

## Data File

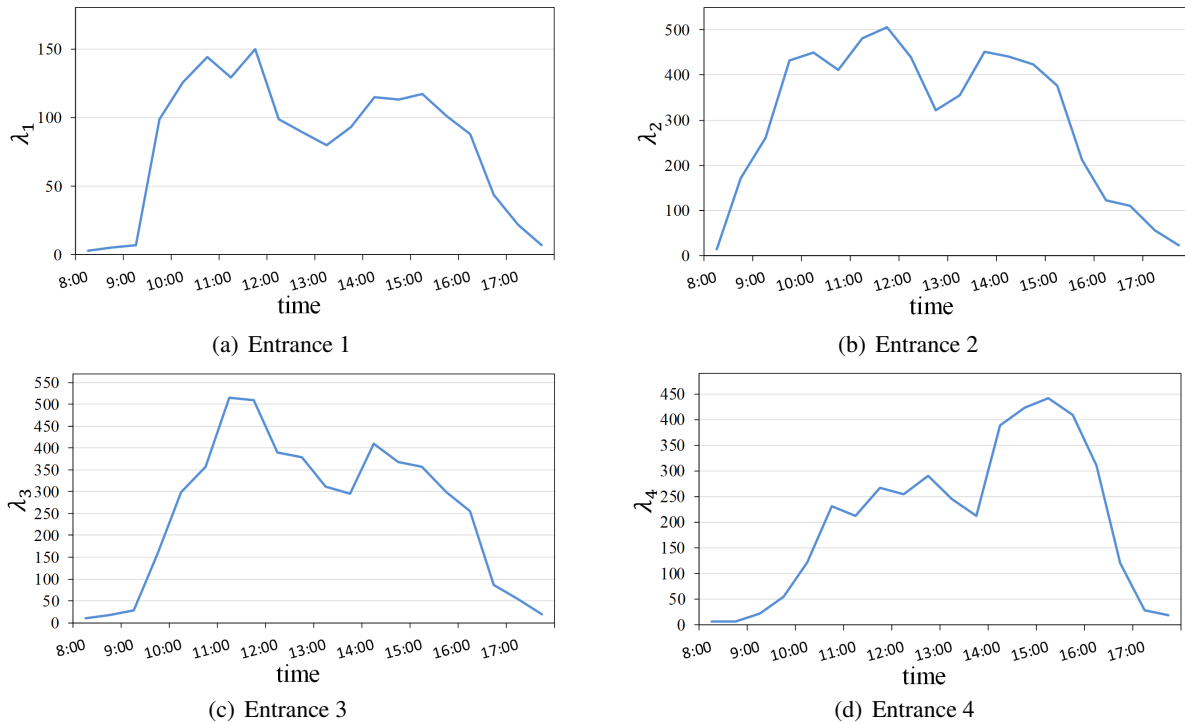
### Data.1 SBG Data and Current SBG Employee Schedules

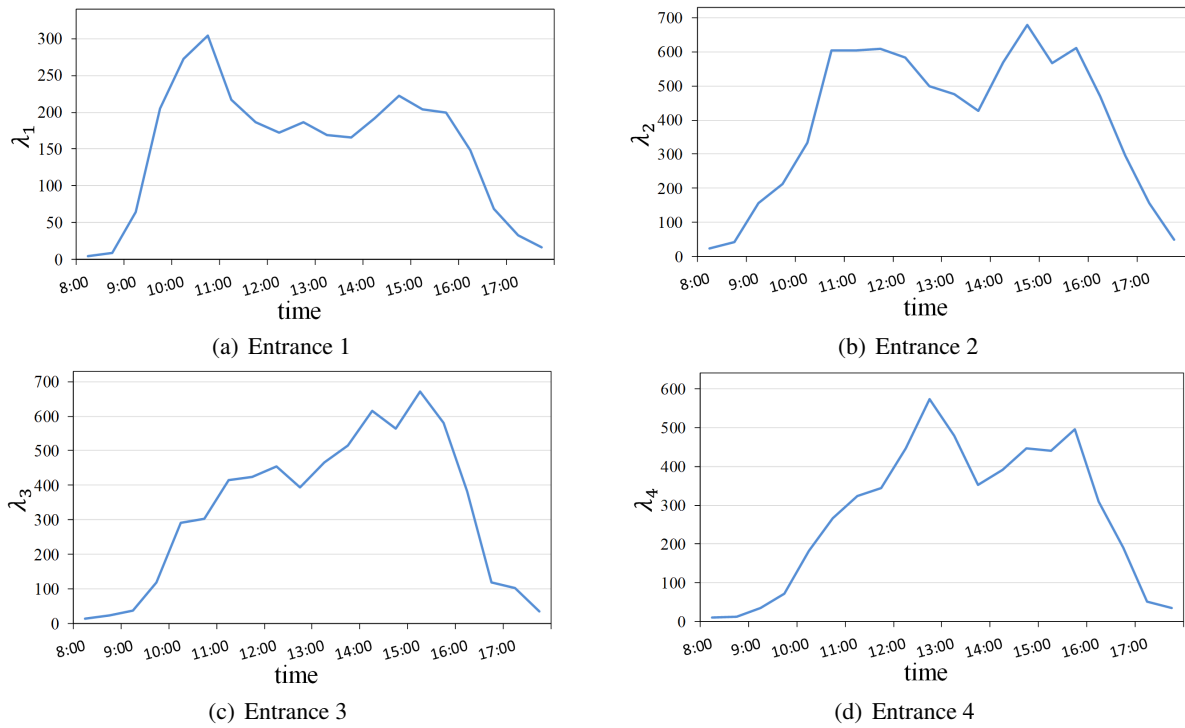
The SBG is located in Shanghai, China, and covers an area of approximately 230 acres. The SBG has four entrances indexed from 1 to 4, each equipped with one or more windows (servers) to sell tickets to visitors. Fixed servers are assigned to different entrances, and some mobile servers can move between entrances to manage queue lengths. The data used were collected over 10 days from the SBG in 2019: five days during the "2019 International Flower Show" and five regular days. The average number of visitors on a regular day is around 15,000, increasing to around 30,000 during the Flower Show. During the 10 days, all four entrances are open from 8:00 to 18:00. The planning horizon is therefore from 8:00 to 18:00 on a half-hourly basis, resulting in  $T = 20$  and  $\Delta = 0.5$  hours in the SBG data.

#### Data.1.1 SBG Arrival Data

We analyze SBG Arrival data. Entrance 1 has a relatively low arrival rate due to traffic inconvenience at this entrance. Entrances 2 to 4 experience significantly higher arrival rates due to their proximity to subway stations and large parking lots. Entrance 2 usually experiences two arrival peaks around 10:30 and 14:00. The peak arrival times at entrances 3 and 4 are typically around 12:00 and in the afternoon, respectively. We select one regular-day test instance (RT-1) and one Flower Show test instance (FS-2) from the SBG data to illustrate the tourist arrival rates and patterns at the four entrances, as shown in Figures Data.1 and Data.2. The data show that the number of tourists entering through each entrance varies considerably due to differences in traffic convenience.

**Figure Data.1** Arrival rates at the four entrances in the RT-1 test instance



**Figure Data.2** Arrival rates at the four entrances in the FS-2 test instance**Data.1.2 Other SGB Data**

The travel time matrix between each pair of SGB entrances is presented in Table E1. The column name “ $i$  to  $j$ ” represents the time required to move from entrance  $i$  to entrance  $j$ . The unit of value in the table is “a period”, i.e., one hour. Note that mobile employees do not move at the beginning of period 1, so in Table Data.1,  $t$  starts from period 2. The other main parameters of the SGB data are listed in Table Data.2

**Table Data.1** The values of  $c_{ijt}$ 

$t \backslash i \text{ to } j$	1 to 2	1 to 3	1 to 4	2 to 1	2 to 3	2 to 4	3 to 1	3 to 2	3 to 4	4 to 1	4 to 2	4 to 3
2	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
3	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
4	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
5	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
6	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
7	0.2	0.2	0.2	0.2	0.167	0.167	0.2	0.167	0.167	0.2	0.167	0.167
8	0.217	0.217	0.217	0.217	0.183	0.183	0.217	0.183	0.183	0.217	0.183	0.183
9	0.233	0.233	0.233	0.233	0.2	0.2	0.233	0.2	0.2	0.233	0.2	0.2
10	0.25	0.25	0.083	0.25	0.217	0.217	0.25	0.217	0.217	0.083	0.217	0.217
11	0.25	0.25	0.25	0.25	0.217	0.217	0.25	0.217	0.217	0.25	0.217	0.217
12	0.25	0.25	0.25	0.25	0.217	0.217	0.25	0.217	0.217	0.25	0.217	0.217
13	0.25	0.25	0.25	0.25	0.217	0.217	0.25	0.217	0.217	0.25	0.217	0.217
14	0.267	0.267	0.267	0.267	0.233	0.233	0.267	0.233	0.233	0.267	0.233	0.233
15	0.267	0.267	0.267	0.267	0.233	0.233	0.267	0.233	0.233	0.267	0.233	0.233
16	0.267	0.267	0.267	0.267	0.233	0.233	0.267	0.233	0.233	0.267	0.233	0.233
17	0.233	0.233	0.233	0.233	0.183	0.183	0.233	0.183	0.183	0.233	0.183	0.183
18	0.2	0.2	0.2	0.2	0.15	0.15	0.2	0.15	0.15	0.2	0.15	0.15
19	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133
20	0.167	0.167	0.167	0.167	0.133	0.133	0.167	0.133	0.133	0.167	0.133	0.133

**Table Data.2** Main parameters of SGB data

Symbol	Value	Explanation
$T$	20	Number of periods in a scheduling horizon
$\delta$	0.5 (hours)	Duration of each period
$K$	1, 2, 2, 2	Number of fixed employees at each entrance
$K'$	3 (Regular days) 4 (Flower Show)	Number of mobile employees during regular days and the Flower Show
$\mu$	197.4	Mean service rate of an employee
$LBD$	1 (hour)	Minimum shift duration for an employee
$UBD$	4 (hours)	Maximum shift duration for an employee
Rmin	0.5 (hours)	Minimum consecutive rest time for an employee
$L_{i,t}$	Regular day: 60, 80, 80, 60	Queue length threshold at the four entrances (each entrance has the same threshold throughout the day)
	Flower Show: 100, 200, 120, 100	Queue length threshold at the four entrances (each entrance has the same threshold throughout the day)

### Data.1.3 Current SBG Schedules

The schedules of SBG employees are described as follows.

On a regular day, at entrance 1, the only fixed employee has two shifts: 8:00–12:00 and 14:00–18:00. At the other three entrances, two fixed employees follow the same schedule. One employee works from 8:00 to 12:00 and from 13:00 to 17:00, while the second employee works from 9:00 to 13:00 and from 14:00 to 18:00.

In terms of mobile employees, on a regular day, there are three mobile employees. The first mobile employee works from 12:00 to 14:00 at entrance 1, then has a half-hour rest, moves to entrance 2 at 14:30 and continues working until 16:30. Employee 2 stays at entrance 2 and works two shifts: 10:00–12:00 and 12:30–16:30. Employee 3 works at entrance 3 from 10:00 to 12:00 and from 12:30 to 14:00, and finally moves to entrance 2, working until 16:30.

During the Flower Show, the schedules of fixed employees remain unchanged. The first and second mobile employees follow the same schedule. The third mobile employee has the same working hours as the second employee but is stationed at entrance 3. The fourth mobile employee works at entrance 4 from 10:00 to 12:00 and from 12:30 to 14:30, then moves to entrance 2 and works until 16:30.

## Data.2 Data from Two Large Airports

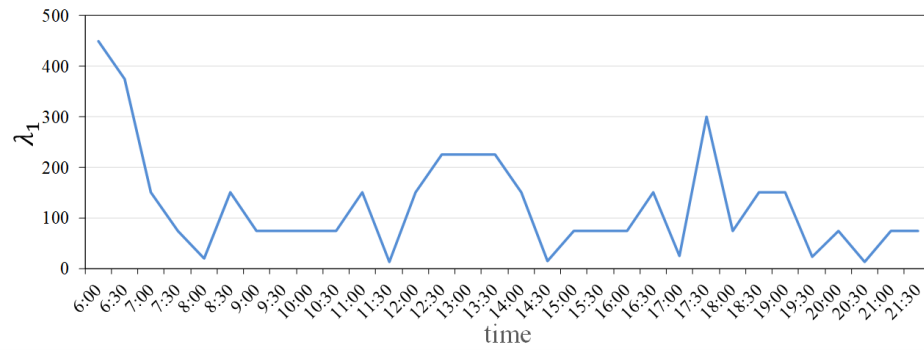
In addition to the SBG, we collect data from two large Chinese airports: SHA and Beijing Capital International Airport (PEK). In 2019, the passenger throughput for the two airports was 46 million and 100 million, respectively. At both airports, security screeners, referred to as servers, are assigned to move between different security checkpoints across multiple terminals. Note that in this context, a "server" denotes a security inspection team comprising several staff members responsible for tasks such as verification, unpacking, and operating screening machines. We collected four daily test instances (named SHA-1 to SHA-4) from SHA in 2019, four daily test instances (SHA-5 to SHA-8) from SHA in 2021, and four daily test instances (PEK-1 to PEK-4) from PEK in 2021. Most flights depart from the two airports between 6:00 and 22:00, so we define this time interval as the planning horizon. The time horizon is divided into half hours, resulting in  $T = 32$  and  $\Delta = 0.5$ .

Both SHA and PEK have two terminals. Both airports experience significant fluctuations in arrival rates. We select one day of SHA data and one day of PEK data to demonstrate their arrival patterns, as shown in Figures Data.3 and Data.4.

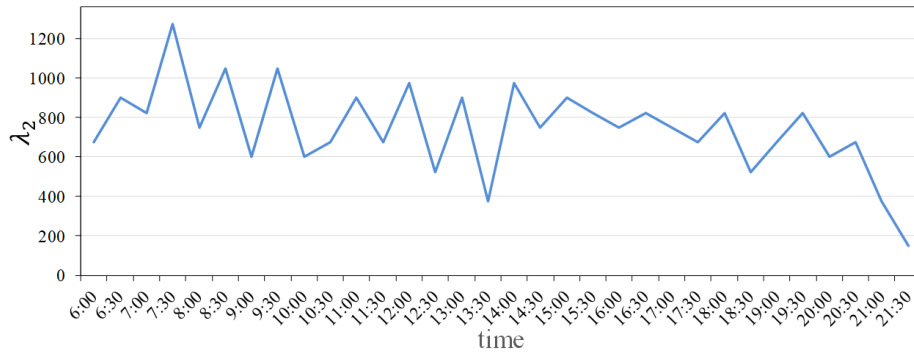
Each airport has six mobile servers and two fixed servers available. A work shift can range from 1 to 6 hours. The travel time between terminals is 20 minutes. Other parameters of the airport data are detailed in Table Data.3.

**Table Data.3** Key parameters of airport data

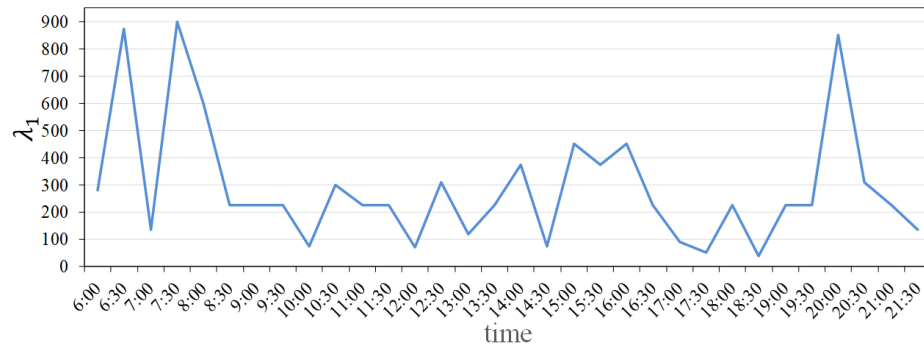
Symbol	Value	Explanation
$T$	32	Number of periods in a scheduling horizon
$\delta$	0.5 (hours)	Duration of each period
$K$	2, 2	Number of fixed employees at each terminal
$K'$	6	Number of mobile employees
$\mu$	168	Mean hourly service rate of employee
$LBD$	1 (hours)	Minimum shift duration for an employee
$UBD$	6 (hours)	Maximum shift duration for an employee
$R^{min}$	0.5 (hours)	Minimum consecutive rest time for an employee
$L_{i,t}$	80, 80	Queue length threshold at the two terminals (each terminal has the same threshold throughout the day)

**Figure Data.3** Arrival rates at the two terminals in the SHA-1 test instance

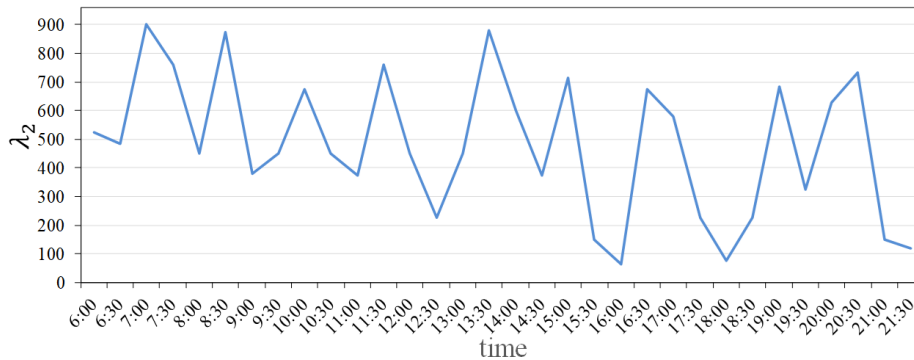
(a) Arrival Pattern of Terminal 1



(b) Arrival Pattern of Terminal 2

**Figure Data.4** Arrival rates at the two terminals in the PEK-2 test instance

(a) Arrival Pattern of Terminal 1



(b) Arrival Pattern of Terminal 2