SHIFT SCHEDULING FOR TRAIN DISPATCHERS

Rabii Zahir

PhD student, LiU

LINKÖPING UNIVERSITY

PROJECT FINANCED BY TRAFIKVERKET: CAPACITY MODELING AND SHIFT OPTIMIZATION FOR TRAIN DISPATCHERS CAPMO-TRAIN

TOMAS LIDÉN, LIU

CHRISTIANE SCHMIDT, LIU

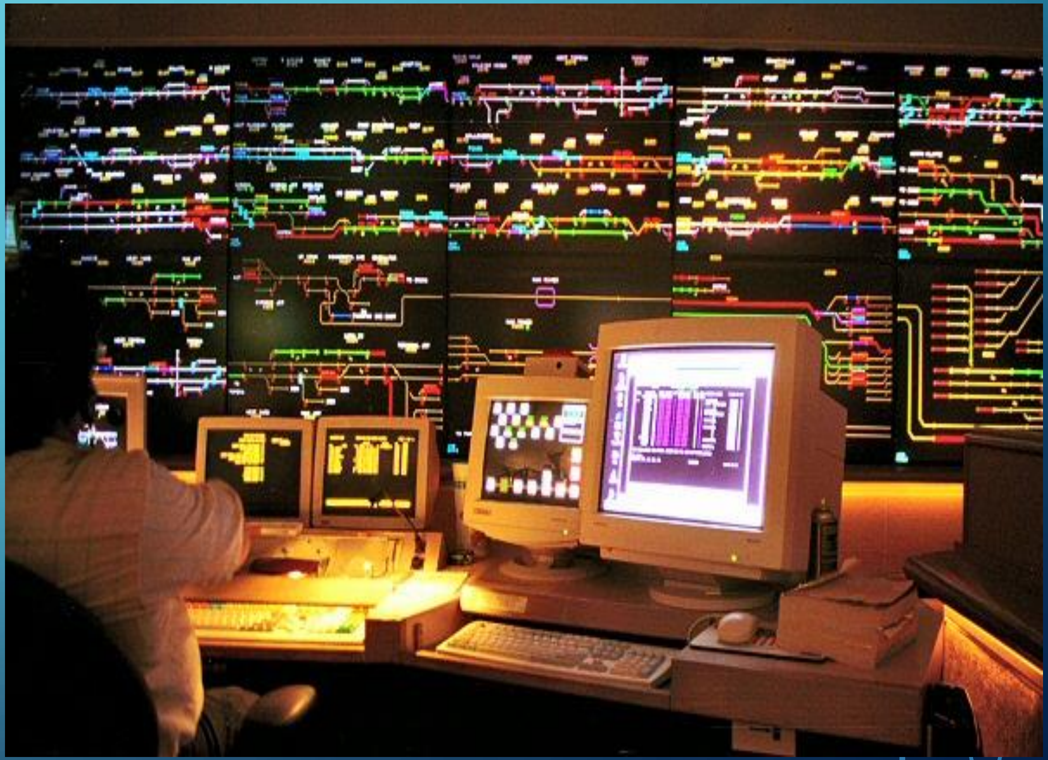
RABII ZAHIR, LIU

Jan Andersson, VTI

Gunilla Björklund, VTI

TRAIN DISPATCHING

- Monitoring & controlling train traffic
- Routing trains
- Open/close railway bridges
- Issue forms, truck warrants, truck permits
- Grant permission to pass red signals
- Communicate by radio/phone with train drivers and other personal
- And more…



Source for the image:
http://www.diplomacyandcommerce.rs/serbian-trains-will-be-even-safer-and-faster-thanks-to-russian-technology/

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PROBLEM DESCRIPTION:
SHIFT SCHEDULING FOR TRAIN DISPATCHERS

- Shift scheduling nowadays: manually performed
- Challenges during scheduling:
  - Legal restrictions
  - Operational restrictions
  - Balanced workload

LEGAL AND OPERATIONAL RESTRICTIONS

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LEGAL AND OPERATIONAL RESTRICTIONS

- The min/max:
  - length of a shift; number of working hours in a time horizon (weekly); number of working days; number of working weekends; number of consecutive night shifts; number of days off after a series of night shifts
- The minimum unit that a train dispatcher can be assigned. How these units could be combined?
- How many can a dispatcher handle of: number of trains and geographical areas…?
- And more…

WORKLOAD & SAFETY

- Safety comes always first
- High workload level
- Low workload level
- Balanced workload
- Previous project (FeIOP), and its extension (BeIOp) run by VTI

Source: http://www.gatewaynmra.org/2000/union-pacific-omaha-harriman-dispatch-center/

OBJECTIVES OF THE PROJECT

The overall goal of this project is to enable Trafikverket to automatically find cost-effective and safe train dispatcher shifts:

Cost-effectiveness: minimize the number of used dispatchers (and other objectives)

Safety: workload within acceptable thresholds

In a later phase: study the effect of stochastically varying events and how to integrate it in the framework

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THE OPTIMIZATION MODEL

- We used an adjusted MIP from Hernandez-Romero* et at.:
  - Sets:
    - D: set of dispatchers i
    - S: set of geographic areas j
    - P: set of number of periods k

*E. Hernández-Romero, B. Joseffson, A. Lametti, T. Polishchuk, C. Schmidt, Integrating Weather Impact in Air Traffic Controller Shift Scheduling in Remote and Conventional Towers. EURO Journal on Transportation and Logistics 11 (2022)

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- **Parameters:**
  - $TL_{j,k}$: task load for each geographic area j in time period k
  - *TUB*: upper bound on the length of despatcher shift in interval units
  - *TLB*: lower bound on the length of despatcher shift in interval units
  - $l_{i,j} = 1$ if dispatcher i holds endorsement to control geographic area j
  - A_{max}: maximum number of areas per despatcher
  - TL_{max}: maximum task load per dispatcher
  - R_{min} : minimum number of rest periods between the shifts
  - R_{max}: maximum number of rest periods between the shifts
  - $p = |P|$ number of periods

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- Decision variables (all binaries):
  - $q_i = 1$ if dispatcher i is used during some period
  - $v_{i,k} = 1$ if dispatcher i starts his shift at period k
  - $y_{j,k} = 1$ if dispatcher i is at work during period k
  - $x_{i,j,k} = 1$ if dispatcher i is assigned to area j during period k

- Constraints:
  - $\sum_{j\ in\ S} x_{i,j,k} * TL_{j,k} \leq TL_{max}\ \forall\ i \in D, \forall\ k \in P$ (max task load per dispatcher & period)
  - $\sum_{j\ in\ S} x_{i,j,k} \leq y_{i,k} * A_{max}\ \ \forall\ i \in D, \forall\ k \in P$ (max number of areas per dispatcher)
  - $x_{i,j,k} \leq L_{i,j} \quad \forall\ i \in D, \forall\ j \in S, \forall\ k \in P$ (endorsement requirement)
  - $v_{i,k} \leq y_{i,k}\ \forall\ i \in D, \forall\ j \in S, \forall\ k \in P$ (connect the variables)
  - $y_{i,k} \geq x_{i,j,k} \quad \forall\ i \in D, \forall\ j \in S, \forall k \in P$ (connect the variables)

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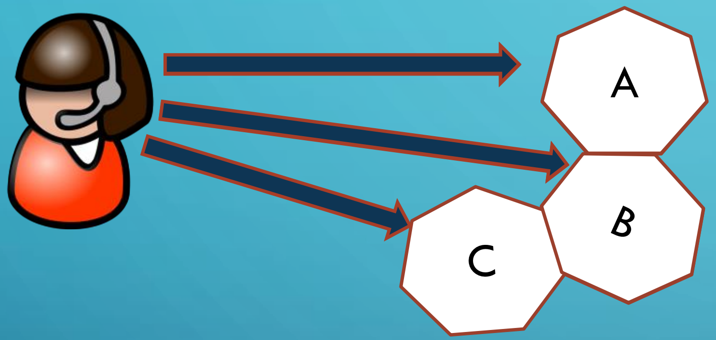
- Constraints:
  - $\sum_{\mu=k+1-TLB}^{k} v_{i,\mu(mod\ p)} \leq y_{i,k} \quad \forall i \in D, \forall k \in P$ (lower bound for shift length)
  - $\sum_{\mu=k+1-TUB}^{k} v_{i,\mu(mod\ p)} \geq \ y_{i,k} \quad \forall i \in D, \forall k \in P$ (upper bound for shift length)
  - $\sum_{\mu=k+1}^{k+R_{max}} v_{i,\mu(mod\ p)} \geq \ q_i - y_{i,k} \quad \forall i \in D, \forall k \in \{1..p - R_{max}\}$ (max rest between two consecutive shifts)
  - $\sum_{\mu=k+1}^{k+R_{min}} v_{i,\mu(mod\ p)} \leq q_i - y_{i,k} \quad \forall i \in D, \forall k \in P$ (min rest between two consecutive shifts)

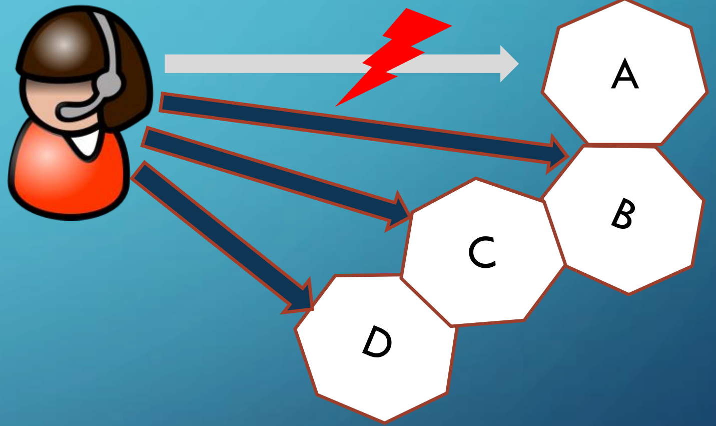
- Constraints:
  - $\sum_{i \text{ in } D} x_{i,j,k} = 1 \;\; \forall\, j \in S, \forall\, k \in P: TL_{j,k} > 0$ (assign one dispatcher to area j during period k if j has positive task load)
  - $\sum_{i \text{ in } D} x_{i,j,k} = 0 \;\; \forall\, j \in S, \forall\, k \in P: TL_{j,k} = 0$ (no assignment for area j if there is no positive task load during period k)
  - $v_{i,k} \le q_i \;\; \forall\, i \in D, \forall\, k \in P$ (if dispatcher i starts in some period then $q_i = 1$)

Extension of the original model

The issue for periods with no task load



Areas A, B and C have positive task load



Areas A has no task load and is substituted by D

- We introduce a new set:
  - V: set of 'virtual' geographic areas j', such that j'=j+100 for each element in D.

- We add new variables:
  - $z_{i,j,k}$ (binary), equal to 1 if area switching is necessary due to capacity constraints.

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- $New\ constraints$:

- $x_{i,j+100,k} = 0\ \forall\ i \in D, \forall\ j \in S, \forall\ k \in P\ if\ TL_{j,k} > 0$ (no virtual area is assigned whenever the task load is positive)

- $\sum_i x_{i,j,k} = 1\ \forall\ j \in V, \forall\ k \in P, if\ TL_{j-100,k} = 0$ (assign the correspondent virtual area whenever the task load becomes null)

- $\sum_i (x_{i,j,k} + x_{i,j+100,k}) = 1\ \forall\ j \in S, \forall\ k \in P$ (an area or its virtual correspondent is assigned to only one dispatcher during each period)

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- $New\ constraints$:

- $x_{i,j,(k+1)mod\ p} + y_{j,(k+1)mod\ p} - 1 \leq x_{i,j,(k+1)mod\ p} + z_{i,j,(k+1)mod\ p}\ \forall\ i \in D,\ \forall\ j \in S, \forall\ k \in P\ if\ TL_{j+(k+1)modp} > 0$ (keep the same assigned area if a dispatcher is still working next period and the area still have a positive task load)
- $x_{i,j+100,k} + y_{j,(k+1)mod\ p} - 1 \leq x_{i,j,(k+1)mod\ p} + z_{i,j,(k+1)mod\ p}\ \forall\ i \in D, \forall\ j \in S, \forall\ k \in P, if\ TL_{j,(k+1)mod\ p} > 0$ (keep the same assigned area (or its virtual) if, after being assigned to a virtual area, a dispatcher Is till at work next period)
- $x_{i,j,k} + y_{j,(k+1)mod\ p} - 1 \leq x_{i,j+100,(k+1)mod\ p} + z_{i,j,(k+1)mod\ p}\ \forall\ i \in D, \forall\ j \in S, \forall\ k \in P, if\ TL_{j,(k+1)mod\ p} = 0$ (if in next period a dispatcher is still at work and its assigned area has no task load then assign the correspondent virtual area)

A possible objective function is to minimize a linear combination of the total number of used dispatchers and the switches:

$$\text{Minimize } \sum_i \sum_j \sum_k \alpha * q_i + \beta * z_{i,j,k} \; with\; \alpha \gg \beta$$

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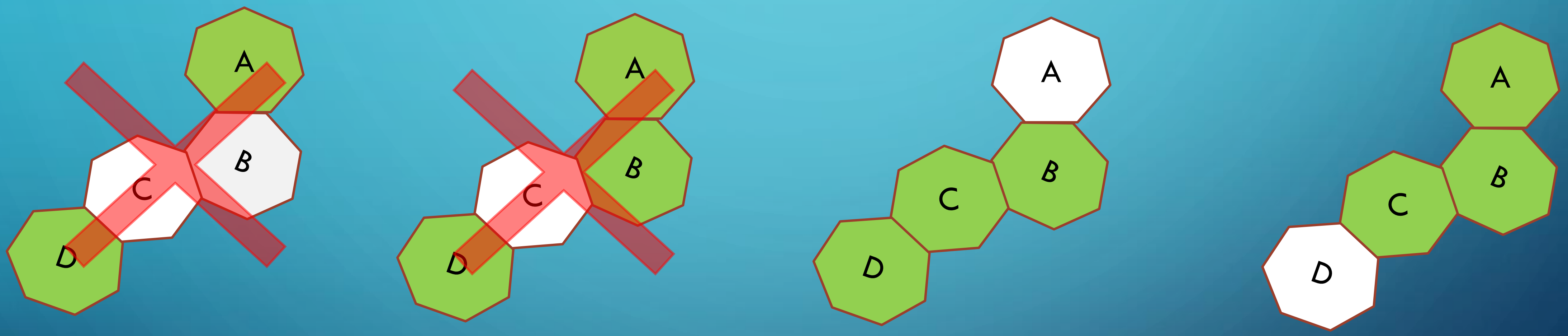
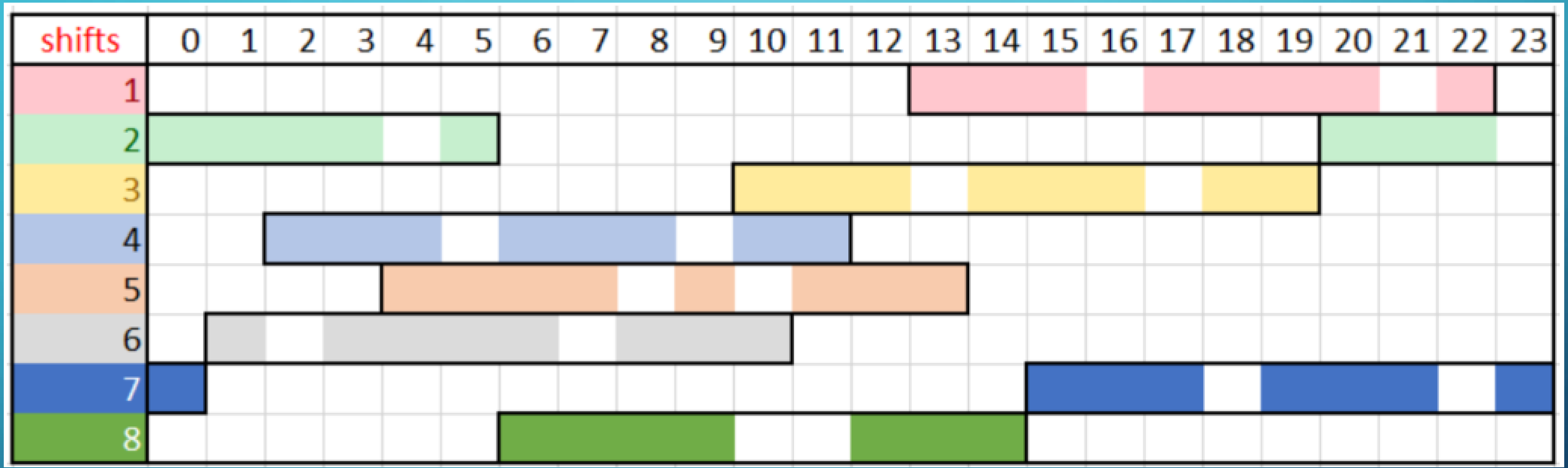
WHAT TO DO NEXT STEP?

- How to combine the geographical areas?



- Elaborate the data provided by BelOp to determine the workload thresholds

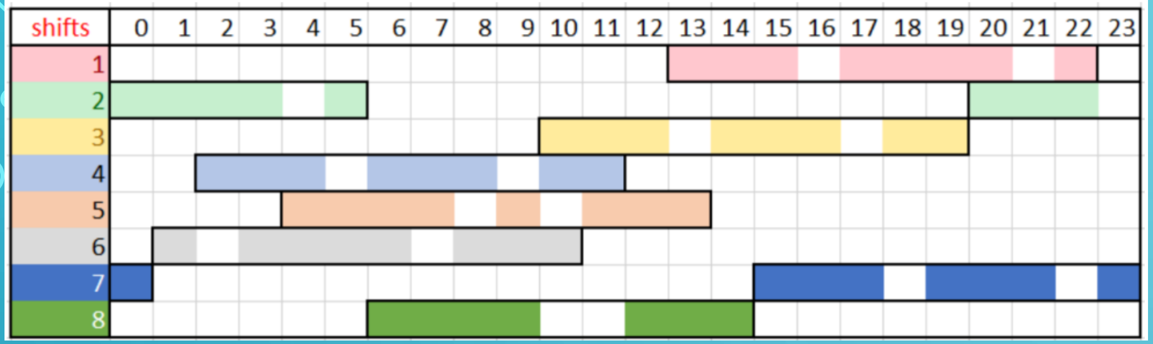
Expected output



An example of one day schedule for eight dispatchers. This example was presented by Josefsson* et al.

*B. Joseffson, T. Polishchuk, V. Polishchuk, C. Schmidt, Scheduling Air Traffic Controllers at the Remote Tower Center, DASC (2017)

THANK YOU FOR LISTENING



Questions?