Project Proposal
Optimization of NYU Shanghai Shuttle Bus Schedule

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1 Introduction

The shuttle bus service is essential to the everyday life of NYU Shanghai students and faculty. Many students choose shuttle buses to commute between residential halls and Pudong campus. Maintaining the shuttle bus service is also a crucial part of the school budget. As convenient as the shuttle bus service may be, there still exist unsatisfactory incidents. Have you ever found yourself waiting in the line to get on the last shuttle in the morning just to be informed there are no more seats? Have you ever gone downstairs ten minutes earlier to go back to Jinqiao just to find the one shuttle bus has been long gone?

In this project, we are hoping to deal with the common pains of wasting time due to the unreasonable shuttle timetable. However, increasing bus frequency to shorten waiting time will cause the service cost to skyrocket. Therefore, we aim to construct a mathematical model to optimize NYU Shanghai shuttle bus timetable that balances the trade-off between total waiting and commuting time for students and service costs for the school.

2 Methodology

While NYU Shanghai has three residential halls and the schedule may be different during weekend, midterm exams and final exams, to simplify our model, we make the following assumptions:

• All shuttle buses commute only between Jinqiao and school since the existing bus schedules (See appendix A) for all residential halls are identical.

• All shuttle buses depart from Jinqiao in the morning and return to Jinqiao at the end of the night with no shuttle bus parking at the academic building (AB) overnight.

• Shuttle bus service starts from 7 am and ends at 1 am every day with no schedule changes on special occasions.

The waiting time is essential in making the timetable. We draw inspirations from a study on Pittsburgh buses by Carnegie Mellon University (See Appendix B) and assume students arrive at even intervals. We will input the number of students waiting between two shuttles to obtain the total waiting time.

Furthermore, to find the best trade-off, we construct the optimization function with the help of a study of flexible timetable optimization (See Appendix C). We will input the distance between dorm and school and the commuting time of each shuttle according to the traffic condition to compute the commuting time and cost of the shuttle bus service. With the interval and the number of shuttle buses as decision variables, we intend to minimize the function of waiting time, commuting time and cost. Main constraints include the maximum of seats, number of shuttles and commuting time.

3 Data Source & Description

Since there is no public data for reference, we will collect or estimate data on our own. We will obtain the commuting time and commuting distance using google map or Gaode map. For basic statistics such as the total number of shuttle bus, we will ask Public Safety or shuttle bus drivers. We plan to get the number of waiting students of different time periods according to course schedules. If we are not able to collect data from Academic Affairs, we will estimate the data based on personal experience and perhaps questionnaire responses from a broader student body. Overall, we will make reasonable assumptions and use mathematical formulation to reduce the difficulty of collecting a massive amount of data.

Appendix A: Existing Shuttle Bus Schedule

Bus Schedule for JINQIAO Residence Halls Fall 2019

Monday to Friday/周一至周五	
JQ/JY Residence to Pudong Campus 宿舍至浦东校园	Pudong Campus to JQ/JY Residence 浦东校园至宿舍
7:15	-
8:45	-
-	9:45
10:30	-
11:45	11:45
12:45	12:45
-	13:45
14:15	14:45
15:15	15:15
16:15	16:15
-	16:45
-	17:15
-	17:45
-	18:15
-	18:45
-	19:15 *
19:30	-
-	19:45
-	20:15 *
-	20:45
-	21:15 *
-	21:45
-	22:15 *
-	22:45
	23:15 *
-	23:45 *

* For Monday to Thursday only. The last bus on Friday departs on 22:45, going from Campus to Dorm

Table 1. Current Shuttle Schedule of Jinqiao (Public Safety)

Appendix B: Pittsburgh Bus Model

To optimize the Pittsburgh bus schedule, Kornfeld, Ma and Resnikoff formulated a model to minimize total waiting time for passengers. The following variables in their model are defined:

- Time intervals of T minutes (chosen to be meaningful based on periods of relatively consistent passenger arrivals)
- Inter-person arrival time $F_{i,k}$ minutes during interval i at stop k
- N buses available
- Gas budget G dollars per day
- x miles traveled during one time interval
- Fuel efficiency y miles per gallon
- Price of gas z dollars per gallon
- H hours of labor available each day
- Average speed v along line of length L
- Operate N_i buses on our line during time interval i
- Inter-bus arrival time B_i during time interval i

Kornfeld, Ma and Resnikoff assume passengers arrive on even interval and formulate the problem as:

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

s.t.

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

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

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

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

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

All variables nonnegative

Appendix C: Optimization Model

The model minimizes the total cost for the kth trip of a vehicle bus with 29 seats. The total cost Z involves in-vehicle time cost V_k with a weight parameter c_1, waiting time cost F_k with a weight parameter c_2 and operation cost O_k with two weight parameters c_3, c_4. The rest of parameters and variables are defined as the following:

- N: The number of stops.
- $P_{i,k}$: The number of passengers in the vehicle when a vehicle driving from stop i to i+1 for the kth bus trip
- $T_{i,k}$: Commuting time from stop i to i+1 for the kth bus trip
- $B_{i,k}$: The number of boarding passengers at stop i for the kth bus trip
- $W_{i,k}$: The average waiting time at stop i for the kth bus trip
- S_i: The distance between stops i and i+1
- σ: the total seats

The model is presented as follows:

$$\min Z = C_k$$

s.t.

$$C_k = V_k + F_k + O_k$$

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

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

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

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

References

NYU Shanghai department of Public Safety, Bus Schedule for Jinqiao Residential Halls Fall 2019.

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.