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Evaluating the Quality of Railway Timetables from Passenger Point of View

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In the railway passenger service planning, the main focus is often on the feasibility of the solutions and/or the associated profit of the Train Operating Company (TOC). The profit of TOCs' is the driver for the non-cyclic version of the Train Timetabling Problem (TTP), whereas feasibility is the main concern of the cyclic version of the same problem. Usually, the passengers for whom the service is designed are not taken into consideration, when creating the timetables. This could be one of the main reasons for which the willingness of passengers to use trains as their mean of transport has reduced. In this research, a choice based optimization approach is introduced that addresses this issue from passenger satisfaction point of view. We validate our model using a semi-real data of a major European railway company and the real data of Israeli Railways.

One of the goals of this study is to evaluate the difference in quality between cyclic and non-cyclic timetables. In the current literature, it is just plainly said that the cyclic timetables are more attractive to the passengers, because they are easier to memorize. The contribution of this talk is then the estimated quantitative cost of the cyclic timetables from the passenger point of view.

First, we quantify customers (passengers) attractiveness towards different type of timetables. The passenger perception could be measured based on four main attributes:

- Traveling time
- Number of connections
- Waiting time at each connection
- Arrival time

The first attribute represents the **in-vehicle-time (VT)**, which is the (total) time passengers spend on board of (each) train. This time allows the passengers to distinguish between the “slow” and the “fast” services.

The second attribute aims at distinguishing between direct and interchange services (simply **number of transfers (NT)**). In literature and practice, it is considered as an extra traveling time to the overall time spent during the whole journey [3].

The third attribute accounts for the **waiting time (WT)**, which is the time passengers spend, when waiting for a connecting train. Many studies show that this time has a different value than the VT [2][8].

The last attribute serves as an indicator of the time of the day passengers want to travel, i.e. following the assumption that the demand is time dependent. Since it is unlikely that a train would arrive to the destination exactly at a desired time, the difference between the actual and desired arrival is then called **scheduled delay (SD)**. This delay is perceived differently, if a passenger arrives early or late [6].

All of the above attributes, can be then combined into one formula capturing a perceived cost of a given path using a given timetable (a path is defined as a sequence of train lines, in order to get from an origin to a destination):

$$C = \text{argmin}\left(\alpha \cdot \sum_{i \in I} VT + \beta \cdot \sum_{j \in J^I} WT + \gamma \cdot NT + \min\left(\epsilon \cdot SD_e, \eta \cdot SD_l\right)\right) \quad (1)$$

for all possible sets I, where:

- I – set of possible trains in a given path
- J^I – set of transfers in a given path using given trains
- α – value of time (monetary units per minute)
- β – value of waiting time (monetary units per minute)
- γ – penalty for having a transfer (monetary units)
- ε – value of being early (monetary units per minute)
- η – value of being late (monetary units per minute)

The resulting cost is in monetary units (whole equation is multiplied by the VOT). There are many combinations of trains on different lines in the path to get from an origin to a destination, however passengers look for combinations with minimum waiting time closest to their desired arrival time into their destination (argmin function). The parameters α, β, γ, ε and η are subject to a sensitivity analysis. We have developed a mixed integer linear programming formulation that designs timetables under the objective of minimizing the perceived costs of every passenger [4]. We have tested our approach on two case studies: the S-Train network of Canton Vaud, Switzerland and the complete network of Israeli Railways.

For the latter case, the number of registered sold tickets from vendor machines have been used as demand representative. The rates are hourly per Origin-Destination (OD) pair and smoothed per minute using (non- homogenous) poisson process on the arrival rate at the origin (that's where the passengers bought their tickets) and shifted by the shortest path value to the destination (as scheduled delay is related to the destination). The OD matrix consists of a whole average working day in Israel during the year 2008 and the VOT has been given to us by Yoram Shiftan [5].

For the case of Swiss data, we use the same total number of passengers as in Israel, however the ODs have been generated based on hourly distribution from the Swiss Federal Railways' annual report of 2014 [7]. The swiss value of time was estimated to 27.81 CHF/hour [1].

The results are compared to the current cyclic timetables for both cases. Our model generates both cyclic and non-cyclic timetables. We compare the two settings and we evaluate the cost difference between the cyclic and non-cyclic timetables.

Finally, we provide several scenarios to improve the efficiency of the system by adding number of trains in service during specific time periods that can improve the current solutions. This comes from the fact that the planning of the passenger railway service is sequential (due to the large complexity) and as such the global optimum cannot be reached, i.e. when executing the line planning problem, which decides on the train frequencies, the timetable is unknown and thus need for an extra train is unforeseen.

Keywords: Railway Passenger Service, Ideal Timetable, Cyclic vs. Non-Cyclic

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