Integrated crew management for rail freight

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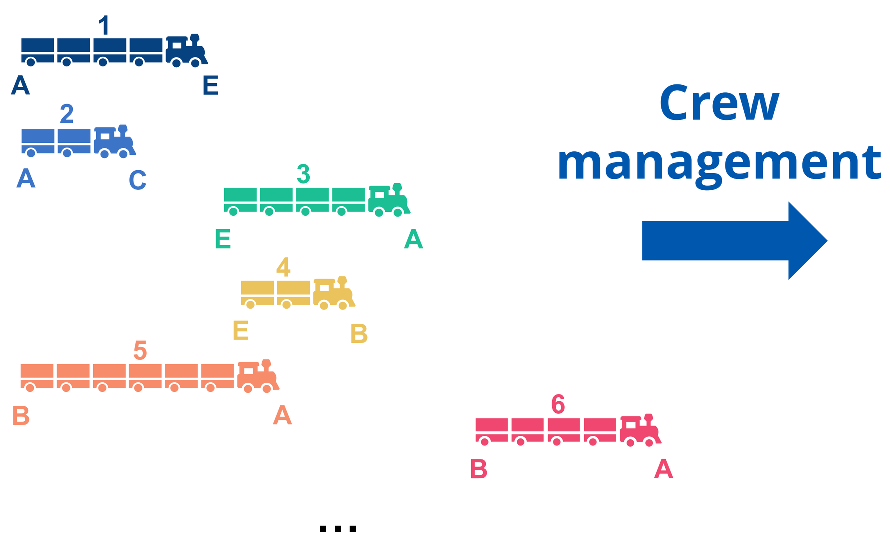
Context

Rail freight in France:
- ➢ 10% of overall freight: [redacted] trains per week
- ➢ Passenger traffic has priority over freight: trains mostly at night

Problem statement

Crew management problem
Input: Trains on a typical week
Output: Covering of trains by "rosters" with minimum cost, each roster assigned to a team



Team A:

mon	tue	wed	thu	fri	sat	sun
shift 1 12h-21h A - A	d	R	R	R	shift 5 11h-17h A - E	shift 6 5h-16h E - A
shift 2 12h-19h A - B	shift 3 5h-11h B - A	R	R	R	R	shift 7 10h-17h A - A

Team B:

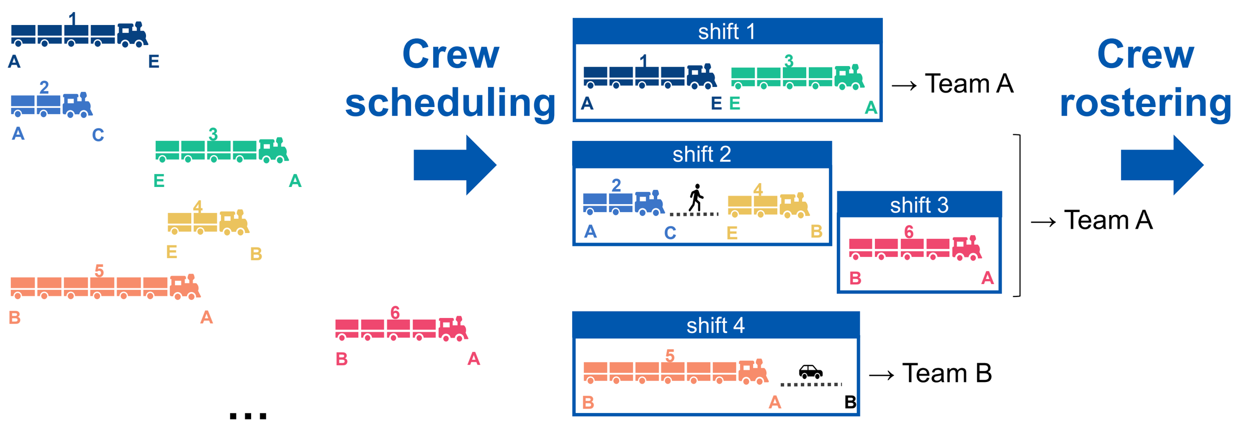
mon	tue	wed	thu	fri	sat	sun
shift 4 12h-20h B - B	shift 8 11h-17h B - B	shift 9 5h-12h E - B	R	R	R	R

cost = 10

Standard decomposition[1,2] (sub-optimal):

Crew scheduling problem +
Input: Trains on a typical week
Output: Covering of trains by daily shifts with minimum cost, each shift assigned to a team

Crew rostering problem
Input: Shifts, each assigned to a team
Output: Covering of trains by "rosters" with minimum cost, each roster assigned to a team



Team A:

mon	tue	wed	thu	fri	sat	sun
shift 1 12h-21h A - A	d	R	R	R	shift 5 11h-17h A - E	shift 6 11h-18h E - A
shift 2 12h-19h A - B	shift 3 5h-11h B - A	R	R	R	d	shift 7 5h-14h A - A

Team B:

mon	tue	wed	thu	fri	sat	sun
shift 4 12h-20h B - B	shift 8 11h-17h B - B	shift 9 5h-12h E - B	R	R	R	R

cost = 11

Contributions

Optimal decomposition:
- ➢ Covering of trains by "shifts blocks" with minimum cost, each assigned to a team ("shifts blocks" = working period between two days off)
- ➢ Construction of rosters with these shifts blocks

Trains' covering problem:

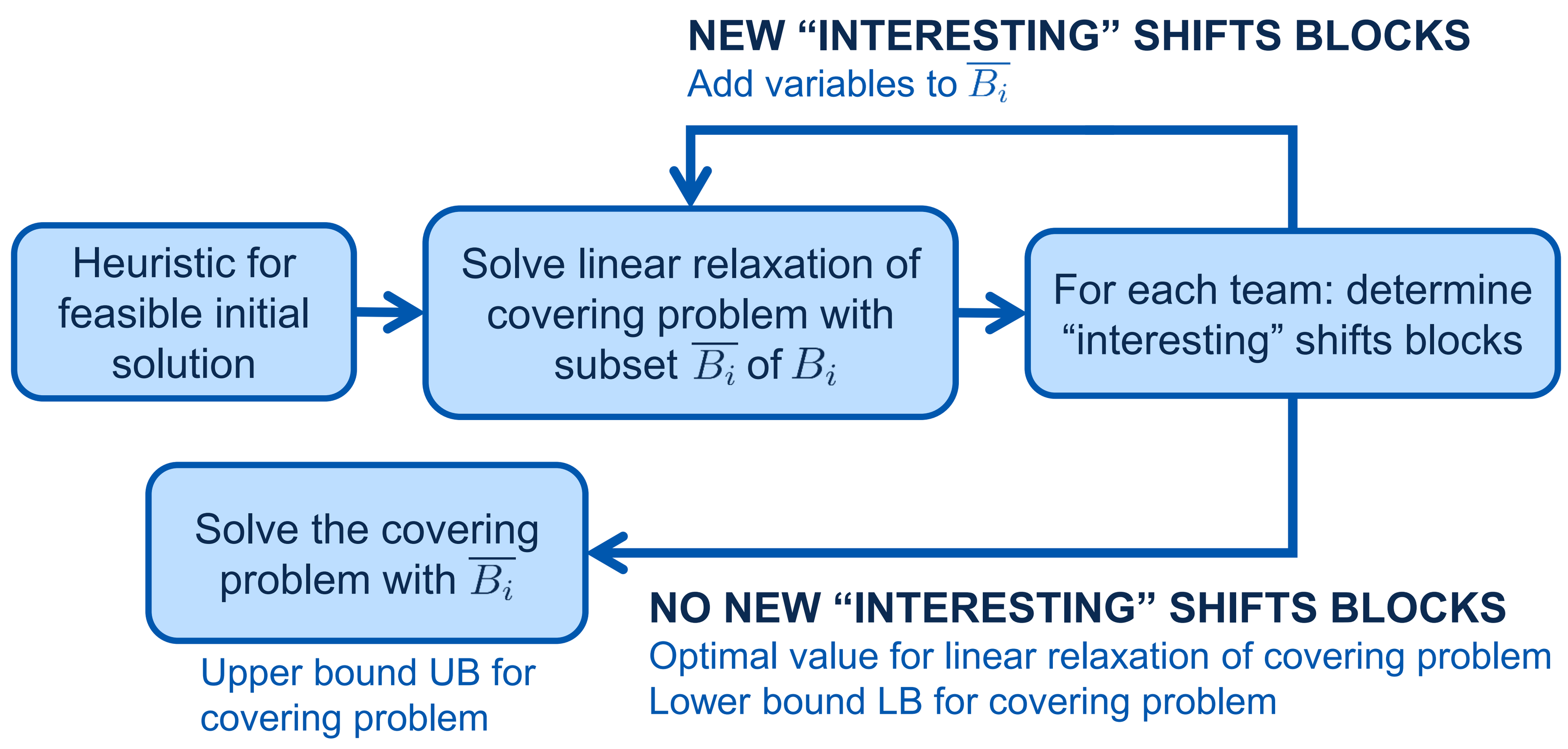
$$\begin{aligned}
\text{Min} \quad & \sum_{i\in I}\sum_{b\in B_i} c_b x_{b,i} \\
\text{s.t.} \quad & \sum_{i\in I}\sum_{\substack{b\in B_i \\ t\in b}} x_{b,i} \geq 1 \qquad \forall t\in T \\
& x_{b,i}\in\{0,1\} \qquad \forall i\in I, \forall b\in B_i
\end{aligned}$$

$t\in T$: train
$x_{b,i}$: the shifts block $b\in B_i$ is selected for team $i\in I$
B_i: set of all feasible shifts blocks for team $i\in I$

Naïve enumeration/selection approach: non tractable

Number of trains: [redacted] → (Enumeration of all feasible rosters) → Number of shifts blocks: [redacted]

Resolution of the relaxation of the covering problem using **column generation**
- ➢ Determining "interesting" shifts blocks = solving the pricing sub-problem
- ➢ Pricing sub-problem = optimization problem with
  - ○ Objective = "reduced costs"
  - ○ Shift feasibility constraints
  - ○ Shifts block feasibility constraints

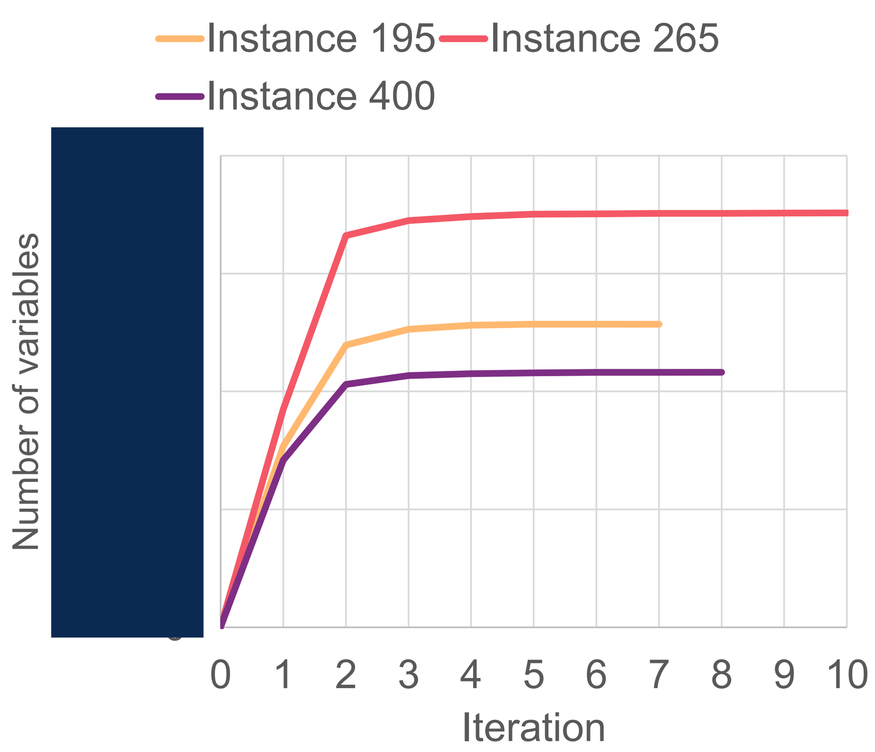


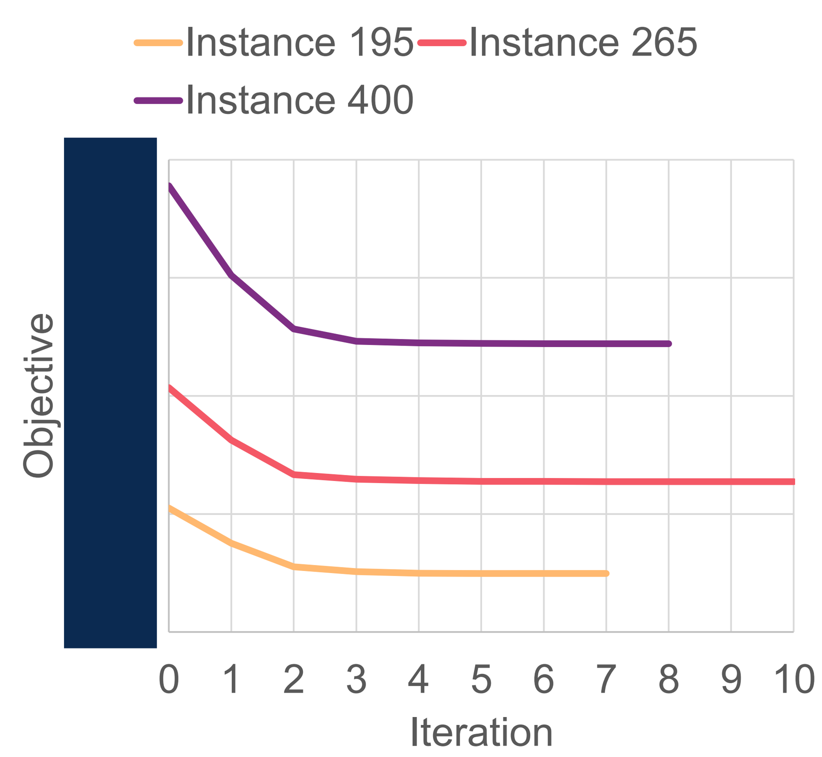
Solving the pricing sub-problem: contribution = modeling as Shortest Path with Constraints Problem
- ➢ Shortest Path with Constraints
  - ○ NP-hard, bound-discarding enumeration algorithms[3]

Results

Results obtained on 3 instances:
- ➢ 195 trains, 265 trains: extracted from a national dataset with [redacted] trains
- ➢ 400 trains: regional dataset

	Crew scheduling + Crew rostering decomposition		Integrated Crew management					
	Objective	Total time	LB	UB	Total time	Number iterations	Number variables
Instance 195 trains	[redacted]	2s	[redacted]	[redacted] (-14%)	15min31	[redacted]	[redacted]
Instance 265 trains	[redacted]	3s	[redacted]	[redacted] (-12%)	28min13	[redacted]	[redacted]
Instance 400 trains	[redacted]	5s	[redacted]	[redacted] (-13%)	32min46	[redacted]	[redacted]





Convergence of column generation with:
- ➢ Average gain of 13%
- ➢ Increased computation time
- ➢ Quality lower bound
- ➢ Tractable number of variables

Perspectives

- ➢ Speeding up the total computation time:
  - ○ Analysis of the parameters in the column generation
    - • Number of variables added at each iteration
    - • Stopping sub-problem resolution before finding best path
  - ○ Implicit description of graph in Shortest Path with Constraints for pricing sub-problem
- ➢ Running the algorithm on a full national dataset

Bibliography

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