Security crew scheduling at Netherlands Railways

Ricardo Saldanha

Innovation Department
SISCOG – Sistemas Cognitivos

Hilbert Snijders

Process Quality and Innovation (π)
Netherlands Railways

Outline

- ***Introduction***

- Problem statement

- Solution method

- Experimental results

- Conclusions

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About Netherlands Railways (NS)

- Passenger traffic only

- 5.000 trains per day

- 1.1 million journeys per day

- 400 stations

- High frequency

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Aggressive behaviour

Zwartrijder bijt en bespuugt conducteurs
zondag 23 februari 2014

Conducteur op spoor geduwd bij handgemeen
zondag 20 oktober 2013

Agressie tegen NS-personeel neemt toe
donderdag 28 november 2013

Treinpersoneel van de NS krijgt steeds vaker te maken met agressieve reizigers. Het aantal incidenten kwam vorig jaar uit op 8100, een stijging van zestien procent ten opzichte van een jaar eerder. Ook dit jaar lijkt het aantal meldingen boven de achtduizend uit te komen, schrijft nu.nl donderdag op basis van cijfers van de NS.

Zwartrijder slaat conducteur bewusteloos
zondag 28 oktober 2012

94 procent rijdend personeel krijgt te maken met agressie
dinsdag 16 december 2014
Dit artikel zit in dossier: Geweld in het OV

Van de conducteurs en machinisten werd 94 procent het afgelopen jaar een of meerdere keren geconfronteerd met agressie. Bijna twee derde had te maken met lichamelijk geweld. Dat blijkt uit een representatieve enquête onder 873 leden van spoorvakbond VVMC in samenwerking met het AD.

Schreeuwen, schelden en intimidatie zijn haast normaal. Ook bedreiging, spugen en duwen komen veelvuldig voor, blijkt uit het onderzoek. Maar het kan nog erger. Een conducteur werd uit de trein gegooid, andere medewerkers naar de keel gegrepen en eentje kreeg urine in het gezicht, aldus een greep uit de meldingen. Si

Conducteur mishandeld in station Duivendrecht
woensdag 18 juli 2012

In het station Duivendrecht is maandagochtend een conducteur mishandeld door een reiziger, nadat hij de reiziger had betrapt op het reizen

Zwaar mishandelde NS-conductrice beland in het ziekenhuis
vrijdag 6 maart 2015

UPDATE. Een conductrice van de Nederlandse Spoorwegen is in de nacht van donderdag op vrijdag zwaar mishandeld in de trein van Schiphol naar Hoofddorp. De 44-jarige Amsterdamse is met diverse breuken in haar gezicht naar een ziekenhuis gebracht, waar ze vrijdag wordt geopereerd. Dat meldde de NS. Het spoorbedrijf roept de politiek op om actie te ondernemen.

aansprak op zijn gedrag. De politie heeft de roker in Nijmegen uit de trein gehaald en aangehouden. Hij zit nog vast, aldus de politie dinsdag.

t gestolen

treinpersoneel

Zwartrijder duwt NS-medewerker op spoor
maandag 10 februari 2014
Dit artikel zit in dossier: Geweld in het OV

Een medewerker van NS is zaterdagavond tijdens een woordenwisseling op station Amsterdam Sloterdijk op het spoor geduwd. Hij liep hierdoor een zware hersenschudding en verwondingen aan zijn gezicht op, liet een politiewoordvoerder maandag weten.

Arriva-

voelen zich eke en toegenomen, t dinsdag met

1C. "Het n werknemer r ook een

steward aanwezig maar lang niet altijd."

er later weer terugkwam in lucteur bewusteloos. Daarna ging

Opnieuw conducteurs mishandeld en bedreigd
zondag 8 maart 2015

Man probeert conducteur te wurgen
donderdag 6 juni 2013

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Aggressive behaviour

- 10.000 reported acts of aggression per year

- 380.000 reported fare evaders

V&S teams

- 700 security guards

- Work in teams

- Perform both preventive and reactive security measures

- Duty cards are prepared locally and contain little detail

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Problem statement

- "Scheduling the daily work of V&S teams in an attempt to reduce risks related to the occurrence of acts of aggression, fare evasion and lack of support and assistance to train passengers."

- Scheduling: assigning detailed jobs to teams

- The subject has not been covered extensively in literature

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Jobs

- Train control jobs (one-or-nothing)

- Platform control jobs (all-or-nothing)

- Priority (mandatory or optional)

- Values (mitigating security risks and fare evasion risks)

Outline

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- ***Solution method***

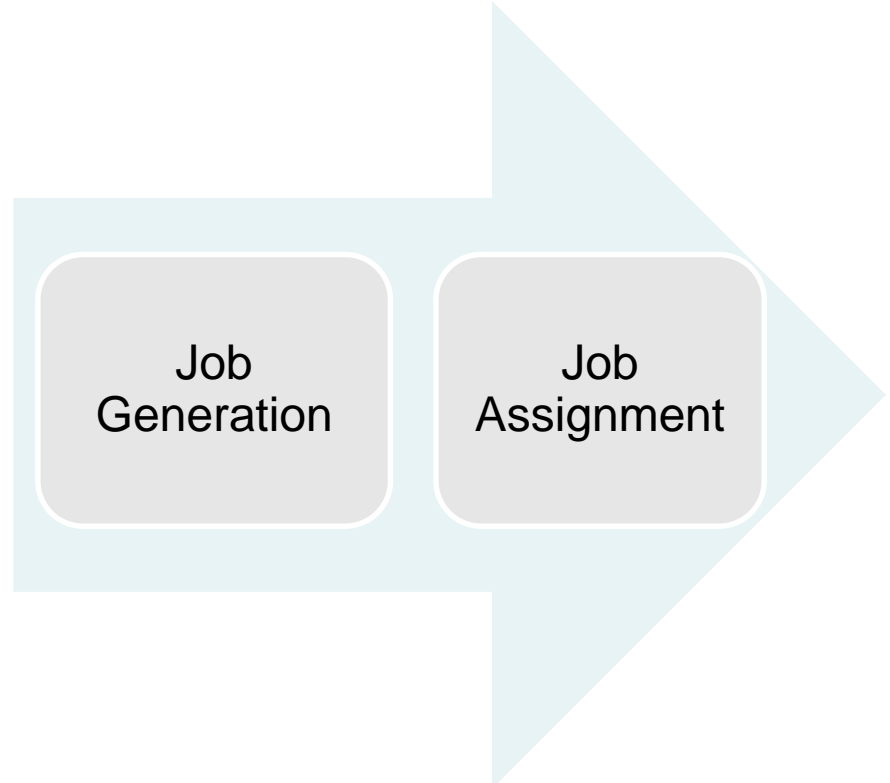- Experimental results

- Conclusions

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Solution method

Problem too complex to be solved in an integrated way.

1) Job generation:
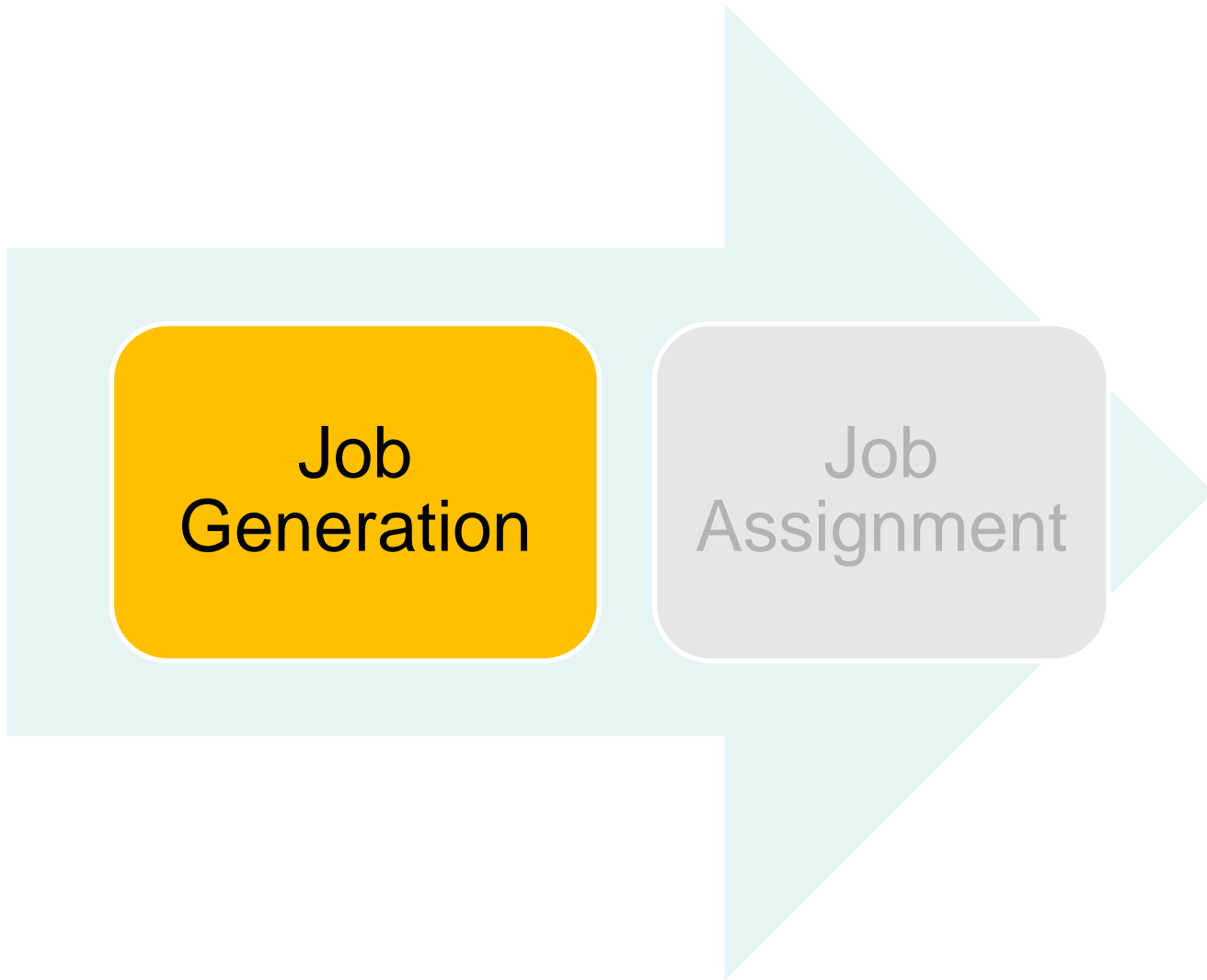
- Generate jobs
- Assign value to jobs
- Pre-select jobs

Job Generation

Job Assignment

2) Job assignment:

- Assign jobs to teams to maximize covered value

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Job generation

Job Generation

Job Assignment

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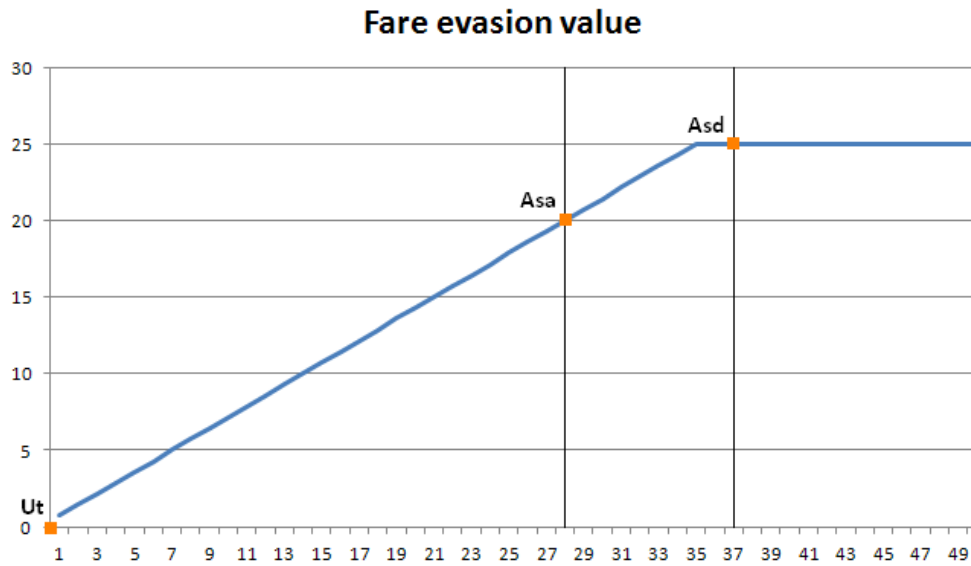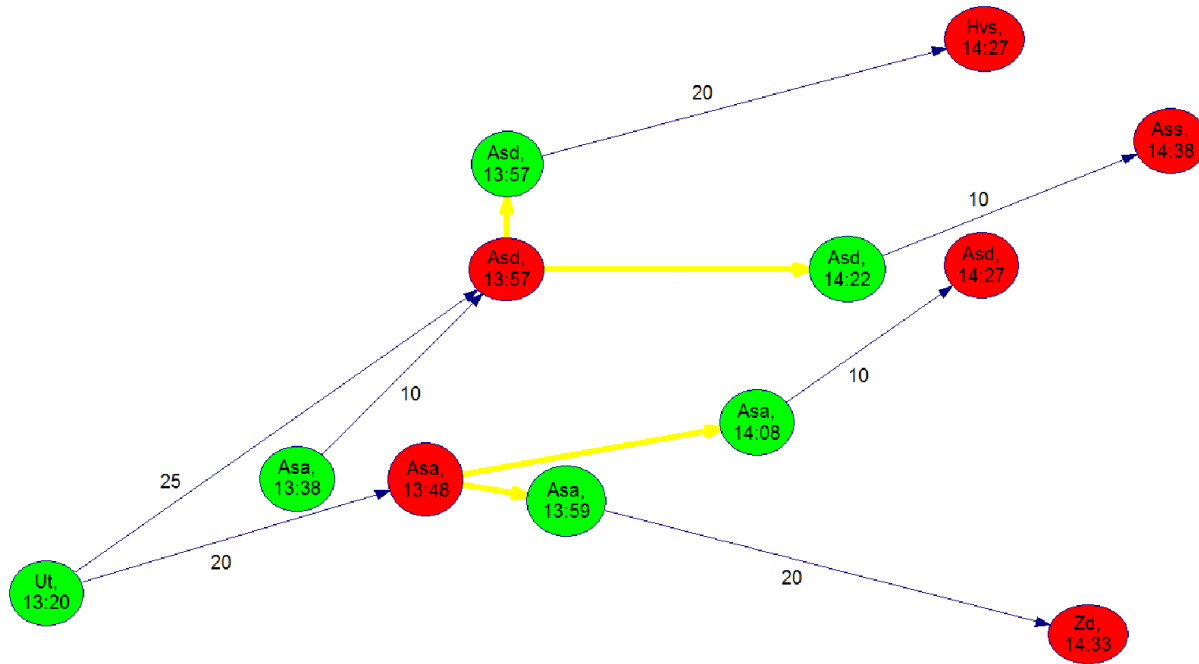
Input

- Aggression reports

- Fare evasion reports

- Calendar of social events

- Passenger forecasts for all train movements

- Timetable

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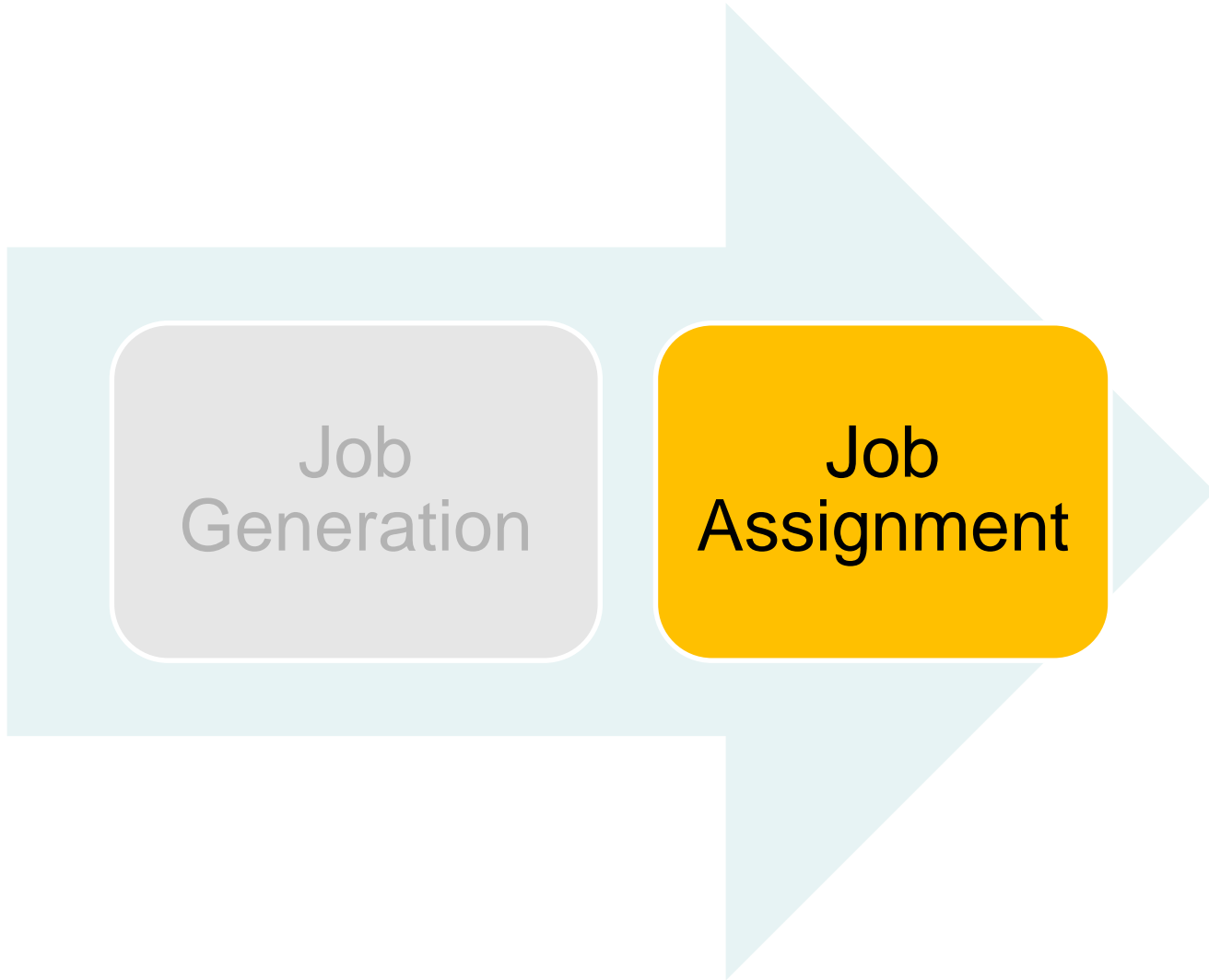
Train control jobs (value)

Fare evasion value

Train control jobs (selecting jobs)

Job assignment

Job Generation

Job Assignment

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Important definitions

- Team
  - Group of two security guards working together
  - Specific home base
  - Pre-defined sign-in and sign-out times
    - Taken from the roster
    - Change from day to day
- Duty template
  - Aggregation of previous
- Task
  - Job performed by a single team
  - For every job requiring N teams
    - N tasks associated with that job
- Duty
  - Set of tasks assigned to a specific duty template

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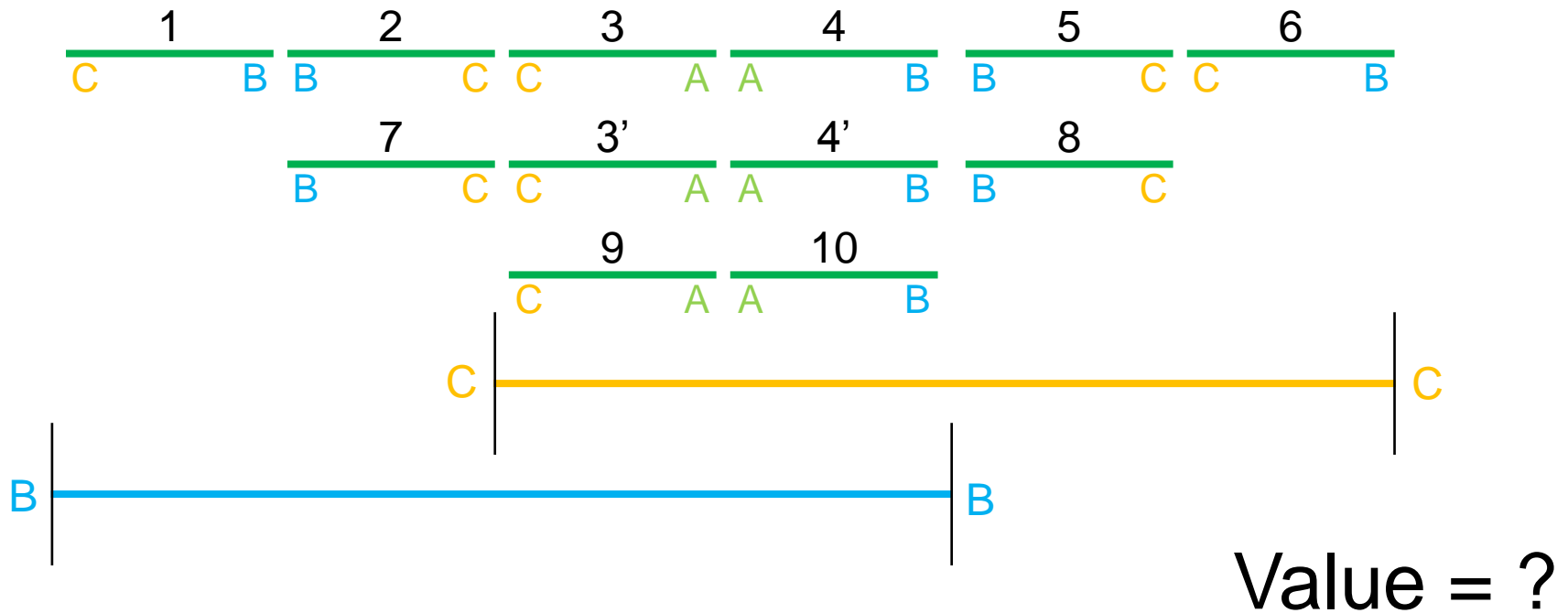22 July 2015

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Job assignment (sub-)problem statement

- Given a set of **tasks** and a set of **duty templates**

- Cover tasks with duties

- Such that

  - All constraints are satisfied

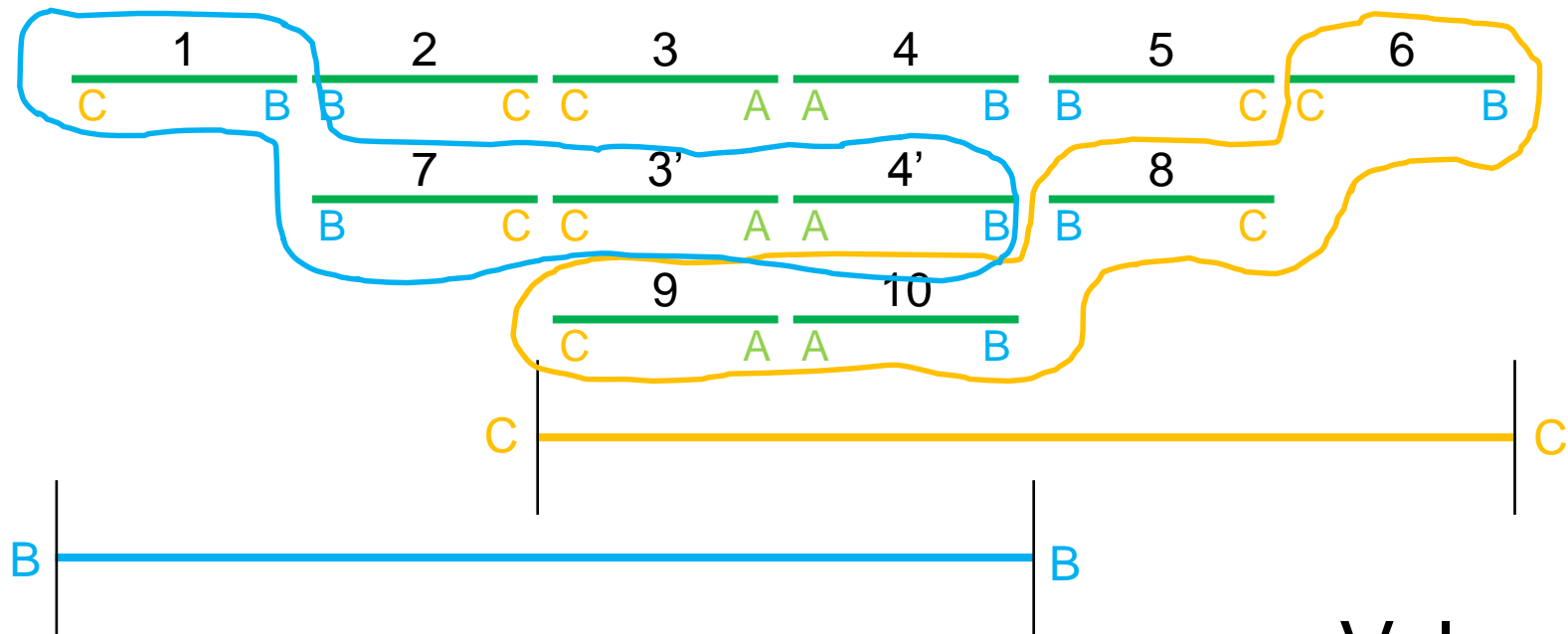 - Maximum amount of value is covered

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Example

- Duty must fit inside template
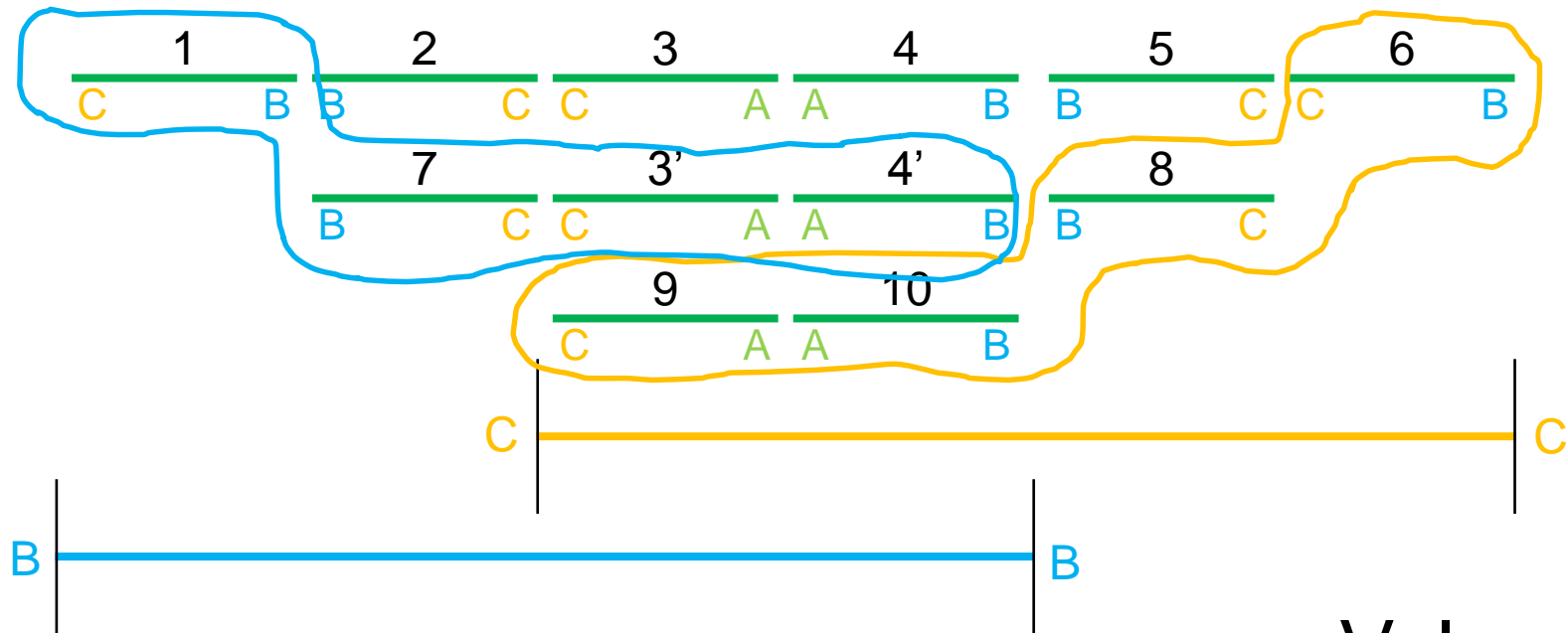
Value = ?

Example

Value = 58

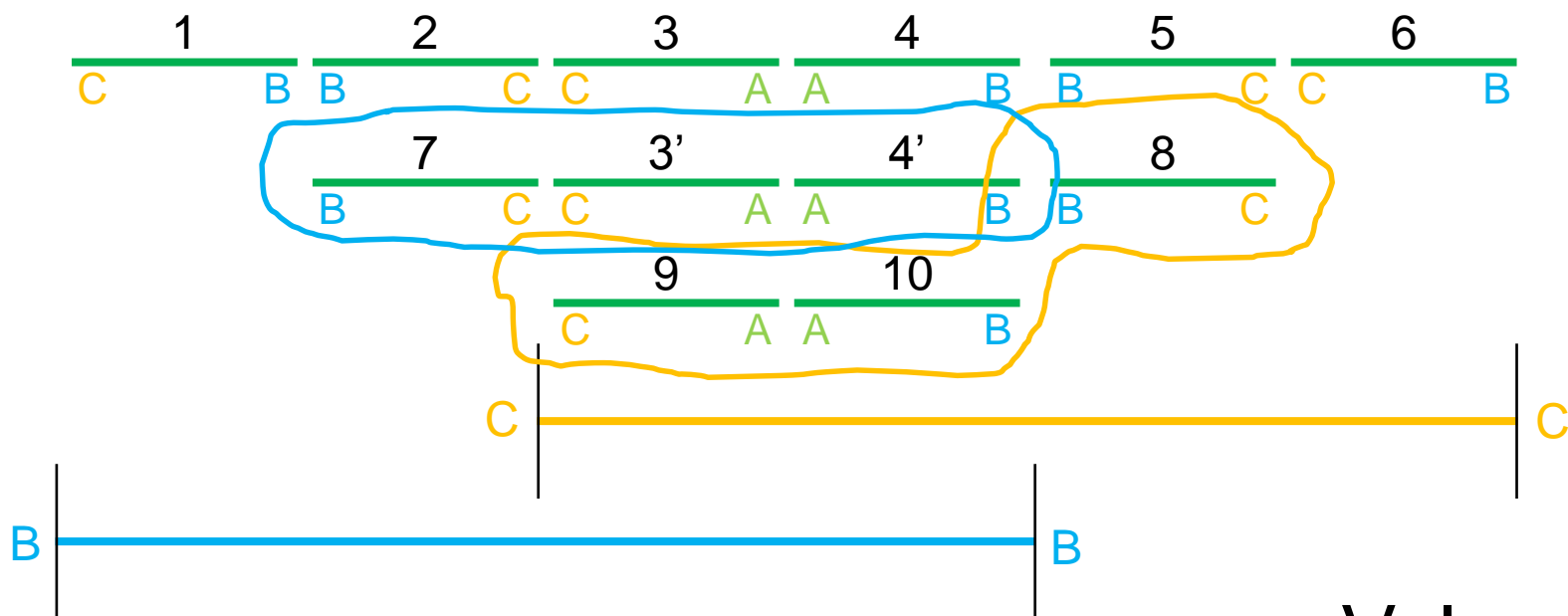- Duty must fit inside template 🙂

Example

Value = 58

- Duty must fit inside template 🙂
- Duty must start and end in template's base ❌

Example

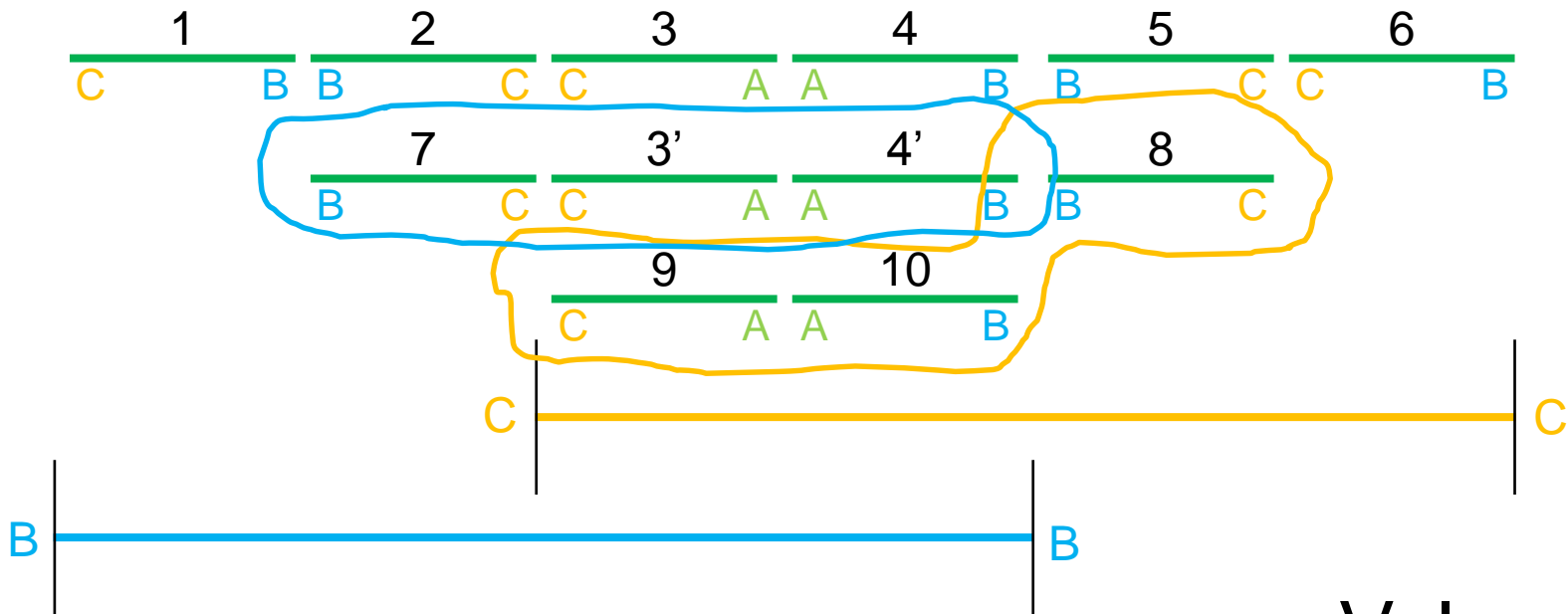Value = 44

Value = 58

- Duty must fit inside template 🙂
- Duty must start and end in template's base 🙂

Example

Value = 44

Value = 58

- Duty must fit inside template 🙂
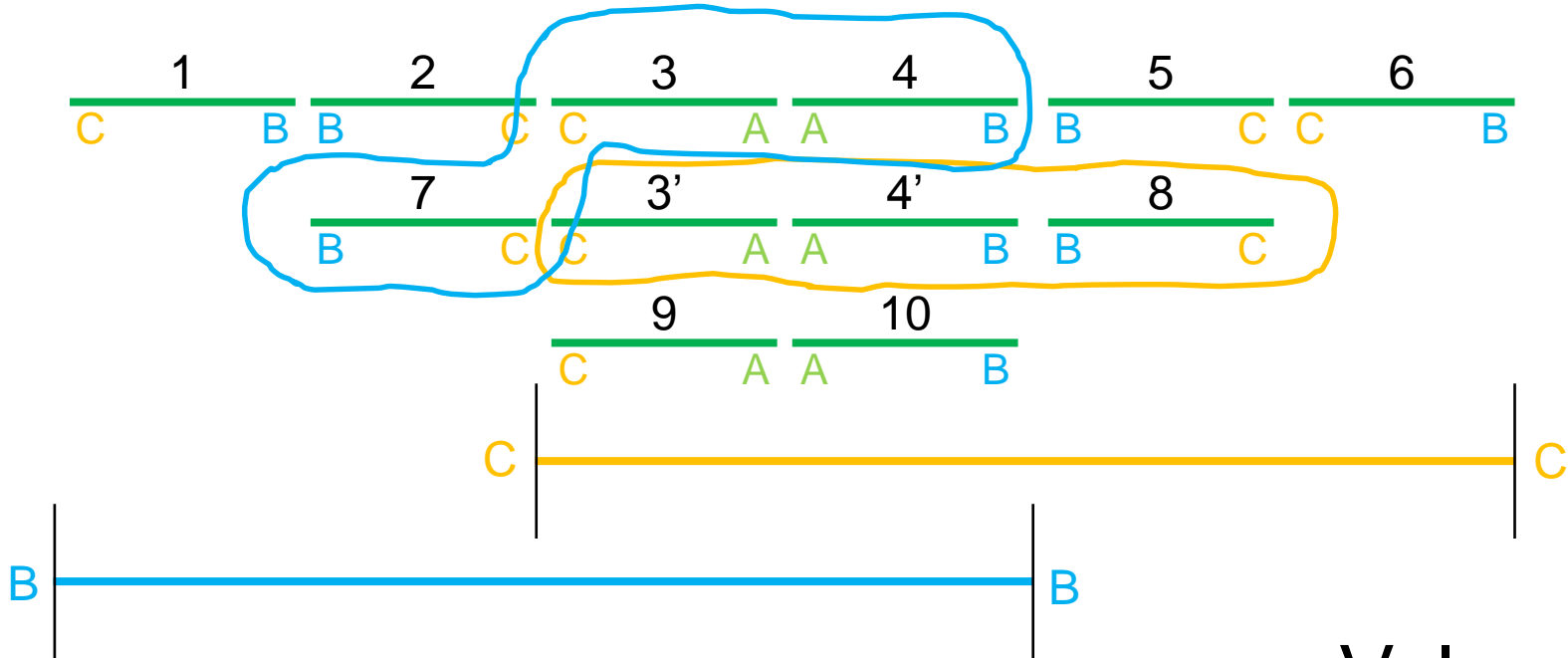- Duty must start and end in template's base 🙂
- All-or-nothing rule ❌

Example

- Duty must fit inside template 🙂
- Duty must start and end in template's base 🙂
- All-or-nothing rule 🙂

Value = 29
Value = 44
Value = 58

Challenges

- Size of problem
  - 5000 jobs (per region)
- Most of the work will be left uncovered
  - Partially covered by
    - Potthoff D, Huisman D, Desaulniers G (2010) *Column generation with dynamic duty selection for railway crew rescheduling*. Transportation Science 44(4):493-505
- Set covering with partitioning and additional constraints
  - Partially covered by
    - Potthoff D, Huisman D, Desaulniers G (2010) *Column generation with dynamic duty selection for railway crew rescheduling*. Transportation Science 44(4):493-505
    - Huisman D (2007) *A column generation approach for the rail crew rescheduling problem*. European Journal of Operational Research 180(1):163-173
- All-or-nothing behaviour

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Strategy

- Instead of an exact approach
- Use the [Abbink *et al.*] heuristic…
  - Lagrangian relaxation, column generation, greedy heuristics, column fixing
  - Min cost set covering problem with additional constraints
- …and adjust it to the job assignment problem

Minimise $c^T x$
Subject to

$$Ax \geq 1$$
$$Bx \geq b$$
$$B'x \leq b'$$
$$x \in \{0,1\}$$

[Abbink *et al.*] Abbink EW, Albino L, Dollevoet T, Huisman D, Roussado J, Saldanha RL (2011) *Solving large scale crew scheduling problems in practice*. Public Transport 3(2):149-164

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Notation

- Use $i \in M$ for denoting a **task**

- Use $l(i)$ for denoting the job l of task i

- Use $j \in N$ for denoting a **duty**

- Use $k \in T$ for denoting a **duty template** (or a **team**)

- Use x_j for denoting the decision variable

  - Value is 1 if j is in the solution and 0 otherwise

Task covering constraints

$$\sum_{j \in N} a_{ij} x_j \geq 1, \qquad \forall i \in M_m$$

$$\sum_{j \in N} a_{ij} x_j + x_i' \geq 1, \qquad \forall i \in M_o$$

Add $C_i x_i'$ to cost function $\qquad \forall i \in M_o$

Minimise $\qquad c^T x$
Subject to

$$Ax \geq 1$$
$$Bx \geq b$$
$$B'x \leq b'$$
$$x \in \{0,1\}$$

- Adjustments made
  - Associate x_i' with a slack duty covering i alone
  - $x_i' = 1$ means i covered by a slack duty
    - Means i left uncovered in real life

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Team assignment constraints

$$\sum_{j \in N_k} x_j = 1, \quad \forall k \in T$$

Minimise $c^T x$
Subject to

$$Ax \geq 1$$
$$Bx \geq b$$
$$B'x \leq b'$$
$$x \in \{0,1\}$$

- Adjustments made
  - Relax $\sum_{j \in N_k} x_j = 1$ into $\sum_{j \in N_k} x_j \geq 1$
  - Add fixed charge Cx_j to cost function
    - # duties in solution as close to T as possible
  - Add two final steps to the greedy heuristic
    - Cleaning step to remove duplicates
    - Improvement step (local search)

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All-or-nothing constraints

$$\sum_{j \in N} a_{ij} x_j + x''_{l(i)} = 1, \quad \forall i \in M_o$$

Minimise $\quad c^T x$
Subject to

$$Ax \geq 1$$
$$Bx \geq b$$
$$B'x \leq b'$$
$$x \in \{0,1\}$$

- Adjustments made
  - Drop the constraints
  - Adjust column fixing step
    - Force some all-or-nothing jobs to be left uncovered
    - When there not enough duty templates to cover all of them
  - Add improvement step in the greedy heuristic

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Cost function

$$\min \sum_{j \in N} c_j x_j + \sum_{i \in M_o} C_i x'_i$$

$$c_j = \text{FixedCharge} - \sum_{i \in M_j} \text{value}_i$$

$$C_i = \text{value}'_i$$

Minimise $c^T x$
Subject to

$$Ax \geq 1$$
$$Bx \geq b$$
$$B'x \leq b'$$
$$x \in \{0,1\}$$

- Fixed charge large enough to keep cost positive
- Value is weighted sum of
  - Security and fare evasion risk
  - Other components

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Prototype

- Based on CREWS
  - Prepare data
  - Run the optimisation model
  - Display solutions
  - Cross-check feasibility of solutions
  - Programming languages
    - Lisp
    - C++
- Intel Core2Quad Q9550 2,83GHz, with 4096 MB of RAM

Problem instance

- *Randstad Noord*
- 4 home bases
  - Almere, Amersfoort, Alkmaar and Amsterdam
- 29 teams
- 87k potential train control jobs
  - Duration <= 1:00
- 5k generated jobs
  - 128 all-or-nothing jobs
- 5164 tasks
  - 274 all-or-nothing tasks
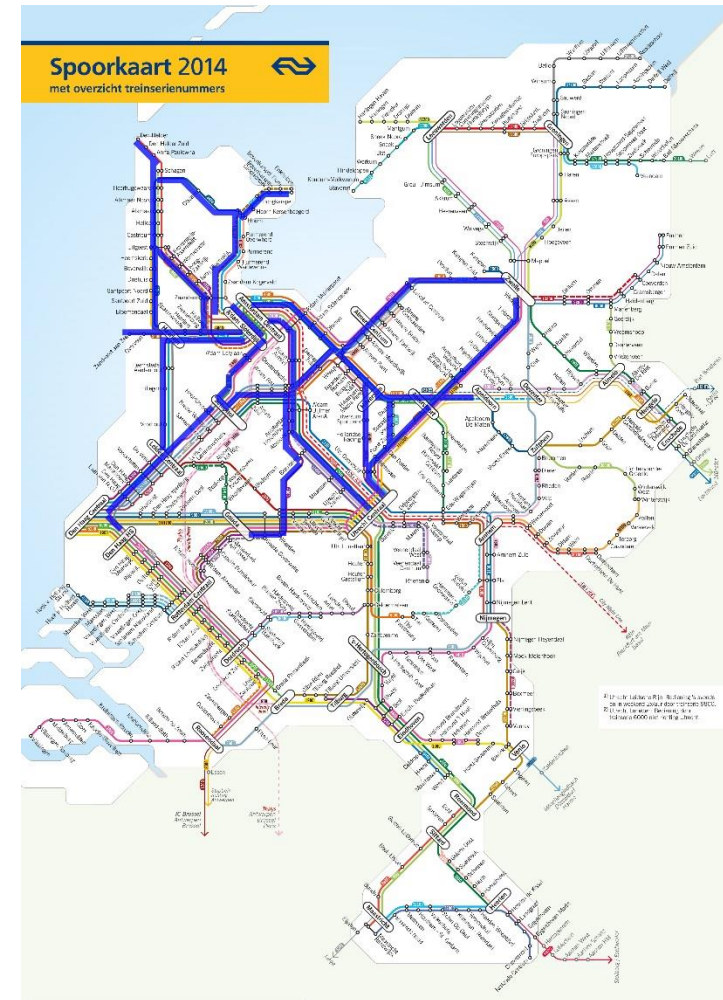
Short range *vs* long range

Scenario	AVG	Train Task Time	Local Task Time	Security Value	Fare Evasion Value	Weighted Value
Short range	7:56	51:49	25:30	20075	19831	19953
Long range	7:57	53:58	23:30	23363	21019	22191

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Route coverage

Scenario	AVG	Train Task Time	Local Task Time	Security Value	Fare Evasion Value	Weighted Value	Routes
Force cover all routes twice	7:57	48:56	24:30	15992	15618	15805	35
No forcing	7:56	51:49	25:30	20075	19831	19953	22

- More what-if scenarios in the paper…

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- İntroduction

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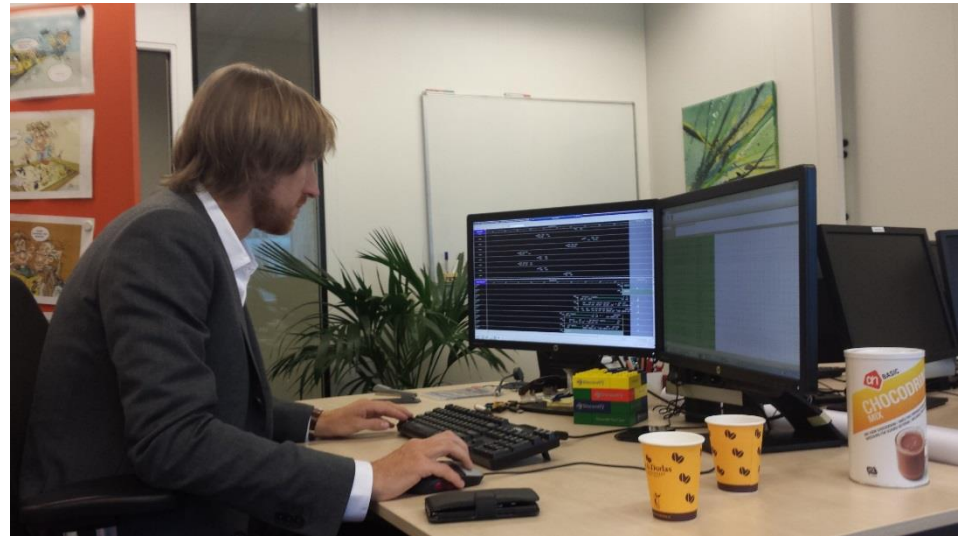
- ***Conclusions***

Conclusions

- Primary goals
  - Schedule daily work of security guards with high level of detail
  - Have decision support for developing new working methods

- Main challenges
  - Global optimisation goal not very well structured
  - Large problem instances
  - One-or-nothing and all-or-nothing behaviour
  - Most of the work will be left uncovered

- OR techniques
  - Not used much in the past
  - Success with heuristics based on LR and CG

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Pilot project (TUTIS)

- February 2014

- Study new ways of deploying security guards in a real production environment

  - Test new rules and working methods and check impact on the theatre of operations

  - Use new version of the prototype as an essential tool

- Region

  - 6 home bases

  - 250 security guards

- In production

  - February 2015

- Under evaluation

- LIVE DEMO available!

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Thank you!

Any questions?