OMAINTEC CONFERENCE EXHIBITION 2024

THE 21ST INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE IN THE ARAB COUNTRIES

Optimizing CBM Scheduling using Dynamic Simulation in a 4.0 Environment

A Case Study for a Fleet of Trains

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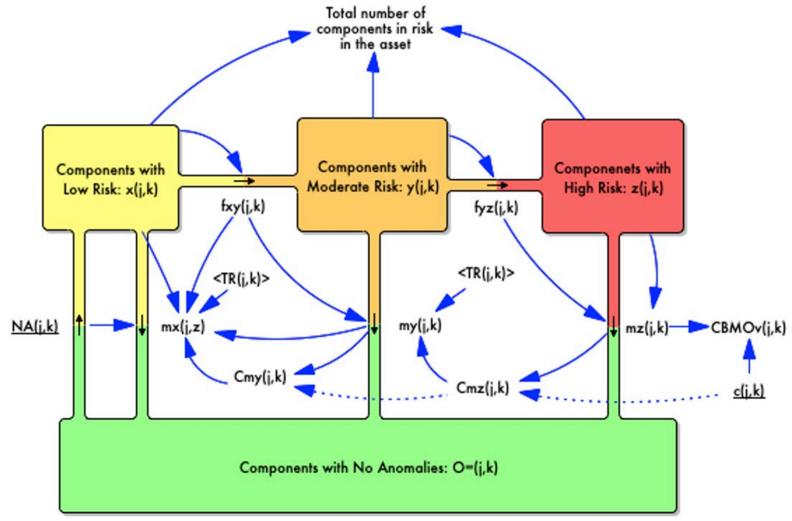
Content



- Abstract & Introduction to the problem
- Research methodology
- The Dynamic Simulation Operational Model
- The Dynamic Simulation Financial Model
- Sample Results
- Conclusions
- Relationship with concurrent research Useville-UCambridge

Abstract

Problem: Maintenance scheduling of a fleet of assets operating under a CBM program for critical components.
Understanding the effects of various CBM capacity levels
Incorporating a cost function that considers: Cost of RUL, CBM capacity costs, overdue CBM cost, and unavailability cost due to overdue CBM.

Methodology: A System Dynamics model is used to determine the optimal capacity level that minimizes the cost function.
Modeled Diverse CBM activity schedules and comparing the results to a base case

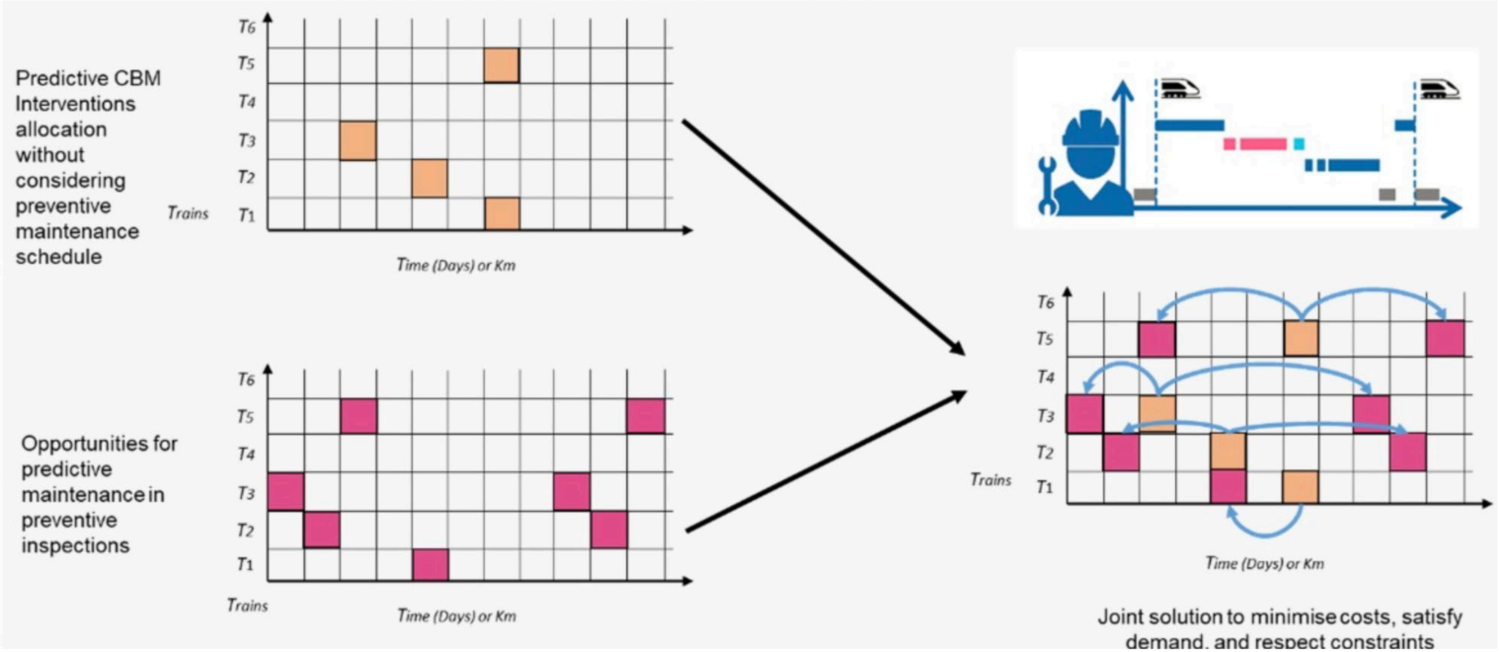
Advantages: The research showcases the advantages of opportunistic CBM task scheduling.
Highlights the benefits of aligning asset stops with predetermined PM (Preventive Maintenance) activities.

Practical implementation: The developed tool has been successfully tested in the railway sector, focusing on a fleet of trains.
Results for different CBM strategies, altering various problem factors and parameters.

Introduction

Facing modern challenges with current CBM models in fleet management under 4.0 :

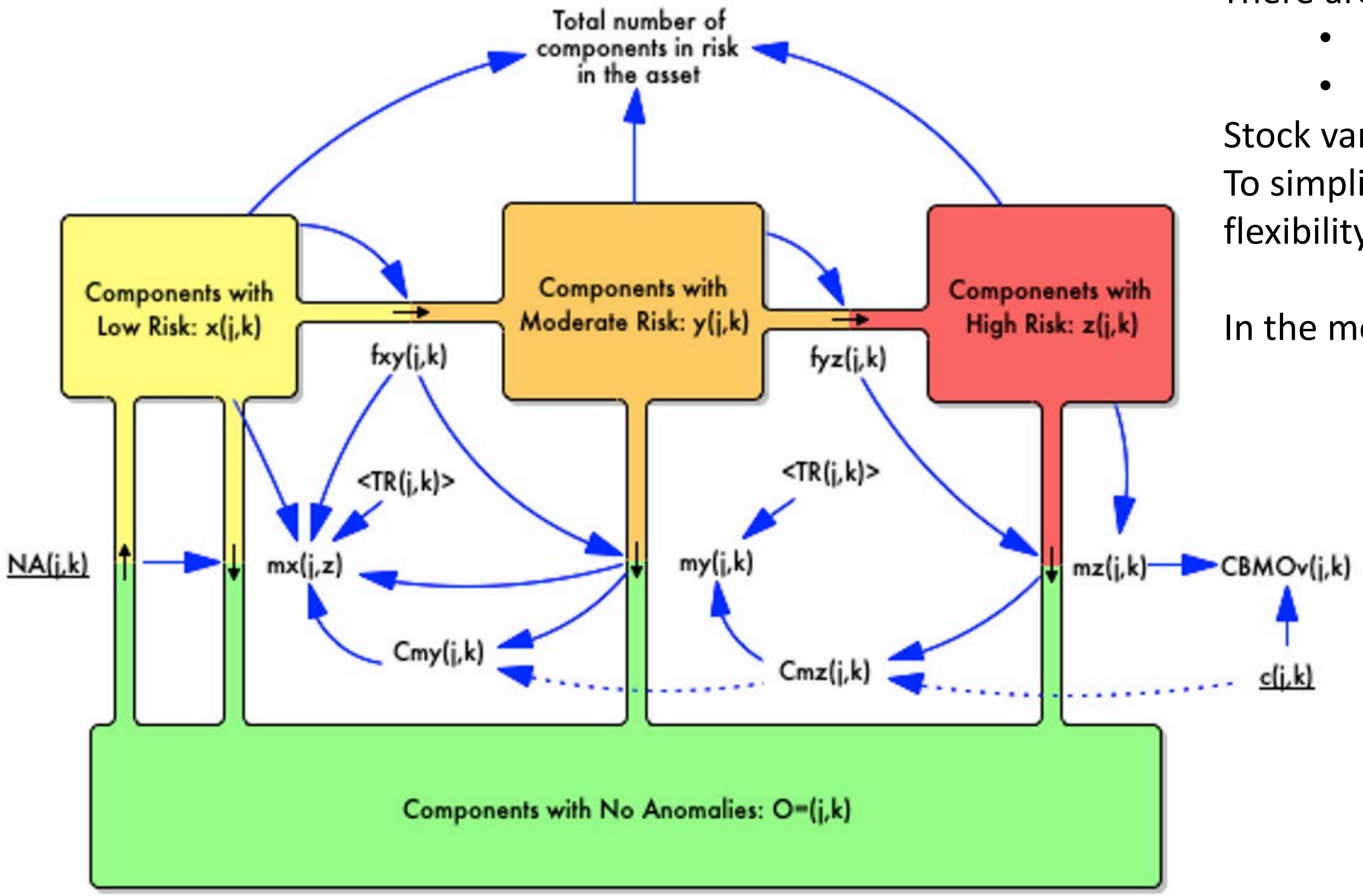
- Integrating predetermined maintenance with new CBM/PdM approach is not seamless.
- Scheduling for capacity/resources considers O&PM but overlooks CBM/PdM.
- Detailed fleet-level cost evaluation for CBM is lacking.
- Maintenance costs are not fully assessed.
- The techniques applied do not provide an optimal solution but rather recommendations.



Methodology

1. Introduction of a continuous-time System Dynamics (SD) simulation model
2. The model Integrates the scheduling of CBM activities & predetermined PM tasks
3. Utilizes RUL considerations.
4. Incorporates capacity for CBM activities & for PM Predetermined activities.
5. All associated costs are carefully estimated.
6. Demonstration ofthe model's effectiveness with a case study in the rail sector.

Operational Model



There are two fundamental types of variables in SD models:

- Stock or level variables and
- Flow or rate variables.

Stock variables remain constant unless they are modified by flow varial
To simplify the formulation of flow variables and enhance the modeler
flexibility, auxiliary variables are utilized

In the model:

Stocks: Status/condition (Risk) of the assets (bearings)
Flows: Number of asset transition between conditions
(number of bearing per time step changing conditio

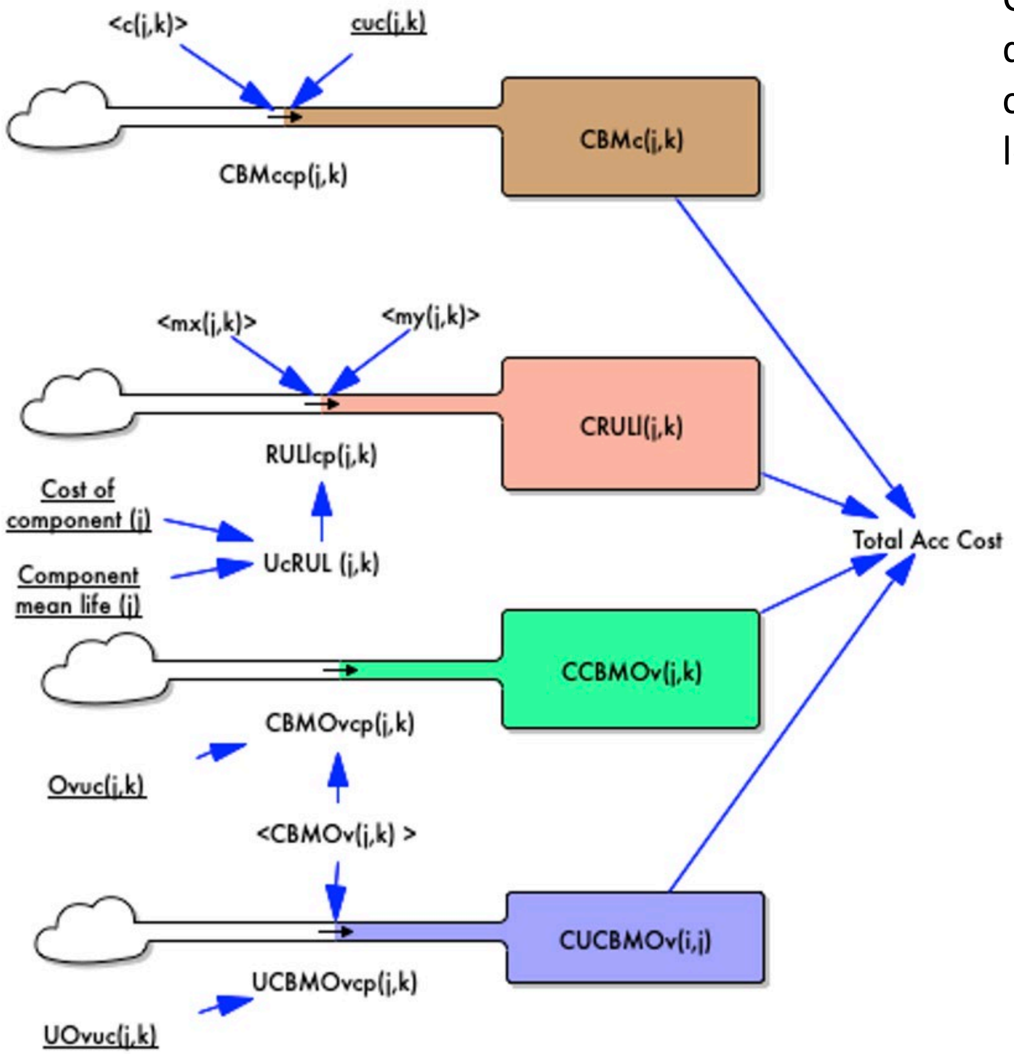
How does it work:

- Number of stocks depending on RUL and selected time st
- Anomalies show up with a certain known probability
- Transitions depend on the number of CBM activities
- Number of CBM activities depend on Capacity
- Capacity is selected per scenario
- If under high risk no capacity is left, train will stop for CBM

Rational:

- Controling capacity. Using current excess capacity to servi
  assets with longer RUL to avoid CBM overdue capacity

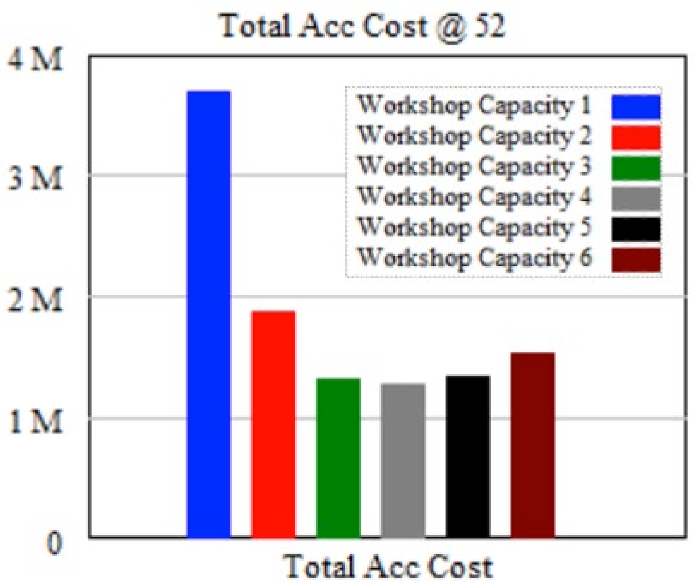
Financial Model



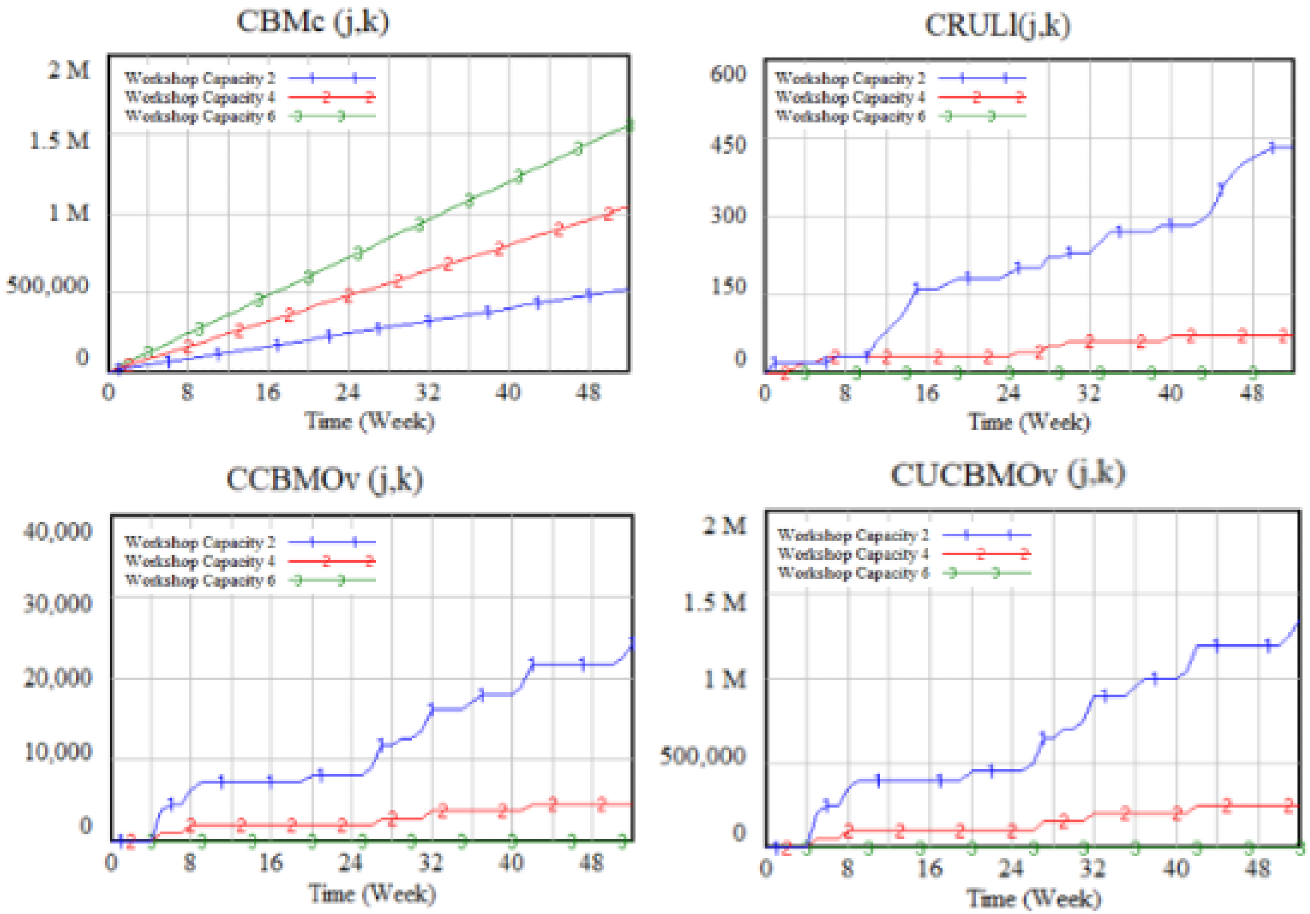
Once the model can estimate the number of components to have a CBM, at different risk levels, in each period t, the next step is to model a function of cost of our CBM strategy, that will then help to determine a suitable capacity level to minimize the cost. Element (Stocks) of this function are:

- **The *cost of CBM capacity*** $(CBMc_t)$is obtained accumulating the cost of the designed capacity level per period over the planning horizon.
- **The *cost of Lost RUL*** $(CRULl_t)$ is the cost of the amount of operating hours (or kms or another suitable unit of RUL measure) lost by the component because of an early forced CBM because of capacity constraints.
- **The *CBM overdue activities cost*** $(CCBMOv_t)$ is the cost service the train when an anomaly is active, no RUL is left, and there is no CBM capacity available during the next predetermined maintenance inspection.
- ***Cost of Unavailability due to overdue CBM*** $(CUCBMOv_t)$ is one of the most important cost factors because is the cost of the services lost because of the train unavailability required to carry out CBM overdue activities.

Results

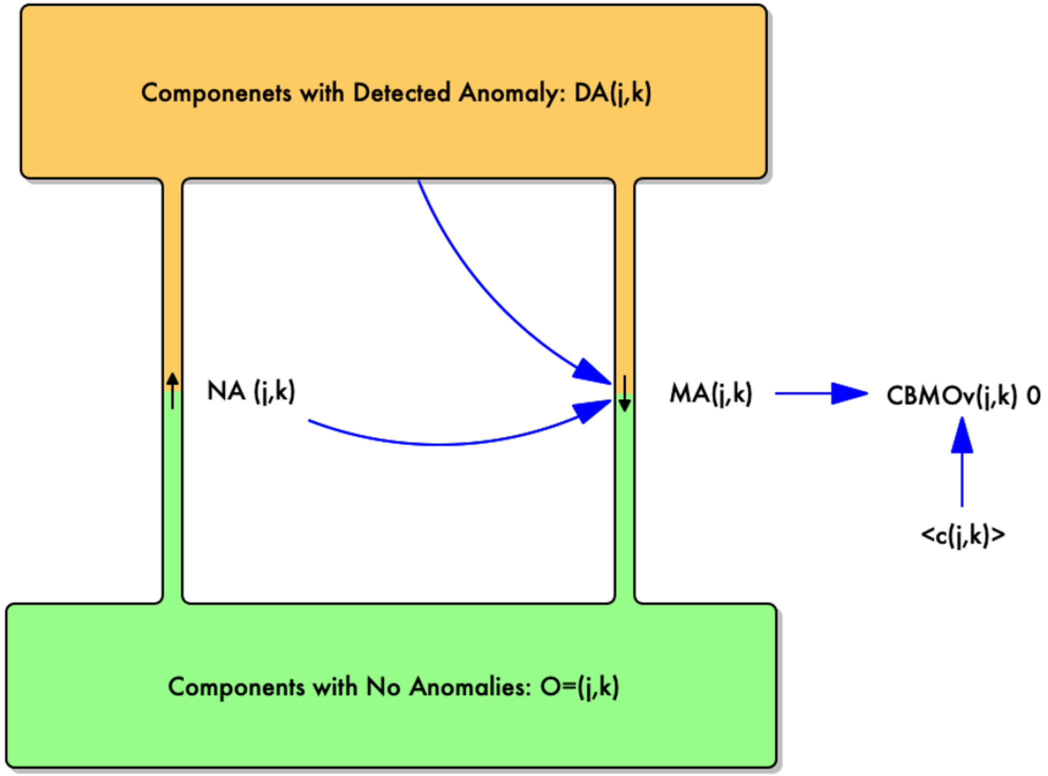


Sample comparison of results obtained per the variable Total Accumulated Cost and for just one simulation when CBM capacity level changes from 1 to 6 units.

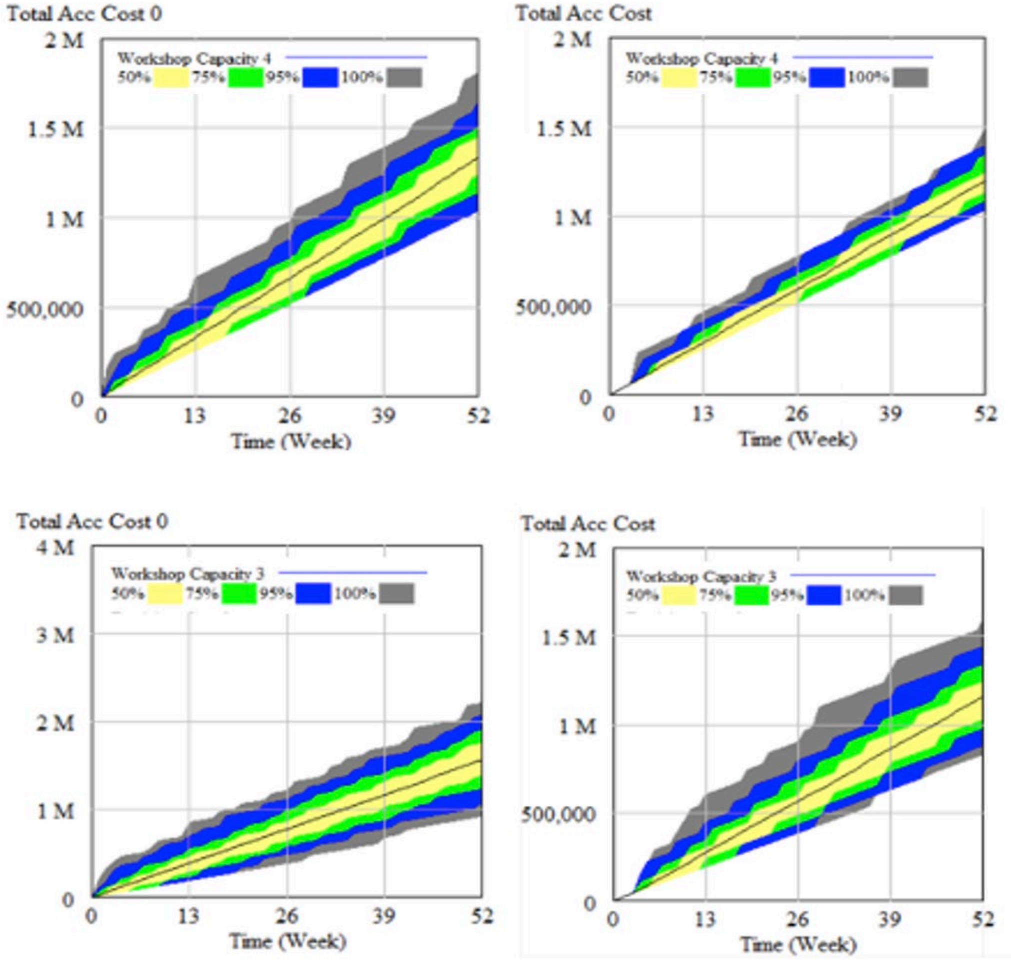


Sample comparison of results (in €) obtained per cost factor and for just one simulation when CBM capacity level is set to 2, 4 and 6 bearings/period.

Results – Comparing with a Base Case Scenario



Complete stock & flow diagram of the status of components in the system



Comparison of RUL and base case CBM scheduling using sensitivity analysis for Total Acc Cost and for two capacity scenarios (top: CBM capacity=4; down: CBM capacity = 3). Base case results (left) and RUL case results (right). The line represents mean value.

Conclusions

- A system dynamic simulation model has been built to schedule CBM activities
- In the operational context it is known the RUL of components presenting anomalies for systems
- There can be a capacity constraint to carry out CBM activities per system.
- A financial part calculates the different costs generated for each one of the simulated scenarios.
- A Montecarlo analysis has been introduced to compare cost results for each CBM capacity scenario and assuming available, or not, the information about the RUL of the components presenting anomalies.
- When the information about the RUL is not available, the strategy followed has been to carry out the CBM activities in the next possible predetermined PM or to stop the asset if capacity is not available at that time.

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