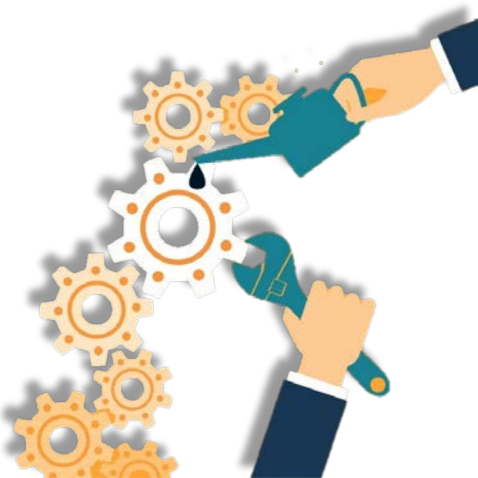
UNIVERSITY OF OULU

INDUSTRIAL ENGINEERING AND MANAGEMENT

INTEGRATED SCHEDULING OF MAINTENANCE AND RENEWAL PROJECTS

Applications to railway and roadway infrastructures

Dr. Farzad Pargar



Infrastructure For The Future: Transport Research Finland

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INTRODUCTION

MAINTENANCE OF RAILWAYS AND ROADWAYS

The maintenance of equipment plays an important role in many industries, especially in transportation industry where a failure can be dangerous or disastrous.

- An effective preventive maintenance program of railways and roadways reduce the probability of costly corrective maintenance and avoid excessive maintenance.

Maintenance scheduling is a decision-making process of allocating resources over time to perform a collection of maintenance tasks.

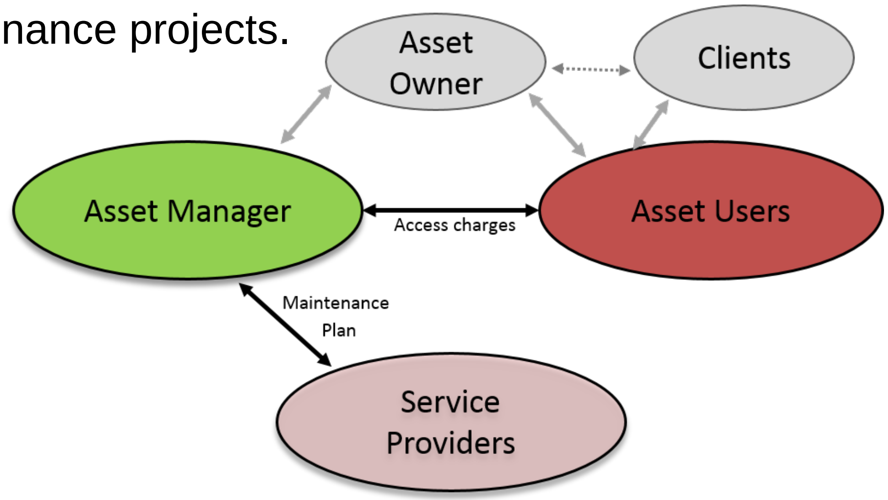
PROBLEM DESCRIPTION

CONFLICT INTEREST OF STAKEHOLDERS

Asset manager carries responsibility for new construction, maintenance, renewal, capacity allocation, as well as traffic management.

The challenge for asset manager is how to collaborate with its stakeholders to meet their mutual goals on getting access to the available resources during infrastructure operation and maintenance.

- There is a great need for sophisticated tool to determine the optimal renewal time and schedule maintenance projects.

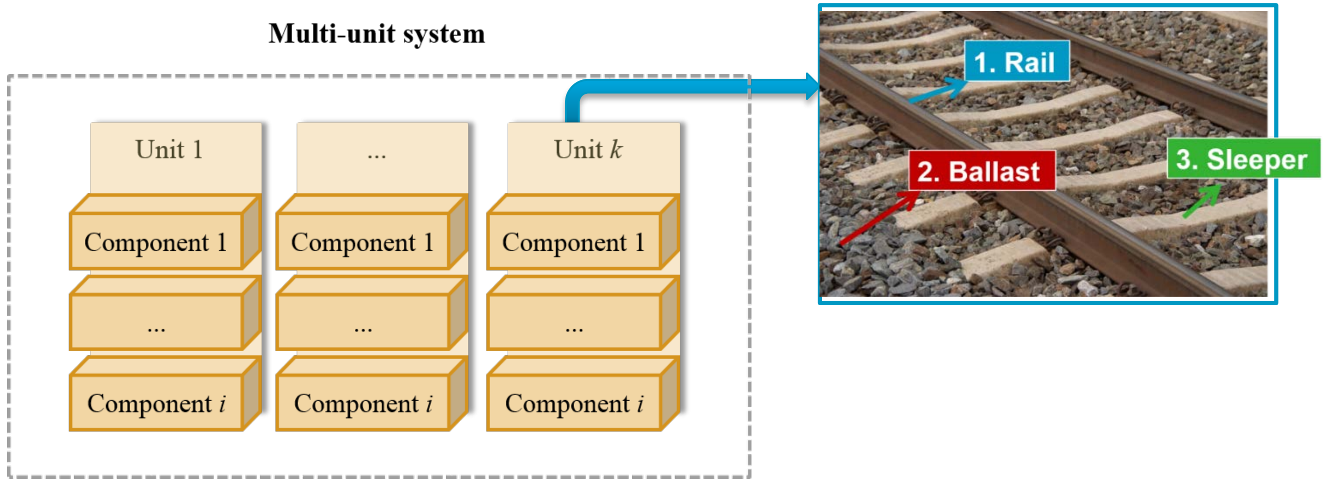


PROBLEM DESCRIPTION

RAILWAY AND ROADWAY AS A MULTI-UNIT SYSTEM

Infrastructure condition is not uniform in all locations and different locations has different maintenance requirements. Thefore, we devide each section of railway or roadway into units.

- Our aim is to find the sequence of maintenance actions with minimum cost and down time.



SOLUTION APPROACH

OPTIMIZATION TOOL

Optimization is the selection of a best element (with regard to some criteria) from set of available alternatives.

- The term optimize is "to make perfect"

Input data → Optimization tool → Output results

Input data:

- Maintenance history
- Maintenance costs
- Setup costs
- Maximum time interval between maintenance actions

Output results:

Maintenance and renewal of each component in different locations (units) should be done in which time period.

SOLUTION APPROACH

MATHEMATICAL MODEL

In our developed tool, we used a mathematical procedure for determining the best value of decision variables in order to minimize the objective function while satisfying the constraints.

minimize

$$\sum_{t=1}^{T} p_t \times SC^d \tag{1.1}$$

$$+\sum_{s=1}^{T}\sum_{i=1}^{I} b_{is} \times SC_i^{pm} + \sum_{t=1}^{T}\sum_{i=1}^{I} q_{it} \times SC_i^{pr} + \sum_{t=1}^{T} Q_t \times SC_0^{pr} \tag{1.2}$$

$$+\sum_{t=1}^{T}\sum_{h=1}^{H}\sum_{s=t}^{T}\sum_{k=1}^{K}\sum_{i=1}^{I} m_{iksht} \times (SC_i^{im} + C_i^{m}) + \sum_{s=1}^{T}\sum_{k=2}^{K}\sum_{i=1}^{I} w_{iks}^{m} \times \left(-SC_i^{im}\right)$$
$$+\sum_{t=1}^{T}\sum_{k=1}^{K}\sum_{i=1}^{I} r_{ikt} \times (SC_i^{ir} + C_i^{r}) + \sum_{t=1}^{T}\sum_{k=2}^{K}\sum_{i=1}^{I} w_{ikt}^{r} \times \left(-SC_i^{ir}\right) \tag{1.3}$$

subject to

$$\sum_{s=1}^{T^l_{i(T_{ik}^{hp}+1)}-T_{ik}^{he}} \left[m_{iks(T_{ik}^{hp}+1)0} + r_{iks}\right] \geq 1 \quad \forall\, i \in I, k \in K \tag{2}$$

$$r_{ikt} \leq \sum_{s=t+1}^{t+1+T_{i1}^{l}} \left[m_{iks1t} + r_{iks}\right] \quad \forall\, i \in I, k \in K, t \leq T-1-T_{i1}^{l} \tag{3}$$

$$m_{iku(h-1)t} \leq \sum_{s=u+1}^{u+1+T_{i(h)}^{l}} \left[m_{iksht} + r_{iks}\right] \quad \forall\, i \in I, k \in K, u \leq T-1-T_{i(h)}^{l}, t \leq u, 2 \leq h \leq H_i \tag{4}$$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Integrated scheduling of preventive maintenance and renewal projects for multi-unit systems with grouping and balancing

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ABSTRACT

This paper studies preventive maintenance and renewal scheduling for multi-unit systems. We develop an integrated optimization method to schedule preventive maintenance and renewal projects by grouping them and simultaneously finding the optimal balance between them. Grouping and balancing are resource utilization techniques to reduce the costs of maintenance without reducing the level of maintenance. We next model the problem as a pure integer linear programming formulation to minimize the costs of maintenance and renewal projects and their relevant preparatory works and downtime costs over the planning horizon. We use a numerical experiment with sensitivity analysis to illustrate the model, and the potential cost reductions that using such an integrated model may lead to. Applications of this model arise in the maintenance of railways, roadways, electricity distribution networks, and distributed pipeline assets. Due to the complexity of the model, two heuristic algorithms based on decomposition approach with problem-specific cutting planes are applied to tackle the problem. Experimental results show that our integrated optimization approach performs well in reducing the cost of preparatory works through proper scheduling. Finally, a case study for the maintenance of railway track shows that using our integrated approach reduces the maintenance and renewal costs by up to 14% as compared with the spreadsheet based approach used currently at the operation.

OUTPUT RESULTS

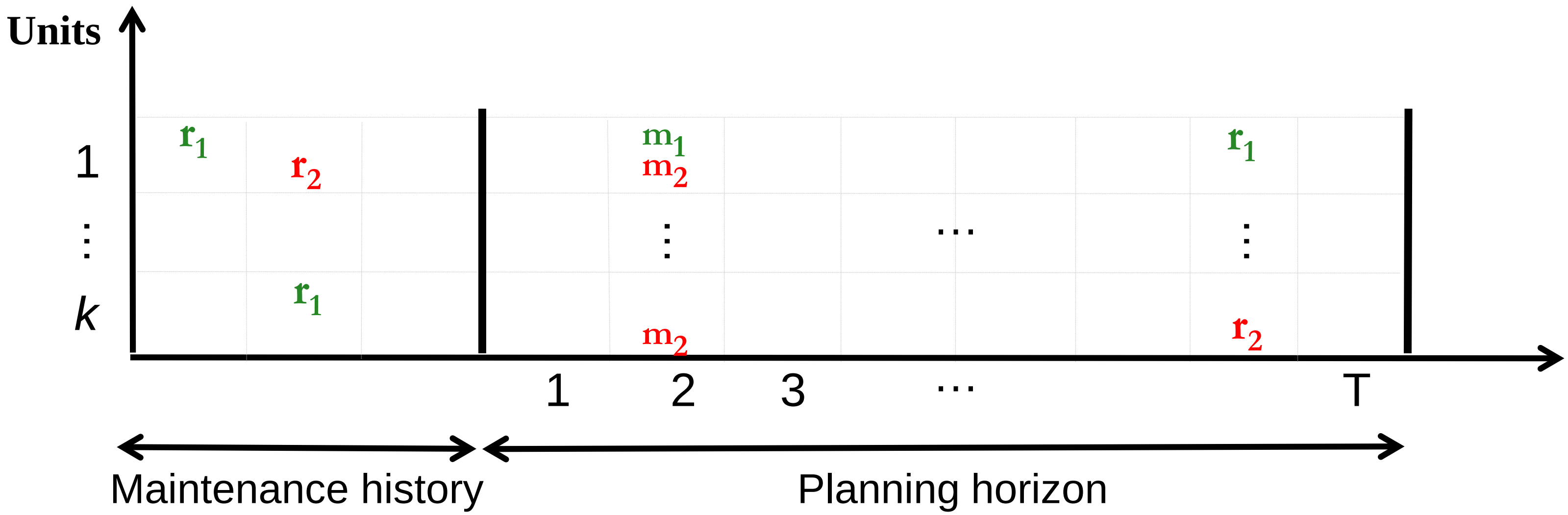
HOW SOLUTIONS LOOK LIKE?

r_1 : renewal of component 1

r_2 : renewal of component 2

m_1 : maintenance of component 1

m_2 : maintenance of component 2



TECHNIQUES TO REDUCE PM COSTS

WITHOUT REDUCING THE AMOUNT OF MAINTENANCE

Grouping:

- A technique to combine the executions of maintenance and replacement activities.
- Grouping allows savings on the preparatory works.

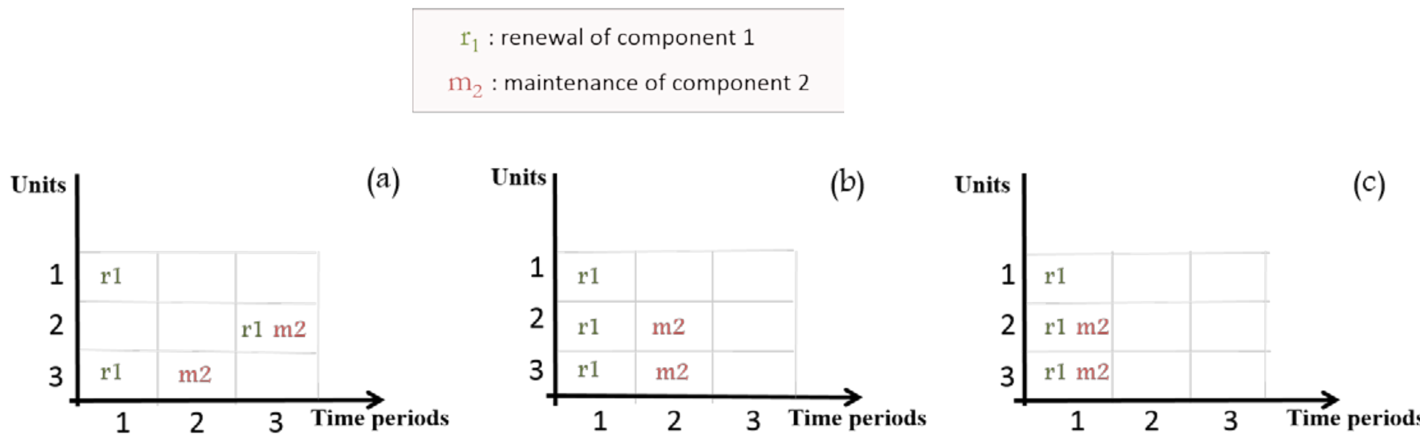
Balancing:

- A technique to find a balance between maintenance and renewal.
- Balancing allows to replace the component on its economic life rather than technical life.

BENEFITS OF GROUPING

EXAMPLE: 3 UNITS, 2 COMPONENTS, 3 TIME PERIODS

Comparing three scenarios for carrying out the replacement of component 1 in units 1-3 and maintenance of component 2 in units 1-2.

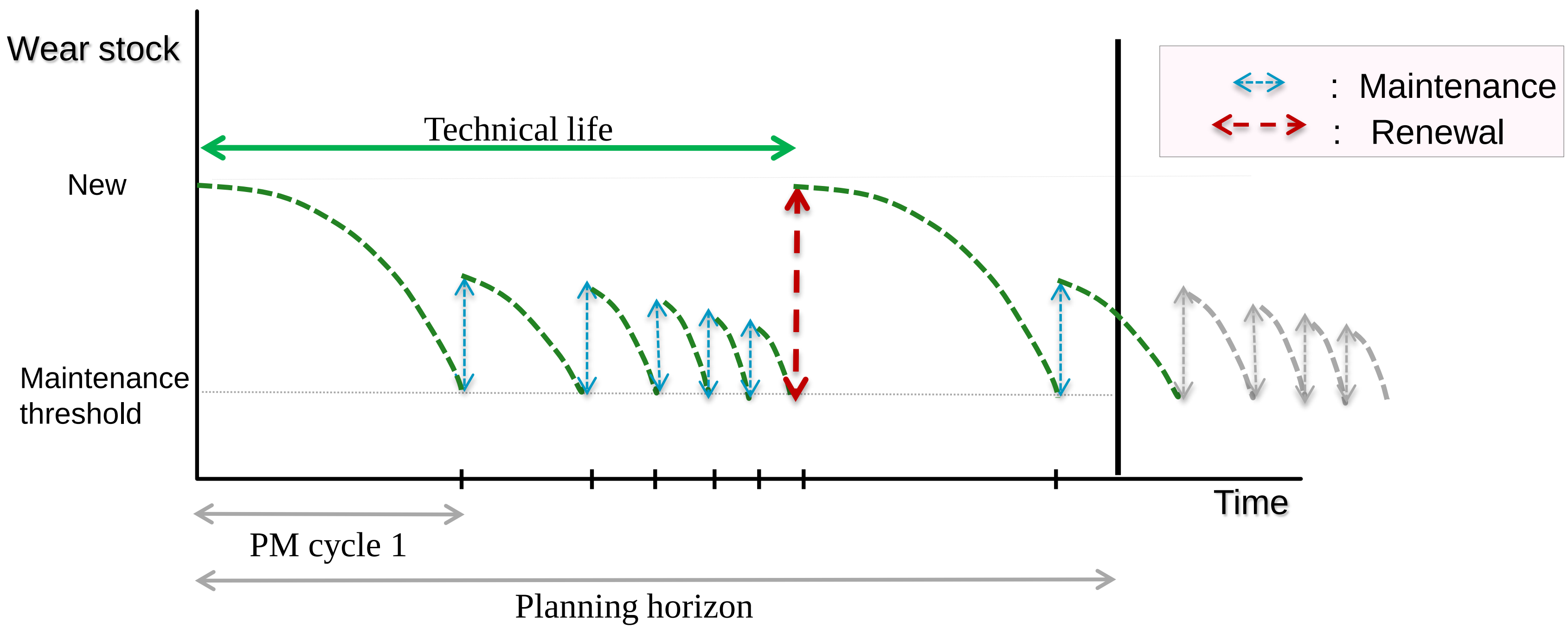


	(a)	(b)	(c)
Down time cost:	3×100	2×100	1×100
Preparation cost:	2×30 + 2×20	1×30 + 1×20	1×30 + 1×20
Installation cost:	3×5 +2×5	1×5 +1×5	1×5 +1×5
Total setup cost:	∑= 425	∑= 260	∑= 160

BENEFITS OF BALANCING

EXAMPLE: 1 UNIT, 1 COMPONENT

- When an asset ages, maintenance is required increasingly often.
- The latest possible time for carrying out the next maintenance/renewal relevant to the previous maintenance is known (planning cycle).



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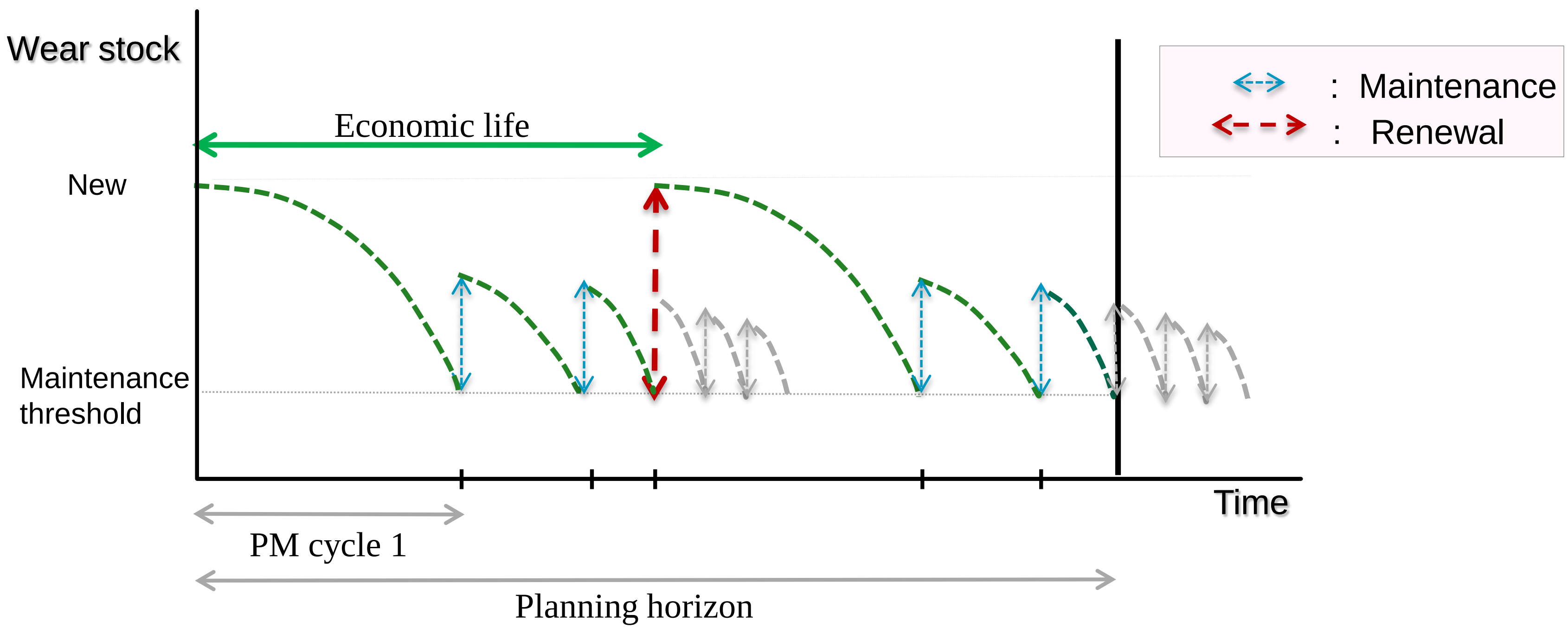
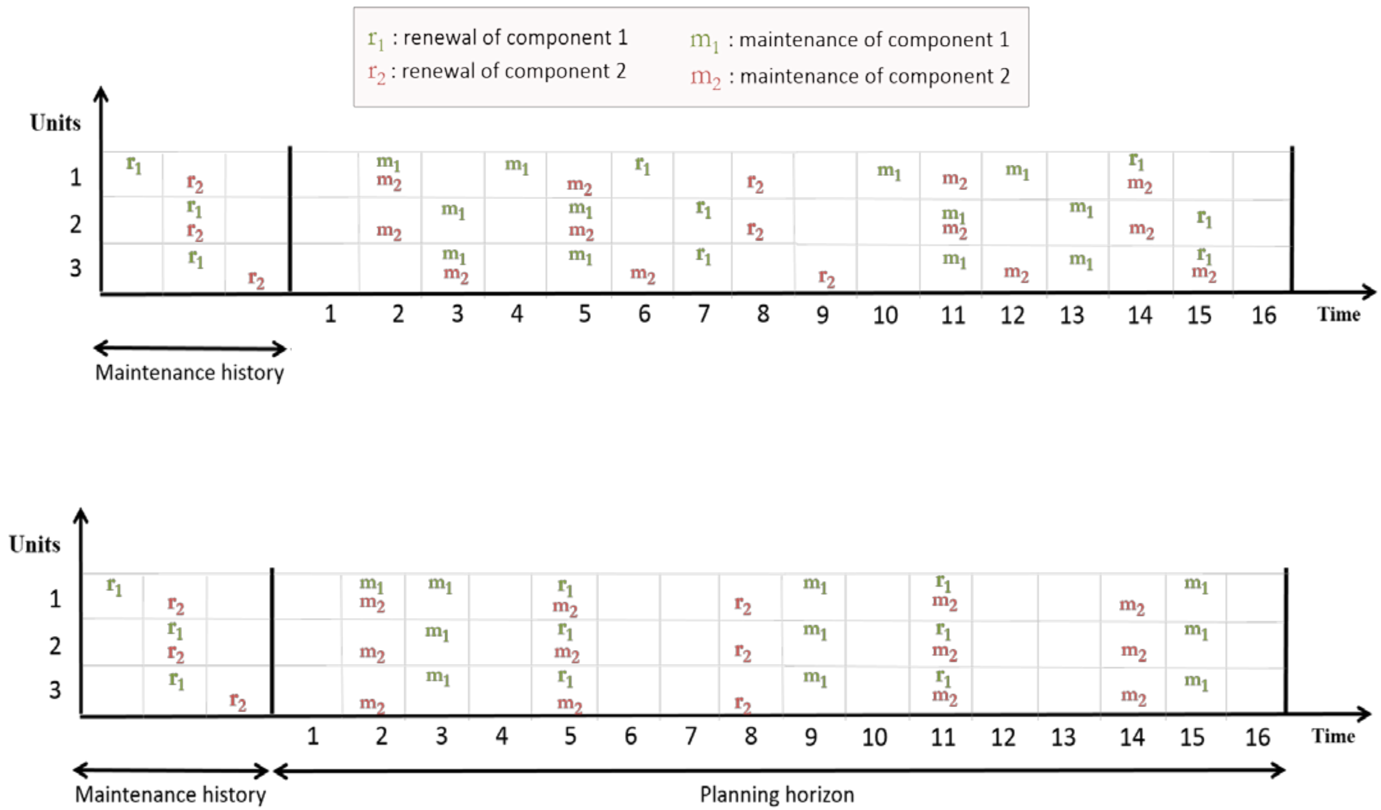


BENEFITS OF GROUPING & BALANCING

EXAMPLE: 3 UNITS, 2 COMPONENTS, 16 TIME PERIODS



No optimization:

Total setup costs= 7440
M&R costs= 4800

32.2% setup reduction due to grouping and balancing

Integrated optimization:

Total setup costs= 4220
M&R costs = 4720

FUTURE WORKS

Multi-objective optimization of maintenance projects

Considering financial and operational concerns of various stakeholders.

- maximize potential traffic throughput,
- minimize disruption durations,
- maximize durations of breaks in between disruptions
- minimizing maximum yearly investment;
- minimizing delays in starting higher priority works
- minimize speed restriction and late night shifts

Managing the delivery of the maintenance projects collaboratively

- Analyzing the applicability of alliancing as a collaborative project delivery method between the key actors of maintenance project

CONCLUSION

IMPLICATIONS

- The developed optimization tool reduce the costs of maintenance without reducing the amount of maintenance by integrating grouping and balancing techniques.
- The tool can be used in capacity management, maintenance and renewal decision making process by considering conflict interests of stakeholders
- The tool can be used by both infra manager and contractors for different types of systems. They can Compare different maintenance and renewal scenarios.

Building good models is an art!

Essentially, good models are not those in papers but models that are in use.

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Thank you!

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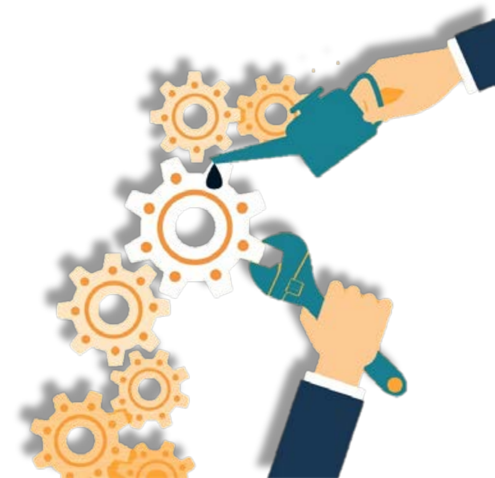

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