



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

 Taketoshi KUNIMATSU

Chikara HIRAI

Railway Technical Research Institute, Japan

Norio TOMII

Chiba Institute of Technology, Japan ₁

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



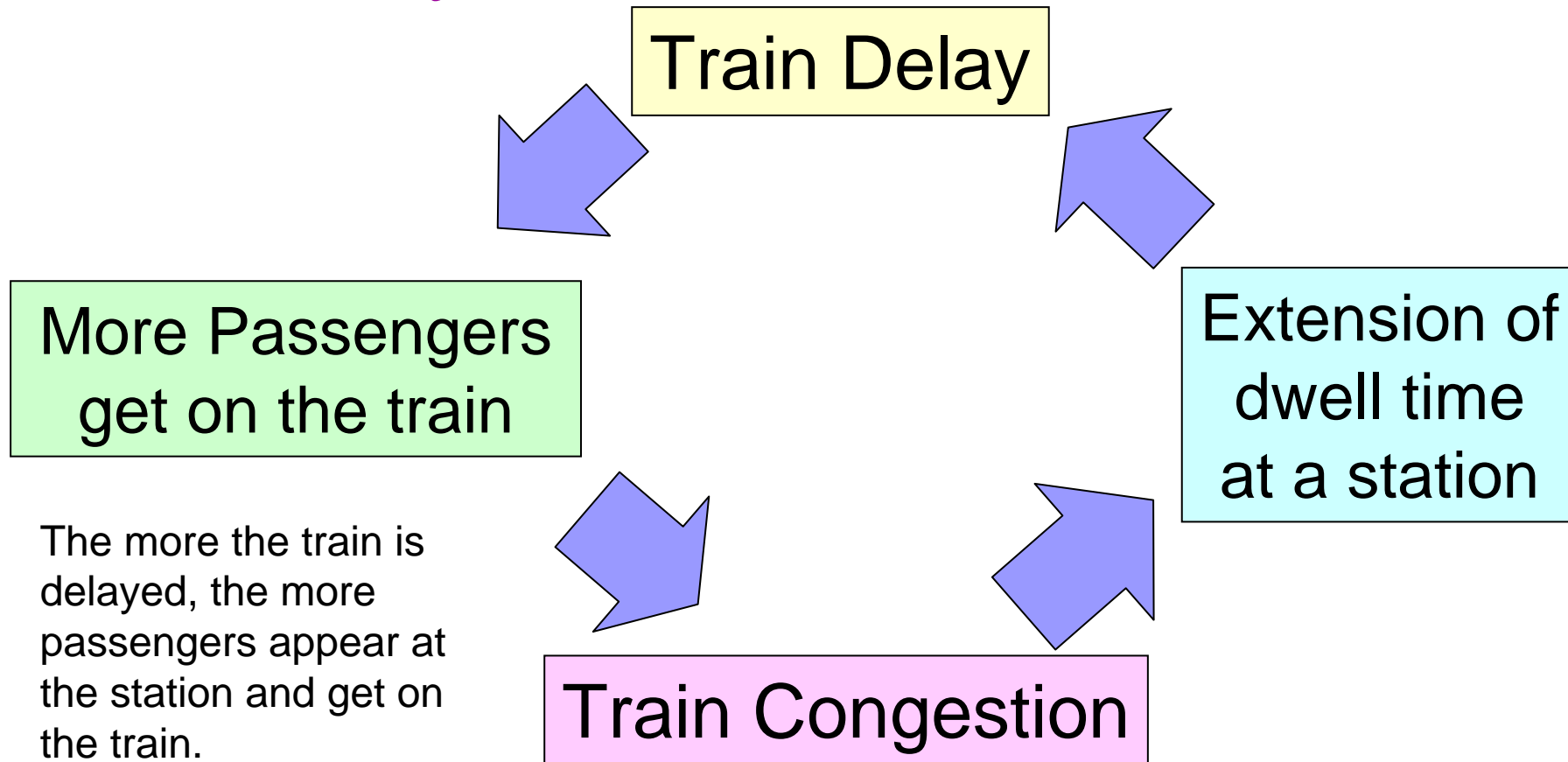
Requirements for Timetable Evaluation Index

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



This effect is caused by [dynamic interaction](#) between passengers and trains.

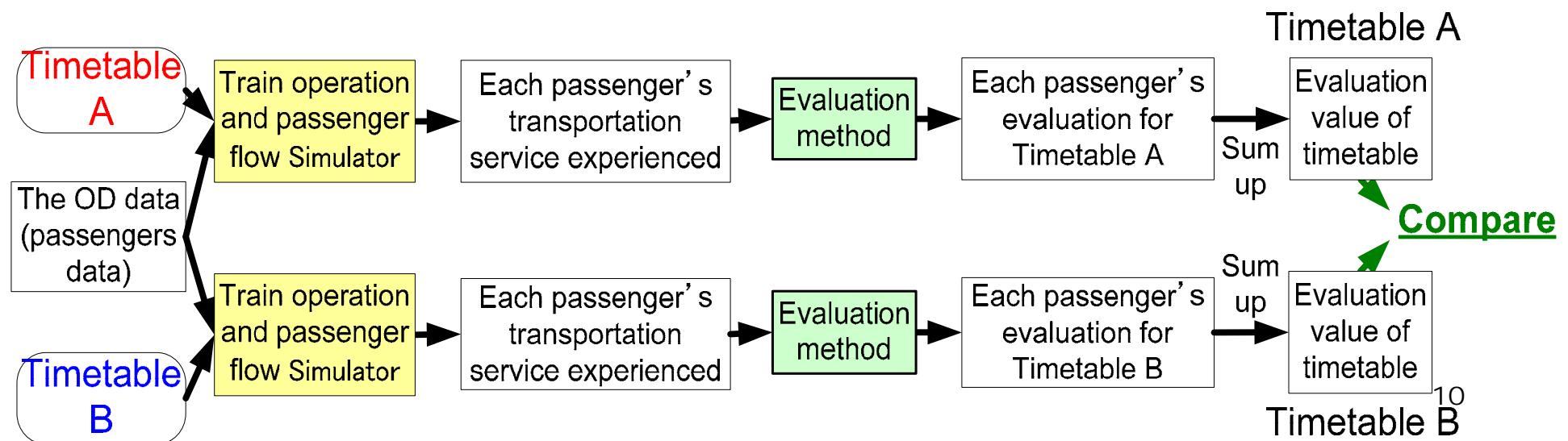
Avoidance of “Snowball effect” is very important

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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

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

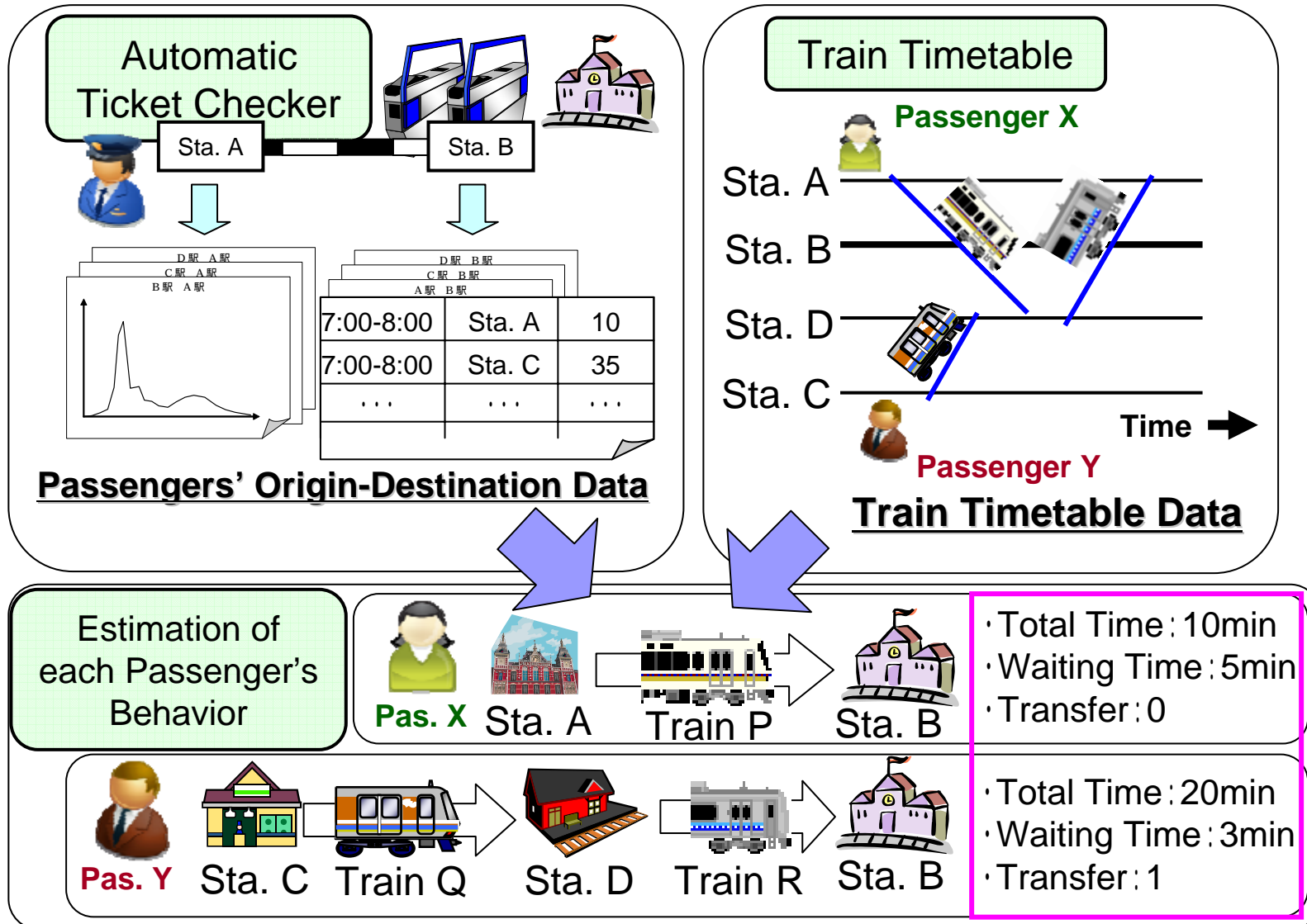
Congestion rate (points to $\left(\frac{C_j}{100} \right)^\beta$)
 Waiting time (points to T_W)
 Times of transfer (points to t_j)
 Dwell time in train car (points to T_R)

:0.019,	:4.52,
:5.62,	:1.202

Outline of Presentation

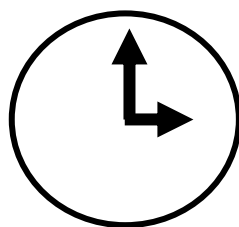
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How Train Operation and Passenger Flow Simulator works?



Simulation Sequence

Based on the amount of passengers getting on or off



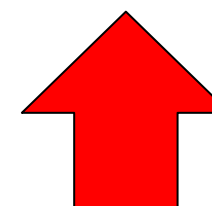
Share the clock

Re-Prediction of passenger's behavior

STEP 4
Estimation of Train Delay

STEP 1
Passenger Appearance

STEP 2
Passenger's Path Search for Destination



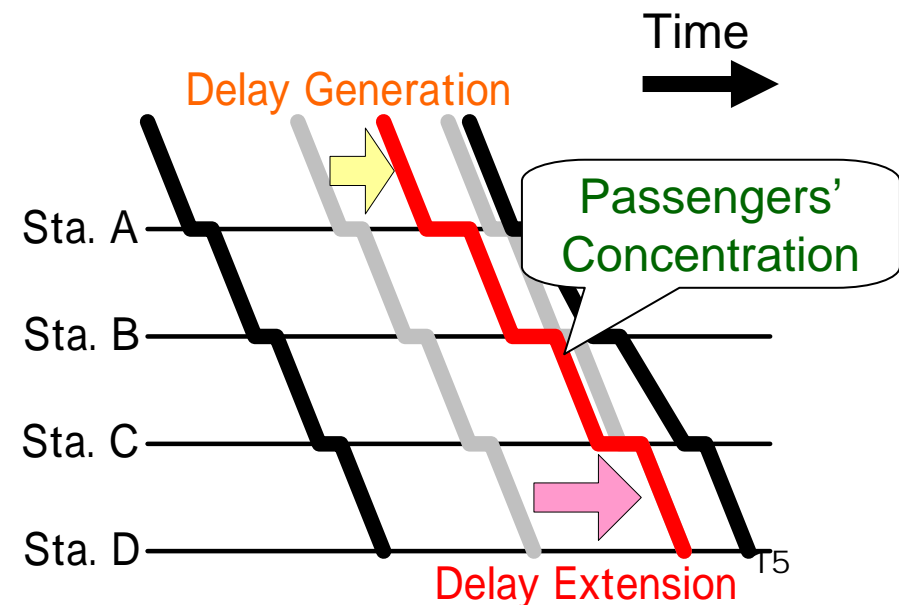
Passengers' Origin-Destination Data

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

View as train diagrams

State of the train

Passengers in the train

N.O. passengers in each train car

operated time and delay

N.O. passengers getting on or off

State of the station

Position of the trains

Red line
Indicate a train with more than 150% of congestion

Green line
Indicate a train with more than 2 minutes of delay

time

The color of each train reflects 17 congestion of the train

現在位置	駅	予定時刻	実績時刻	遅延	乗込人数	乗降人数	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	乗降率	
前	08:19:15	08:23:45	0	08:19:15	08:23:45	270	0	0	0	2509	2509	99.2%	前	120753	200	08:05:10	前	1号車11区
前	08:20:25	08:24:50	255	08:20:25	08:24:50	255	0	0	0	2509	2509	99.2%	前	121806	200	08:06:29	前	1号車11区
前	08:22:05	08:26:30	265	08:22:05	08:26:30	265	0	0	0	2609	2609	99.2%	前	124859	300	08:08:01	前	1号車11区
前	08:24:30	08:29:00	305	08:24:30	08:29:00	305	0	0	0	3210	3210	99.2%	前	130191	200	08:12:16	前	1号車11区
前	08:26:10	08:30:40	270	08:26:10	08:30:40	270	0	0	0	3499	3499	99.2%	前	128372	200	08:11:01	前	1号車11区
前	08:28:20	08:32:50	189	08:28:20	08:32:50	189	0	0	0	3499	3499	99.2%	前	132276	200	08:13:40	前	1号車11区
前	08:30:50	08:35:20	189	08:30:50	08:35:20	189	0	0	0	3499	3499	99.2%	前	145716	200	08:23:32	前	1号車11区
前	08:33:40	08:38:10	123	08:33:40	08:38:10	123	0	0	0	3499	3499	99.2%	前	129798	200	08:11:59	前	1号車11区
前	08:36:40	08:41:10	153	08:36:40	08:41:10	153	0	0	0	3499	3499	99.2%	前	138987	300	08:18:27	前	1号車11区
前	08:40:00	08:45:00	123	08:40:00	08:45:00	123	0	0	0	3499	3499	99.2%	前	143866	300	08:24:52	前	1号車11区
前	08:43:10	08:48:10	103	08:43:10	08:48:10	103	0	0	0	3082	3082	99.2%	前	147090	300	08:31:03	前	1号車11区
前	08:46:15	08:51:15	153	08:46:15	08:51:15	153	0	0	0	3449	3449	99.2%	前	146623	300	08:37:14	前	1号車11区
前	08:49:15	08:54:15	160	08:49:15	08:54:15	160	0	0	0	3667	3667	99.2%	前	146782	300	08:43:25	前	1号車11区
前	08:51:40	08:56:40	160	08:51:40	08:56:40	160	0	0	0	3667	3667	99.2%	前	146782	300	08:49:36	前	1号車11区
前	08:54:10	08:59:10	106	08:54:10	08:59:10	106	0	0	0	3667	3667	99.2%	前	146782	300	08:55:47	前	1号車11区
前	08:56:25	09:01:25	106	08:56:25	09:01:25	106	0	0	0	3667	3667	99.2%	前	146782	300	09:01:58	前	1号車11区
前	08:58:35	09:03:35	106	08:58:35	09:03:35	106	0	0	0	3667	3667	99.2%	前	146782	300	09:08:09	前	1号車11区
前	09:00:20	09:05:20	106	09:00:20	09:05:20	106	0	0	0	3667	3667	99.2%	前	146782	300	09:14:20	前	1号車11区

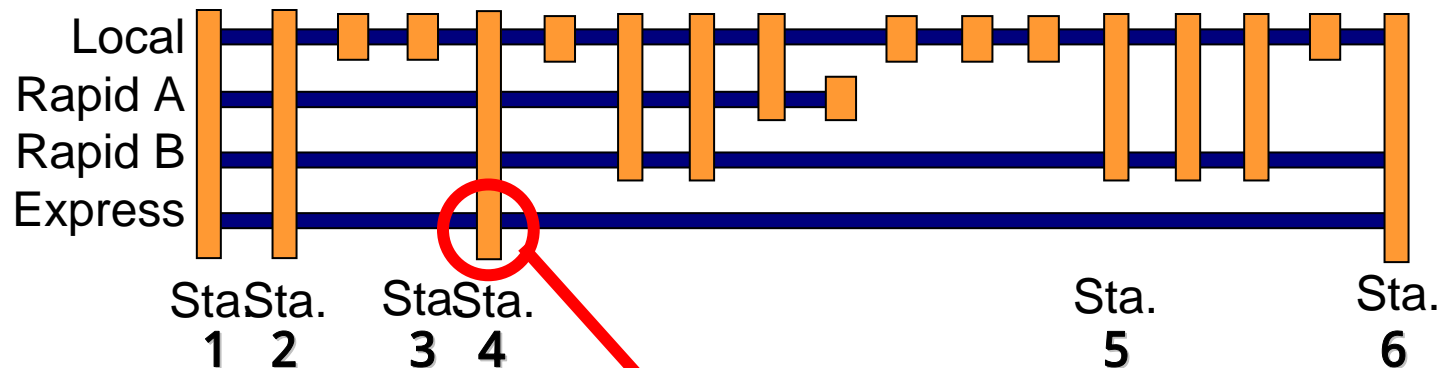
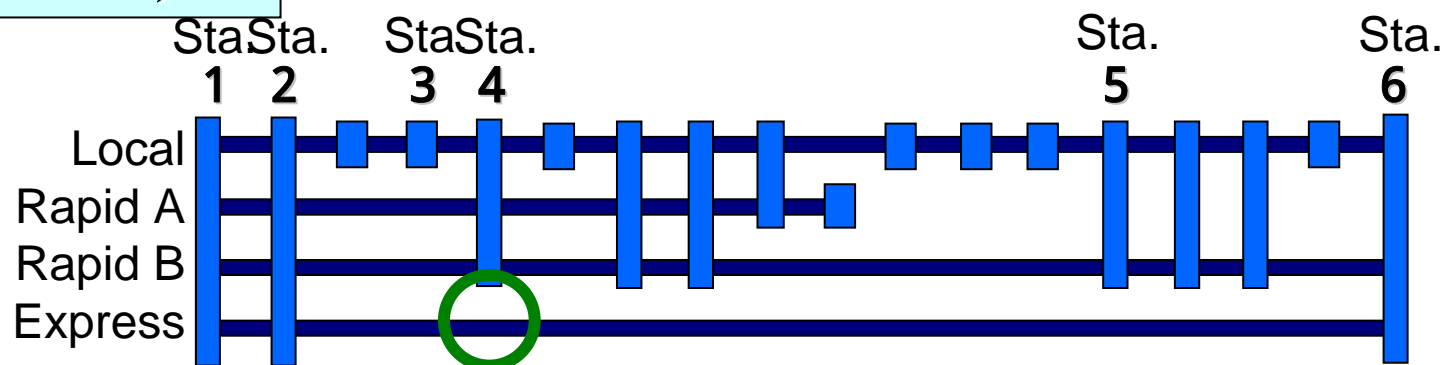
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Two Timetables to be Compared

Temporal timetable (Timetable A)

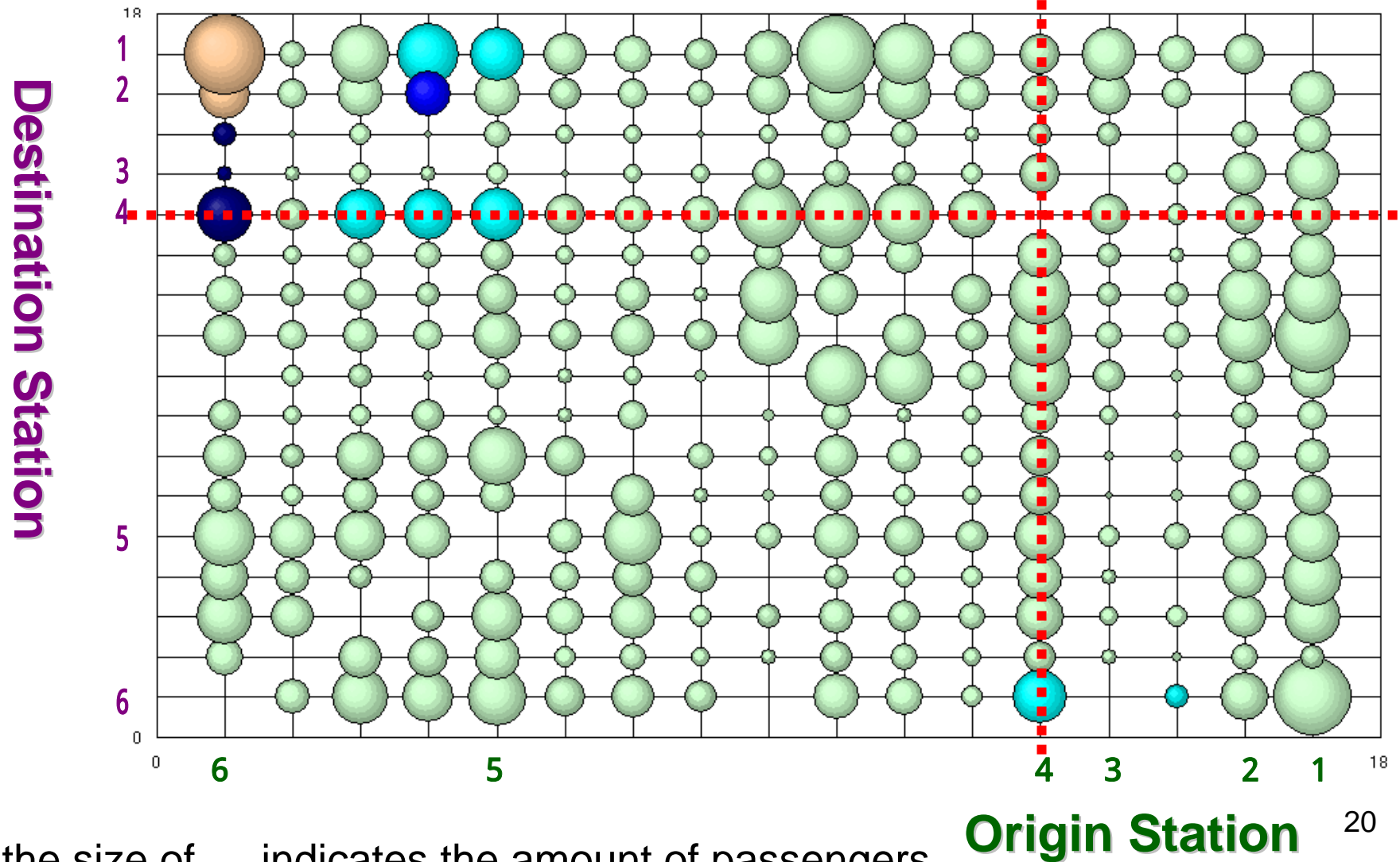


Revised timetable (Timetable B)

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



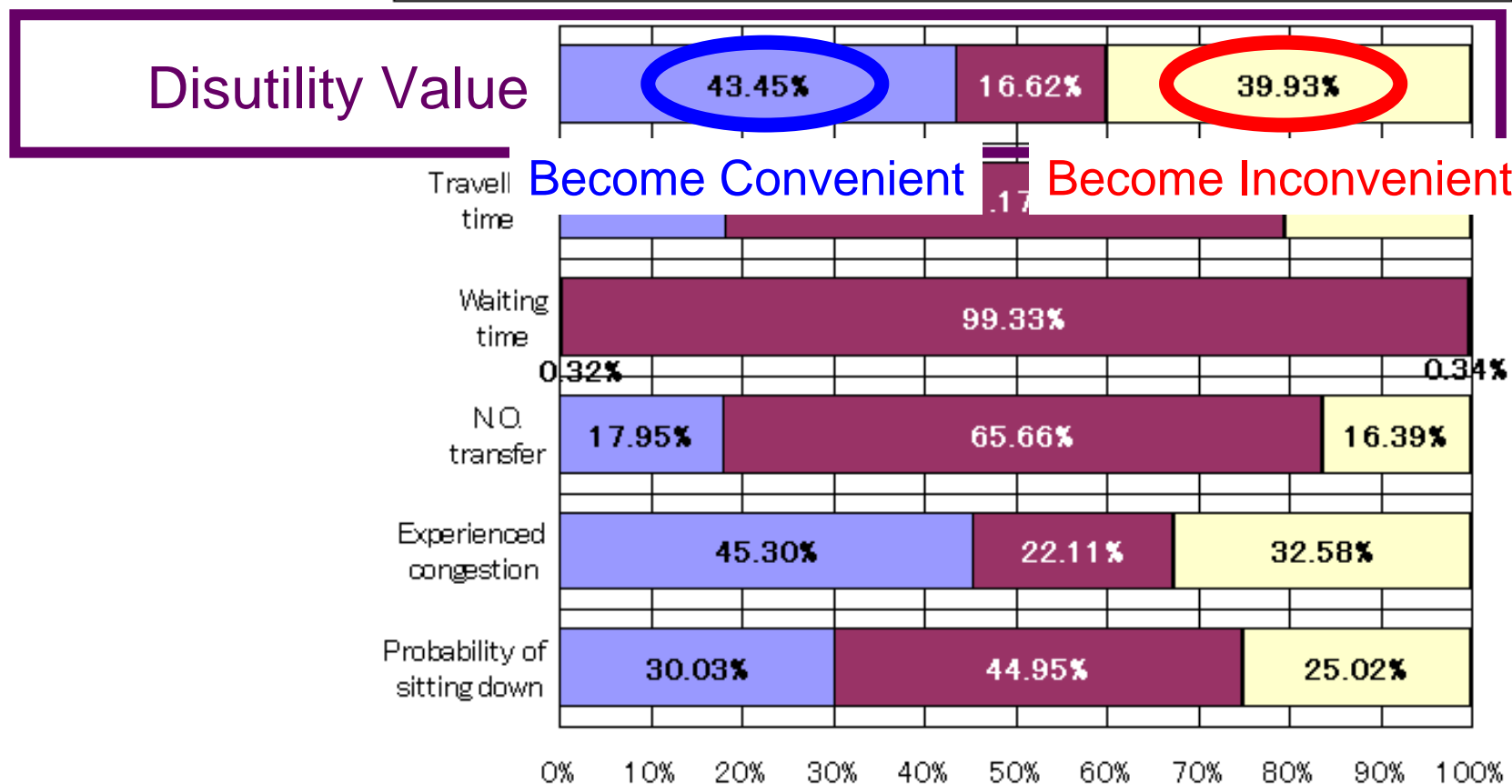
the size of indicates the amount of passengers

Origin Station 20

Comparison of the Timetables from other aspects

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

■ Become convenient
 ■ Almost the same convenience
 ■ Become inconvenient



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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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