Evaluation of timetables by estimating passengers' personal disutility using micro-simulation

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Outline

- Motivation and Aim
- Proposing method for Timetable Evaluation
- Structure of Train Operation and Passenger Flow Simulator
- Examples of Timetable Evaluation
- Conclusions and Future Works
Outline of Presentation

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Features of Railways in Japan

- Too Many Passengers
  (More than 1,000,000 passengers in a day in a certain line)

- Too Many Trains
  (30 trains per hour in one direction of a double track line)

- Dense rail line network
Requirements for Timetables

To improve passengers’ satisfaction

- Provide sufficient transport capacity
  - as many trains as possible during rush hours
- Avoid train and platform congestion
  - sometimes risky!
- Avoid train delay
- Connection with other trains / lines

Appropriate timetable evaluation is essential
Motivation and Aim of our Research

Motivation

- Compare two or more timetables in advance from the viewpoints of passengers
- Express interactions between train operation and passengers’ flow

Aim

- Establish an appropriate evaluation method for train timetables
Requirements for Timetable Evaluation

Index

Requirements

- Evaluation can be done before the timetable has enforced
- Explicitly reflects transportation services that each passenger experiences
- Reflect each passenger’s preference of trains
- Include chronic train delays caused by passengers’ flow
- Include dynamic interaction between passengers and trains (eg. snowball effect!)
**“Snowball Effect” of Train Congestion and Delay**

- **Train Delay**
- **More Passengers get on the train**
- **Train Congestion**
- **Extension of dwell time at a station**

The more the train is delayed, the more passengers appear at the station and get on the train.

This effect is caused by dynamic interaction between passengers and trains.

Avoidance of “Snowball effect” is very important.
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Our Approach for Timetable Evaluation

- Use “Train Operation and Passenger Flow Simulator” to predict each passenger’s behavior.
- Evaluate a timetable using “disutility value” calculated from each passenger’s experienced service.
Calculation of Disutility Value

- Aggregate some aspects of transportation service (congestion, times of transfer, waiting time, dwell time in train car) that each passenger has experienced.

- Passengers’ experience oriented evaluation.

Disutility Value

\[ \alpha \sum_j \left\{ t_j \left( \frac{C_j}{100} \right)^\beta \right\} + \gamma N + \delta T_W + T_R \]

- Congestion rate: 0.019
- Times of transfer: 4.52
- Waiting time: 5.62
- Dwell time in train car: 1.202
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How Train Operation and Passenger Flow Simulator works?

Automatic Ticket Checker

Train Timetable

Passengers’ Origin-Destination Data

Estimation of each Passenger’s Behavior

Passenger X

Passenger Y

Train Timetable Data

Estimate These Experienced Services

- Total Time: 10min
- Waiting Time: 5min
- Transfer: 0

- Total Time: 20min
- Waiting Time: 3min
- Transfer: 1
Simulation Sequence

Based on the amount of passengers getting on or off

Share the clock

STEP 1
Passenger Appearance

STEP 2
Passenger’s Path Search for Destination

STEP 3
Getting on or off at Station

Re-Prediction of passenger’s behavior

Prediction of passenger’s behavior
• which train to use?
• where to transfer?

STEP 4
Estimation of Train Delay

Passengers’ Origin-Destination Data

Based on the amount of passengers getting on or off
Features of our Simulator

- Predict each passenger’s behavior **in great detail**
  - Detailed estimation of transportation services (congestion, times of transfer, waiting time, dwell time in train car)
- Preferences of each passengers can be expressed
  - As fast as possible
  - Hate transferring
  - Hate congestion
- “Snowball effect” can be expressed
Demonstration of our Simulator

- **Number of Trains**
  550 trains per day

- **Number of Passengers**
  about 650 thousand passengers

- **Simulation Time for a whole day**
  about 30 min (using a standard desktop PC)
Screenshots of our Simulator

- **View as train diagrams**

- **State of the train**
  - Indicate a train with more than 150% of congestion
  - Indicate a train with more than 2 minutes of delay

- **Passengers in the train**
  - N.O. passengers
  - N.O. passengers getting on or off

- **State of the station**
  - Time

- **Position of the trains**
  - The color of each train reflects congestion of the train

- **Operated time and delay**
  - N.O. passengers in each train car

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Two Timetables to be Compared

Temporal timetable (Timetable A)

Revised timetable (Timetable B)

Express trains stop at Sta.4
Comparison of the Timetables from OD pairs

- Timetable A is better
- Almost the same convenience
- Timetable B is better

The size of the dots indicates the amount of passengers.
Comparison of the Timetables from other aspects

- Shift of passengers’ convenience when the timetable has been changed from A to B

Disutility Value

<table>
<thead>
<tr>
<th>Factor</th>
<th>Become Convenient</th>
<th>Almost the Same Convenience</th>
<th>Become Inconvenient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel time</td>
<td>43.45%</td>
<td>16.62%</td>
<td>39.93%</td>
</tr>
<tr>
<td>Waiting time</td>
<td></td>
<td>99.33%</td>
<td></td>
</tr>
<tr>
<td>N.O. transfer</td>
<td>17.95%</td>
<td>65.66%</td>
<td>16.39%</td>
</tr>
<tr>
<td>Experienced congestion</td>
<td>45.30%</td>
<td>22.11%</td>
<td>32.58%</td>
</tr>
<tr>
<td>Probability of sitting down</td>
<td>30.03%</td>
<td>44.95%</td>
<td>25.02%</td>
</tr>
</tbody>
</table>
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Conclusions

- Develop the evaluation method of timetables using the **micro-simulation system**.
- By calculating and aggregating **disutility value**, appropriate timetable evaluation can be done from the viewpoint of passengers in advance.
- The **micro-simulation system** also provide some useful information about the timetable, the **prediction of train congestion or delay**.
- An example of timetable evaluation showed the effectiveness of the method.
Future Works

- Apply for various railway lines and verify the estimated congestion or delay
- Apply for train rescheduling plans under disrupted train operation
  - Develop passenger behavior models under timetable disruption (including retouring)
Thank you very much for your attention.

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