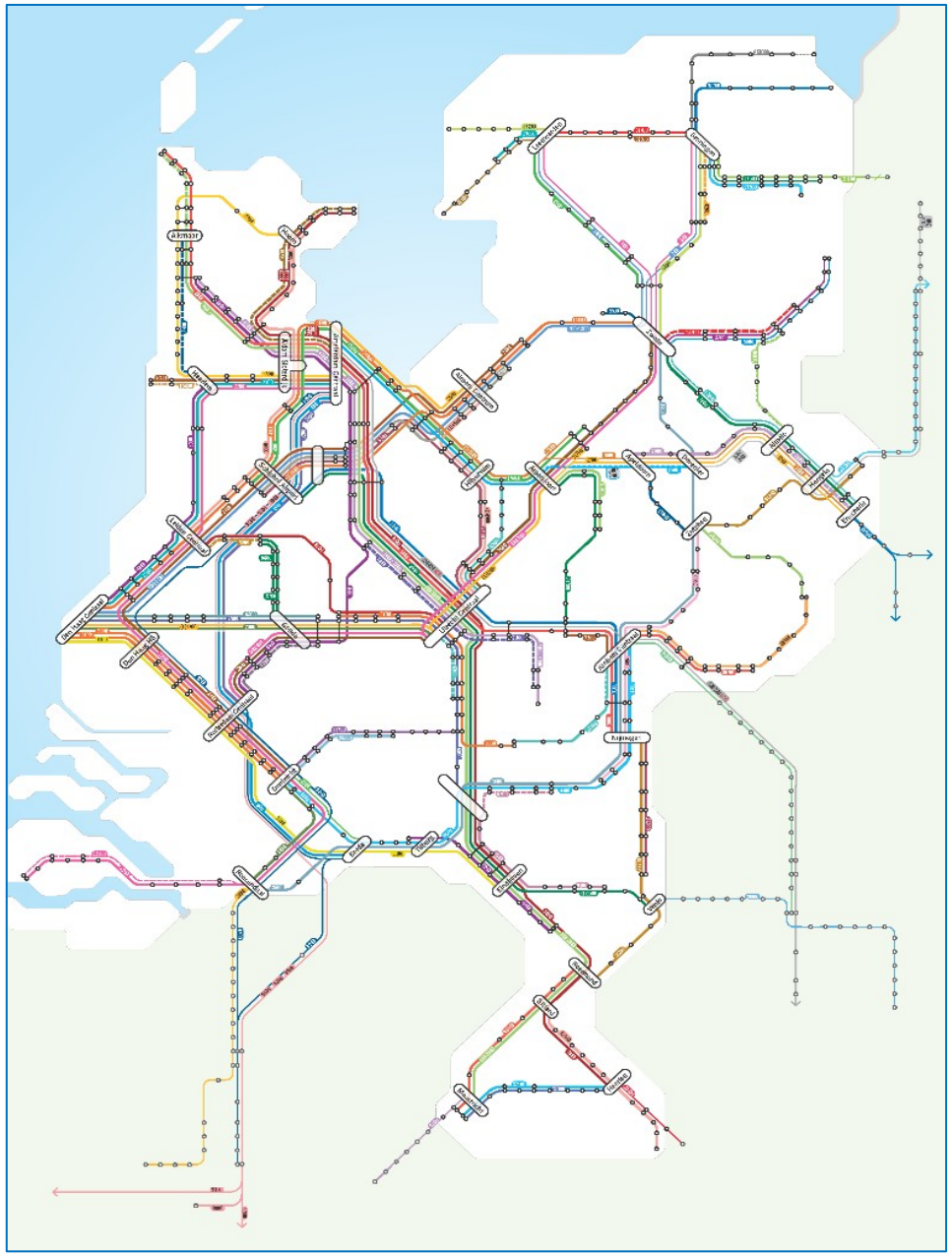
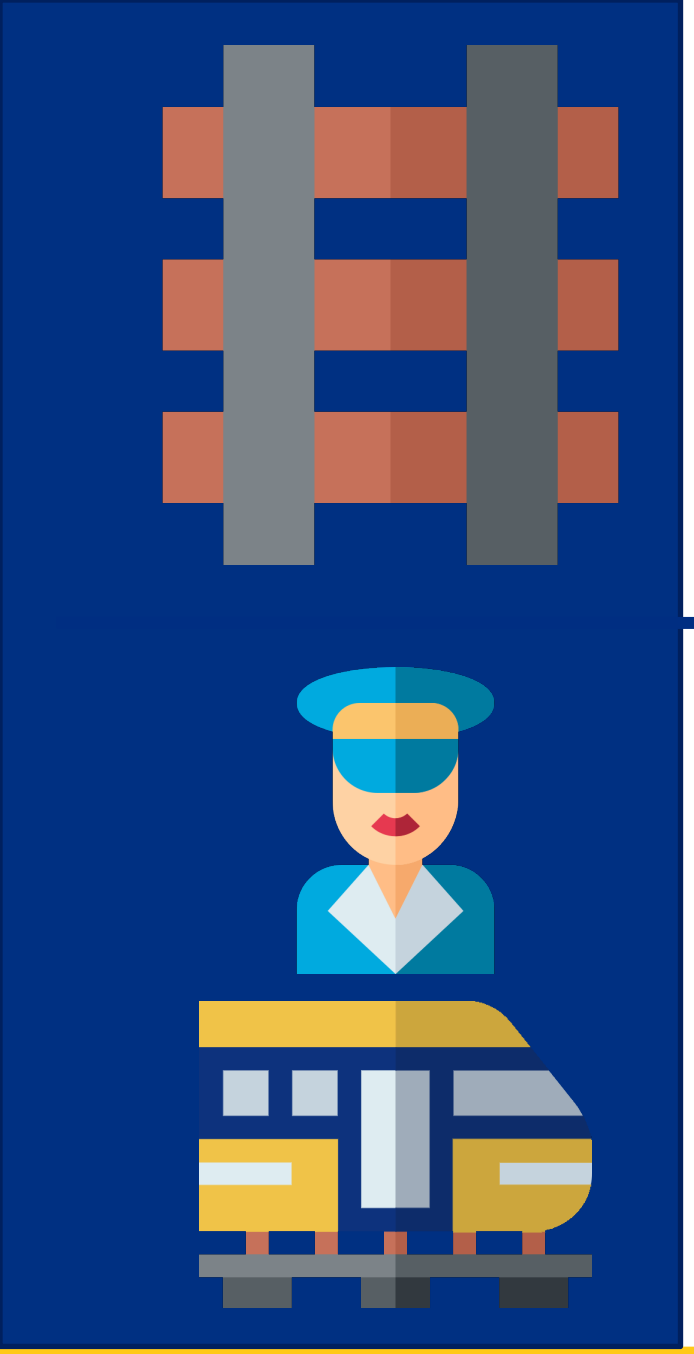
Optimizing seating probability in passenger trains

Simone Griffioen, Netherlands Railways (NS)

Railways in The Netherlands





ProRail

NS

arriva

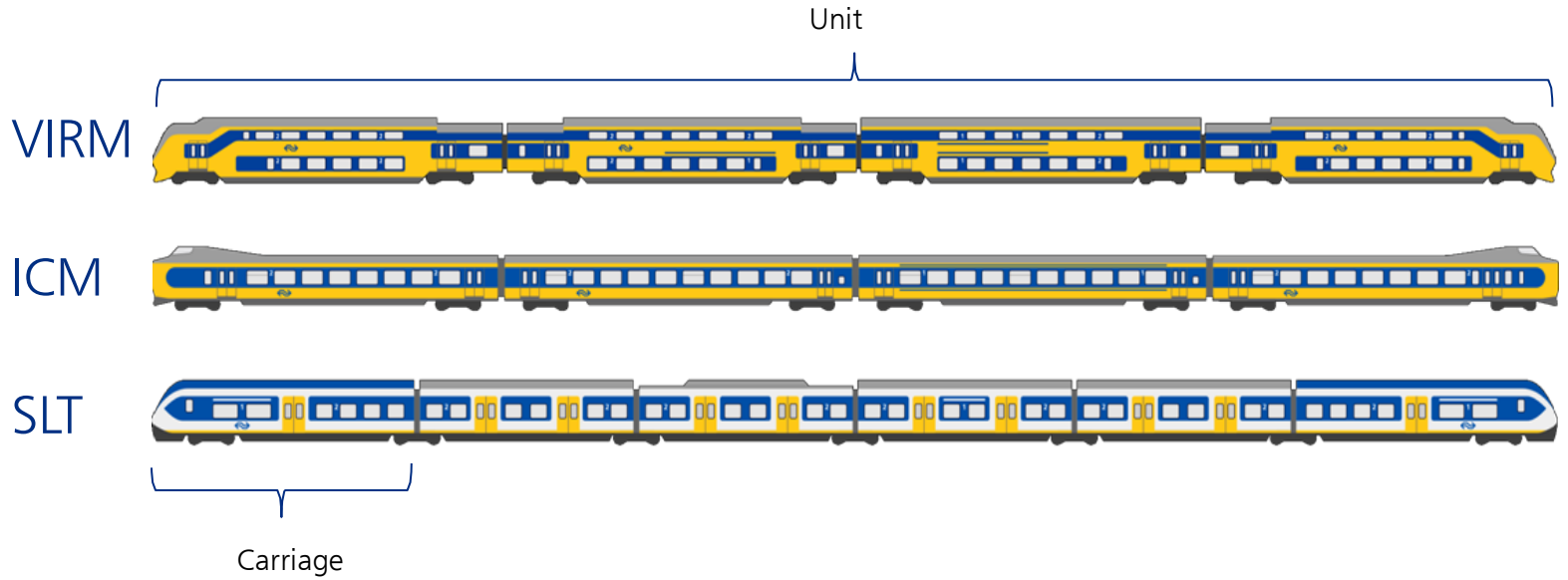
connexxion

breng

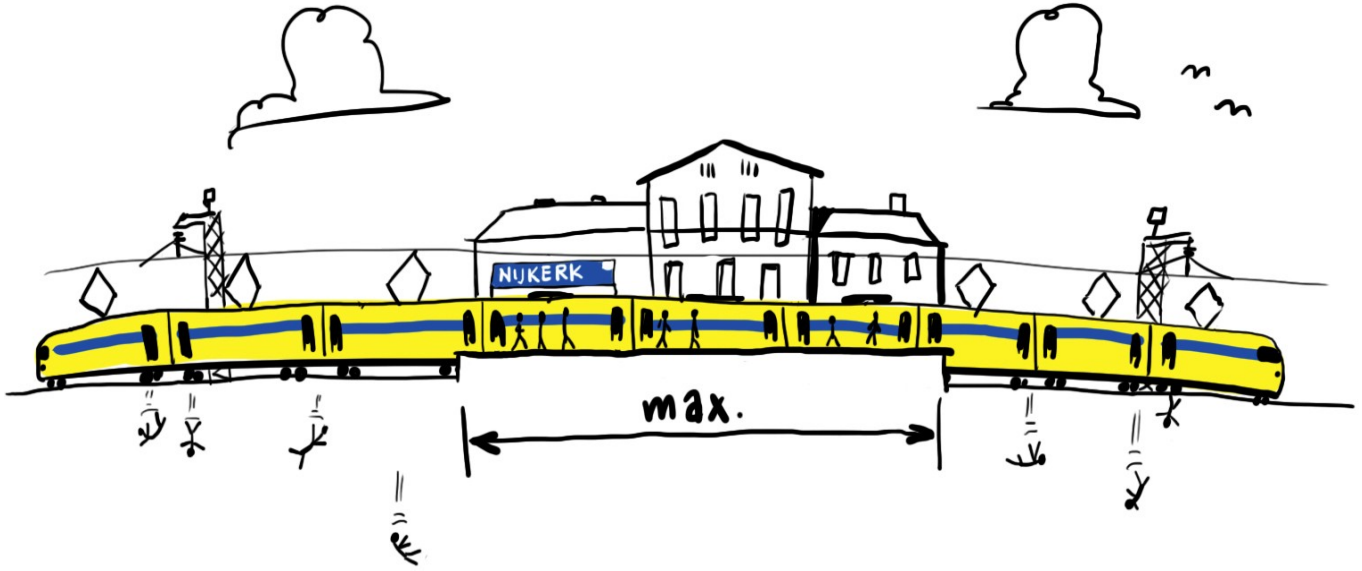
KEOLIS

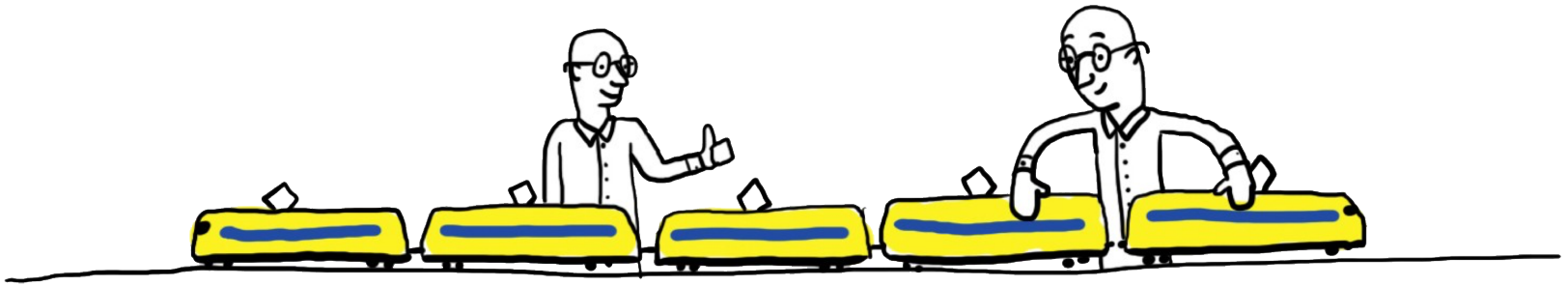
NS Rolling Stock Planning

- 5000 trains in timetable per day
- 9 different rolling stock types
- 700 rolling stock units
- Which composition on which trip?

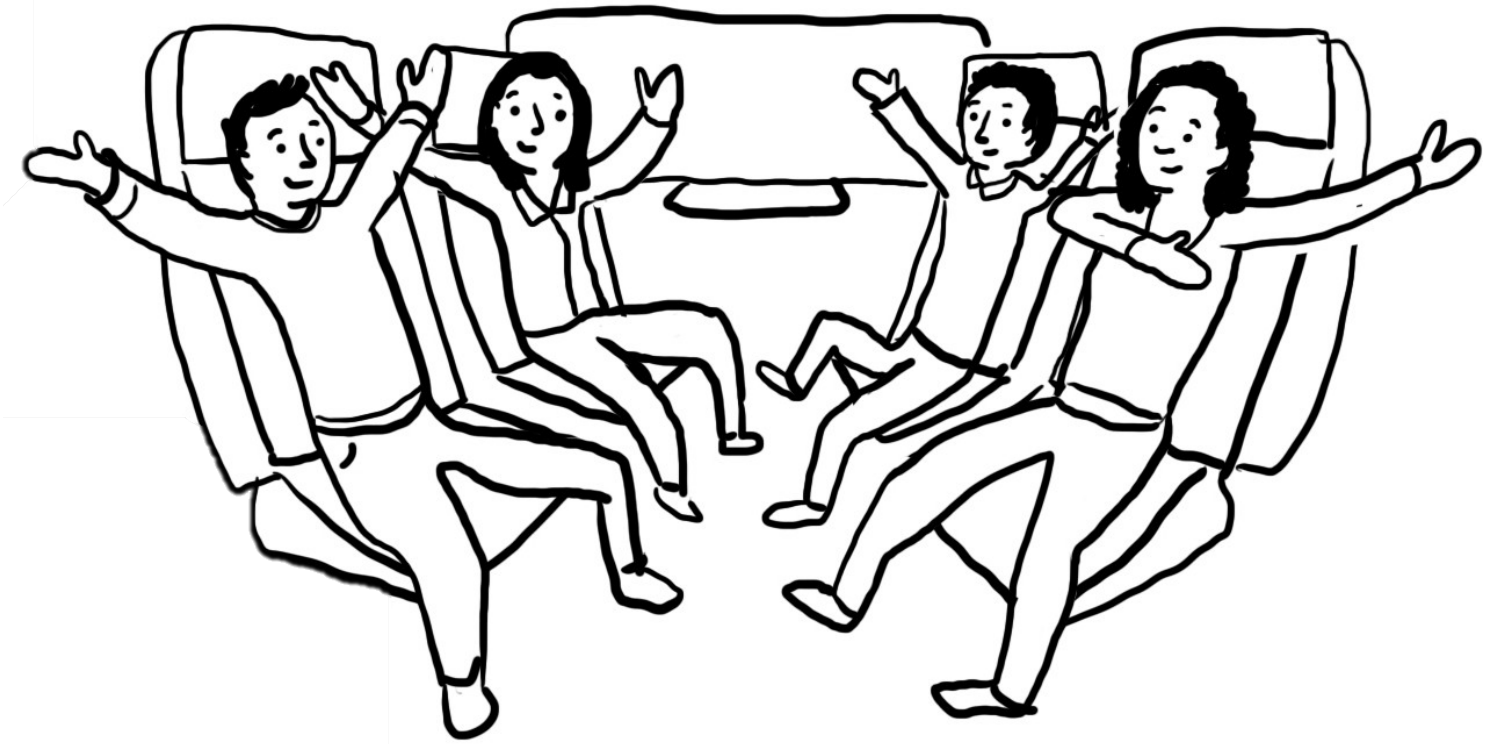


Subject to a lot of constraints, for example





Objective: Minimise costs, maximize service quality

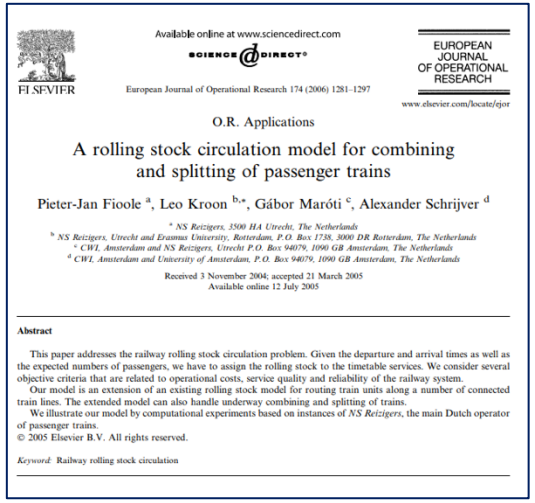


TAM – rolling stock scheduling tool of NS

- in-house developed software, based on *Fioole et al. 2006*
  - flexible, well-behaved MIP model, solved by CPLEX
  - in production since 2011 (predecessor since 2007)

- maintained by ORTEC since 2016

- TAM's essence
  - trips $t \in T$ and compositions $p \in P$
  - assigns a composition to each trip ($x_{tp} \in \{0; 1\}$)



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O.R. Applications

A rolling stock circulation model for combining and splitting of passenger trains

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Abstract

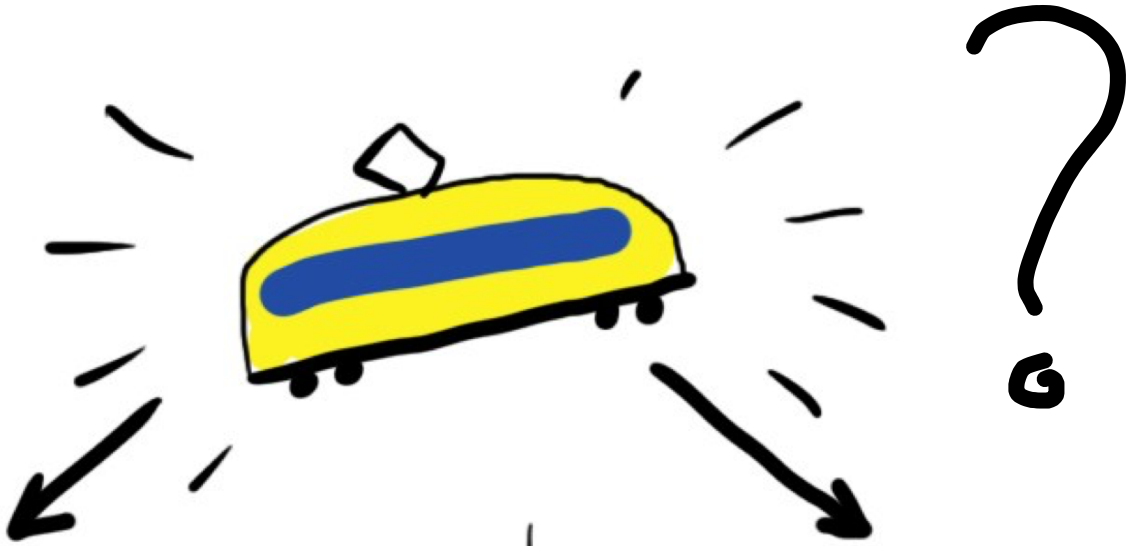
This paper addresses the railway rolling stock circulation problem. Given the departure and arrival times as well as the expected numbers of passengers, we have to assign the rolling stock to the timetable services. We consider several objective criteria that are related to operational costs, service quality and reliability of the railway system.
Our model is an extension of an existing rolling stock model for routing train units along a number of connected train lines. The extended model can also handle underway combining and splitting of trains.
We illustrate our model by computational experiments based on instances of *NS Reizigers*, the main Dutch operator of passenger trains.

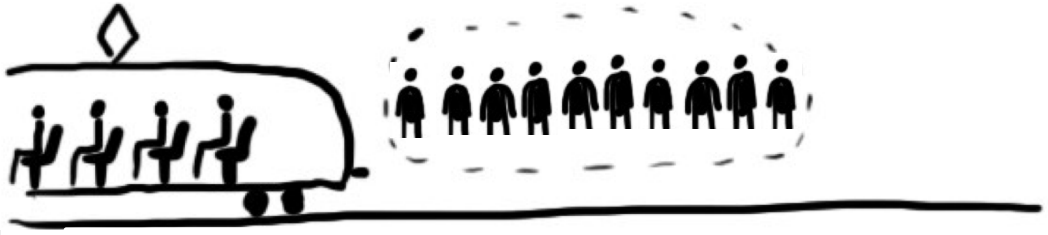
Keyword: Railway rolling stock circulation

Definition old KPI: "Passenger capacity"

Capacity of train differs per time of day

- Seat capacity: only seats in use
- Total capacity: all seats in use and 2 standing pax per m^2 (rush hour <15min)

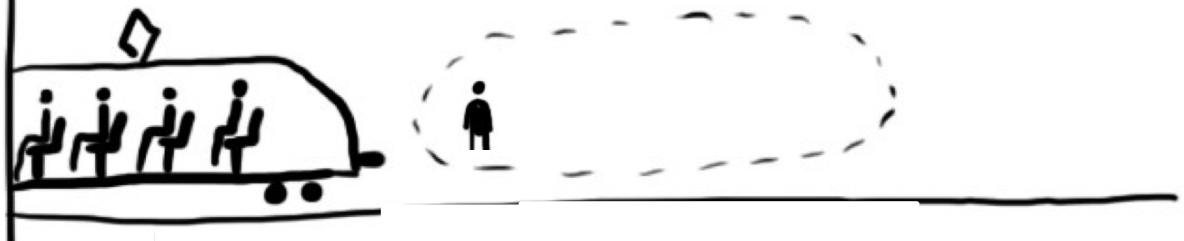




= 10

= 14 min

Standing spots included



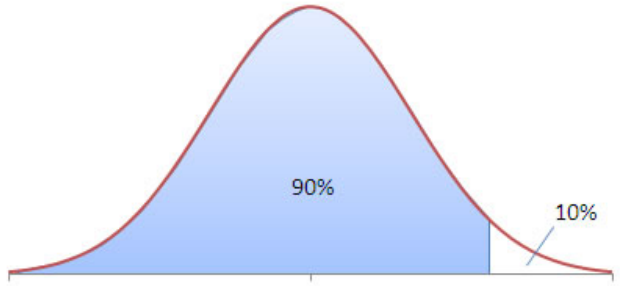
= 1

= 16 min

Standing spots **not** included

Service in the context of the old KPI: passenger capacity

- *d* : demand, namely **90th percentile**
- *c*: allocated capacity (incl./excl. standing)

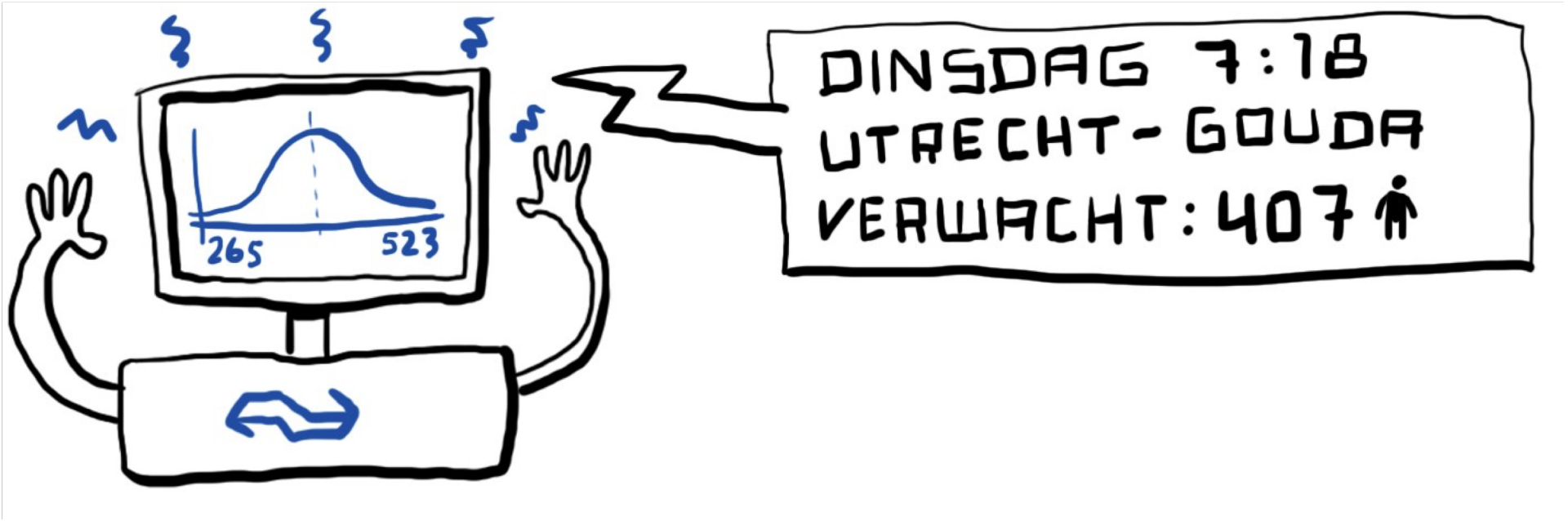


Old quantification of service quality

- dissatisfaction (“service pain”) per trip, added up
- Service pain of a trip := shortage kilometres, defined as

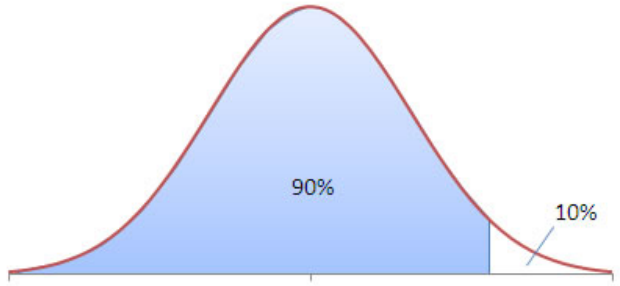
$$\text{pain} = \text{distance} \cdot \max\{0; d - c\}$$

Better forecasts: better KPI possible?



Service in the context of the new KPI

- c: allocated seat capacity
- ξ: demand, a **random variable**



New quantification of service quality

- dissatisfaction ("service pain") per trip, added up
- Service pain of a trip := **expected standing minutes**

$$\text{pain}' = \text{duration} \cdot \mathrm{E}(\text{number of standing passengers})$$

  - i.e.,

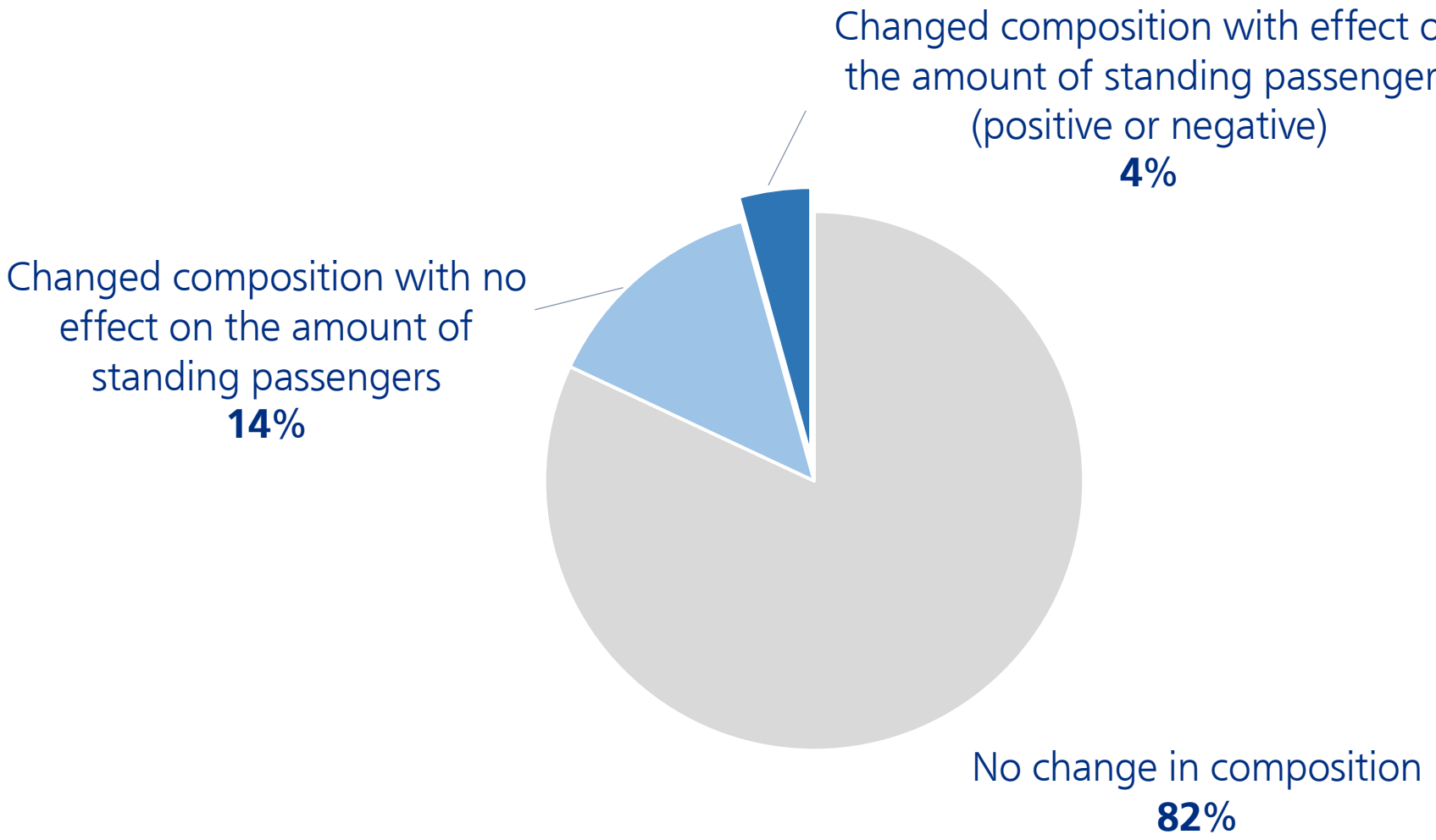
$$\text{pain}' = \text{duration} \cdot \int_0^\infty max\{0; \xi - c\}\, dF(\xi)$$

Service quality in TAM

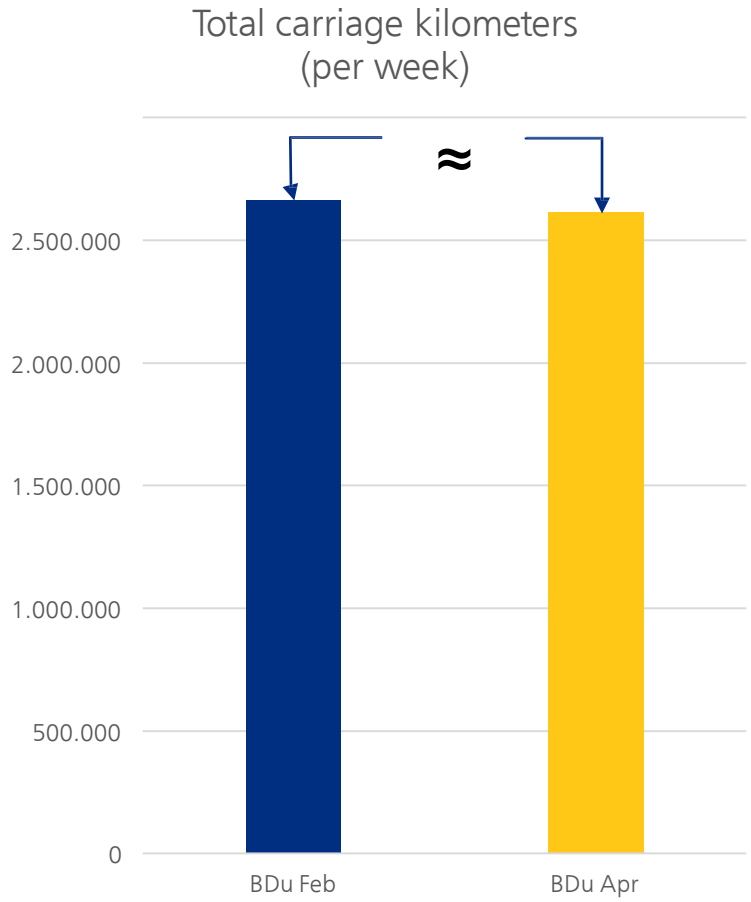
- Classic TAM (with shortage kilometres)
  - minimise $\Sigma_t \Sigma_p$ pain$_{tp}$ x_{tp}
  - *linear objective* in terms of x_{tp}

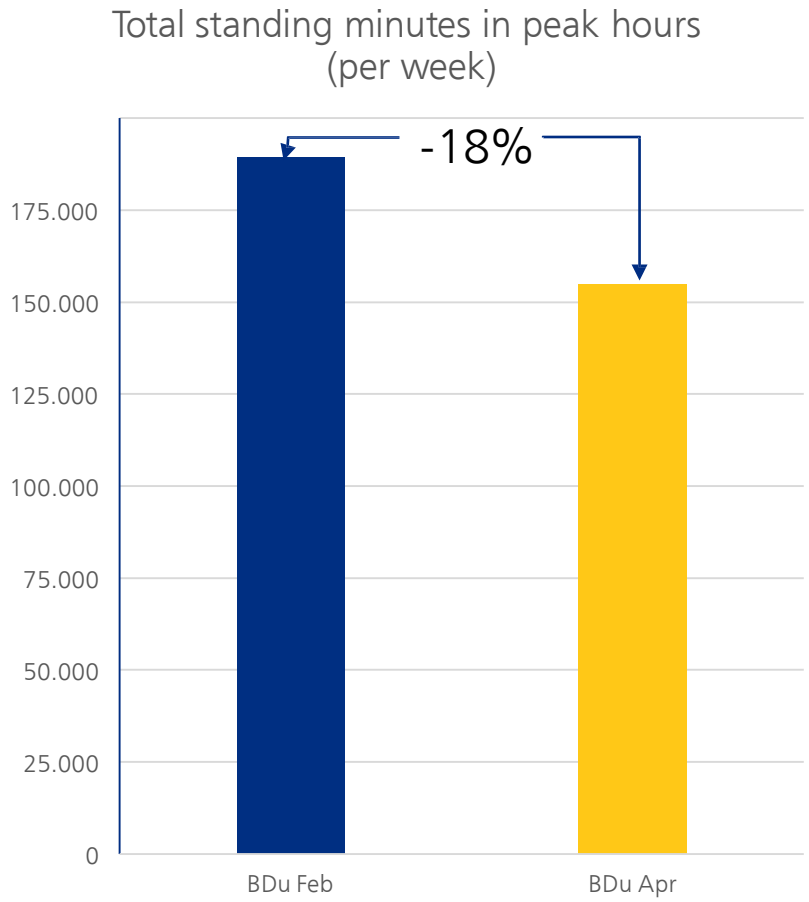
- TAM$^+$ (with standing minutes)
  - minimise E(total standing minutes)
  - looks like a stochastic program
  - good news: no recourse action
  - minimise $\Sigma_t \Sigma_p$ pain'$_{tp}$ x_{tp}
  - again, *linear objective* in terms of x_{tp}

Small amount of changes ….



… lead to a significant decrease in planned standing minutes against the same amount of costs





From theory to practice

The plan changes!?!

Managing stakeholder expectations

trust in optimization

Black/white to sliding scale

New sofa creates dust?

Changing forecasts to enforce a composition

399 seats

Complaint!

P90=~~350~~ 400

Does not work with new service KPI!

The plan changes!?!

Managing stakeholder expectations

It does fit in the official workschedule,
but not in the "real" one

trust in optimization

Changing forecasts to enforce a
composition does not "work" anymore

Black/white to greyscale

And much more…

Success factors in the implementation

- Strong management support
- Early involvement of planners and continuous support available
- Changing tooling to help planners with other work
- Compromise: lose optimality but win in willingness to change

Are we there yet?

- ”Standing minutes” is now a household name, used in more and more places, decision making dashboards, etc.
- New KPI did also in practice improve the actual passenger service

But…

- Transition from long term planning to short term planning can be improved
- Remnants of old KPI can still be found in mindsets
- We still need to provide support for dealing with the optimization and the new KPI

…we still have a job! (luckily)