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

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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

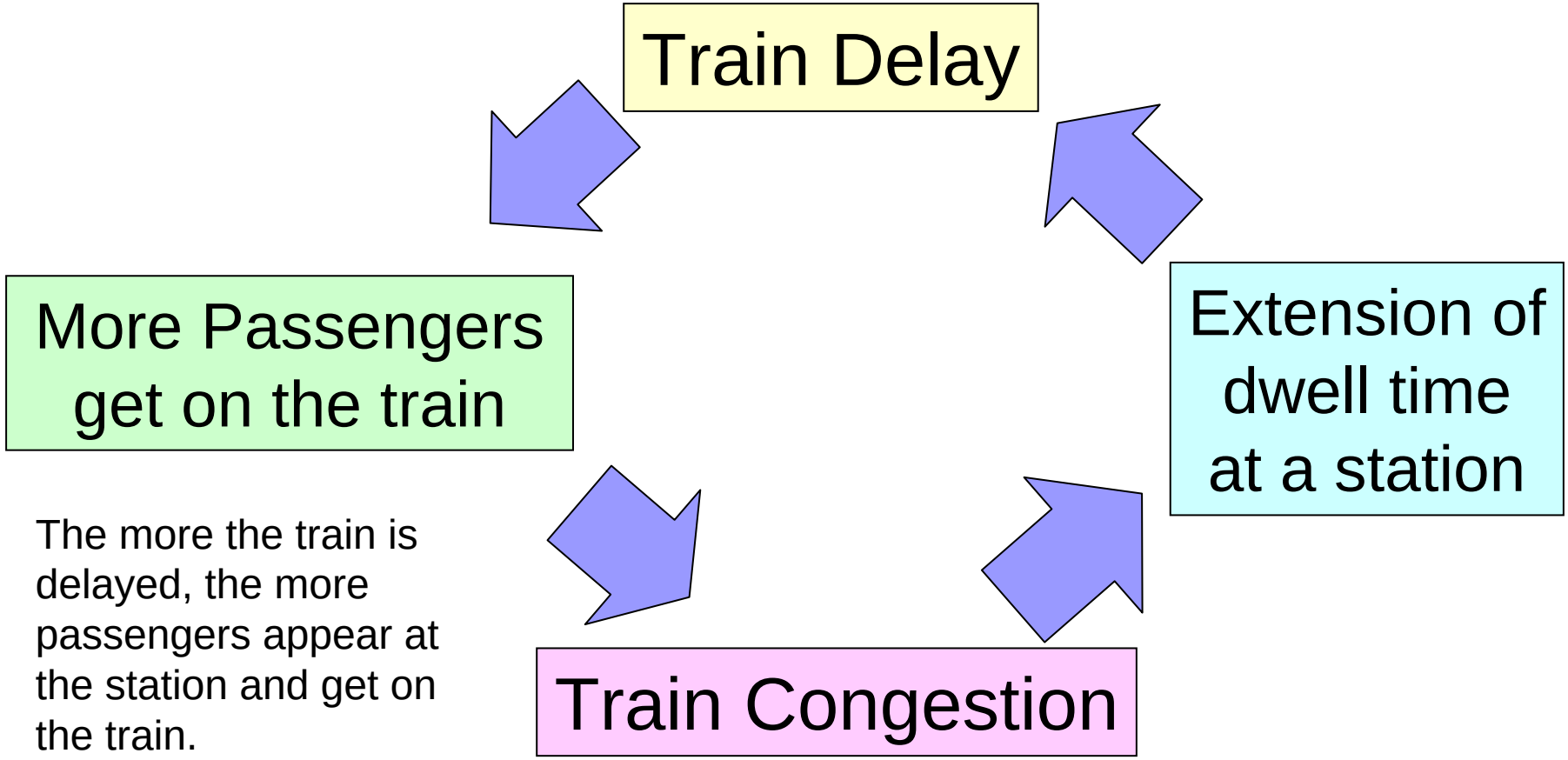
- Establish an appropriate evaluation method for train timetables

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



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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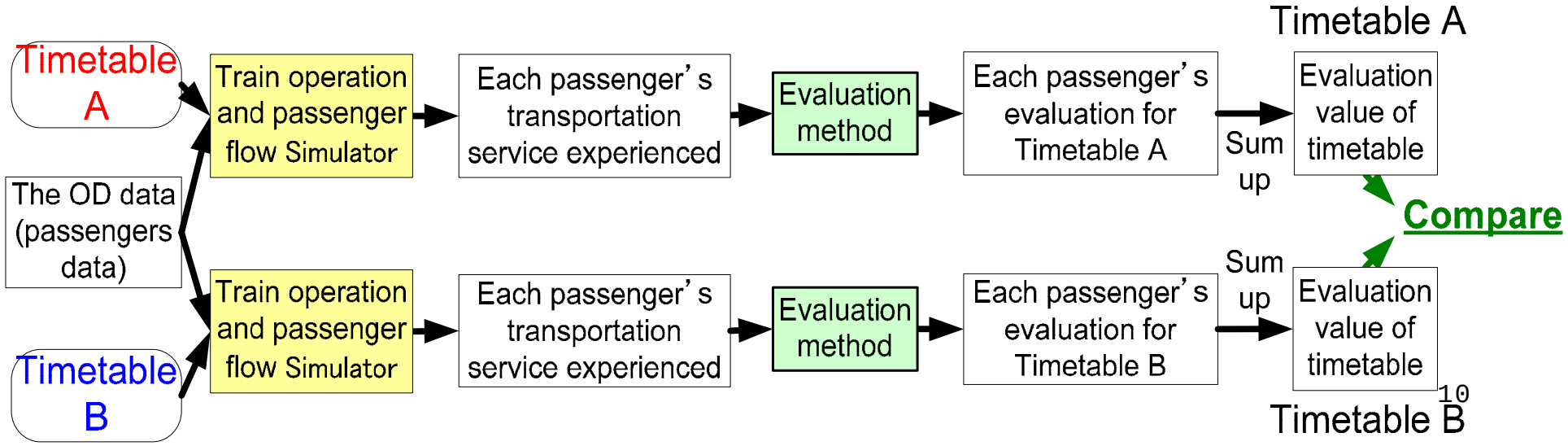
Our Approach for Timetable Evaluation

- 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

Congestion rate

Waiting time

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

Times of transfer

Dwell time in train car

α：0.019, **β**：4.52,
γ：5.62, **δ**：1.202

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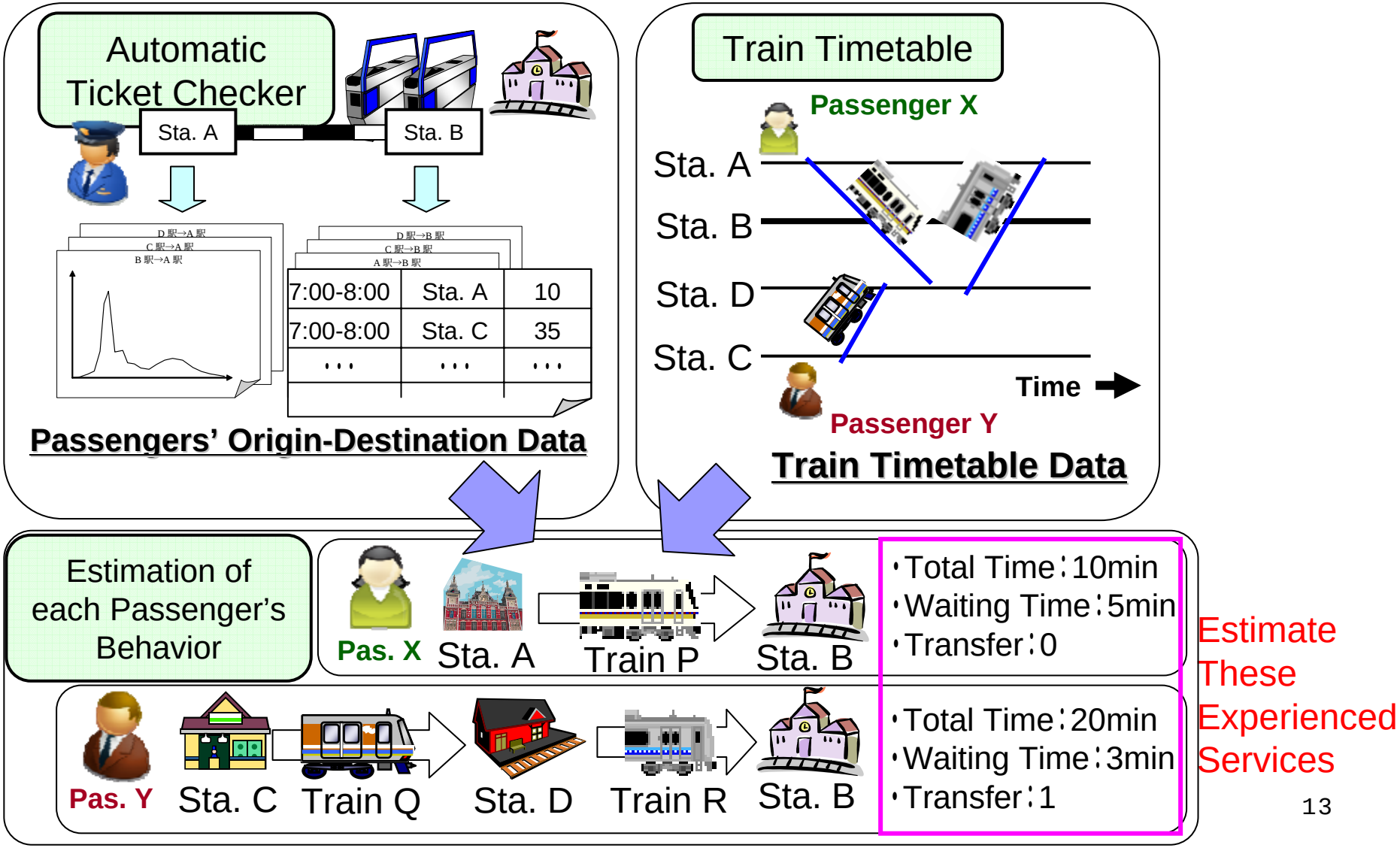
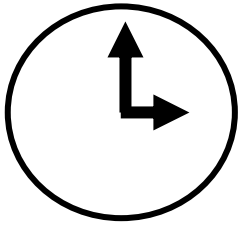
How Train Operation and Passenger Flow Simulator works?



Simulation Sequence

Based on the amount of passengers getting on or off



Share the clock

Re-Prediction of passenger's behavior

STEP 4 Estimation of Train Delay

STEP 1 Passenger Appearance

STEP 2 Passenger's Path Search for Destination

Passengers' Origin-Destination Data

Prediction of passenger's behavior

・which train to use?

・where to transfer?

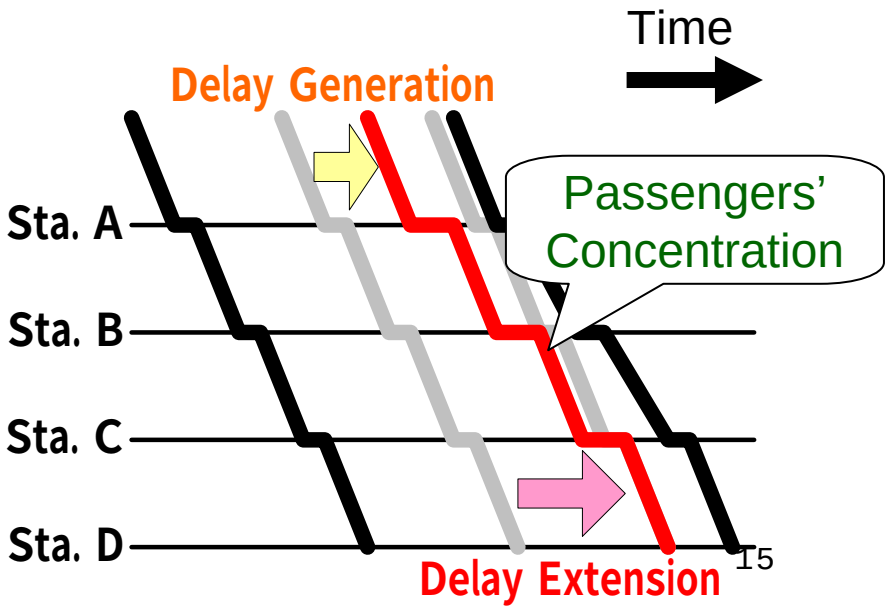
STEP 3 Getting on or off at Station

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

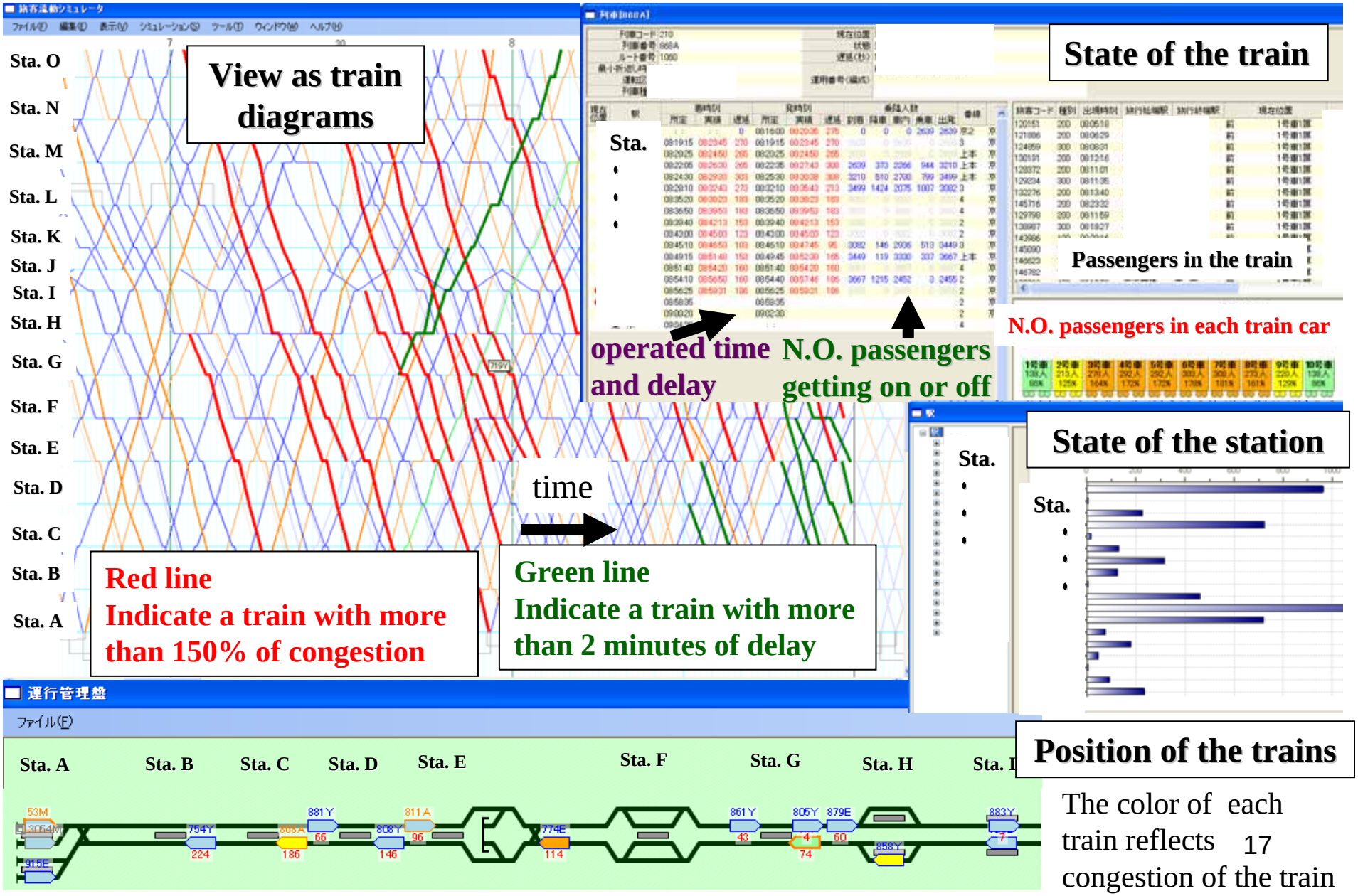
- Number of Passengers

  about 650 thousand passengers

- Simulation Time for a whole day

  about 30 min (using a standard desktop PC)

Screenshots of our Simulator



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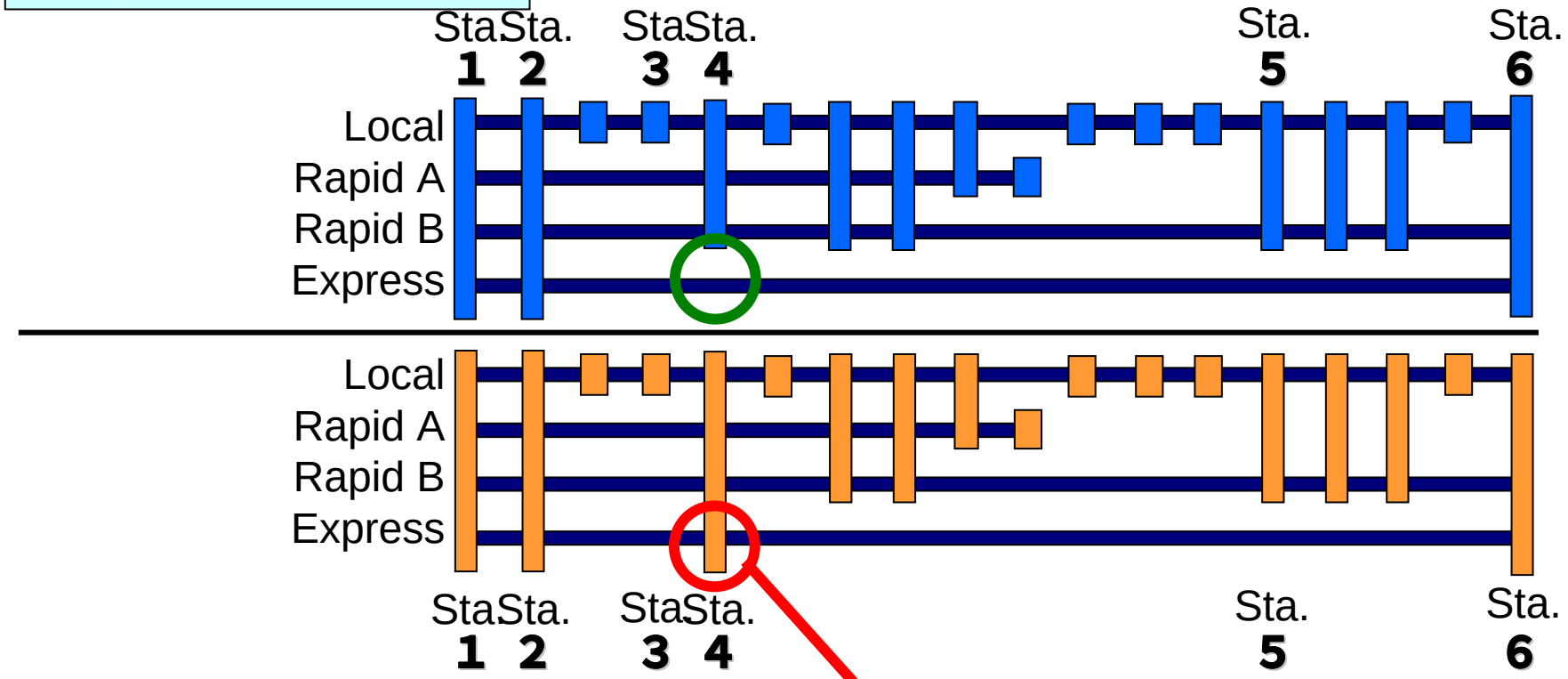
Two Timetables to be Compared

Temporal timetable (Timetable A)

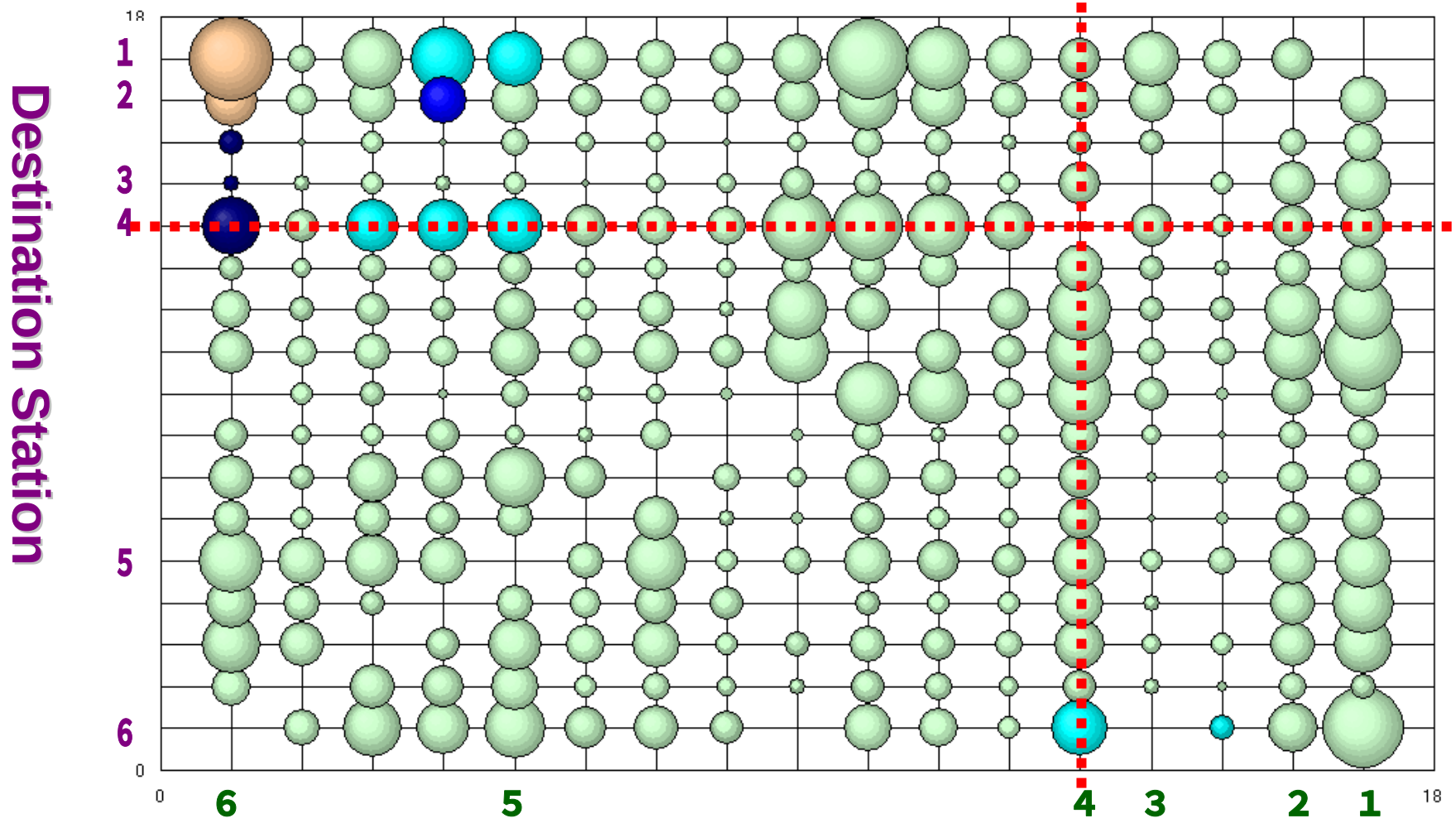


Revised timetable (Timetable B)

Express trains stop at Sta.4

Comparison of the Timetables from OD pairs

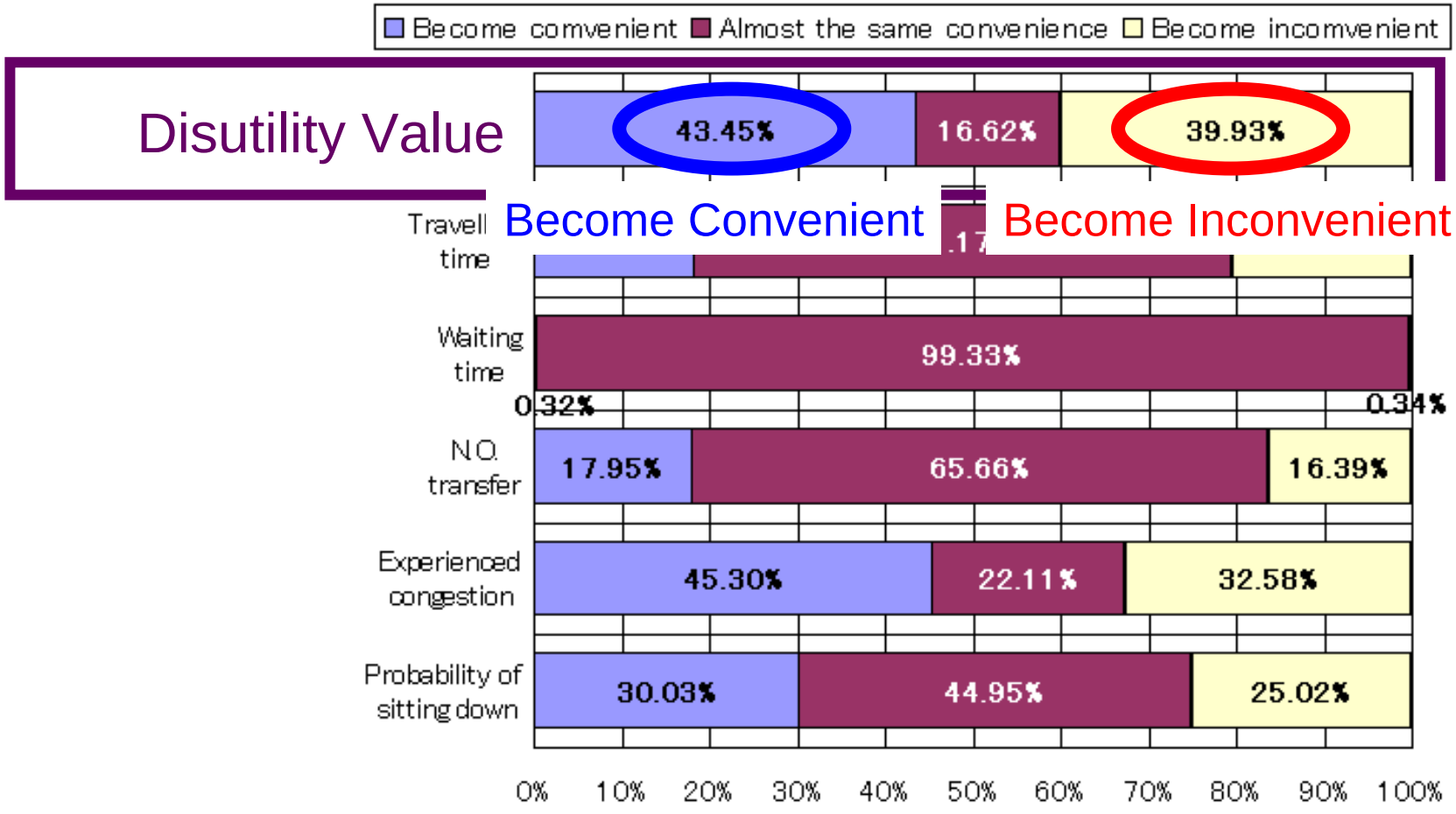
●：Timetable A is better ●：Almost the same convenience ●●：Timetable B is better



※the size of ○ 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



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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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