International Journal of Emerging Technology and Innovative Engineering
Volume 2, Issue 2, February 2016 (ISSN: 2394 – 6598)

ENHANCING THE WORK PERFORMANCE OF COASTAL AND SUBURBAN DIVISION OF SRI LANKA FORT RAILWAY STATION USING GRAPH COLORING

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ABSTRACT

Sri Lanka Railway (SLR) department being the only rail transport service in Sri Lanka plays a major role as a transport service provider in the country. Itprovides transportation for about 0.3 million passengers daily.However, Fort railway station is the main railway station in Sri Lanka which caters 0.2 million commuters every day. It consists of 10 platforms and two divisions called Main line division and Coastal and Suburban area division.

Since the most of the government and private sector workers use trains for their daily commute, the Coastal and Suburban area division is more crowded compared to Main line division. Hence, the objective of the project was to introduce anemployee friendly roster so as to enhance the work performance of Coastal and Suburban division of Fort railway station.Currently, Coastal and Suburban division uses a manual methodin creating the employee scheduling system. The existing manual scheduling method does not have an efficient work plan.Therefore as the first step, the shortcomings and the limitations of the prevailing system were identified. Then arosterwas developed with the aid of graph coloring. In the end, a computerized employee friendly roster was introduced.

Keywords
Edge Coloring,Graph

1. INTRODUCTION

The Coastal and Suburban area division issues tickets for four railway lines namely Main line (Maradana to Rambukkana), Coastal line (Slave Island to Matara), Puttalum line (Peralanda to Puttalum) and Kelaniweli line- KV line (Baseline road to Avissawella). It comprises 7 ticketing counters and there are 11 Station Master III (SMIII) employees to issue tickets.

The work force consists of the head of the division,SM I; another SM responsible for signaling system together with 11 SM III employees to issue tickets in the 7

ticketing counters. Further, every employee can work on any shift. Among these employees only 2 experienced SM III are accountable for season tickets, which are issued in the first week of the month.

Therefore, there is an additional counter which is only operating in the first week of the month.

SM I who is the head of the division is in chargeof making the employee roster weekly and at present this scheduling is done manually which is a rather exhausting process. In this task a manuallydeveloped table is used with days of week along the columns and all work shiftsin the rows. Work shifts are the divisional tasks with a well-defined start and end time. The feasibility of the scheduling system has a direct impact on the quality of the service and their budgets.Hence, this project was designed to introduce an employee friendly roster to guarantee theaugmentation of the work performance of Coastal and Suburban area division of Fort railway station.

2. METHODOLOGY

The following figure depicts the four railway lines and the 7 ticketing counters of the Coastal and Suburban area division. Counter 10 issues tickets for Puttalum line and KVline,Counter 12 and Counter 15issue tickets for Main line, Counter 13 and Counter 15 issue tickets for Coastal line. Moreover, Counter 20 issues tickets for all stations whereas Counter 21 issues tickets only for selected stations.

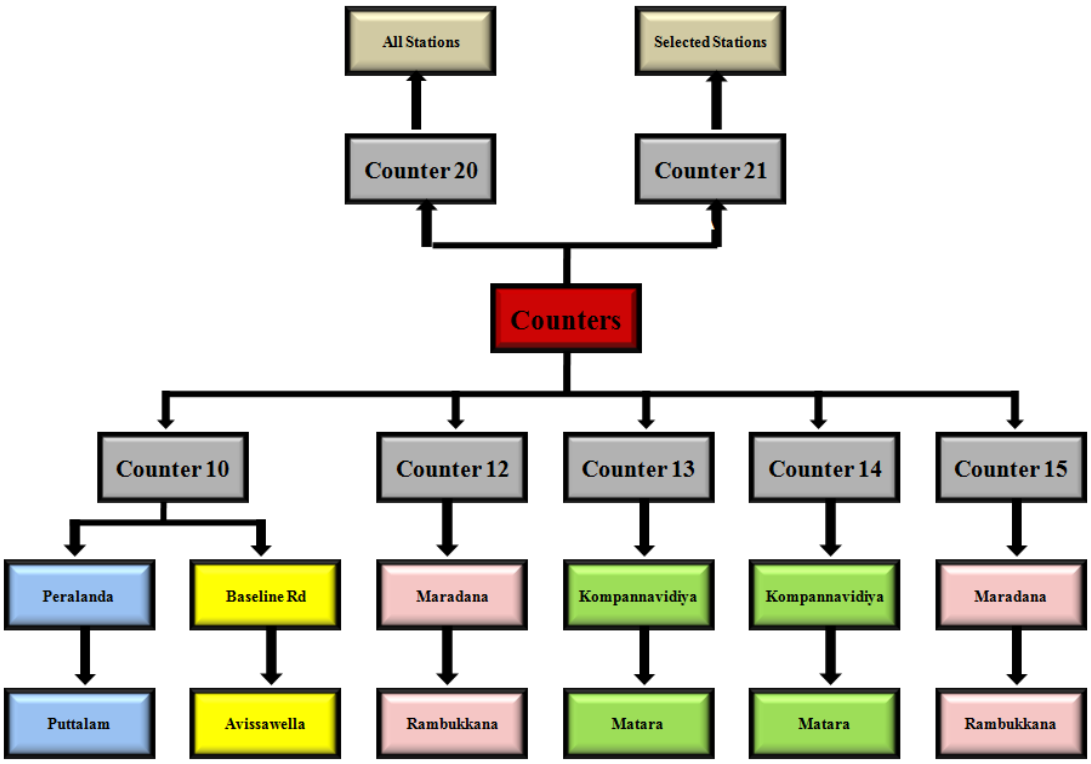

Figure 01:Counter name and duty

As the initial step, the existing system of work shifts which is illustrated below was studied in detail.

				Counters						
	SM C/L	Signal	S/T	Counter 10	Counter 12	Counter 13	Counter 14	Counter 15	Counter 20	Counter 21
Shifts (Hr)	0600 - 1800	0600 - 1400 1400 - 2200	0500 - 1400 1300 - 2100	0600 - 1400 1300 - 2200	0000 - 0900 0730 - 1700 1530 - 2400	0000 - 0900 0730 - 1700 1530 - 2400	1230 - 2130 0600 - 2130	0600 - 1500 1330 - 2200	0600 - 1500 1300 - 2200	1600 - 1900
Hours	12	16	16	16	24	24	9 15.5	16	16	3

Functioning only first 7 days of the month , Functioning only on Sundays , Not functioning on Sundays

Table 01: Existing work shifts of the counters

It was realized that the length of the shifts in the existing system is not equal. Therefore, to make their shift hours equal as possible,all theshiftswere rearranged without disturbing the functioning period of each counter. The following table demonstrates the proposed work shifts.

Counter	Shifts	Shift hours	Shift Number
10	0330 - 1300	9.5	Shift 01
10	1230 - 2200	9.5	Shift 02
12	0000 - 0900	9	Shift 03
12	0730 - 1630	9	Shift 04
12	1500 - 2400	9	Shift 05
13	0000 - 0900	9	Shift 06
13	0730 - 1630	9	Shift 07
13	1500 - 2400	9	Shift 08
14	1230 - 2130	9	Shift 09
15	0600 - 1500	9	Shift 10
15	1330 - 2230	9	Shift 11
20	0600 - 1500	9	Shift 12
20	1300 - 2200	9	Shift 13
21	1600 - 1900	3	Shift 14

Table 02: Proposed work shifts

Since there are 14 work shifts, the task was to assign the 11 SM IIIemployees to the 14 work shifts. Itwas found that this scenario can be represented by a graph; where the vertices areSM III and workshifts andedgesindicate which employee works on which work shift. There is an equal probability for each employee to work on every work shift.

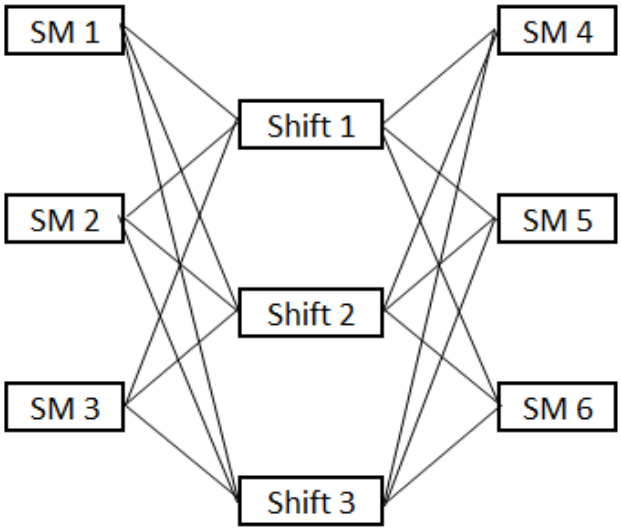

Figure02: Graph (Only considering 6 employees and 3 shifts)

The preceding objective was addressed through the concept of *edge coloring* in graph theory. At this point an assumption was made that every employee should work at least one work shift per day. Then the graph was colored using the edge coloring method. Figure 02 illustrates how the employees are assigned for a particular shift (shift 1) whereas Figure 03 demonstrates how a certain employee (SM 1) is linked to the work shifts.

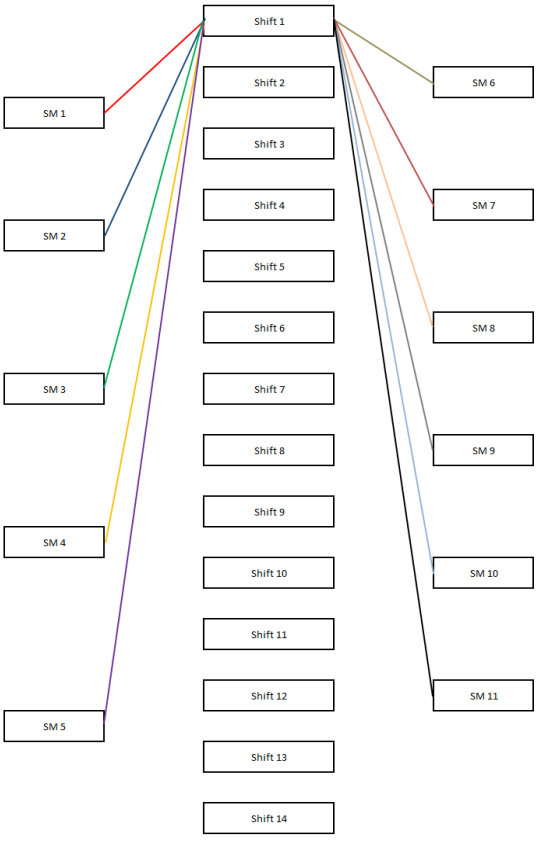

Figure 03: Edge coloring(considering one shift)

Figure 04:Edge coloring(considering one employee)

3. RESULTS AND DISCUSSION

The entire graph was colored with the fewest possible number of colors so that no two adjacent edges have the same color.

Theanalysis of the colored graph can be summarized as below.

SM / Work shift														
SM 1	Shift 1	Shift 2	shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
SM 2	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13
SM 3	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12
SM 4	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11
SM 5	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10
SM 6	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9
SM 7	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8
SM 8	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift1	Shift 2	Shift3	Shift4	Shift5	Shift6	Shift7
SM 9	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6
SM 10	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5
SM 11	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14	Shift 1	Shift 2	Shift 3	Shift 4

Table 03: Analysis of the colored graph

Finally, the information in Table 03 was equipped indeveloping the required work groups.

Group	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
Group 1	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2
Group 2	SM 2	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3
Group 3	SM 3	SM 2	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4
Group 4	SM 4	SM 3	SM 2	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5
Group 5	SM 5	SM 4	SM 3	SM 2	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6
Group 6	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1				SM 11	SM 10	SM 9	SM 8	SM 7
Group 7	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1					SM 10	SM 9	SM 8
Group 8	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1				SM 11	SM 10	SM 9
Group 9	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1				SM 11	SM 10
Group 10	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1				SM 11
Group 11	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1			
Group 12		SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1		
Group 13			SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	
Group 14				SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1

Table 04: Required work groups with empty slots to be filled

Although there were 14 work shifts,only 11 employees were there to work for a day. As a result some employees had to work on more than one work shift in a day. Then the task was to assign a particular employee to the empty slot such that there were no clashes (i.e. if the time period of two shifts overlaps, then the same employee cannot be assigned for both shifts) within

the work shifts. So as to achieve the above task the following table was prepared in accordance with the Table 02 that indicates the proposed work shifts.

Shifts	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
Shift 1	0	1	0	0	1	0	0	1	0	0	1	0	1	1
Shift 2	1	0	1	0	0	1	0	0	0	0	0	0	0	0
Shift 3	0	1	0	1	1	0	0	1	1	0	1	0	1	1
Shift 4	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Shift 5	1	0	1	1	0	1	0	0	0	1	0	1	0	0
Shift 6	0	1	0	0	1	0	1	1	1	0	1	0	1	1
Shift 7	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Shift 8	1	0	1	0	0	1	1	0	0	1	0	1	0	0
Shift 9	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Shift 10	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Shift 11	1	0	1	0	0	1	0	0	0	1	0	0	0	0
Shift 12	0	0	0	0	1	0	0	1	0	0	0	0	1	1
Shift 13	1	0	1	0	0	1	0	0	0	0	0	1	0	0
Shift 14	1	0	1	0	0	1	0	0	0	1	0	1	0	0

0 same time

1 separate time

Table 05: Analysis of same time and separate time work shifts

The following procedure identifies the possible combinations of employees to generate work groups.

Procedure:

I. Locate a work shift to which an employee is not assigned: i.e. an empty slot in Table 04
II. Check the row corresponding to the selected work shift in Table 05
III. Recognize the work shifts that function at separate time periods other than the time interval of the selected work shift: i.e. shifts indicated by '1' in Table 05
IV. Pick a particular shift randomly, among those possibilities
V. Detect the employee working in that particular shift from Table 04
VI. Assign that employee to the empty slot that was needed to be filled
VII. Repeat until all the empty slots in a specific work group are filled

For instance; the employee who worked on shift 1 can work on shift 2,but not on shift 3 and the given below is one of the options of completing Group 1.

	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
Group 1	SM 1	SM 10	SM 5	SM 11	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2

Table 06: One of the options for completing Group 1

Again it was possible to obtain many combinations by assigning different employees to the empty slots. So, a Java computer program was developed to complete all the work groups.

OUTPUTS OF THE ANALYSIS

The random select method was used to fill the empty slots of Table 04.

Groups	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
Group 1	SM 1	SM 10*	SM 5*	SM 11*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2
Group 2	SM 2	SM 1	SM 8*	SM 8**	SM 7*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3
Group 3	SM 3	SM 2	SM 1	SM 1*	SM 1*	SM 7*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4
Group 4	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 1**	SM 11*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5
Group 5	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 1**	SM 10*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6
Group 6	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 6*	SM 1*	SM 11	SM 10	SM 9	SM 8	SM 7
Group 7	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 5*	SM 5*	SM 3*	SM 7*	SM 10	SM 9	SM 8
Group 8	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 6*	SM 4*	SM 8*	SM 11	SM 10	SM 9
Group 9	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 2*	SM 4*	SM 11*	SM 11	SM 10
Group 10	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 10*	SM 11*	SM 8*	SM 11
Group 11	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 7*	SM 9*	SM 7**
Group 12	SM 8*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 10*	SM 8**
Group 13	SM 9*	SM 8*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 8*
Group 14	SM 10*	SM 9*	SM 2*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1

Table 07: Computer output 1

Groups	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Shift 11	Shift 12	Shift 13	Shift 14
Group 1	SM 1	SM 1*	SM 5*	SM 5**	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2
Group 2	SM 2	SM 1	SM 9*	SM 9**	SM 7*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3
Group 3	SM 3	SM 2	SM 1	SM 1*	SM 1*	SM 2*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4
Group 4	SM 4	SM 3	SM 2	SM 1	SM 7*	SM 10*	SM 10**	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5
Group 5	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 1**	SM 5*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6
Group 6	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 1*	SM 4*	SM 11	SM 10	SM 9	SM 8	SM 7
Group 7	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1*	SM 2*	SM 3*	SM 3**	SM 10	SM 9	SM 8
Group 8	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 6*	SM 1*	SM 1**	SM 11	SM 10	SM 9
Group 9	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 5*	SM 7*	SM 11*	SM 11	SM 10
Group 10	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 10*	SM 6*	SM 5*	SM 11
Group 11	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 4*	SM 11*	SM 11*
Group 12	SM 2*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 2**	SM 2**
Group 13	SM 1*	SM 11*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1	SM 1**
Group 14	SM 7*	SM 9*	SM 10*	SM 11	SM 10	SM 9	SM 8	SM 7	SM 6	SM 5	SM 4	SM 3	SM 2	SM 1

Table 08: Computer output 2

Similarly many combinations can be obtained as the outputs of the computer program.

4. CONCLUSION

The computer program generates random work groups,ensuring that the employees are assigned in an optimal manner without experiencing any clashes within a particular group. So that the SM Grade I can select work groups for each day, to meet the practical situation at the railway station and prepare the roster without much effort.

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