Redesigning the Endorsement Structure for Train Dispatchers

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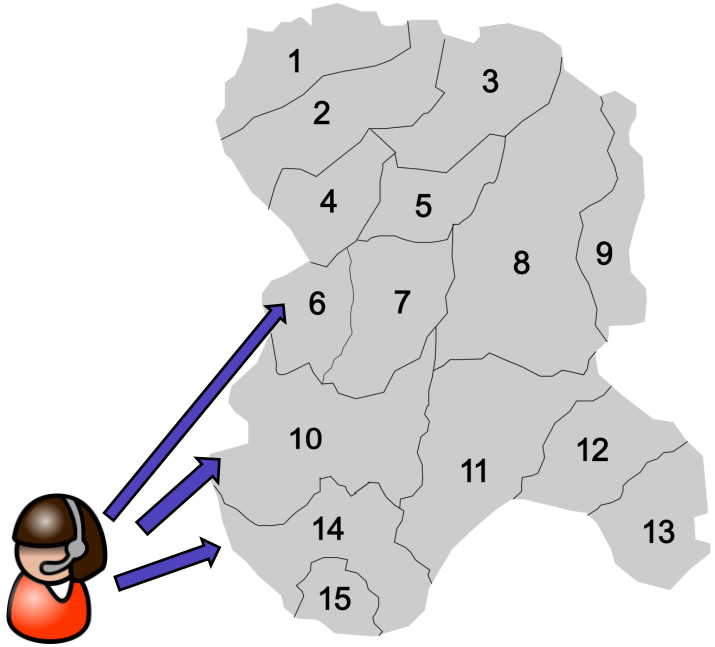
Optimized Shift Schedule



- A set of dispatchers
- A set of geographical areas (adjacency constraints)
- Some of the constraints:
  - Allowed shift length
  - Daily rest
  - Task load (train movements per area and time period) as approx. for WL
  - Endorsement per dispatcher (was given)
- The objective in the IP: Minimize the number of used dispatchers

Optimal One-Day Schedule

	pr.0	pr.1	pr.2	pr.3	pr.4	pr.5	pr.6	pr.7	pr.8	pr.9	pr.10	pr.11	pr.12	pr.13	pr.14	pr.15	pr.16	pr.17	pr.18	pr.19	pr.20	pr.21	pr.22	pr.23
D1						10 11	10 11	10 11	10	12 13	12 13	12	12	12	12	12								
D2	6	6														6	6	6	6	6	6 7	6 7	6 7	6
D3									11	10 11	6 10 11	6 10 11	6 10 11	6 10 11	6 10 11	10 11	10 11	10 11	10					
D4											3	3	3	3	3	3	3	3	3	3	3			
D5											14 15	14 15	14 15	14 15	14	14	14	14	14	14	14			
D6	3	3	3	3	3 4	3 4	3 4	3 4	3 4	3														3
D7	4 5	4 5	4 5	4															4	4	4 5	4 5	4 5	4 5
D8									1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2	2	2	2					
D9	10 11	10 11	10 11	10 11	10 11														11	10 11	10 11	10 11 14	10 11 14	10 11
D10										4	4 7	4 7	4 7	4 7	4 7	4 7	4 7	4 7	7	7				
D11												13	13	13	13	13	12 13	12 13	12 13	12 13	12 13	12 13		
D12															8	8	8	8	8	8	8 9	8 9		
D13																	1	1	1	1 2	1 2	1 2	1 2	1
D14	8 9	8 9	8 9	5 8 9	5 8 9	5 8 9	5 8 9	5 8 9	5 8 9														8 9	8 9
D15															15	15	15	15	15	15	15	15	15	
D16	12 13	12 13	12 13	12 13	12 13	12 13	12 13	12 13	12 13														12 13	12 13
D17										9	9	9	9	9	9	9	9	9	9	9				
D18										5 8	5 8	5 8	5 8	5 8	5	5	5	5	5	5				
D19	1 2	1 2	1 2	1 2	1 2	1 2	1 2	1 2														3	3	2
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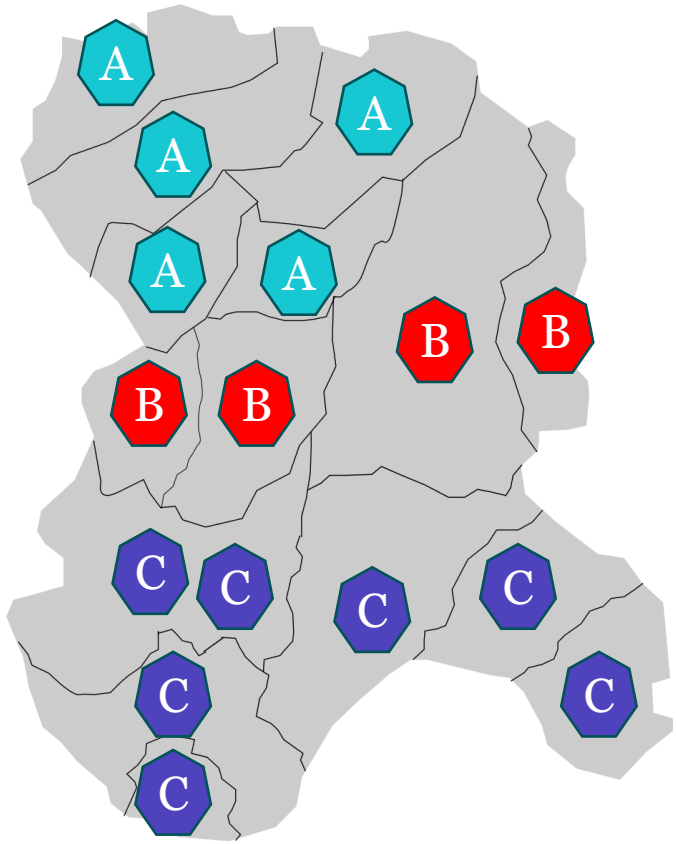
D21	7	7	6 7	6 7	6 7	6 7	6 7	6 7	6 7	6 7														7

Endorsement Structure for Dispatchers

- We study how the endorsement structure (who is qualified for which dispatching areas) impacts the dimensioning and flexibility for the shift planning and implementation
- We analyze the impact of optimized endorsement structures on the scheduling performance, in terms of operational costs and robustness

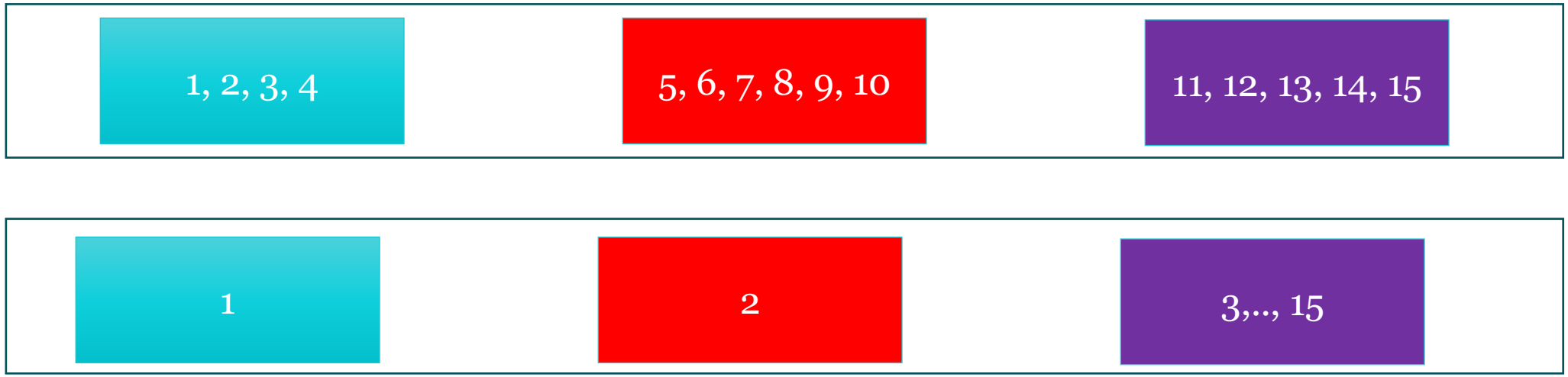
Endorsement Structure

- We want to determine the endorsement profile that gives more flexibility during the scheduling
- How many subsets (competence areas) of endorsements do we need?
- Which areas are within each competence area?



Endorsement Structure

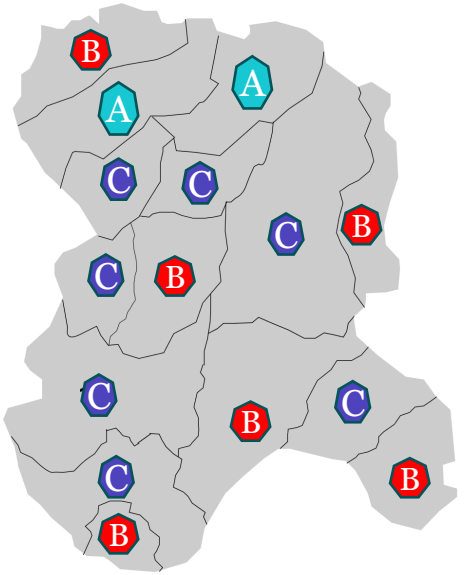
- Assume we have three competence areas
- Deciding which areas are within each competence area



Endorsement Structure: Three-Set-Partition (3SP)

- A **3SP** is a set of three sets of areas: [[part1],[part2],[part3]]
- With 15 areas, we can get 14 348 906 partitions
- How to evaluate and rank these 3SPs?
- We suggest a few approaches

Approach 1: Max-Min Over all Periods



- The idea is to find a 3SP that gives us more possibilities to combine areas
- Ex: [[2,3],[1,7,9,11,13,15],[4,5,6,8,10,12,14]]
- The score for a 3SP is given by the score of the worst "part"
- The score of the part is the **sum** of all feasible combinations (at least 2 areas) for **all periods** (feasibility in terms of TL and adjacency)

Approach 2: Max-Min over Low-TL Periods

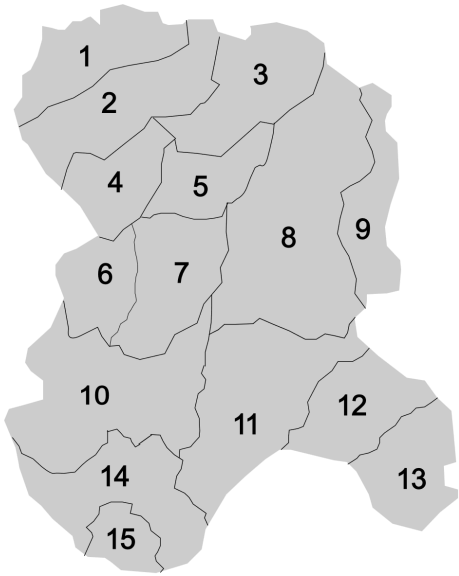
- The score for a 3SP is given by the score of the worst "part"
- The score of the part is the **sum** of all feasible combinations (at least 2 areas) for **at least 9 periods** (low-TL periods)

Approach 3: Lexicographic Order of the 3SPs' Parts over Low-TL Periods

- Instead of considering only the worst part of a 3SP, we look at **all the three parts**
- A score of each 3SP is a list of three numbers sorted ascendingly. We order the 3SPs with a **lexicographic** order starting by the lowest scores among the parts
- Example:
  - Scores_3SP_A = [4,5,6], Scores_3SP_B = [4,5,7]

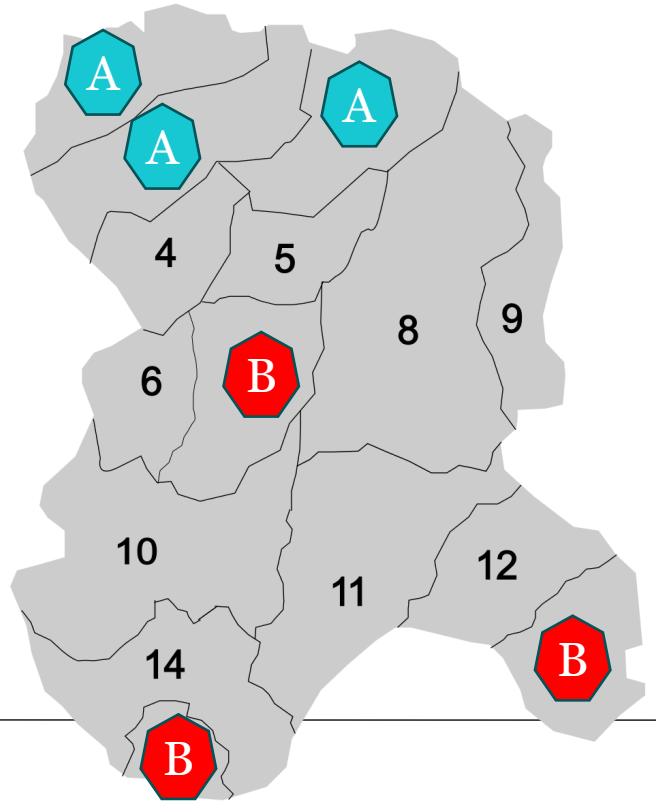
Approach 4: Lexicographic Order of the 3SPs' Parts with weighted combinations' sum

- The score of the part is the **weighted sum** of all feasible combinations (at least 2 areas)
- The **weight** of a combination is proportional to the number of periods it appears (we **divide** this number **by 24)**
- Example: Which is better?
  - A 3SP that has different combination each time?
  - A 3SP that has some combination that kept most of the time?



Two More Approaches: Minimum Number of Duty Hours

- Given a 3SP. What is the minimum number of dispatchers are needed to cover the included areas within each part?
- Example of parts:
  - [1,2,3]: may require 1 disp
  - [7,13,15]: requires 3 disp

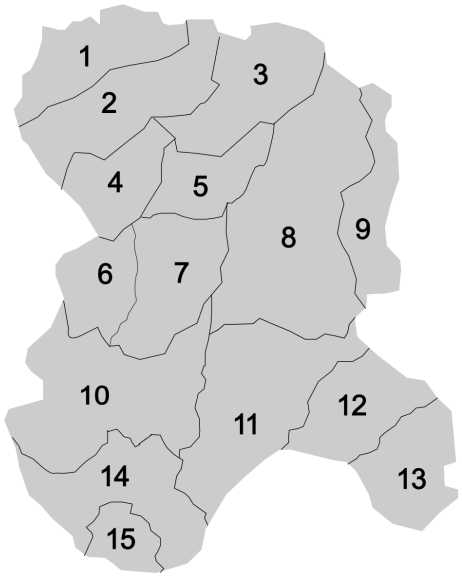


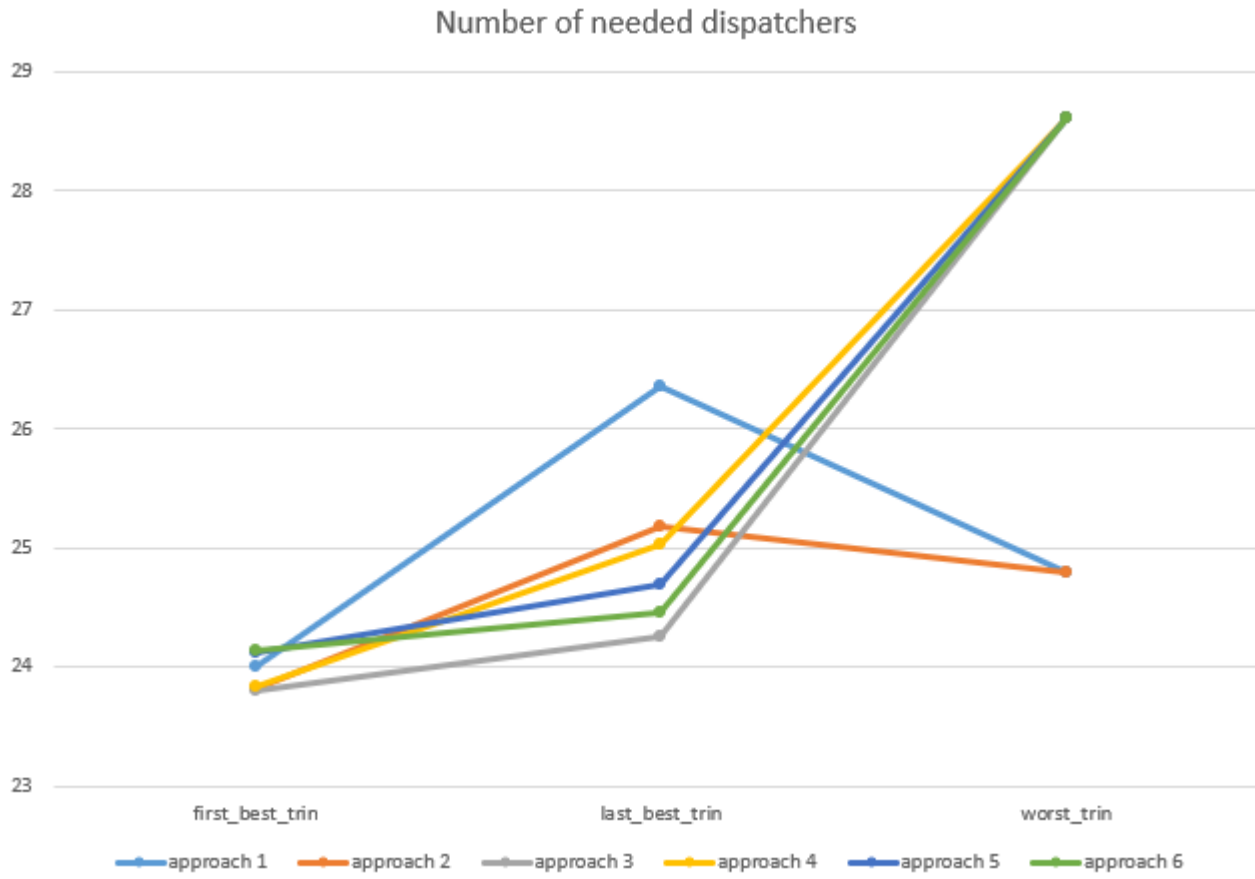
Evaluation of the 3SPs: KPIs

- KPIs:
  - Daily operational cost: Number of needed dispatchers
  - Personnel buffer: Robustness against sick leaves (buffer)
  - Endorsement costs: How many dispatchers have endorsement per competence area?
- We use our model for a one-day shift scheduling, with 100 task load instances (reporting averages)
- We rank best 20, worst of the best 1000 and the absolute worst 20 3SPs
- We expect that the “good” 3SP would generate more scheduling flexibility → fewer needed dispatchers to cover a working day

Evaluation of the 3SPs: Nr needed disp.

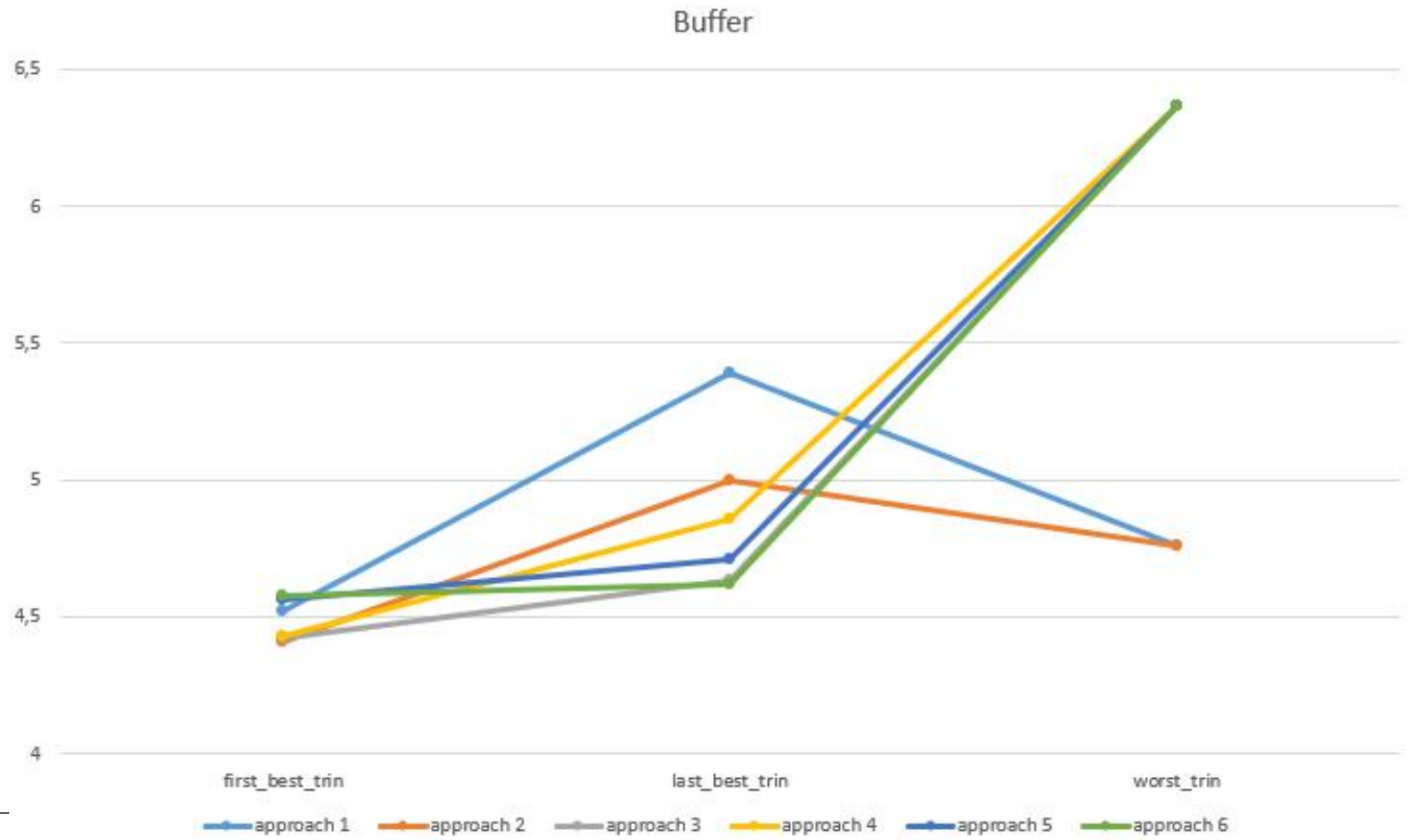
- Fewer dispatchers are needed for a one-day schedule with "good" 3SPs according to all 6 approaches
- Worst for approaches 1 & 2:
  - [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11],[12, 14, 15],[**13**]





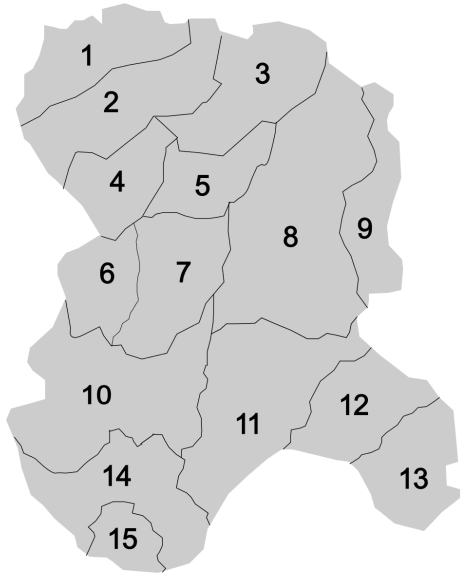
Evaluation of the 3SPs: Buffer

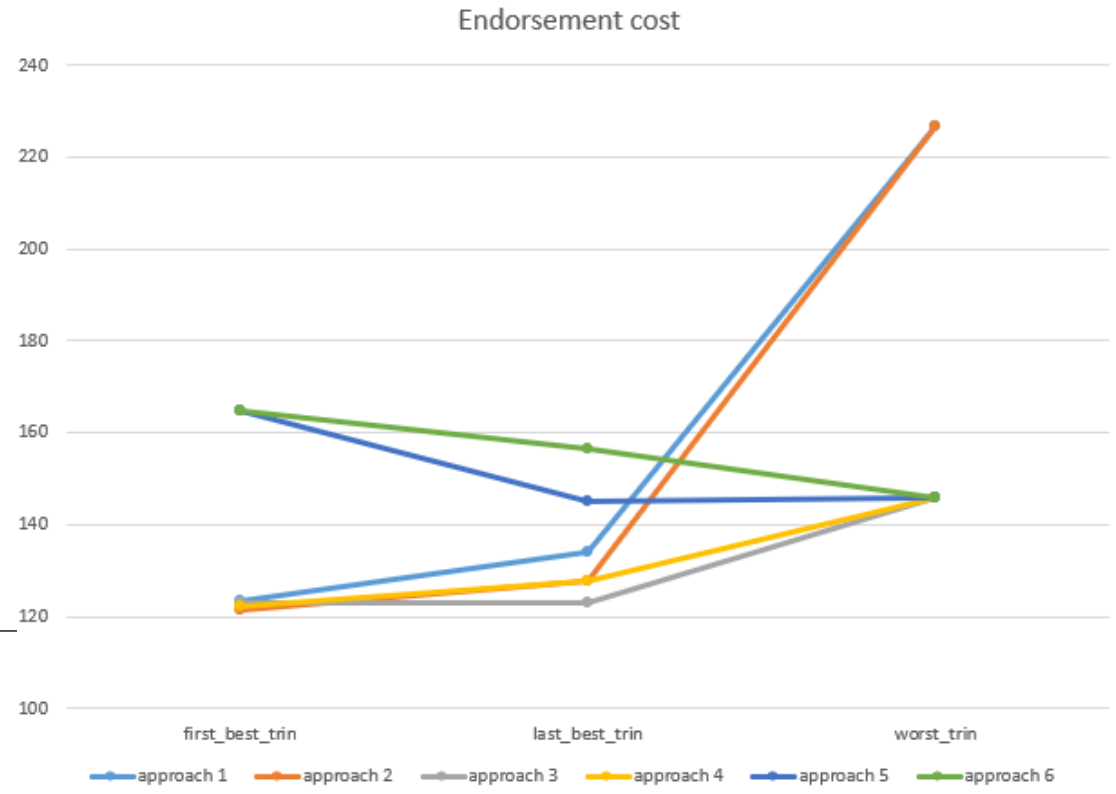
- Best 3SPs give lower buffer
- Trade-off operational costs and robustness



Evaluation of the 3SPs: Endorsement Cost

- Lower endorsement costs for the best 3SPs for approaches 1,2,3,and 4, but not for the approaches 5 and 6
- **Best** using approaches **5 & 6**: [1, 4], [2, 3], [5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]
- **Worst** using approaches **5 & 6**: [1, 5, 9], [2, 4, 6, 10, 11, 12, 14], [3, 7, 8, 13, 15]

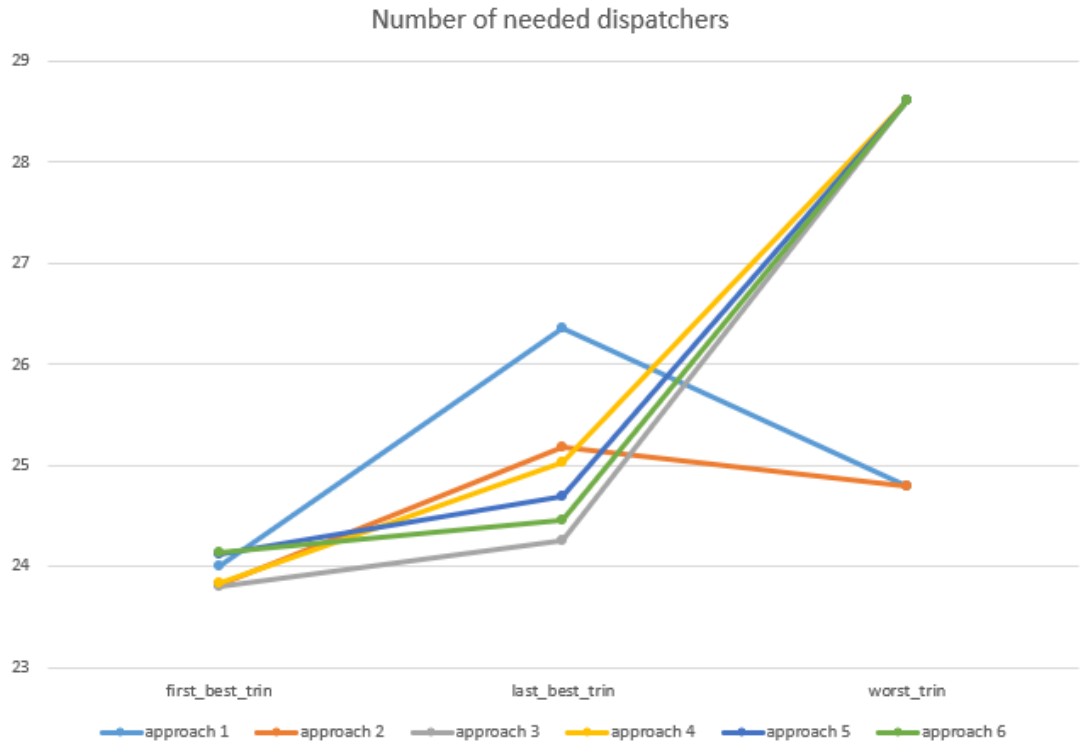




Conclusion and Future Work

- Approaches 3 and 4 are slightly better for all KPIs, while 5 and 6 give high endorsement cost
- Typically, well balanced 3SP are among the best ones
- Next:
  - Integrating feedback from TrV experts
  - Changing the endorsement cost for the areas
  - Fewer or more competence areas

Thank You


Number of needed dispatchers
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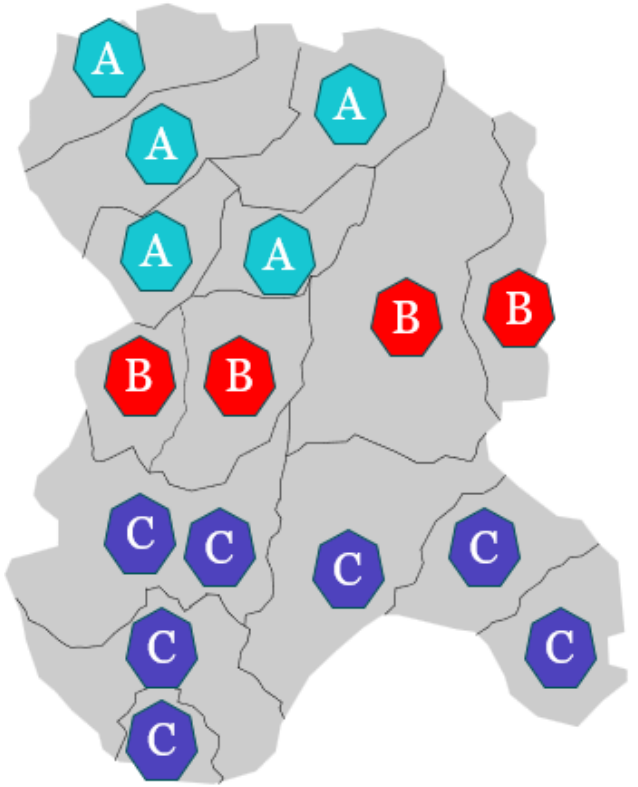
first_best_trin
last_best_trin
worst_trin
approach 1
approach 2
approach 3
approach 4
approach 5
approach 6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