Multi-model Maintenance Scheduling

Christian Brunbjerg Jespersen

Technical University of Denmark

Introduction

Operations research (OR) traditionally focuses on optimizing processes within a single organization. However, many real-world problems involve multiple actors with diverse objectives and constraints. This poster explores a multi-actor approach to OR, emphasizing collaboration and conflict resolution among stakeholders.

Objectives

1. Integrate multiple stakeholder perspectives into OR models.
2. Develop methods to handle conflicting objectives.
3. Propose collaborative optimization strategies.

Results

- Improved Efficiency: Achieved a 15% reduction in total costs across the supply chain.
- Stakeholder Satisfaction: Increased satisfaction scores among all actors by 20%.
- Collaborative Strategies: Developed joint policies that benefit all parties.

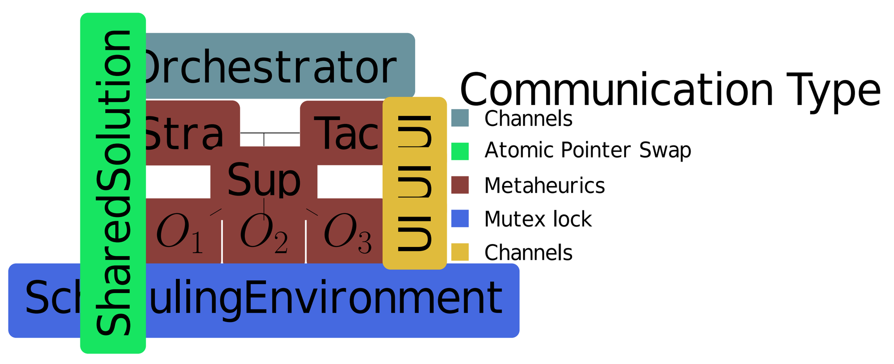
Conclusion

Incorporating a multi-actor approach in operations research leads to more sustainable and acceptable solutions. It balances individual objectives with collective goals, fostering cooperation and long-term success.

Future Work

- Extend the approach to international supply chains.
- Incorporate real-time data analytics for dynamic decision-making.
- Explore applications in other sectors like healthcare and transportation.

Solution Method



Case Study

Supply Chain Management

A complex supply chain involving suppliers, manufacturers, distributors, and retailers. Each actor aims to optimize its own performance metrics, which may conflict with others. The multi-actor approach seeks a globally optimal solution that considers the objectives of all stakeholders.

Methodology

1 Strategic

Meta variables:

$$s \in S \tag{1}$$
$$\tau \in [0, \infty] \tag{2}$$

Minimize:

$$\sum_{w \in W(\tau)} \sum_{p \in P(\tau)} strategic\_value_{wp}(\tau) \cdot \alpha_{wp}(\tau) + \sum_{p \in P(\tau)} \sum_{r \in R(\tau)} strategic\_penalty \cdot \epsilon_{pr}(\tau) + \sum_{p \in P(\tau)} \sum_{w1 \in W(\tau)} \sum_{w2 \in W(\tau)} clustering\_value_{w1,w2} \cdot \alpha_{w1p}(\tau) \cdot \alpha_{w2p}(\tau) \tag{3}$$

Subject to:

$$\sum_{w \in W(\tau)} work\_order\_work_{wr} \cdot \alpha_{wp}(\tau) \leq resource_{pr}(\tau, \beta(\tau)) + \epsilon_{pr}(\tau) \quad \forall p \in P(\tau) \quad \forall r \in R(\tau) \tag{4}$$
$$\sum_{w \in W(\tau)} \alpha_{wp}(\tau) = 1 \quad \forall p \in P(\tau) \tag{5}$$
$$\alpha_{wp}(\tau) = 0 \quad \forall (w,p) \in exclude(\tau) \tag{6}$$
$$\alpha_{wp}(\tau) = 1 \quad \forall (w,p) \in include(\tau) \tag{7}$$
$$\alpha_{wp}(\tau) \in \{0,1\} \quad \forall w \in W(\tau) \quad \forall p \in P(\tau) \tag{8}$$
$$\epsilon_{pr}(\tau) \in \mathbb{R}^+ \quad \forall p \in P(\tau) \quad \forall r \in R(\tau) \tag{9}$$

2 Tactical

Meta variables:

$$s = S \tag{10}$$
$$\alpha(\tau) \tag{11}$$
$$\tau \in [0, \infty] \tag{12}$$

Minimize:

$$\sum_{o \in O(\tau,\alpha(\tau))} \sum_{d \in D(\tau)} tactical\_value_{do}(\tau) \cdot \beta_{do}(\tau) + \sum_{r \in R(\tau)} \sum_{d \in D(\tau)} tactical\_penalty \cdot \mu_{rd}(\tau) \tag{13}$$

Subject to:

$$\sum_{o \in O(\tau,\alpha(\tau))} work_o(\tau) \cdot \beta_{do}(\tau) \leq tactical\_resource_{dr}(\tau) + \mu_{rd}(\tau) \forall d \in D(\tau) \quad \forall r \in R(\tau) \tag{14}$$
$$\sum_{d=earliest\_start_o(\tau)}^{latest\_finish_o(\tau)} \sigma_{do}(\tau) = duration_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{15}$$
$$\sum_{d^* \in D_{duration_o(\tau)}(\tau)} \sigma_{d^*o}(\tau) = duration_o(\tau) \cdot \eta_{do}(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall d \in D(\tau) \tag{16}$$
$$\sum_{o \in O(\tau,\alpha(\tau))} \eta_{do}(\tau) = 1, \quad \forall d \in D(\tau)$$
$$\sum_{d \in D(\tau)} d \cdot \sigma_{do1}(\tau) + \Delta_o(\tau) = \sum_{d \in D(\tau)} d \cdot \sigma_{do2}(\tau) \quad \forall (o1, o2) \in finish\_start_{o1,o2} \tag{17}$$
$$\sum_{d \in D(\tau)} d \cdot \sigma_{do1}(\tau) = \sum_{d \in D(\tau)} d \cdot \sigma_{do2}(\tau) \quad \forall (o1, o2) \in start\_start_{o1,o2} \tag{18}$$
$$\beta_{do}(\tau) \leq number_o(\tau) \cdot operating\_time_o \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{19}$$
$$\beta_{do}(\tau) \in \mathbb{R} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{20}$$
$$\mu_{rd}(\tau) \in \mathbb{R} \quad \forall r \in R(\tau) \quad \forall d \in D(\tau) \tag{21}$$
$$\sigma_{do}(\tau) \in \{0,1\} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{22}$$
$$\eta_{do}(\tau) \in \{0,1\} \quad \forall d \in D(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{23}$$
$$\Delta_o(\tau) \in \{0,1\} \quad \forall o \in O(\tau, \alpha(\tau)) \tag{24}$$

3 Supervisor

Meta variables:

$$z \in Z \tag{25}$$
$$\alpha(\tau) \tag{26}$$
$$\theta(\tau) \tag{27}$$
$$\tau \in [0, \infty] \tag{28}$$

Maximize:

$$\sum_{a \in A(\tau,\alpha(\tau))} \sum_{t \in T(\tau)} supervisor\_value_{at}(\tau, \lambda_t(\tau), \Lambda_t(\tau)) \cdot \gamma_{at}(\tau) \tag{29}$$

Subject to:

$$\sum_{a \in A_o(\tau,\alpha(\tau))} \rho_a(\tau) = work_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{30}$$
$$\sum_{t \in T(\tau)} \sum_{a \in A_o(\tau,\alpha(\tau))} \gamma_{at}(\tau) = \phi_o(\tau) \cdot number_o(\tau) \quad \forall o \in O(\tau, \alpha(\tau)) \tag{31}$$
$$\sum_{o \in O_w(\tau,\alpha(\tau))} \phi_o(\tau) = |O_w(\tau, \alpha(\tau))| \quad \forall w \in W(\tau, \alpha(\tau)) \tag{32}$$
$$\sum_{a \in A_o(\tau,\alpha(\tau))} \gamma_{at}(\tau) \leq 1 \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{33}$$
$$\gamma_{at}(\tau) \leq feasible_{at}(\theta(\tau)) \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{34}$$
$$\gamma_{at}(\tau) \in \{0,1\} \quad \forall o \in O(\tau, \alpha(\tau)) \quad \forall t \in T(\tau) \tag{35}$$
$$\rho_a(\tau) \in [lower\_activity\_work_a(\tau), work_a(\tau)] \quad \forall a \in A(\tau, \alpha(\tau)) \tag{36}$$

4 Operational

Meta variables:

$$t \in T(\tau) \tag{37}$$
$$\alpha(\tau) \tag{38}$$
$$\gamma(\tau) \tag{39}$$
$$\tau \in [0, \infty] \tag{40}$$

Maximize:

$$\sum_{a \in A(\tau,\gamma_t(\tau))} \sum_{k \in K(\gamma(\tau))} \delta_{ak}(\tau) \tag{41}$$

Subject to:

$$\sum_{k \in K(\gamma(\tau))} \delta_{ak}(\tau) \cdot \pi_{ak}(\tau) = activity\_work_a(\tau, \rho(\tau)) \cdot \theta \quad (\tau) \forall a \in A(\tau, \gamma_t(\tau)) \tag{42}$$
$$\lambda_{a21}(\tau) \geq \Lambda_{a1last(a1)}(\tau) + preparation_{a1,a2} \quad \forall a1 \in A(\tau, \gamma_t(\tau)) \quad \forall a2 \in A(\tau, \gamma_t(\tau)) \tag{43}$$
$$\lambda_{ak}(\tau) \geq \Lambda_{ak-1}(\tau) - constraint\_limit \cdot (2 - \pi_{ak}(\tau) + \pi_{ak-1}(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{44}$$
$$\delta_{ak}(\tau) = \Lambda_{ak}(\tau) - \lambda_{ak}(\tau) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{45}$$
$$\lambda_{ak}(\tau) \geq event_{ie} + duration_{ie} - constraint\_limit \cdot (1 - \omega_{akie}(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{46}$$
$$\Lambda_{ak}(\tau) \leq event_{ie} + constraint\_limit \cdot \omega_{akie}(\tau) \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{47}$$
$$\lambda_{a1}(\tau) \geq time\_window\_start_a(\beta(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{48}$$
$$\Lambda_{alast(a)}(\tau) \leq time\_window\_finish_a(\beta(\tau)) \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{49}$$
$$\pi_{ak}(\tau) \in \{0,1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{50}$$
$$\lambda_{ak}(\tau) \in [availability\_start(\tau), availability\_finish(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{51}$$
$$\Lambda_{ak}(\tau) \in [availability\_start(\tau), availability\_finish(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{52}$$
$$\delta_{ak}(\tau) \in [0, work_{a\_to\_o(a)}(\tau)] \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \tag{53}$$
$$\omega_{akie}(\tau) \in \{0,1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \quad \forall k \in K(\gamma(\tau)) \quad \forall i \in I(\tau) \quad \forall e \in E(\tau) \tag{54}$$
$$\theta_a(\tau) \in \{0,1\} \quad \forall a \in A(\tau, \gamma_t(\tau)) \tag{55}$$