Integrated Rolling Stock and Shunting Driver Rescheduling

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INFORMS Annual Meeting

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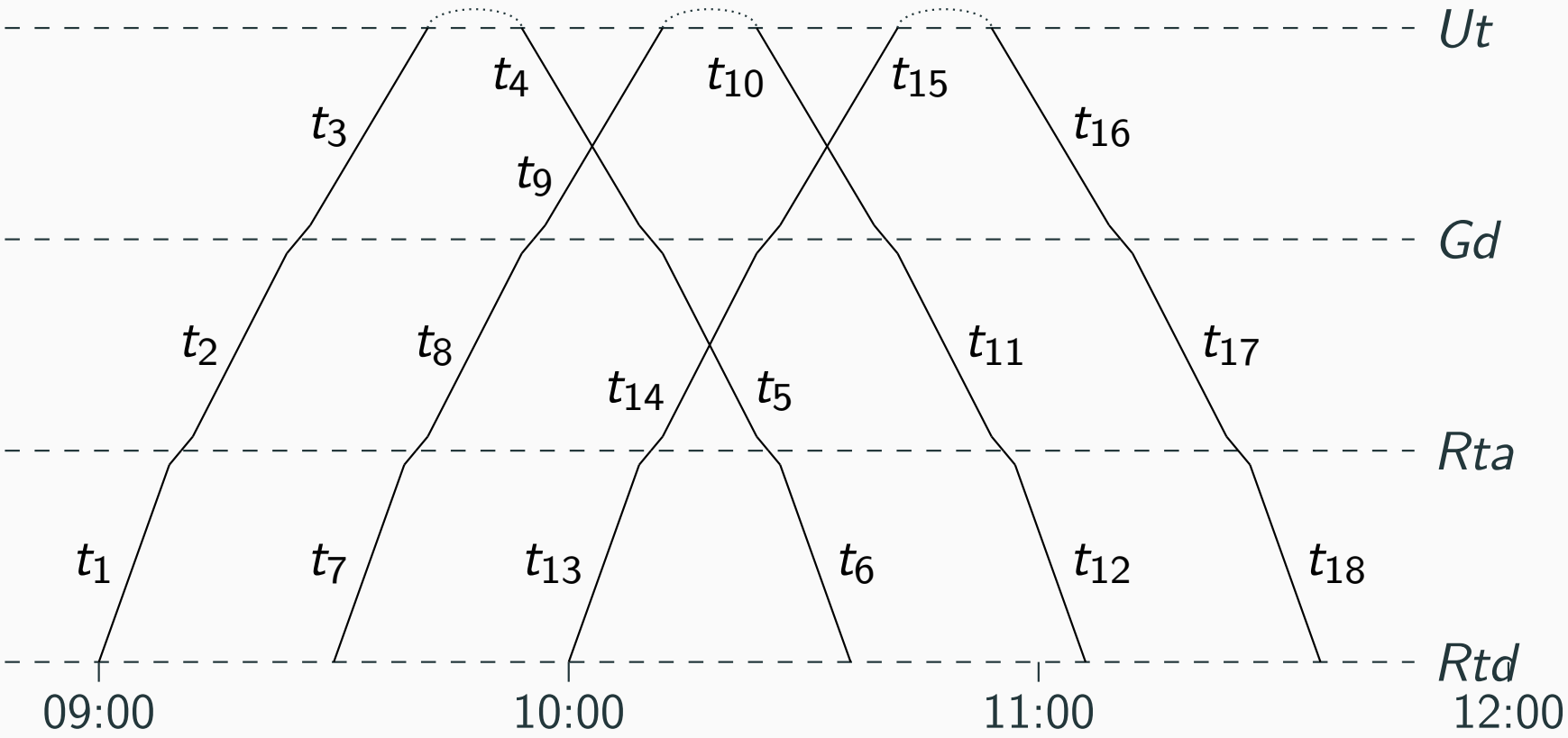
Rolling Stock Scheduling

Example of a Timetable

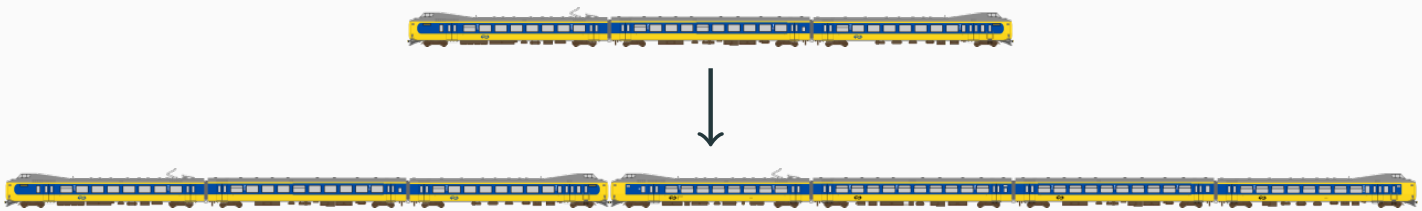


Rolling Stock Compositions

- Different types of train units are available
  - 
  - 
  - 
- Compatible train units can be combined into compositions
  - 
  - 
  - 

Shunting Actions

- Compositions can be changed at transitions between trips
- Composition changes through shunting
  - coupling
  - uncoupling



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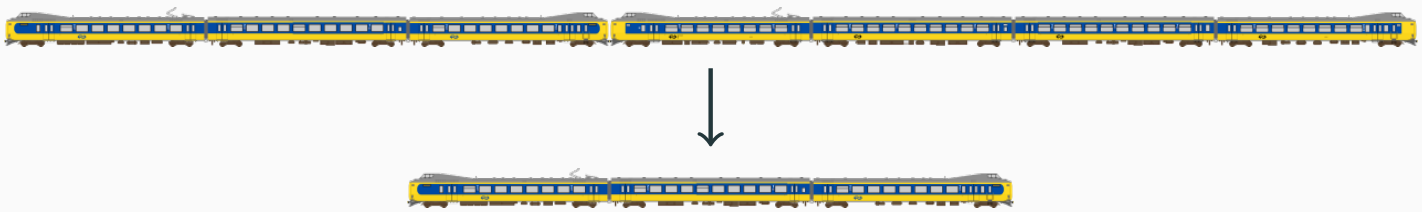
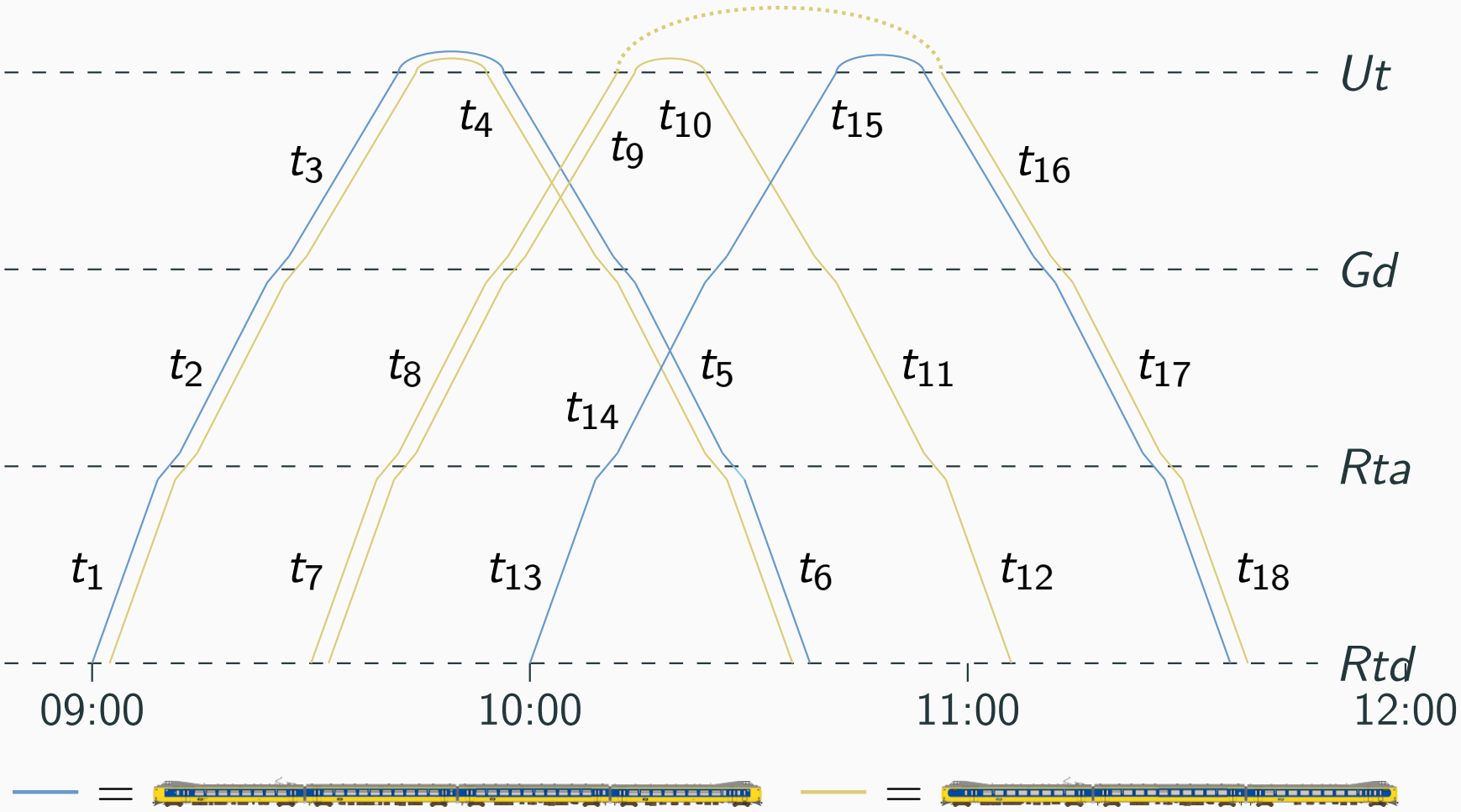


Rolling Stock Scheduling

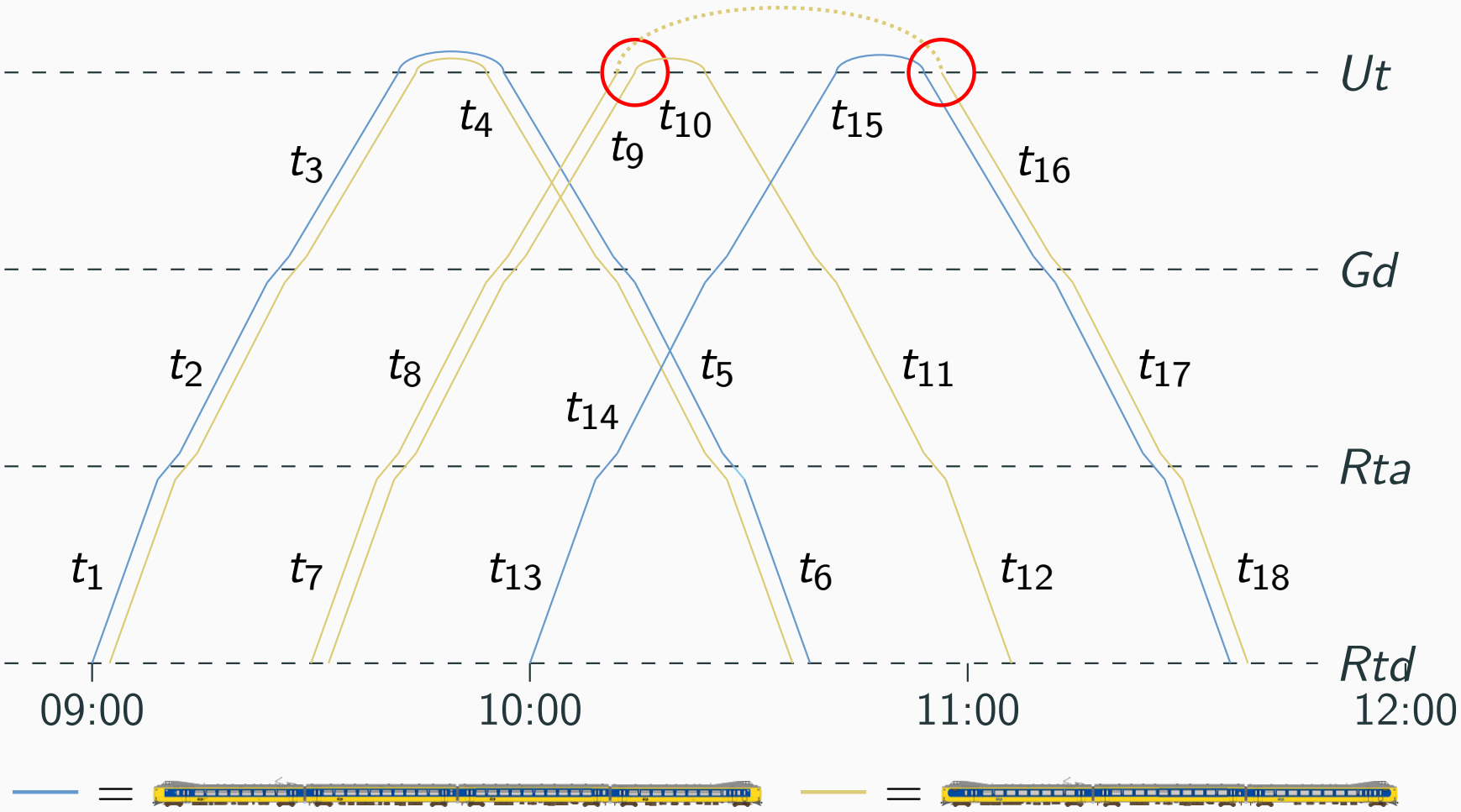
We need to assign trip sequences to the available rolling stock.



Shunting Driver Scheduling

Shunting Actions at Stations

Shunting actions consume resources at the stations



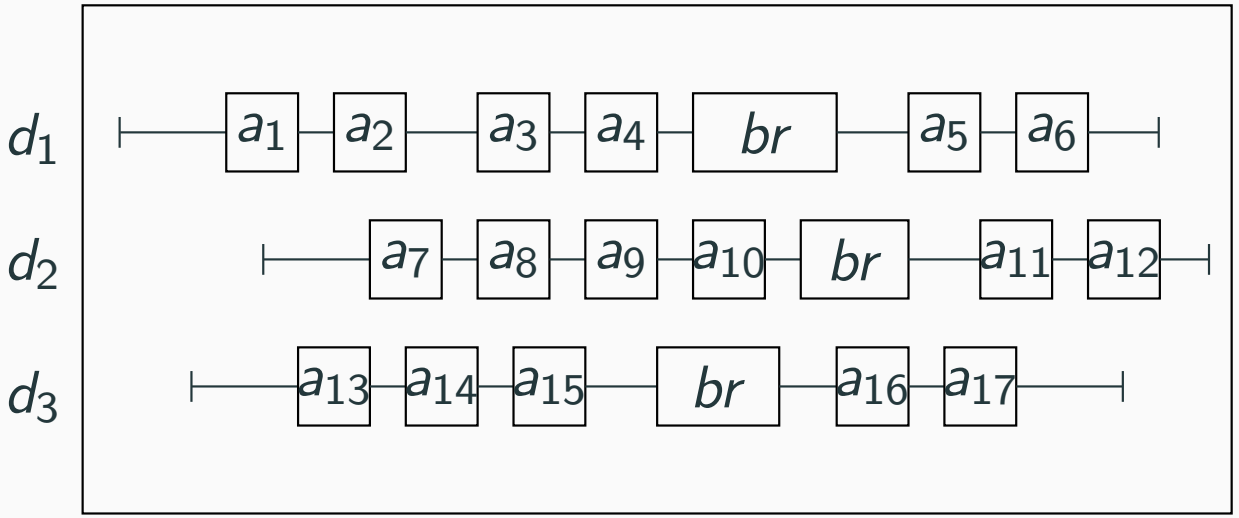
Station and Shunting Yard

Shunting Driver Scheduling

We focus on the availability of shunting drivers:

- Each station has a dedicated set of shunting drivers
- Shunting drivers move trains at the station and to and from its shunting yards

We need to find duties for the shunting drivers that cover all shunting tasks:



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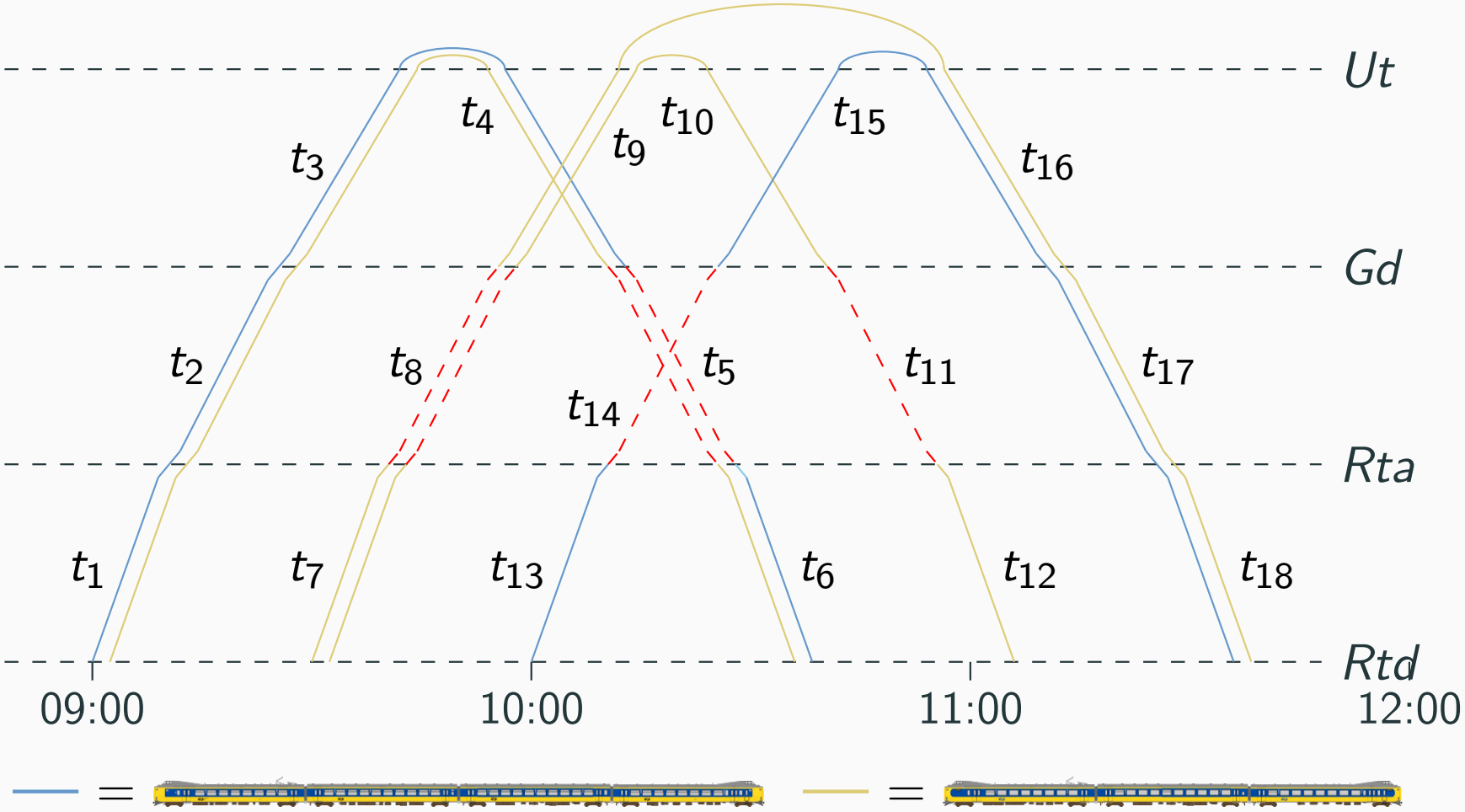
Disruptions

Disruptions can disturb the original rolling stock plans



Traditional Rescheduling

Traditional workflow:

- Apply a disruption scenario to adjust the timetable
- Reschedule the rolling stock for the new timetable
- Reschedule the shunting driver duties for the new rolling stock circulation

Infeasibilities can occur in the last step.

We propose to solve rolling stock rescheduling and shunting driver rescheduling in an integrated way.

Solution Approaches

Integrated Formulation

$$\min \quad f(X, Z)$$

$$\text{s.t.} \quad \sum_{p \in \eta(t)} X_{t,p} = 1 \qquad \forall t \in \mathcal{T},$$

$$X_{t,p} = \sum_{q \in \varrho(\delta^+(t)) : p_{q,t} = p} Z_{\delta^+(t),q} \qquad \forall t \in \mathcal{T}, p \in \eta(t),$$

$$X_{t,p} = \sum_{q \in \varrho(\delta^-(t)) : p'_{q,t} = p} Z_{\delta^-(t),q} \qquad \forall t \in \mathcal{T}, p \in \eta(t).$$

$$(\dots)$$

$$\sum_{d \in \mathcal{D}_{\sigma(c)}} \sum_{k \in \mathcal{K}_d} \kappa^d_{a,k} Y_{d,k} = \sum_{q : a \in \mathcal{A}_q} Z_{c,q} \qquad \forall c \in \mathcal{C}, a \in \bigcup_{q \in \varrho(c)} \mathcal{A}_q,$$

$$\sum_{k \in \mathcal{K}_d} Y_{d,k} = 1 \qquad \forall d \in \mathcal{D},$$

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$$(\dots)$$

Benders Decomposition

We apply Benders decomposition, where:

- Rolling stock rescheduling is the Benders master problem
- Shunting driver rescheduling for each station is a Benders subproblem

This implies that cuts are added to the Benders master problem, which are generated by solving the shunting driver rescheduling problems.

An Arc-Based Model

As a second model, we consider an integrated model where:

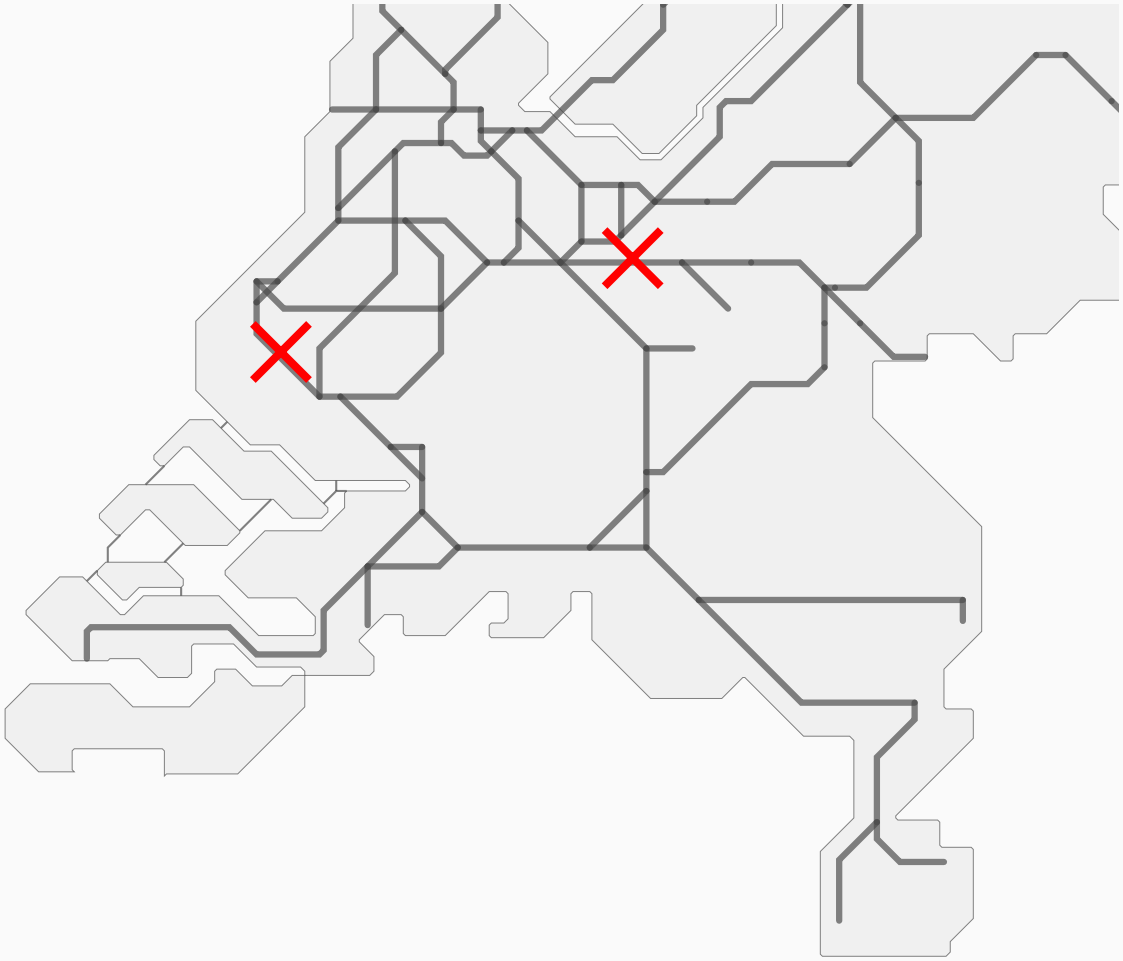
- We use the same model for rolling stock rescheduling
- We use an arc-based model for shunting driver rescheduling
- The models are linked in a similar way as before

This MIP model is solved by CPLEX.

Numerical Experiments

Considered Instances

We consider two infrastructure failure locations:



Objective function considers seat availability and operational costs.

Model Comparison

Instance	Arc-Based Model		Benders Model	
	Gap (%)	Time (s)	Gap (%)	Time (s)
Ut-Db 7–10	0.00	222	0.00	210
Ut-Db 10–12	0.00	280	0.00	261
Ut-Db 14–18	0.00	28	0.00	32
Rtd-Sdm 9–11	0.00	718	2.98	909
Rtd-Sdm 12–14	0.00	58	0.00	55
Rtd-Sdm 14–18	0.00	25	0.00	52

Settings: time limit of 900 seconds, allowed gap of 0.01%

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Solver Statistics

	Arc-Based	Benders			
Instance	Nodes	Nodes	Cuts	Master (s)	Subpr. (s)
Ut-Db 7-10	1	491	108	119	61
Ut-Db 10-12	78	667	205	156	64
Ut-Db 14-18	6	120	66	7	10
Rtd-Sdm 9-11	254	1124	257	708	129
Rtd-Sdm 1214	1	156	75	18	19
Rtd-Sdm 14-18	1	254	67	12	18

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Conclusion

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- We proposed the integrated rolling stock and shunting driver rescheduling problem
- We presented a Benders decomposition approach and an arc-based model to solve the integrated problem
- We showed the performance of the models on instances of NS

References

Cordeau JF, Stojković G, Soumis F, Desrosiers J, 2001 *Benders decomposition for simultaneous aircraft routing and crew scheduling*. *Transportation Science* 35(4):375–388, URL `http://dx.doi.org/10.1287/trsc.35.4.375.10432`.

Fioole PJ, Kroon L, Maróti G, Schrijver A, 2006 *A rolling stock circulation model for combining and splitting of passenger trains*. *European Journal of Operational Research* 174(2):1281–1297, URL `http://dx.doi.org/10.1016/j.ejor.2005.03.032`.

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