Optimization of NYU Shanghai Shuttle Bus Schedule

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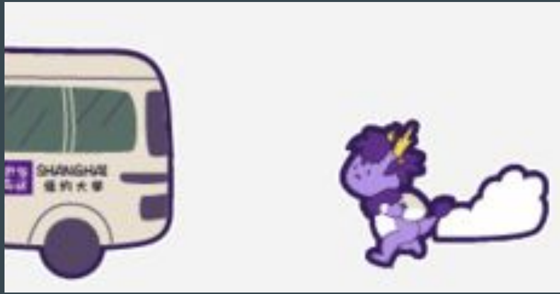
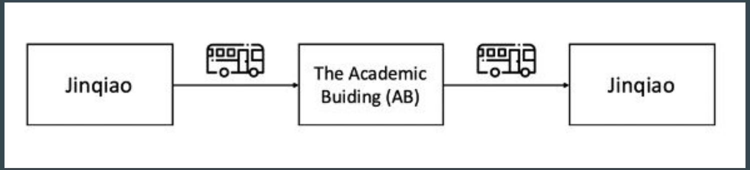
Background: Identify problem

NYU Shanghai shuttle bus

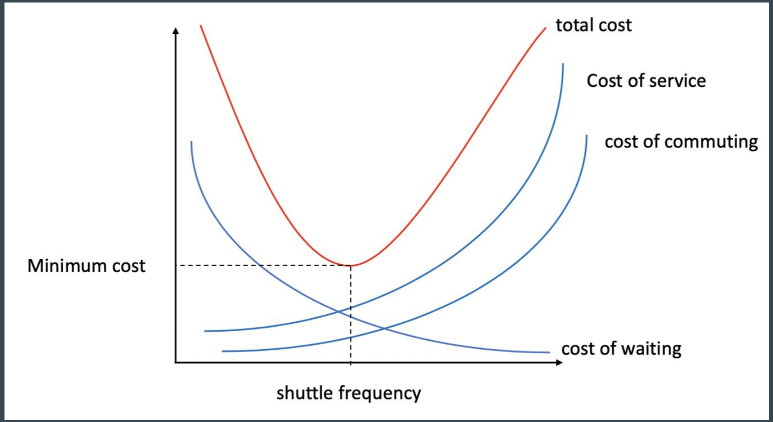


WeChat meme named “late for school”

Assumption & Objective



Z = cost of waiting + cost of commuting + cost of service



Model

Z = cost of waiting + cost of commuting + cost of service

$$\min \sum_{k=1}^{S} \sum_{i=1}^{\frac{1080}{T}} \frac{T}{B_i} \sum_{j=1}^{\frac{B_i}{F_{i,k}}} (B_i - F_{i,k})$$

s.t.

$$N_i \le N, for\ \forall i$$

$$\frac{xz}{y} \sum_{i=1}^{\frac{1080}{T}} N_i \le G$$

$$\sum_{i=1}^{\frac{1080}{T}} \frac{N_i T}{60} \le H$$

$$N_i = \frac{60L}{vB_i}$$

$$\frac{T}{B_i}, N_i \in \mathbb{Z}, for\ \forall i$$

All variables nonnegative

$$\min Z = C_k$$

s.t.

$$C_k = V_k + F_k + O_k$$

$$V_k = c_1 \sum_{i=1}^{N-1} P_{i,k} T_{i,k}$$

$$F_k = c_2 \sum_{i=1}^{N} B_{i,k} W_{i,k}$$

$$O_k = c_3 \sum_{i=1}^{N-1} T_{i,k} + c_4 \sum_{i=1}^{N-1} S_i$$

$$P_{i,k} \le \sigma$$

Model

$$\min Z = V + F + O$$

s.t.

$$V = c_1 \sum_{i=1}^{\frac{18}{T}} \left[\frac{T}{B_{xi}} \sum_{j=1}^{N_{xki}} \left(B_{xi} - \frac{B_{xi}}{N_{xki}} j\right) + \frac{T}{B_{yi}} \sum_{j=1}^{N_{yki}} \left(B_{yi} - \frac{B_{yi}}{N_{yki}} j\right) \right]$$

$$F = c_2 \sum_{i=1}^{\frac{18}{T}} \left| Hi\left(\sum_{k=1}^{\frac{T}{B_{xi}}} \text{Nxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \text{Nyki}\right) \right|$$

$$O = \sum_{i=1}^{\frac{18}{T}} \left[c_3 Hi\left(\sum_{k=1}^{\frac{T}{B_{xi}}} \text{Lxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \text{Lyki}\right) + c_4 S \left(\sum_{k=1}^{\frac{T}{B_{xi}}} \text{Lxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \text{Lyki}\right) \right]$$

$$L_{xi} = \sum_{k} L_{xki}$$

$$L_{yi} = \sum_{k} L_{yki}$$

$$0 \le N_{xi} \le \sigma L_{xi}$$

$$0 \le N_{yi} \le \sigma L_{yi}$$

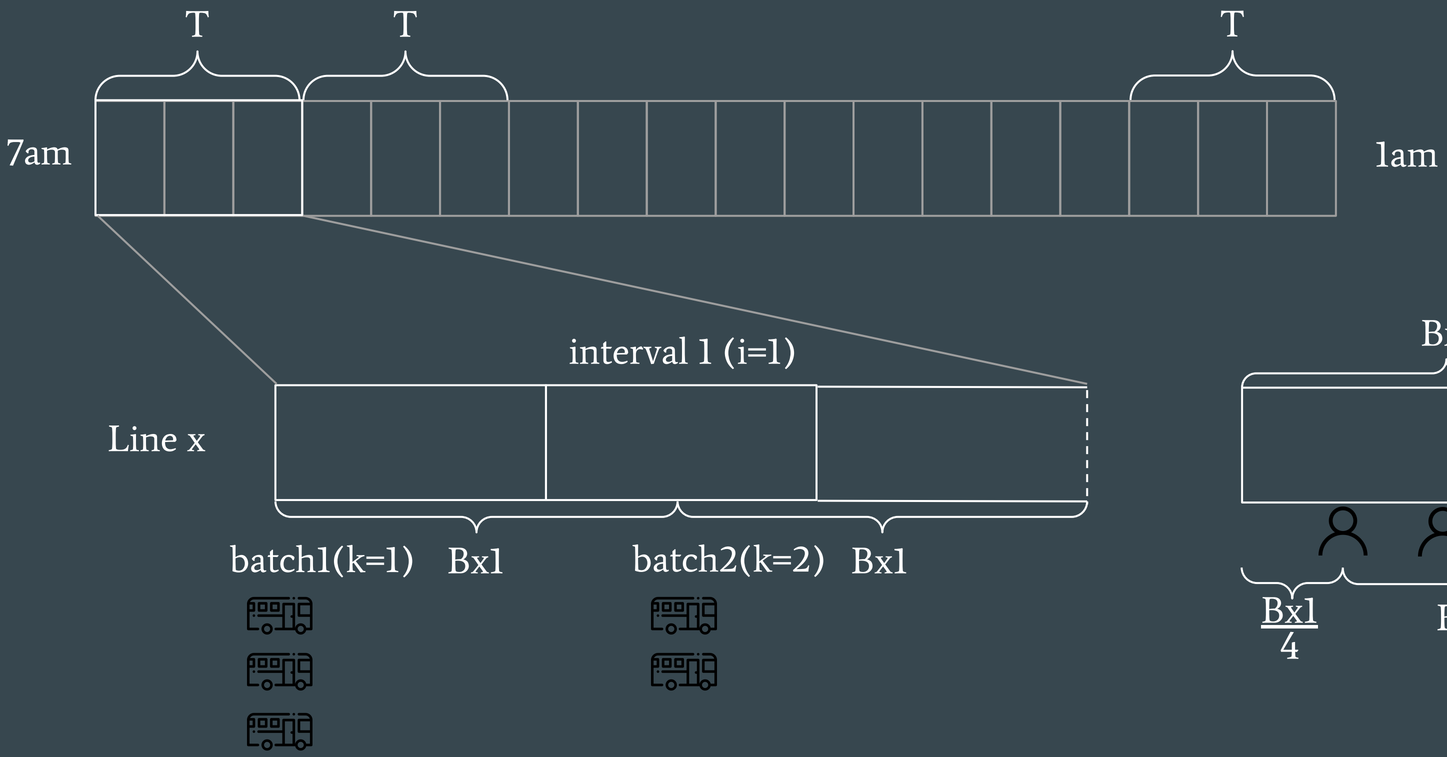
$$\sum_{i=1}^{\frac{18}{T}} L_{xi} - \sum_{i=1}^{\frac{18}{T}} L_{yi} = 0$$

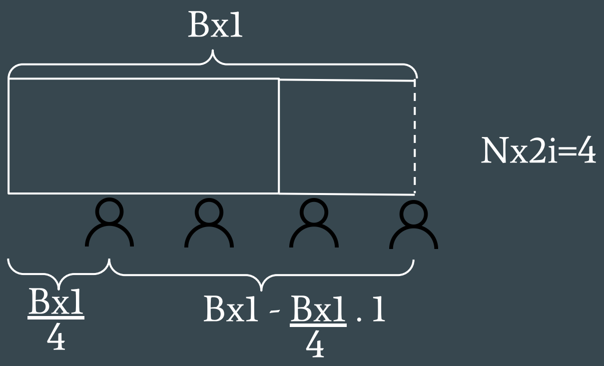
All variables non-negative

Model：Cost of waiting

$$V = c_1 \sum_{i=1}^{\frac{18}{T}} \left[\frac{T}{B_{xi}} \sum_{j=1}^{N_{xki}} \left(B_{xi} - \frac{B_{xi}}{N_{xki}} j\right) + \frac{T}{B_{yi}} \sum_{j=1}^{N_{yki}} \left(B_{yi} - \frac{B_{yi}}{N_{yki}} j\right) \right]$$

x: from Jinqiao to AB
y: from AB to Jinqiao
i: interval number
k: batch number





x: from Jinqiao to AB
y: from AB to Jinqiao
i: interval number
k: batch number

Cost of commuting & Cost of service

$$F = c_2 \sum_{i=1}^{\frac{18}{T}} \left[Hi\left(\sum_{k=1}^{\frac{T}{B_{xi}}} \mathrm{Nxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \mathrm{Nyki}\right) \right]$$

$$O = \sum_{i=1}^{\frac{18}{T}} \left[c_3 Hi\left(\sum_{k=1}^{\frac{T}{B_{xi}}} \mathrm{Lxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \mathrm{Lyki}\right) + c_4 S\left(\sum_{k=1}^{\frac{T}{B_{xi}}} \mathrm{Lxki} + \sum_{k=1}^{\frac{T}{B_{yi}}} \mathrm{Lyki}\right) \right]$$

H: commuting time
N: number of people
S: distance
L: number of buses
c1 c2: unit time value
c3: unit personnel cost
c4: unit operational cost

Constraint

σ : total seats on one shuttle

There should be enough seats for all students:

$$0 \leq N_{xi} \leq \sigma L_{xi}$$
$$0 \leq N_{yi} \leq \sigma L_{yi}$$

All buses return to Jinqiao at night:

$$\sum_{i=1}^{\frac{18}{T}} L_{xi} - \sum_{i=1}^{\frac{18}{T}} L_{yi} = 0$$

All variables non-negative

Data

NYU Shanghai Academic Affairs

Where to go?

- Modify model: poisson instead of uniform distribution
- More constraints
- Probability of students missing the shuttle
- Gather authentic data when the campus reopens
- etc...

References

Kornfeld, S., Ma, W. and Resnikoff, A. Optimizing Bus Schedules to Minimize Waiting Time, Operations Research II, 21-393.

Sun, Daniel (Jian), et al. Timetable optimization for single bus line based on hybrid vehicle size model, Journal of Traffic and Transportation Engineering (English Edition) Volume 2, Issue 3, June 2015, Pages 179-186.

Thank you for listening!

Q&A