We transport numerous guests comfortably and flexibly

## Abstract

Shuttle bus service planning is determined by the route network and timetable. Achieving an appropriate balance between the operating company's costs and passenger convenience is an important issue. Our new formulation of an integer linear programming problem incorporates waiting time, calculated from the number of people waiting in line at bus stops, in the objective function. Furthermore, our method automatically determines the optimal route network and number of buses based on demand forecasts. By developing this technology and making it applicable to conventional route buses, we aim to contribute to a future with flexible and convenient public transportation networks.

Research Goal

To generate appropriate **shuttle bus operation plans** for massive events with **difficult to predict number of visitors**

Station → Transportation ← Route ← Event Site
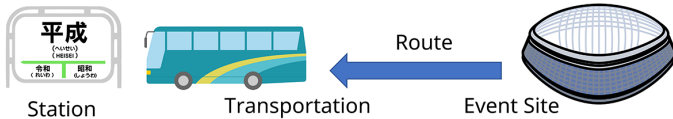
When a route with multiple bus stops is efficient?

- ☺ The numbers of vacant seats and vehicles can be reduced
- ☹ Multiple bus stops make ride time longer
- ☹ Less bus service leads to longer wait time

Issue : Fixing the bus route network based on the number of visitors increases operating costs, ride time, and wait time when predictions come out wrong.

Formulation

Integer linear programming problem including **both visitor burden and operator cost** in the objective function

| Ride Cost | Path Cost |
| Wait Cost | Overflow Cost | Vehicle Cost |
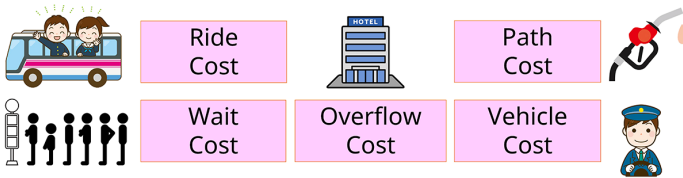
Visitors want to reach their destination as quickly as possible.

The operator wants to keep # vehicles and vehicle mileage small.

We use an ILP solver to minimize total costs

→ · Optimizing Simultaneously route networks & timetables
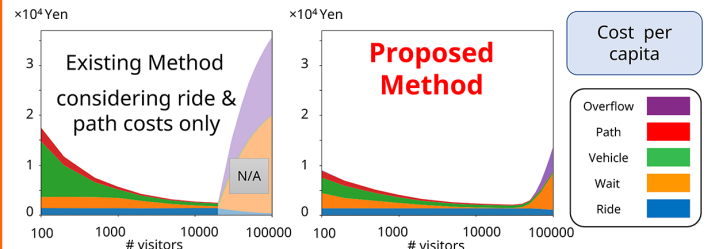· Reducing computational complexity by limiting # routes

Proposed Method [1]

To include wait cost in the objective, we introduce a constraint based on **the law of conservation** of # people in the queue

Change in # in the queue

riding

$$w_{(t+1)}^m - w_t^m = x_t^m - \sum_{\ell \mid m \in \ell} b_{t\ell}^m$$
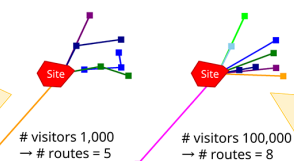
arriving

t ··· $t+1$
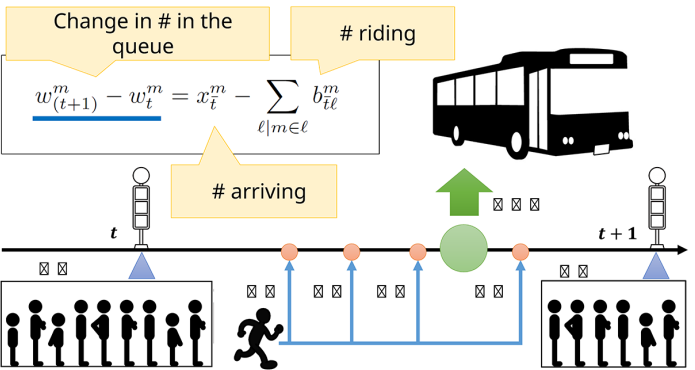
Experiment

Assuming a massive event in Osaka

Our method can generate a shuttle bus operation plan that **balances both visitor burden and operator cost**

×10⁴ Yen

Existing Method considering ride & path costs only

N/A

×10⁴ Yen

Proposed Method

Cost per capita

- Overflow
- Path
- Vehicle
- Wait
- Ride

visitors

For few visitors
- Adopt routes that visit multiple bus stops
- Reduce operator cost

For many visitors
- Adopt direct routes to their destinations
- Increase usability & transportation capacity

visitors 1,000 → # routes = 5

visitors 100,000 → # routes = 8

→ Route network is optimized according to # visitors

References

[1] H. Shimizu, A. Fujino, H. Sawada, N. Ueda, "Optimizing Route Network and Timetable of Shuttle Bus for Massive Events," (in Japanese) *Transactions on Mathematical Modeling and its Applications (TOM) of the Information Processing Society of Japan (IPSJ)*, 2023 (To appear).

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