# Dynamic Railway Crew Planning with Fairness over Time

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# Introduction







- At Netherlands Railways, fairness and attractiveness are guaranteed by incorporating Sharing-Sweet-and-Sour rules in the crew planning process.
- These rules were introduced in 2001 to resolve large nationwide strikes.
- Sweet and sour work, as measured along several attributes, should be fairly allocated over the different crew bases:
  - Duty length
  - Fraction of Type-A work
  - Fraction of aggression work
  - Fraction of double-decker work

#### Current

- *Level* Crew base
- Content Generic duties
- *Evaluation* Single moment

	Current	Proposed		
Level	Crew base	Individual		
Content	Generic duties	Operational duties		
Evaluation	Single moment	Planning period		

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The individual Sharing-Sweet-and-Sour rules offer stronger and more reliable guarantees to crew members, resulting in solutions that are fair over time.

## **Problem Description**

We have the following inputs:

- A planning period of fixed length
- Template-based individual rosters (capacity planning)
- Dynamically revealed daily task sets
- Individual SS&S rules

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We must respect several roster rules (e.g., rest time and forward rotation) and duty rules (e.g., meal break and duty length).

In the dynamic crew planning process, a typical duty undergoes the following planning steps:



# **Solution Approach**



## **Rolling Horizon Framework**





For a given attribute, the penalty of assigning a piece of work to a crew member depends on

- The current score of the crew member on the attribute.
- The score of the work on the attribute.

The total penalty is obtained by summing over all attributes.



Figure 1: Example of penalty function.

#### **Duty generation**

#### **Duty assignment**

#### **Duty generation**

**Duty assignment** 

Sequential CSP with SS&S at crew base level Opti

Optimal swapping

	Duty generation	Duty assignment
Sequential	CSP with SS&S at crew base level	Optimal swapping
Integrated	CSP with penalties on ta	asks

## Results

### Instances



#### Planning period: October 4 to November 21 of 2021.

Crew bas	se Crew	Templat	tes	Task	Ś	Type-A	Aggression	Double	e-decker
Amf	104	2,2	82	22,26	0	0.51	0.20		0.15
Asd	230	4,2	35	39,69	6	0.34	0.31		0.30
Ut	227	4,5	57	38,59		0.32	0.17		0.20
Total	561	11,0	74	100,55	1	0.37	0.23		0.23
	Duty length (h)		Ту	/pe-A	Ag	gression	Double-	decker	
		≤ 8:00	$\geq$	0.35		≤ 0.30	-	≤ 0.30	

	Satisfaction level (%)						
Method	Duty length	Type-A	Aggression	Double-decker			
Sequential	64.6	85.1	86.6	88.0			
Integrated	99.1	98.0	97.6	96.9			

## **Distribution of Attribute Scores**



## **Temporal Evolution of Satisfaction Levels**



		Time (s)					Iterations	
Method	Total	Pricing	RMP	Columns	Assignment	Total	Fixing	
Sequential	217.2	68.1	143.6	5.3	0.2	103.7	14.1	
Integrated	228.0	39.2	182.8	6.0	-	111.3	12.0	

Scalability



# Conclusion

- We introduce dynamic railway crew planning with fairness over time.
- Our rolling horizon approach with integrated penalty-based steering is able to achieve high SS&S satisfaction levels at no additional computational cost.
- Open questions:
  - How to construct template-based individual rosters?
  - How to handle more complex attributes, such as unique kilometers or repetition within duty?
  - How to scale this approach to larger instances, e.g., the full Dutch network?
- Feel free to contact me at vanrossum@ese.eur.nl.