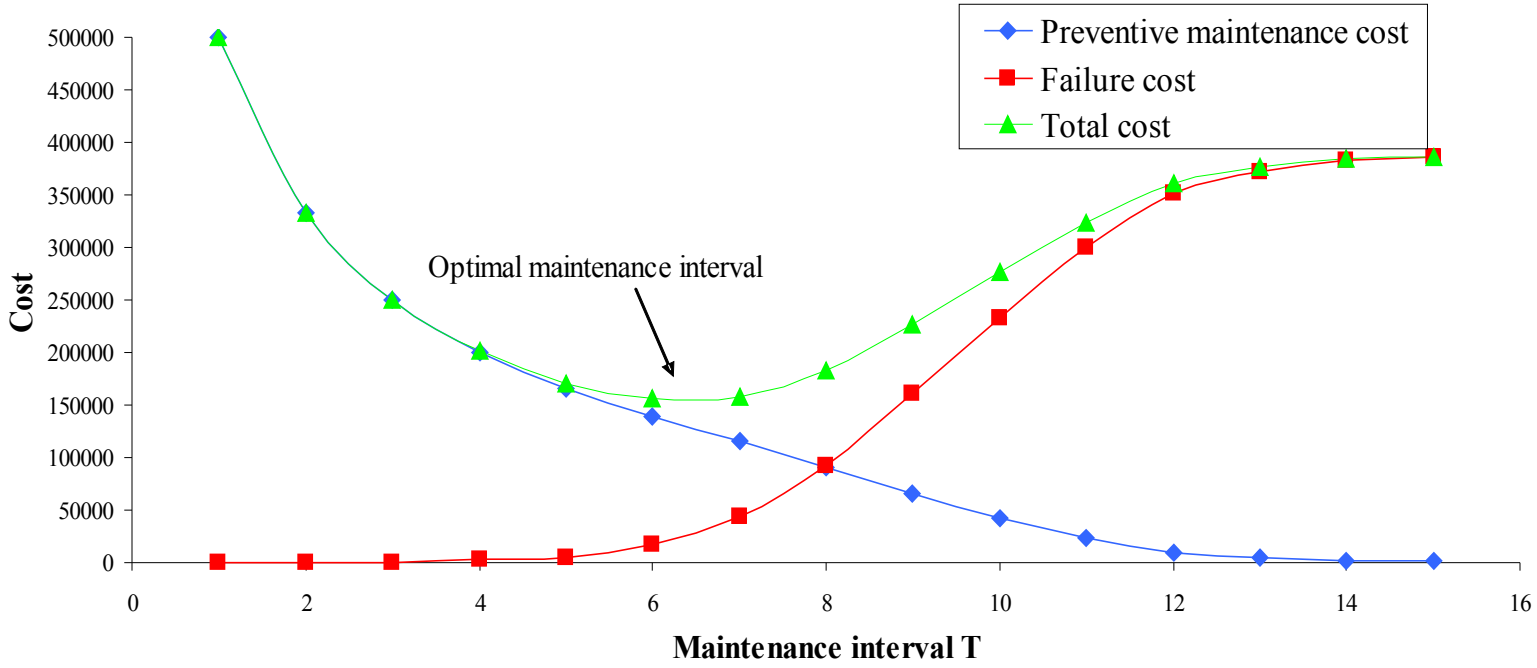


- Gantt diagrams illustrating the maintenance actions undertaken on each component
- Trend of average maintenance cost per unit of time and system availability along the simulation period
- Other performance indicators: number of preventive or corrective maintenance, total cost, period of unavailability of components, etc.

Why Using Optimization ?

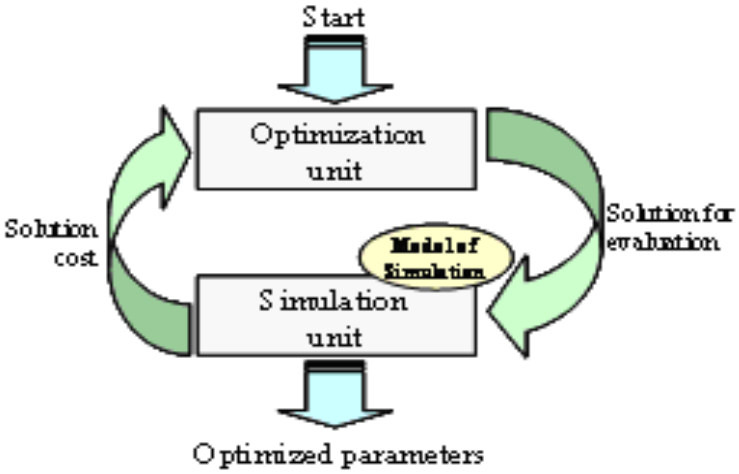
To find the optimal parameters of the selected maintenance strategies applied to the components of the system. Two criteria :

- Minimize maintenance cost
- Maximize system availibility

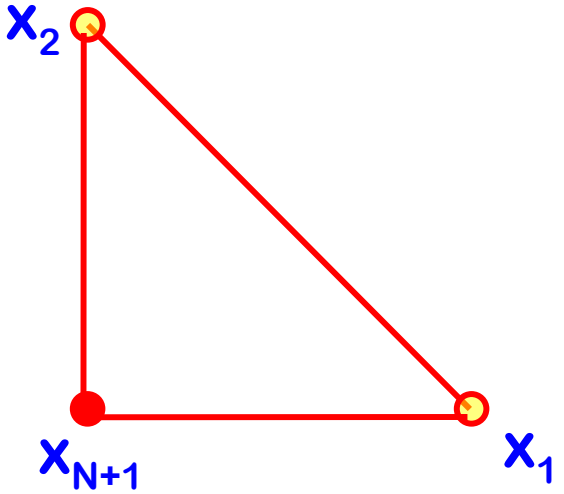


Optimization Method

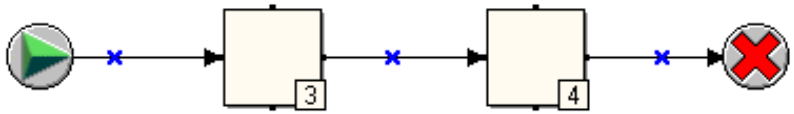
Coupling between the model of simulation and a module of optimization._



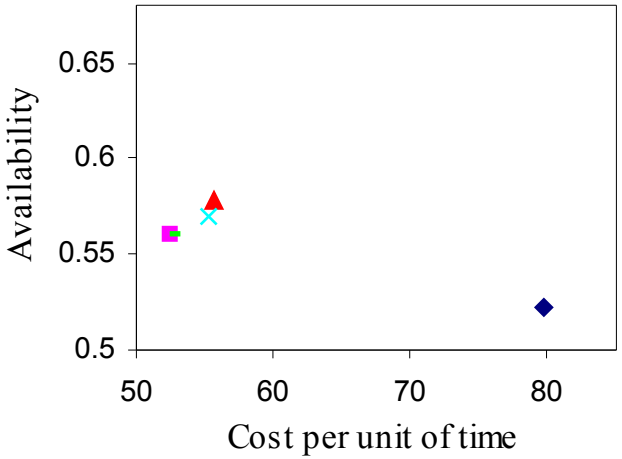
Optimization method used :
Nelder-Mead
(Nelder-Mead, 1965)

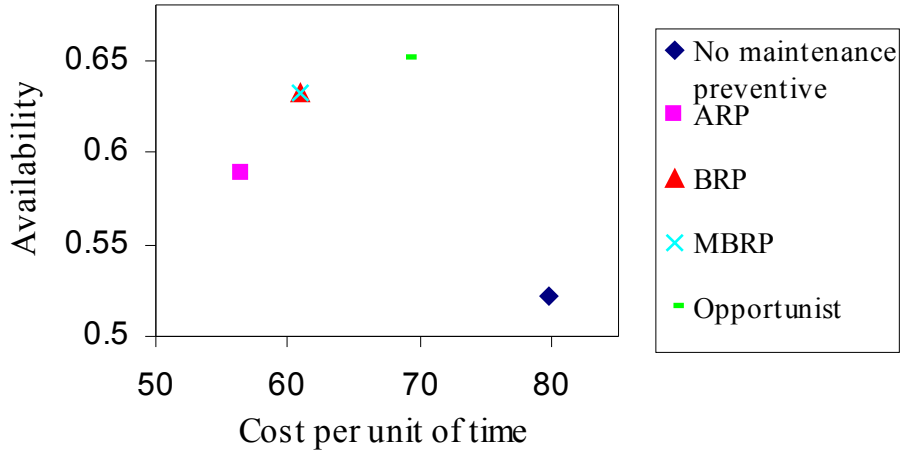


Example of results



	No preventive maintenance	ARP	BRP	MBRP	Opportunist
Cost minimization	∅	{T3=2,24; T4=6,19}	{T3=3,84; T4=10,34}	{T3=3,44; b3=0,70; T4=10,43; b4=3,26}	{N3=2,24; n3=2,24; N4=6,19; n4=6,19}
Cost*	79,64	52,60	55,67	55,36	52,61
Availability	0,52	0,56	0,58	0,57	0,56
Availability Maximization	∅	{T3=4,02; T4=7,10}	{T3=4,00; T4=8,00}	{T3=4,00; b3=0,25; T4=8,00; b4=0,00}	{N3=4,02; n3=0,64; N4=8,11; n4=1,2}
Availability*	0,52	0,59	0,63	0,63	0,65
Cost	79,64	56,56	60,95	60,94	68,94





Summary

One thus presented a framework of modeling, simulation and optimization of maintenance strategies for multi-components systems.

- ✓ Simple to use
- ✓ Not requiring particular knowledge

However, certain points can be improved:

- ✓ To be able to easily integrate industrial data and to identify the laws of reliability starting from a breakdown history
- ✓ To be able to hold account of the production, human and material resources
- ✓ To integrate other continuous algorithms of optimization
- ✓ To offer a real multicriteria decision-making aid for the choice of the maintenance strategy

Thank you for your attention !

Remarks or Questions ?