Retail Store Scheduling

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Abstract

Retail stores employ a large amount of full time and part time employees. With the addition of many different departments, making efficient schedules can be a challenge. In this paper, we will develop a binary integer programming problem which will be used to minimize the total employee cost, while ensuring proper employee coverages.

1 Introduction

In Canada, the retail industry provides a large contribution to full time and part time employment. Because retail stores are pervasive, they are constantly employing new employees. Furthermore, the total amount of employees working varies on the size of the store, the type of the store, and the departments.

Store managers face employee scheduling difficulties which may include the following: employee shortages during certain times of the day; unreasonable shift rotations; and dynamic availabilities of part-time employees. Depending on the departments, managers in large retail stores (e.g. Safeway), may manually schedule employees based on their expertise. Fortunately, many employees can switch between different departments, or are able to help out in different departments during busy hours.

In this model, our focus is on a small grocery store that operates 24 hours, while opened to the public from 8:00am to midnight. Furthermore, this store includes the following departments: Cashiers, Bakery, Pharmacy, Meat and Deli, Produce, and Management. Based on past experiences and research, we have estimated the employment demands for each department that will require during each hour of the day, as well as the daily employment demands. Using these demands, we have formulated a binary integer programming problem which ensures adequate staffing in each of these departments.

2 Goals

- Minimize total employee cost over 24 hour period.
- Meet the daily and hourly job demands of the employees.
- Meet hourly demand of employees required at each hour.

3 Generalizations of the Problem

In this problem, there are a few assumptions which will be made in order to make the problem solvable.

- Full time employees work 8 hour shifts with $1/2$ hour unpaid lunch breaks.
- Full time employees work 37.5 hours per week.
- Part time employees work a minimum of 4 hour a week up to a maximum of 20 hours per week.

- 15 minute paid coffee breaks are given every 2 hours to both part time and full time employees, the timing will be at the discretion of the department manager on duty.

4 Daily Employee Demands

For each day, the store will face different employee demands in each department. Figure 1 illustrates the hourly demands that we have estimated for each department.

Figure 1. Hourly Employee Demands

Sunday																								
t=	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	#	21	#	#
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Monday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Tuesday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Wednesday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Thursday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Friday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Monday																								
Manager	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	1	1	1	0
Bakery	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Cashier	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1
Meat	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pharmacy	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1
Produce	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

5 Parameters

- $b =$ index of the day of week. $b = \{1, 2, 3, 4, 5, 6, 7\}$ where Sunday = 1, Monday = 2,..., Saturday = 7.
- $i =$ index of full time employees. $i = \{1, 2, \ldots, n\}$ where n is the total number of full time employees.
- $j =$ index of part time employees. $j = \{1, 2, \ldots, m\}$ where m is the total number of part time employees.
- $t =$ index of hourly starting times. $t = \{0, 1, 2, \ldots, 23\}$
- $k =$ index of departments. $k = \{1, 2, 3, 4, 5, 6\}$
- $D_{k,t} =$ hourly employee demand for department k at hour t.
- $W_i =$ employee wage for full time employee i.
- $W_j =$ employee wage for part time employee j.

6 Variables

- $Q_{i,b} = \sum_{u=1}^{b} x_{i,u}$ sum of hours full time employee i has worked from Sunday to day b.
- $Q_{j,b} = \sum_{u=1}^{b} x_{j,u}$ sum of hours part time employee j has worked from Sunday to day b.
- $P1_{t,k} =$ total number of full time employees starting at time t.
  $\forall t : P1_{t,k} = \sum_{i=1}^{n} x_{i,t}$.
- $P2_{t,k} =$ total number of part time employees starting at time t.
  $\forall t : P2_{t,k} = \sum_{j=1}^{m} x_{j,t}$.
- $Z1_t =$ sum of full time employees working at time t.
  $Z1_{t,k} = \sum_{u=t-7}^{t} P1_u$
- $Z2_{t,k} =$ sum of part time employees working at time t.
  $Z2_{t,k} = \sum_{u=t-7}^{t} P2_u$

7 Decision Variables

$$x_{i,t} = \begin{cases} 1 & \text{if employee } i \text{ begins shift at time } t \\ 0 & \text{otherwise} \end{cases}$$

$$x_{j,t} = \begin{cases} 1 & \text{if employee } j \text{ begins shift at time } t \\ 0 & \text{otherwise} \end{cases}$$

8 Constraints

- $\sum_{b=1}^{7} Q_{i,b} = 40$
  Full time employees work five 8 hour shifts each week.

- $4 \leq \sum_{b=1}^{7} Q_{j,b} \leq 20$
  Part time employees can only work between one and five 4 hour shifts per week.

- $P1_t = 0$ for $t = 16, ..., 23$
  Full time employees can not start later than 16:00.

- $P2_t = 0$ for $t = 0, ..., 8$ and $t = 20, ..., 23$
  Part time employees can not start earlier than 8:00 and no later than 23:00.

- $\forall i \sum_{t=0}^{23} x_{i,t} \leq 1$
  This ensures full time employees can only have one shift per day.

- $\forall j \sum_{t=0}^{23} x_{j,t} \leq 1$
  This ensures part time employees can only have one shift per day.

- $Z_{itk} > Z_{jtk}$
  This ensures that more full time workers will always be working than part time workers, otherwise Open Solver will chose all part time employees.

- $\sum_{i=1}^{n} x_{i,t} + \sum_{j=1}^{m} x_{j,t} \geq \sum_{k=1}^{6} D_{k,t}$
  The sum of full time and part time workers must exceed or be equal to the hourly demand in each department.

9 Objective Function

In order to get a schedule for each day, the problem must be solved individually using Excel's Open Solver. The cost for each day is equal to 7.5, the number of paid hours worked by full time employees, multiplied by a matrix which sums up which employees have worked that day, and again multiplied by their respective wages. The objective function then minimizes C, the employee cost.

$$\text{Minimize } C = 7.5 \begin{bmatrix} x_{1,1}+ & x_{1,2}+ & ,\dots, & +x_{1,23} \\ x_{2,1}+ & x_{2,2}+ & ,\dots, & +x_{2,23} \\ \vdots & \vdots & \vdots & \vdots \\ x_{i,1}+ & x_{i,2}+ & ,\dots, & +x_{i,23} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_i \end{bmatrix}$$

$$+4 \begin{bmatrix} x_{1,1}+ & x_{1,2}+ & ,\dots, & +x_{1,23} \\ x_{2,1}+ & x_{2,2}+ & ,\dots, & +x_{2,23} \\ \vdots & \vdots & \vdots & \vdots \\ x_{j,1}+ & x_{j,2}+ & ,\dots, & +x_{j,23} \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_j \end{bmatrix}$$

$$= 7.5 \sum_{t=0}^{23} x_{i,t} \sum_{i=1}^{n} W_i + 4 \sum_{t}^{23} x_{j,t} \sum_{j=1}^{m} W_j$$

10 Linear Programming Problem to be solved

$$\text{Minimize } C = 7.5 \sum_{t=0}^{23} x_{i,t} \sum_{i=1}^{n} W_i + 4 \sum_{t}^{23} x_{j,t} \sum_{j=1}^{m} W_j$$

Subject to:

$$\sum_{b=1}^{7} Q_{i,b} = 40$$

$$4 \leq \sum_{b=1}^{7} Q_{j,b} \leq 20$$

$$\forall i \sum_{t=0}^{23} x_{i,t} \leq 1$$

$$\forall j \sum_{t=0}^{23} x_{j,t} \leq 1$$

$$\sum_{i=1}^{n} x_{i,t} + \sum_{j=1}^{m} x_{j,t} \geq \sum_{k=1}^{6} D_{k,t}$$

$$\forall i, t, k \; Z_{itk} > Z_{jtk}$$

$$P1_t = 0 \text{ for } t = 16, \dots, 23$$

$$P2_t = 0 \text{ for } t = 0, \dots 8 \text{ and } \; t = 20, \dots, 23$$

11 Solution

Figure 2. Weekly Schedule for the Produce Department

	Produce							
	Employee	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Full Time	BO	2:00 PM	7:00 AM	7:00 AM		4:00 PM		12:00 AM
	BP	12:00 AM	12:00 AM	7:00 AM		12:00 AM	12:00 AM	
	BQ	11:00 AM	4:00 PM		7:00 AM	10:00 AM		
	BR	11:00 AM		12:00 AM	11:00 AM	11:00 AM	7:00 AM	
	BS	4:00 PM		4:00 PM	4:00 PM	3:00 AM	4:00 PM	4:00 PM
	BT	7:00 AM	7:00 AM	12:00 PM		7:00 AM	2:00 PM	3:00 PM
	BU	7:00 AM	12:00 PM		7:00 AM	3:00 AM	7:00 AM	7:00 AM
	BV	2:00 PM		12:00 AM	12:00 AM	4:00 PM		12:00 AM
	BW	12:00 AM	12:00 AM		12:00 AM	12:00 AM	12:00 AM	
Part Time	N	4:00 PM					4:00 PM	
	O	3:00 PM	3:00 PM					3:00 PM
	P	6:00 PM					8:00 AM	
	Q	11:00 AM			4:00 PM			
	R	11:00 AM					8:00 PM	12:00 PM
	S	2:00 PM			8:00 AM			8:00 AM
	T	8:00 AM		8:00 AM				4:00 PM
	U	8:00 PM	8:00 PM		8:00 PM			
	V	12:00 PM					12:00 PM	
	W	8:00 AM		8:00 PM				
	X	6:00 PM					12:00 PM	
	Y	2:00 PM	8:00 AM					8:00 PM
	Z	12:00 PM		4:00 PM				7:00 PM

In conclusion, we were unable to solve a 7 day employee schedule that met all demands using Excel's Open Solver. Figure 2. shows a weekly schedule made for the produce department. Furthermore, all constraints were met except for full time employees working more than 5 days. From the previous example, we can see that there are 2 full time employees working 6 days a week.

Further improvements could be made to our model by acquiring more accurate data for employee demands and the quantity of employees.