Decision Support for Maintenance Planning

1st INFRALERT Open Workshop 16.11.2016

Fraunhofer IVI

Agenda

- What is maintenance planning?
- Context of INFRALERT
- Achieved results
- Conclusion

What is maintenance planning?

What is maintenance planning?

Decision-making regarding:

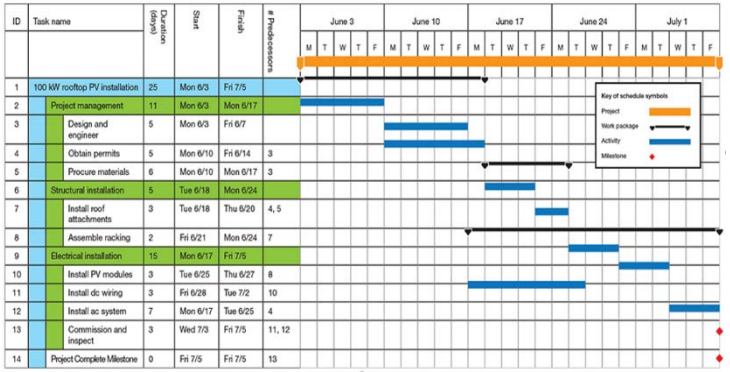
- **WHAT?** e.g. tamping, grinding, road retrofitting/upgrading

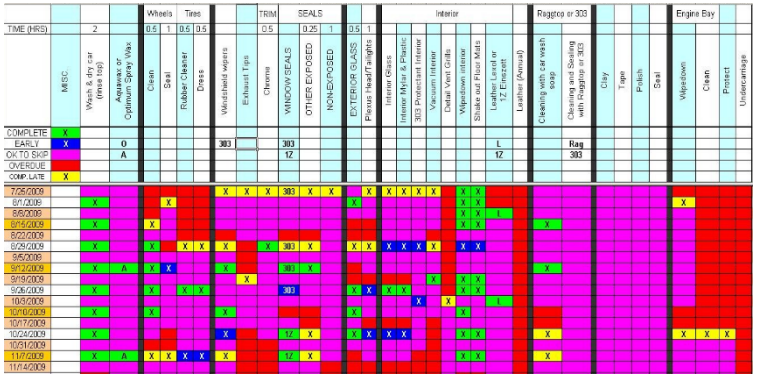
Decision support for maintenance & interventions planning

What is maintenance planning?

Decision-making regarding:

- WHAT?
- **WHEN?** e.g. next year, month 8, 12.04.2016 8:00-8:30



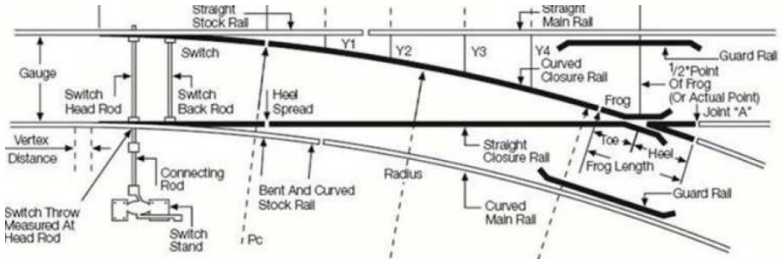


Decision support for maintenance & interventions planning

What is maintenance planning?

Decision-making regarding:

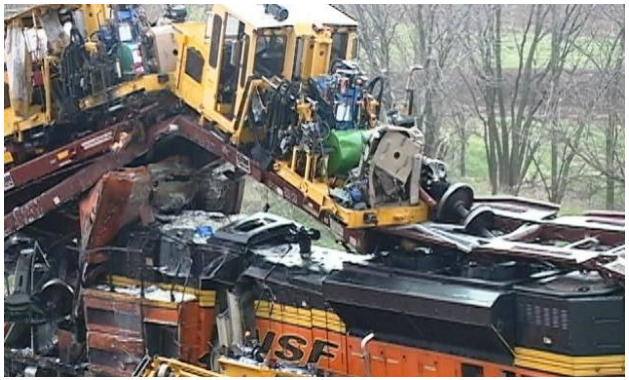
- WHAT?
- WHEN?
- **WHERE?** e.g. section A,B and C, switch #129



What is maintenance planning?

Decision-making regarding:

- WHAT?
- WHEN?
- WHERE?
- **HOW?** e.g. How many and which staff is needed?
  Which safety restrictions have to be considered?



What is maintenance planning?

Complex process to be modelled, including:

- **Decisions to make** e.g. Which policy to apply?
  Which possessions to book?,
  When to start an intervention?

What is maintenance planning?

Complex process to be modelled, including:

- Decisions to make

- **Objectives to achieve** e.g. Cost
  Availability
  Robustness

What is maintenance planning?

Complex process to be modelled, including:

- Decisions to make
- Objectives to achieve
- **Constraints to consider** e.g. Limited budget
  Time windows for maintenance
  Resource availability

Decision support for maintenance & interventions planning

This is maintenance planning!

Decisions regarding:

- **WHAT?** tamping, grinding, road retrofitting/upgrading
- **WHEN?** next year, month 8, 12.04.2016 8:00-8:30
- **WHERE?** section A,B and C, switch #129
- **HOW?** How many and which staff is needed?
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Complex process of maintenance planning involves:

- **Decisions tom make** Which policy to apply?, Which possessions to book?,
  When to start an intervention?
- **Objectives to achieve** Cost, Availability, Robustness
- **Constraints to consider** Limited budget, Time windows for maintenance, Resource availability

Decision support for maintenance & interventions planning

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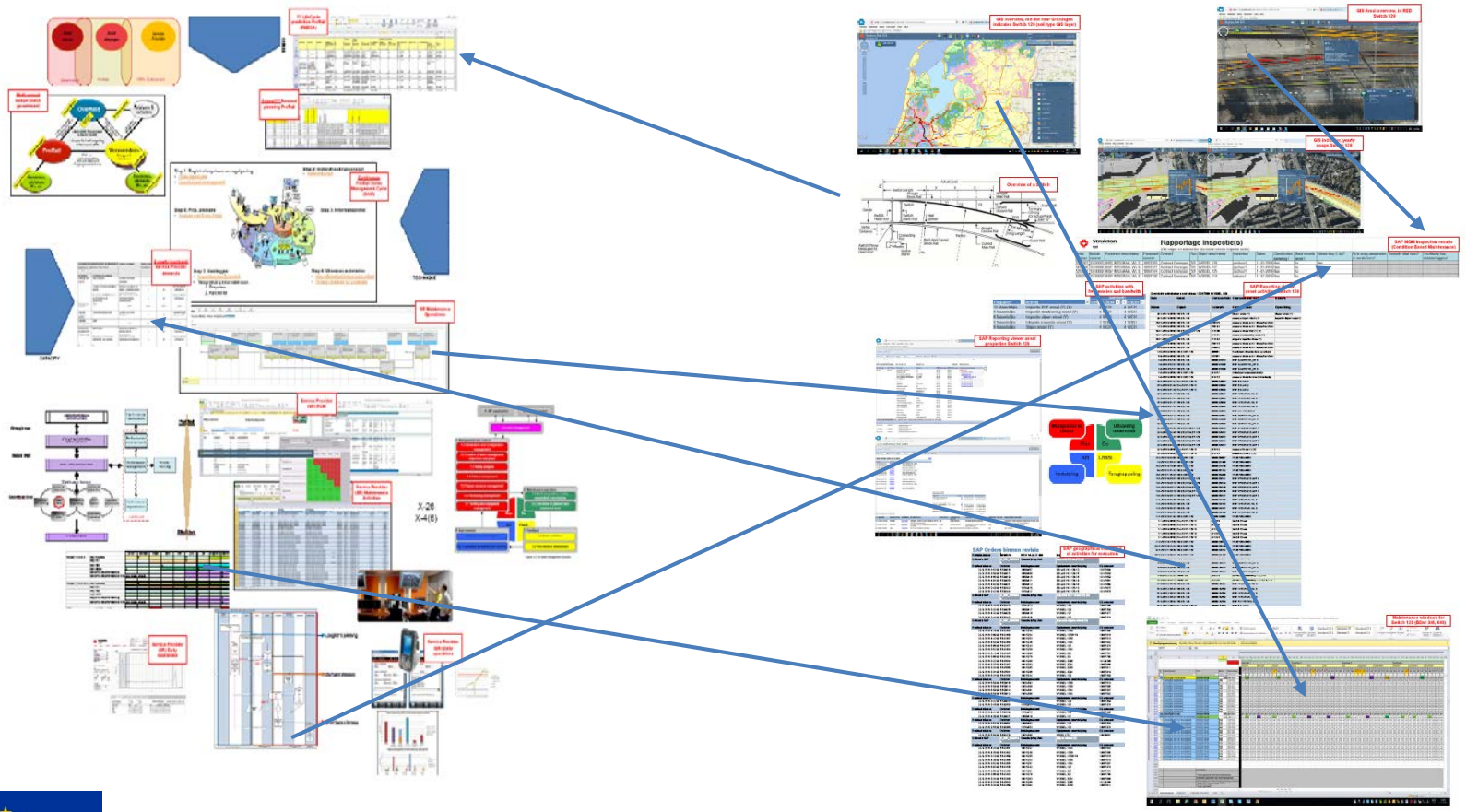

Source: Strukton Rail

Decision support for maintenance & interventions planning

This is maintenance planning!

Decisions regarding:

- **WHAT?** tamping, grinding, road retrofitting/upgrading
- **WHEN?** next year, month 8, 12.04.2016 8:00-8:30
- **WHERE?** section A,B and C, switch #129
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Complex process of maintenance planning involves:

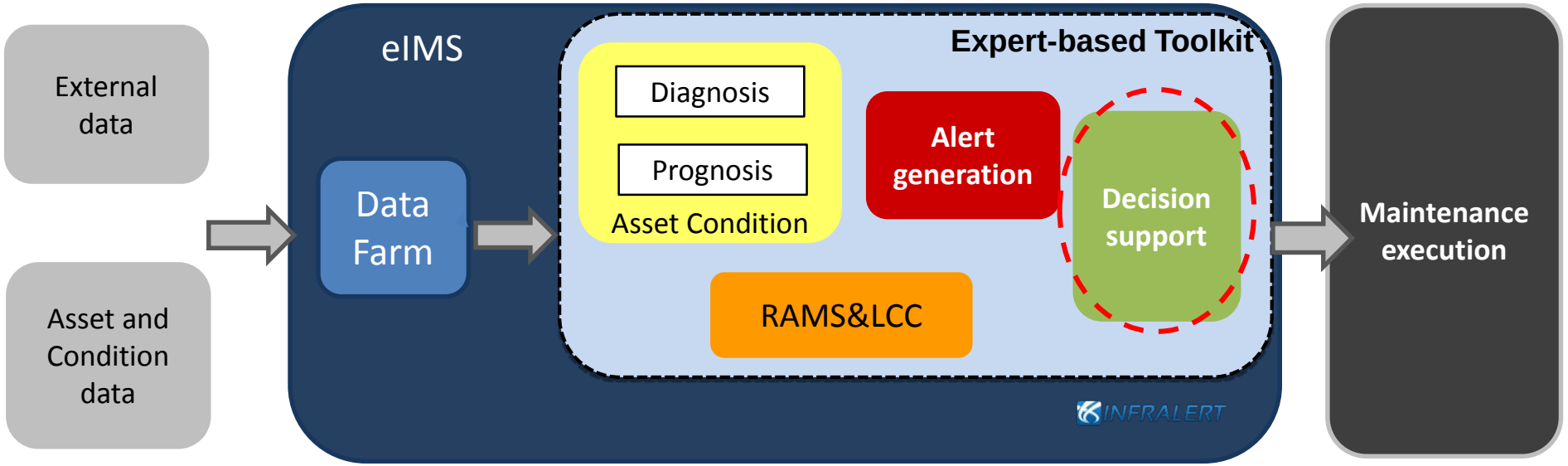
- **Decisions tom make** Which policy to apply?, Which possessions to book?,
  When to start an intervention?
- **Objectives to achieve** Cost, Availability, Robustness
- **Constraints to consider** Limited budget, Time windows for maintenance, Resource availability

➢ **Structured approach using a formal model**

➢ **Support by IT tools to :** → Make use of all information
→ Tackle complexity
→ Evaluate alternatives

Context of INFRALERT

- Decision support as “final step” combining und using the generated information/knowledge from the previous investigations

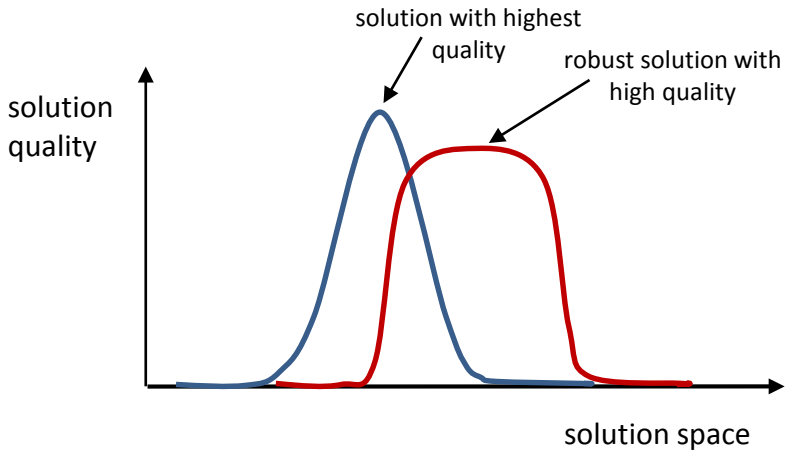


Managing uncertainty in planning

Uncertain information has to be considered:

- Predictions of future conditions
  → result in “most probable interventions”
  → costs/efforts for maintenance vary (planned vs. actual)
- RAMS parameter only estimated

Calls for robust planning concepts:



Achieved results

- **Theoretical part**

  → **Framework for Decision Support**

- **Practical part**

  → **Modelling of use cases**

  (i.e. from informal to formal description)

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

   strategic - tactical - operational

- **Different time horizons:**

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

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- **Different time horizons:** → long term

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

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- **Different time horizons:** → long term
  → mid term

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

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- **Different time horizons:**
  - → long term
  - → mid term
  - → short term

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

   strategic - tactical - operational

- **Different time horizons:**
  → long term
  → mid term
  → short term

- **Different levels of details:**

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

   strategic - tactical - operational

- **Different time horizons:** → long term
  → mid term
  → short term

- **Different levels of details:** → policies for assets/groups

Achieved results - Theoretical part

Framework definition includes:

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- **Different time horizons:**
  → long term
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- **Different levels of details:**
  → policies for assets/groups
  → monthly allocation of interventions

Achieved results - Theoretical part

Framework definition includes:

1. **Identification of planning levels**:

strategic - tactical - operational

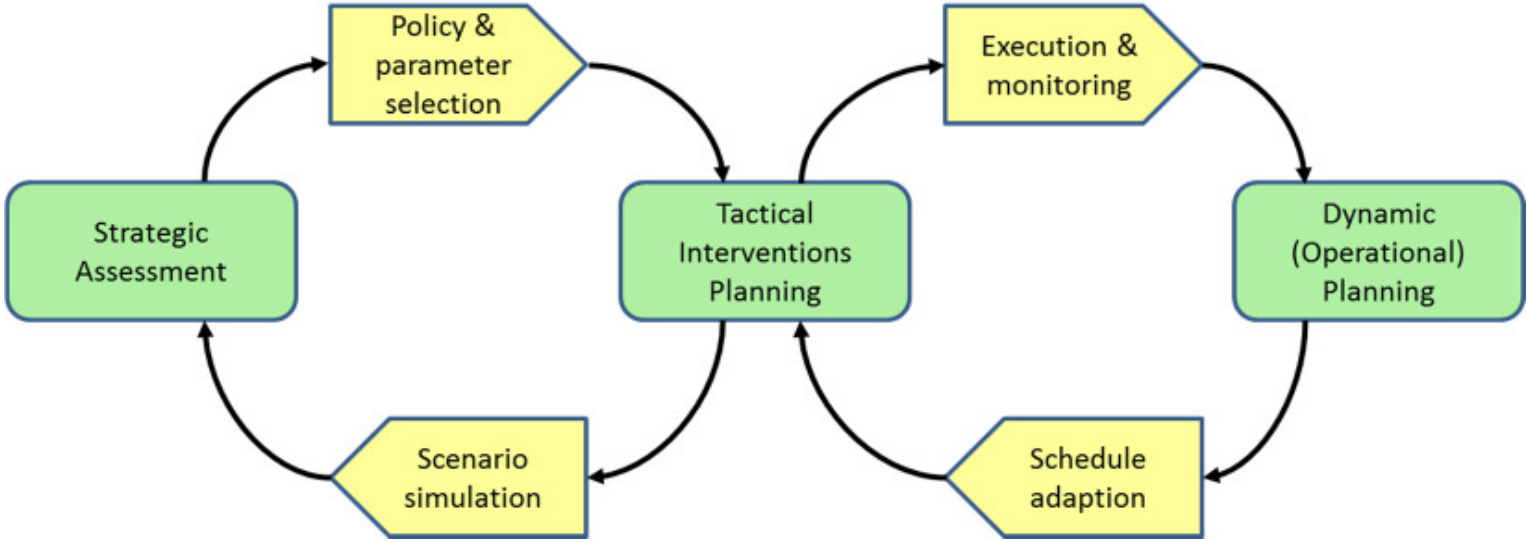
- **Different time horizons:**
  - → long term
  - → mid term
  - → short term

- **Different levels of details:**
  - → policies for assets/groups
  - → monthly allocation of interventions
  - → detailed scheduling

Achieved results - Theoretical part

Framework definition includes:

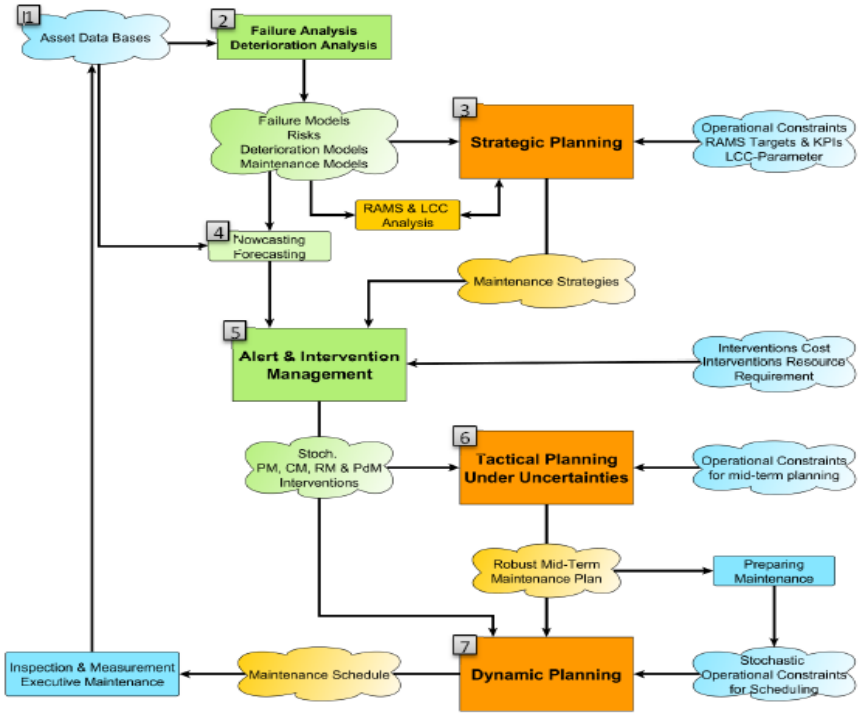
1. **Identification of planning levels**: strategic - tactical – operational
2. **Adaptive approach: Feedback loop**



Achieved results - Theoretical part

Framework definition includes:

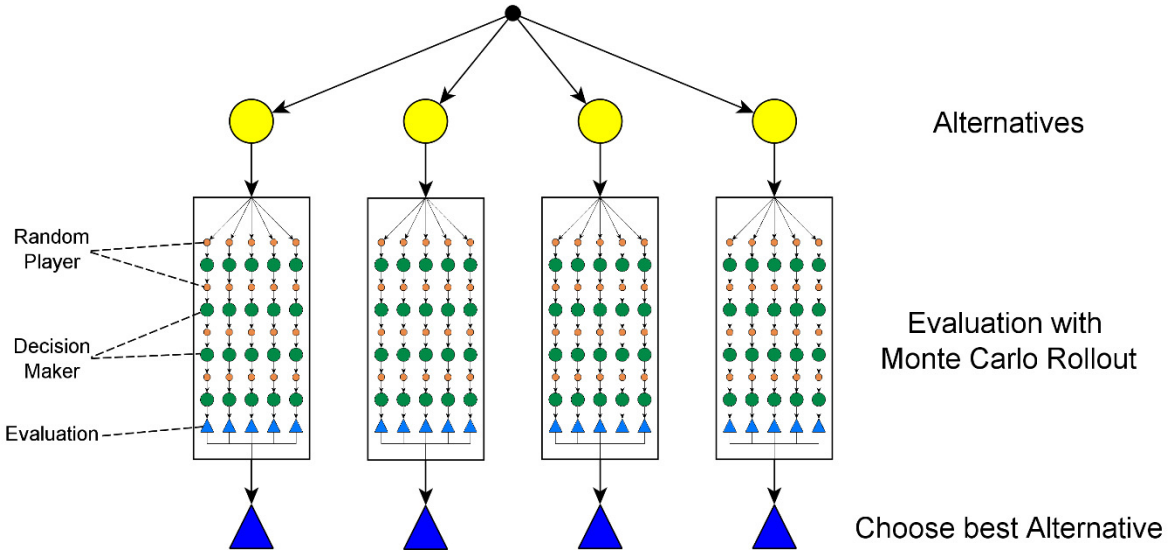
1. **Identification of planning levels**: strategic - tactical – operational
2. **Adaptive approach: Feedback loop**
3. **Description of overall workflow for maintenance planning**



Achieved results - Theoretical part

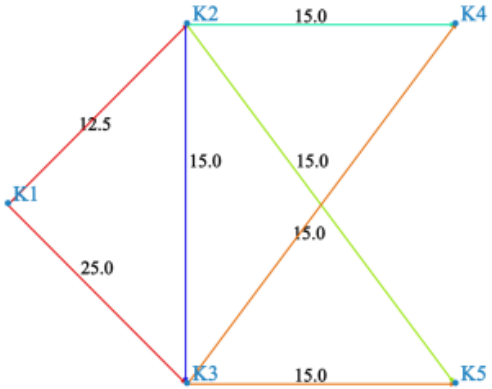
Framework definition includes:

1. **Identification of planning levels**: strategic - tactical – operational
2. **Adaptive approach: Feedback loop**
3. **Description of overall workflow for maintenance planning**
4. **Algorithmic approach to incorporate uncertainties/ robust planning**



Achieved results - Practical part

Road use case

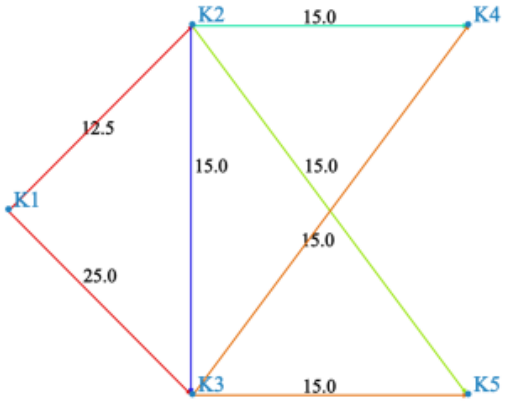


- Scope: → Tactical planning phase (5 years)
  → Allocation of major interventions
  → Min of the costs and max of the overall network quality

- Highlights: → Consider predicted conditions
  → Integration of traffic / capacity analysis
  → Robust planning

Achieved results - Practical part

Road use case



$$\min \sum_{a \in A} c_{y_a}$$ overall costs

$$\max \sum_{a \in A} \sum_{t=1}^{t_{\max}} q_a(t) w_a$$ average quality index

$$\text{s.t.} \sum_{a \in A} c_{y_a} \leq C_5$$ bounded 5-year-budget

$$\sum_{a \in A: \left\lceil \frac{t^s_{y_a}}{52} \right\rceil = j} c_{y_a} \leq C_1 \qquad \forall j = 1, \ldots, 5$$ bounded annual budget

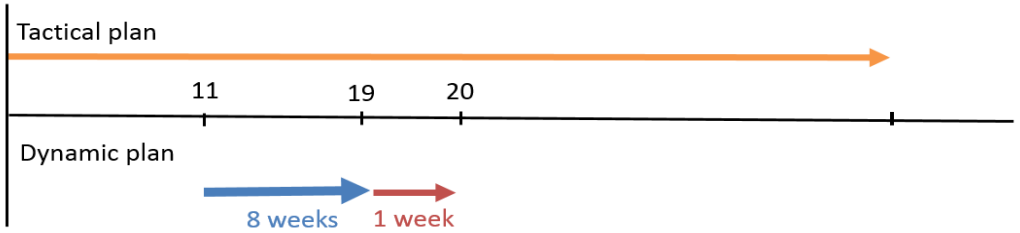
$$\sum_{a \in A: r_a \in r \wedge t^s_{y_a} \in \{t - d_{y_a}(t^s_{y_a}), \ldots, t\}} 1 \leq n_r \qquad \forall r \in R, \forall t \in T$$ limited supervising teams

$$q_a(t) \geq \bar{Q}_a \qquad \forall a \in A, \forall t \in T : t \leq t^s_{y_a}$$ keep quality limits

$$\sum_{k=y_a+1}^{K} p^k_a(x_{y_a}) \leq P_{\max} \qquad \forall a \in A$$ keep robustness level

Achieved results - Practical part

Rail use case

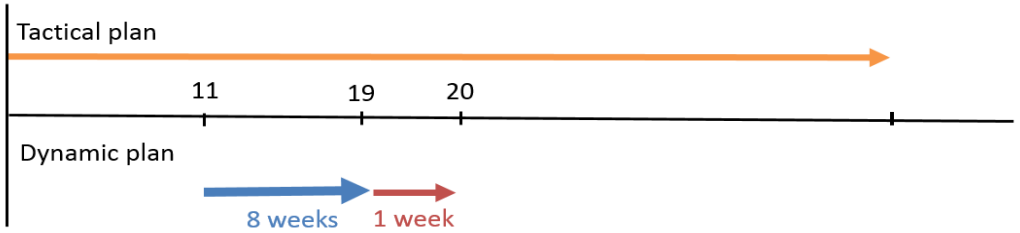


- Scope: → Dynamical planning phase
  → Adaption of the tactical plan
  → Min of costs (including costs for the possession booking) and max the overall network quality

- Highlights: → Integration of tasks from the dynamical plan into the tactical plan and vice versa to reduce possession time
  → Considering predicted conditions
  → Combining asset types (track and switches)

Achieved results - Practical part

Rail use case



$$\min \left(\sum_{j=1}^{W} \left(1 - r_j^w(t)\right) c_j^w + \sum_{a \in A} \sum_{\tau \in M_a} c_{y_{a,\tau}} \right)$$ overall costs

$$\max \sum_{a \in A} \sum_{t=1}^{t_{\max}} q_a(t) w_a$$ average quality index

$$\text{s.t.} \sum_{j=1}^{W} \left(1 - r_j^w(t)\right) c_j^w + \sum_{a \in A} \sum_{\tau \in M_a} c_{y_{a,\tau}} \leq C_1$$ bounded annual budged

$$t^1_{y_{a,\tau}} \leq l_{y_{a,\tau}} \qquad \forall a \in A, \forall \tau \in M_a$$ keep time limits

$$q_a(t) \geq \bar{Q}_a \qquad \forall a \in A, \forall t \in T : t \leq t^1_{y_{a,\tau}}$$ keep quality limits

$$\sum_{a \in A, \tau \in M_a : \sigma_{y_{a,\tau}} \in \sigma \wedge t^1_{y_{a,\tau}} \in D_{y_{a,\tau}}(t)} 1 = 1 \qquad \forall \sigma \in S, \forall t \in T$$ combination possibilities

$$p\left(z_{a,\tau}(x_{y_{a,\tau}}) > k\right) \leq P_{\max} \qquad \forall a \in A, \forall \tau \in M_a$$ keep robustness level

Conclusions

→ We set up a theoretical framework for maintenance planning

→ We mange to include uncertainties into the decision support

→ We investigated two use cases and provided the corresponding mathematical model

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