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The railway timetable rescheduling problem with capacity constraints

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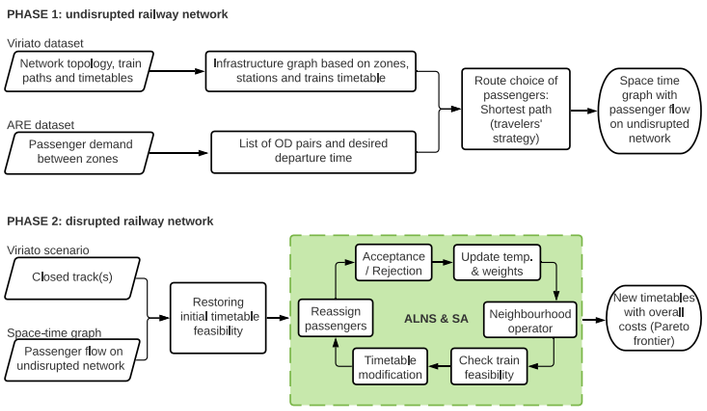
The increasing demand for travelling forces railway operators to use their network at maximum capacity. When unforeseen events occur, the time needed to make the proper adjustments before reaching a gridlocked state is too short. The timetable rescheduling models aim to quickly support experienced dispatchers with various optimal solutions to the problem according to predetermined objectives. The master thesis proposes an extension of the meta-heuristic adaptive large neighbourhood search (ALNS) model from Buschor (2020) to solve the railway rescheduling problem that takes into consideration, in this master thesis, the train capacity constraints. In addition, a new efficient passenger assignment is proposed to reduce the computation effort at each iteration. The model is tested on a real railway network with the collaboration of a railway consulting company. The results show a substantial impact of the train's capacity on the passenger assignment and the number of successful trips. Moreover, the passenger assignment algorithm provides an efficient time saving on the computation for the ALNS.

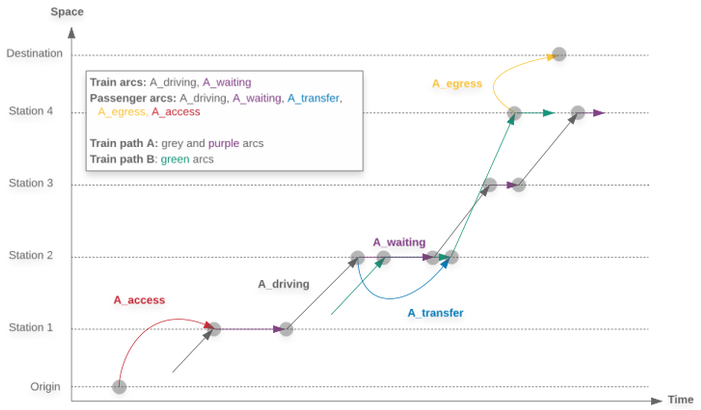
Flow chart

The figure below illustrates the methodology's flow chart in two phases.



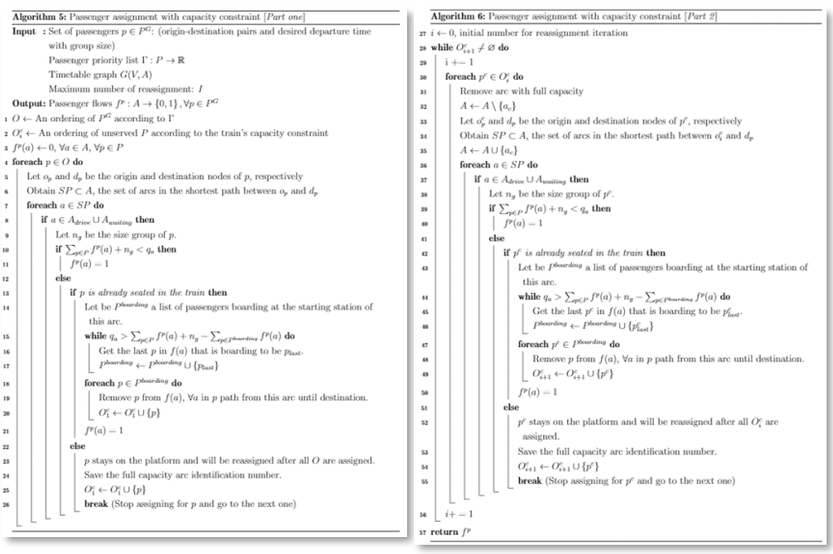
Space-time graph

The figure shows a simple example of a complete passenger trip on a space-time graph..



Passenger assignment algorithm

The pseudo-code is designed to simulate realistic behaviours of the passenger when facing full occupancy trains.



Algorithm 5: Passenger assignment with capacity constraint *[Part one]*

Input : Set of passengers $p \in P^G$: (origin-destination pairs and desired departure time with group size)
Passenger priority list $\Gamma : P \to \mathbb{R}$
Timetable graph $G(V, A)$
Maximum number of reassignment: I

Output: Passenger flows $f^p : A \to \{0, 1\}, \forall p \in P^G$

$O \leftarrow$ An ordering of P^G according to Γ
$O'_i \leftarrow$ An ordering of unserved P according to the train's capacity constraint
$f^p(a) \leftarrow 0, \forall a \in A, \forall p \in P$
foreach $p \in O$ **do**
  Let o_p and d_p be the origin and destination nodes of p, respectively
  Obtain $SP \subset A$, the set of arcs in the shortest path between o_p and d_p
  foreach $a \in SP$ **do**
    if $a \in A_{drive} \cup A_{waiting}$ **then**
      Let n_g be the size group of p.
      if $\sum_{op \in P} f^p(a) + n_g < q_a$ **then**
        $f^p(a) = 1$
      else
        if *p is already seated in the train* **then**
          Let be $P^{boarding}$ a list of passengers boarding at the starting station of this arc.
          while $q_a > \sum_{op \in P} f^p(a) + n_g - \sum_{op \in P^{boarding}} f^p(a)$ **do**
            Get the last p in $f(a)$ that is boarding to be p_{last}.
            $P^{boarding} \leftarrow P^{boarding} \cup \{p_{last}\}$
          foreach $p \in P^{boarding}$ **do**
            Remove p from $f(a)$, $\forall a$ in p path from this arc until destination.
            $O'_i \leftarrow O'_i \cup \{p\}$
          $f^p(a) = 1$
        else
          p stays on the platform and will be reassigned after all O are assigned.
          Save the full capacity arc identification number.
          $O'_i \leftarrow O'_i \cup \{p\}$
          break (Stop assigning for p and go to the next one)

Algorithm 6: Passenger assignment with capacity constraint *[Part 2]*

$i \leftarrow 0$, initial number for reassignment iteration
while $O'_{i+1} \neq \varnothing$ **do**
  $i \mathrel{+}= 1$
  foreach $p' \in O'_i$ **do**
    Remove arc with full capacity
    $A \leftarrow A \setminus \{a_c\}$
    Let o'_p and d_p be the origin and destination nodes of p', respectively
    Obtain $SP \subset A$, the set of arcs in the shortest path between o'_p and d_p
    $A \leftarrow A \cup \{a_c\}$
    foreach $a \in SP$ **do**
      if $a \in A_{drive} \cup A_{waiting}$ **then**
        Let n_g be the size group of p'.
        if $\sum_{op \in P} f^p(a) + n_g < q_a$ **then**
          $f^p(a) = 1$
        else
          if *p' is already seated in the train* **then**
            Let be $P^{boarding}$ a list of passengers boarding at the starting station of this arc.
            while $q_a > \sum_{op \in P} f^p(a) + n_g - \sum_{op \in P^{boarding}} f^p(a)$ **do**
              Get the last p' in $f(a)$ that is boarding to be p'_{last}.
              $P^{boarding} \leftarrow P^{boarding} \cup \{p'_{last}\}$
            foreach $p' \in P^{boarding}$ **do**
              Remove p from $f(a)$, $\forall a$ in p path from this arc until destination.
              $O'_{i+1} \leftarrow O'_{i+1} \cup \{p'\}$
            $f^p(a) = 1$
          else
            p' stays on the platform and will be reassigned after all O'_i are assigned.
            Save the full capacity arc identification number.
            $O'_{i+1} \leftarrow O'_{i+1} \cup \{p'\}$
            break (Stop assigning for p' and go to the next one)
  $i \mathrel{+}= 1$
return f^p

Disruption scenario

The disruption scenario shows a closed track between 6:00 AM and 8:00 AM, represented by the red rectangle below.

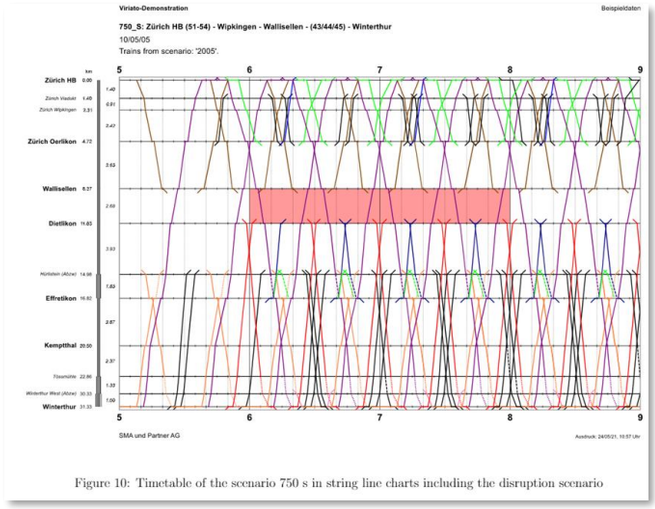
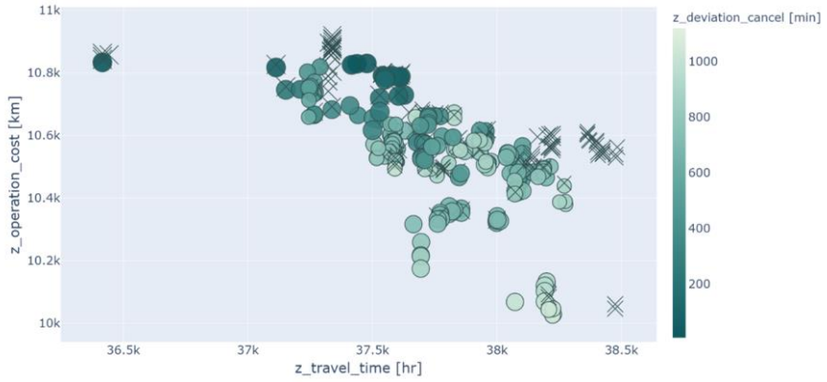


Figure 10: Timetable of the scenario 750 s in string line charts including the disruption scenario

Solution

The graph shows the Pareto frontier with the non-dominated solutions of the multi-objective problem.



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