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ADAPTIVE OPTIMIZATION IN DYNAMIC ENVIRONMENTS

An Open Ended Multi-Objective Approach for Solving a Dynamic Optimization Problem in Steel Logistics

Andreas Beham, Sebastian Leitner, Stefan Wagner

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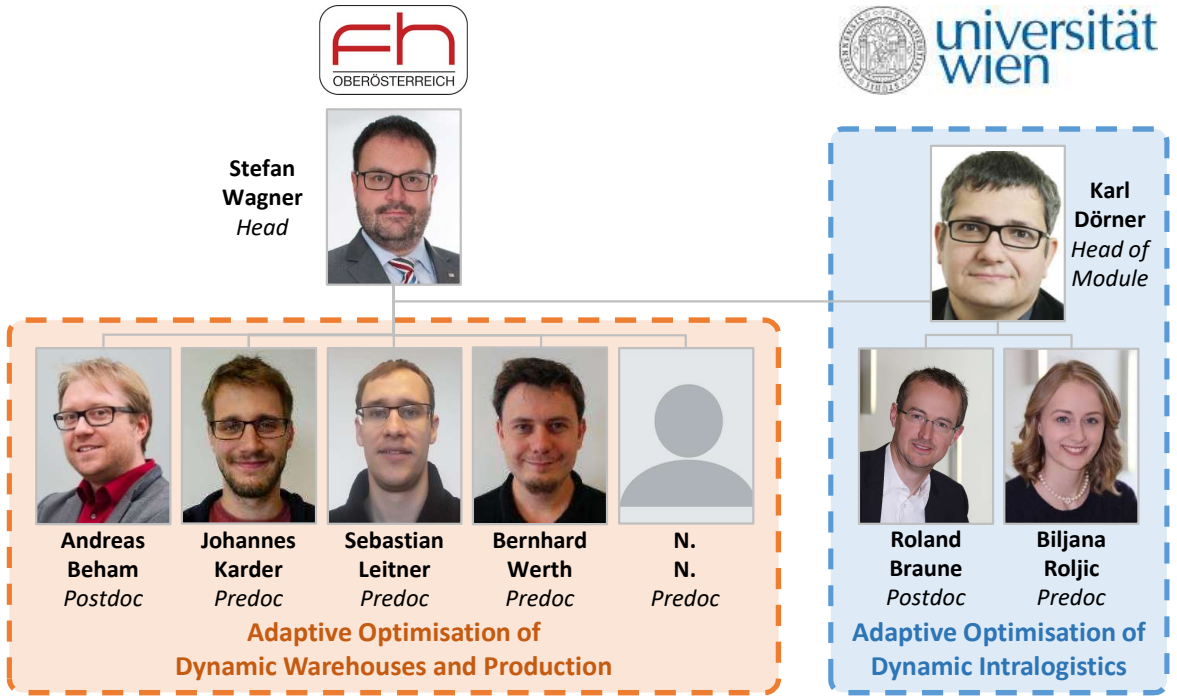
Introduction

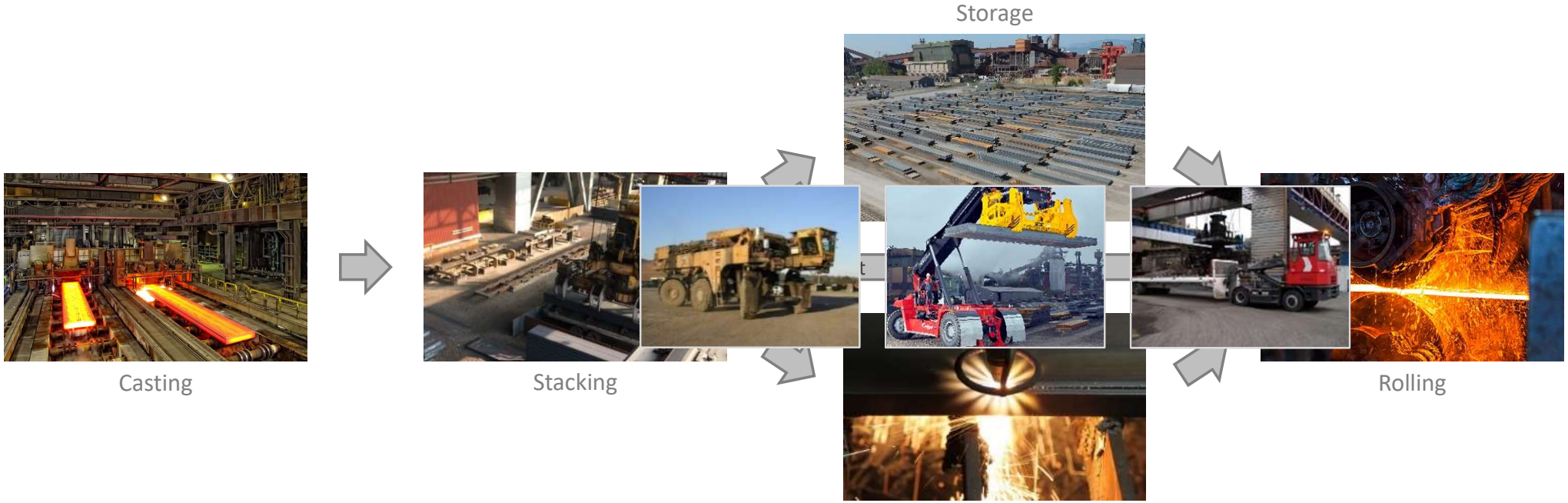
JRZ adaptOp Research Project

- Josef Ressel center for adaptive optimization in dynamic environments
  - 5 year project
  - 2 Scientific Partners
  - 4 Company Parnters
  - Started at 01/10/2019



Motivation

Processes in Steel Production



A long long time ago…

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Analysing a Hybrid Model-Based Evolutionary Algorithm for a Hard Grouping Problem

Sebastian Raggl[1], Andreas Beham[12], Stefan Wagner[1], and Michael Affenzeller[12]

[1] Heuristic and Evolutionary Algorithms Laboratory
University of Applied Sciences Upper Austria, Hagenberg
Softwarepark 11, 4232 Hagenberg, Austria
[2] Institute for Formal Models and Verification
Johannes Kepler University Linz,
Altenberger Straße 69, 4040 Linz, Austria
sebastian.raggl@fh-hagenberg.at

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$\mathcal{I} = \{i\}_{i=1}^{N}$	Set of items
$\mathcal{S} = \{s\}_{s=1}^{S}$	Ordered set of transport lots
$G_p = (\mathcal{I}, R)$	Weighted undirected graph of pairwise grouping costs
$G_d = (\mathcal{I}, \mathcal{D})$	Directed graph of item dependencies
N	Maximal number of items per lot

$$\min \ |S| + \sum_{s \in \mathcal{S}} C(s) \tag{1}$$

$$s.t. \ (a, b) \in R \qquad \forall_{s \in \mathcal{S}} \ \forall_{a \in s, \ b \in s} \tag{2}$$

$$S(a) \leq S(b) \qquad \forall_{(a,b) \in \mathcal{D}} \tag{3}$$

$$|s| \leq N \qquad \forall_{s \in \mathcal{S}} \tag{4}$$

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Hotstorage Environment

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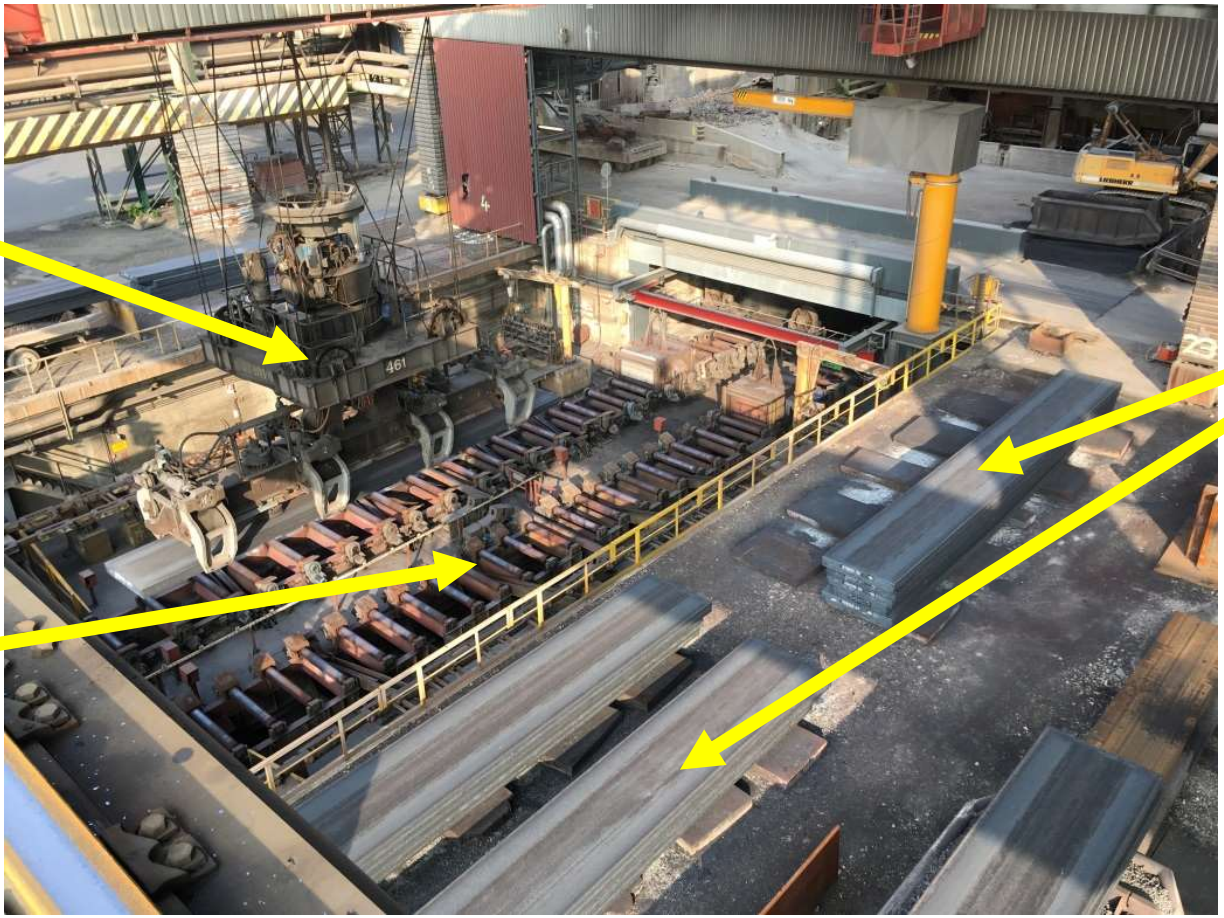

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Hotstorage Environment

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Transport lot

Pallet

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Hotstorage Environment

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Straddle carrier

Tractor + Pallet

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Objective and method

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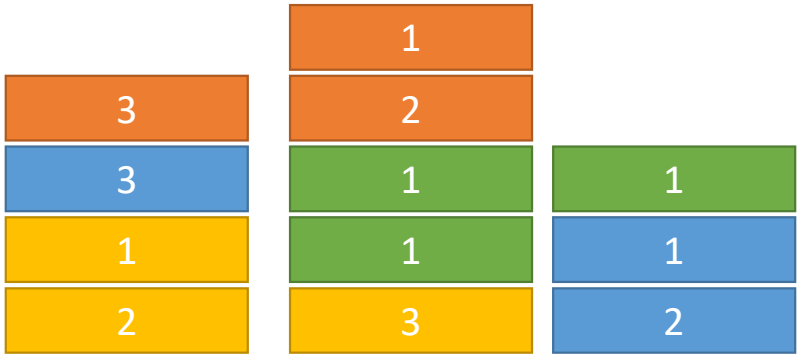
- Stack the slabs into suitable transport lots and deliver those to the right destinations
  - Given a large number of restrictions

- We created a mathematical model of a stacking problem and a fast branch & bound solver
- However, the model describes only the stacking solution and not the lot composition
- Alas, we created a grouping model to group the slabs into lots

Challenge: Model Scope

- The grouping model has several deficiencies
  - It needs to take into account the position of the slab in the stack to avoid time consuming restackings
  - It still doesn't provide all the necessary inputs, because it does not decide on the order of delivery
  - It does not consider vehicle availability or timing



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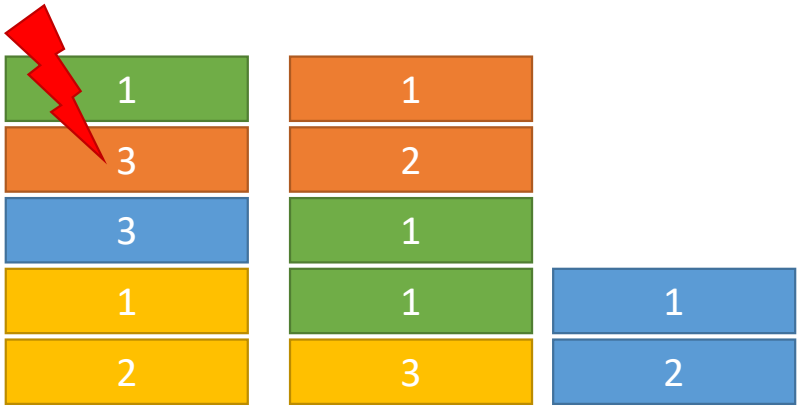
- For instance, the stacking solver would sometimes create moves that would cause the lots to become infeasible
- Sometimes symmetries cause solver to find many different solutions



A New Model

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- Considers
  - The capacity in the facility
  - Both types of vehicles
  - The stacking restrictions dependent on destination and type of vehicle
  - Sorting within the transport lots
  - The necessary times of the vehicles to perform the operations
  - Temperature and related stacking constraints
- Decides
  - The lot for each slab
  - The group for each lot
  - The handover stack for each group
  - The vehicle for each group
  - The handover time for each slab
  - The delivery time for each lot

A New Model - Objectives

- The model is multi-objective and considers as trade-offs
  - The efficient utilization of the transport
  - The costs of a certain grouping (as in the previous model)
  - The priority of delivering certain slabs before others
  - The time required to complete all deliveries

Improvements

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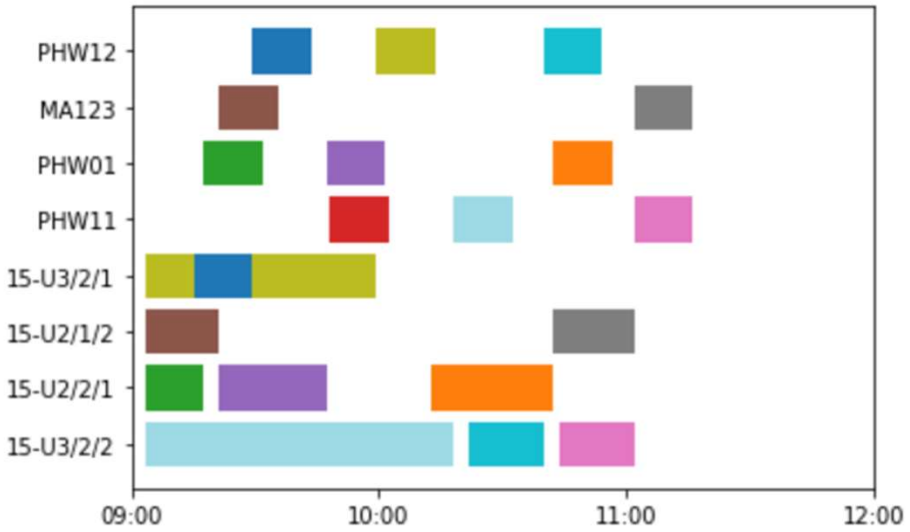
- The new model does not consider a slab's location
  - The B&B solver considers that as part of the stacking problem
- The new model determines handover stacks and handover times
  - Previously the B&B solver would deliver lots ad-hoc whenever transport capacity was available
- The new model considers complex handover constraints that are security-relevant
  - For instance, drivers have to be able to safely abandon their vehicles in case of an emergency
- The new model considers sorting sequences that involve the type of vehicle
  - Some lots have to be stacked in reverse order when they're picked up by straddle carriers

Solution Method

- Construction heuristic
  - Determines the time plan and vehicle assignment
  - Given the groupings, handover assignment and sequence as input
- NSGA-II evolutionary algorithm
  - Determines the best inputs for the construction heuristic
  - Calculates trade-offs among the solutions with respect to the objectives



Challenge: Uncertainties

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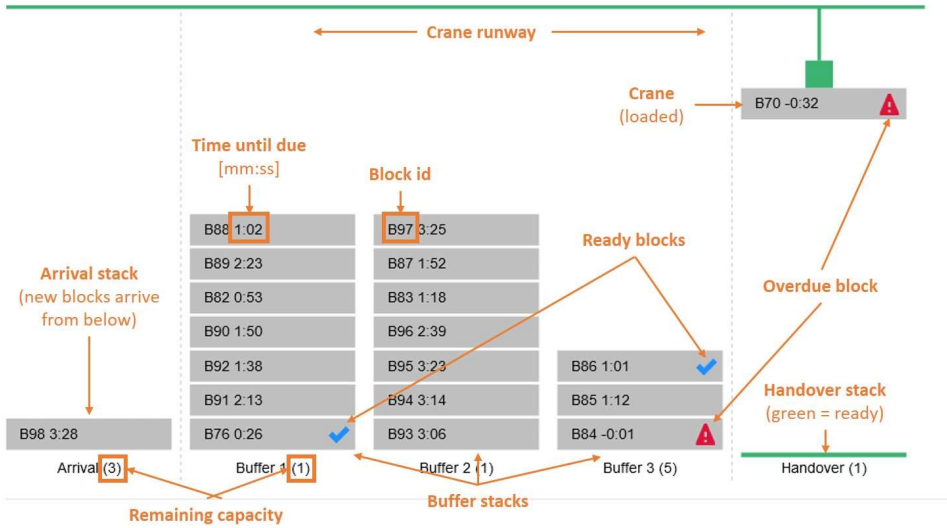
- The situation in the hotstorage environment changes constantly
  - Environmental uncertainties
    - Stochastic manipulation times and material properties (e.g., length)
    - Interdepencies (e.g., accumulating delay)
    - Availability of transport
  - Implementation uncertainties
    - Material is moved to a wrong position
    - Moves are too late or in the wrong order
  - Dynamic and disruptive changes
    - Destinations of slabs change
    - Breakdowns, maintenances, closing of stacks

Beham A, Raggl S, Wagner S, Affenzeller M. Uncertainty in real-world steel stacking problems. In Proceedings of the Genetic and Evolutionary Computation Conference Companion 2019 Jul 13 (pp. 1438-1440).

Dynamic Environments

- DynStack competition
  - Was held as part of GECCO 2020 and GECCO 2021
  - Is currently open for submissions as part of GECCO 2022
  - Contains two environments
    - Hotstorage
    - Rolling Mill
  - Code is open source, everyone can run these simulations on his/her computer
- https://dynstack.adaptop.at
- https://github.com/dynstack/dynstack



A new Environment

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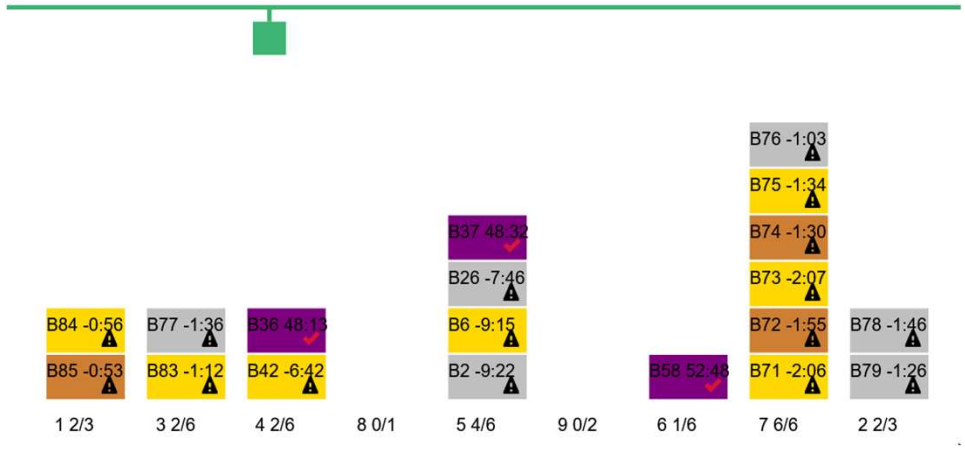
- The hostorage environment is rather simplistic
  - It does not require elaborate methods to be solved well
  - It does not feature challenges with respect to the composition of lots
  - But it's a lot of fun to watch the environment and the interaction with the solver



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Improvements

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- Blocks get additional properties
  - Grade: Gold, Silver, Bronze, Scrap
  - Destination: Mill, Yard, Adjustment, Treatment, Scrap Yard
  - Priority and temperature as numeric values
- Retains stacking as a main challenge
- Lots should be formed by considering
  - Grade, Destination, Priority, Temperature
- Contains a simplistic model of heating and cooling
  - Putting a hot block atop a cold one causes heat exchange
  - A stack full of blocks cools slower
- Two types of handover stacks and vehicles are present
  - As in the real environment
  - The straddle carrier is limited by temperature

Conclusions

- The optimization of this dynamic problem still poses a lot of challenges
- A new model is introduced that considers more restrictions and includes more decisions
- A construction heuristic + evolutionary algorithm is used to solve the model
- A new dynamic environment is presented that provides some of these challenges in an abstracted way

- We hope to be able to host the competition in the future
- We hope for participation and building of a scientific community around these environments