International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 05 – Issue 06 || June 2020 || PP. 25-28

Assigning Associates to Shifts for an On-Site Before and After Child Care Program

Abstract: This article addresses scheduling associates to shifts for at-school child care providers. The at-school programs avoid the costs of child care facilities and transport costs to and from school and the child care locations. Complications of the assignments are addressed such as balancing seniority with wage cost and accommodating planned leave and travel costs of the associates to the schools. A solution is discussed using open source software: R and LPsolve.
Keywords*:* binary programming, assignment, scheduling, LPsolve

Consider an organization that places child care workers at a school before and after classes begin as an alternative to placing young students at child care facilities. The parents drop off and pick up their children at schools instead of at child care locations. This avoids the cost of the child care facility and the cost the facility incurs transporting students to and from the schools. These cost savings are passed along to parents. Characteristics of assigning associates to shifts at the schools involve:

- Having enough workers to cover the shifts. That is, there needs to be a feasible solution.
- Having workers who can cover a variety of shifts, such as 6:30-7:45am, 4:30-6:30pm shifts.
- Being able to force schedule a worker even if they are high cost or low priority. This could be to have a certified food handler at the school or a worker with special child care training.
- Being able to accommodate an associate's scheduled leave in order not to assign them to a shift that would overlap the leave.
- Paying attention to seniority so that more senior associates get assigned before more junior associates.
- Paying attention to wage costs in order to budget effectively.
- Paying attention to travel costs for associates to and from schools.
- Being aware that there typically are more associates on the roster than there are shifts to be covered.

Some Earlier Works

Gottlieb and Rao (1990) were among the first to present the generalized assignment problem. Nauss (2003) discusses solution approaches to such problems. King (2010) presents an assignment problem as a multiple knapsack problem, and then later King, *et al*., discusses a healthcare application of the generalized assignment problem.

Special Considerations of the On-Site Assignment Problem

Accommodating Travel Costs

Given two associates with the same wages and seniority, it is preferable to give the shift assignment to the associate who lives closer to the school needing a worker. This is accomplished by calculating the distance from the centroid of the associate's zip code and the centroid of the school's zip code. The travel cost is added to the wage cost using a scaling factor alpha, a small proportion such as 0.10, in order that travel costs do not dominate the wage cost.

A Mix of Minimum Cost and Attention to Seniority

We developed a parameter, beta, to be decided by management, on how much effort the solver should spend minimizing costs and how much to assigning shifts to the most senior associates first. Seniority is measured as the number of days since hire. If no hire date is given, a default hire date of one day earlier than the current date is used.

Beta produces a linear combination. Beta equal to 1, instructs the solver to minimize wage and travel costs without paying any attention to seniority. Beta equal to 0 instructs the solver to assign associates strictly on the basis of seniority, ignoring wage and travel costs. Beta equal to 0.5 instructs the solver to pay approximately equal attention to wage and travel costs, and seniority.

Example Input

Associate Data

In Table 1, a lookup table, shift a630/p430 indicates a shift that begins at 6:00am and continues at 4:30pm. This table is used to calculate wages for an associate at an assignment.

Table 1, Time Associated with a Shift Identifier

	Morning		Afternoon	
Shift	Begin	End	Begin	End
a6	6:00:00 AM	8:30:00 AM		
p4			4:00:00 PM	6:15:00 PM
a630/p430	6:30:00 AM	7:45:00 AM	4:30:00 PM	6:30:00 PM
a7/p330	6:00:00 AM	8:15:00 AM	3:30:00 PM	5:30:00 PM

The Must Assign column in Table 3 indicates that the associate must be assigned since they may possess a skill, such as certified food handler, that will be needed in the schedule.

Travel area is linked to a lookup table, Table 2, for the most prominent zip code in the Travel Area. The zip code is used to calculate travel cost to and from a school.

Table 2, Dominant Zip Code for a Travel Area

Travel Area	Zip
Broad Ripple	46205
Butler	46208
Carmel	46220
Decatur Twp	46202
Speedway	46214
Washington & Emerson	46217

The Scheduled Leave column in Table 3 indicates the start date of an associate going on leave. The assignment algorithm will avoid assigning a shift that overlaps leave.

Table 3, Associate Input Data

Associate ID	Employee	Travel Area	Shift	Hourly Rate	Hire Date	Must Assign?	Scheduled Leave
116229	Shieasha	Speedway	a6	11.50	4/14/2002	Yes	
175922	Michelle	Broad Ripple	a6	16.21	10/30/2007		
261528	Tavell	Butler	a6	13.14	6/23/2005		
398147	Detra	Speedway	a6	11.00	7/6/2015		
115334	Kristina	Broad Ripple	a630/p430	11.00	11/30/2016		
161963	Jonathan	Butler	a630/p430	10.62	7/13/2012		
435937	Whitney	Butler	a630/p430	15.09	8/24/2015		
518528	Pat	Broad Ripple	a630/p430	14.26	1/21/2005		
775497	Charlesetta	Broad Ripple	a630/p430	20.99	9/30/2009		
151384	Sedara	Decatur Twp	a7/p330	14.28	9/24/2017		
770228	Nicholas	Decatur Twp	a7/p330	14.50	3/5/2006		5/15/2020
940464	Gail	Carmel	a7/p330	12.32	12/15/2002		
749056	Pamela	Washington & Emerson	p4	10.18	5/25/2012		
933242	Shyanna	Decatur Twp	p4	10.00	8/6/2011		12/24/2019
782965	Tasha	Carmel	p4	10.25	9/15/2010		

Shift Data

In Table 4, Location is the school or camp requiring at least one worker.

As the Associate Input Data of Table 3, Travel Area points to a lookup table that returns the zip code of the prominent zip code in the area.

Begins and Ends indicate the beginning date and ending date of a shift. Blank cells indicate that the shift has already begun and will continue for a year.

Number of shifts indicates the number of shifts of the Shift type needed at the Location.

Table 4, Shifts to Receive an Assignment

Location	Travel Area	Begins	Ends	Shift	Number of Shifts
Academy 1	Washington & Emerson			a630/p430	1
Academy 2	Broad Ripple	9/18/2019	12/21/2019	a630/p430	1
Academy 2	Broad Ripple			a7/p330	1
Academy 2	Broad Ripple	1/3/2020	5/25/2020	p4	2
Camp A	Butler			a6	2
Camp A	Butler		10/31/2019	a630/p430	1
Camp A	Carmel			a630/p430	1
Camp B	Broad Ripple	7/31/2019	10/31/2019	a6	1
Private School 1	Washington & Emerson			a7/p330	1
Private School 1	Washington & Emerson	1/3/2020	5/15/2020	p4	1

Mathematical Formulation

Let

$x_{ij} = the\ binary\ decision\ variable\ of\ placing\ associate\ i\ in\ shift\ j.$

$\alpha = the\ proportion\ of\ travel\ cost\ to\ be\ added\ to\ wages\ cost.$

$\beta = the\ paramter\ (0,1) to\ mix\ wages\ cost\ with\ travel\ cost.$

$k = the\ set\ of\ associates, i, that\ must\ be\ assigned.$

$$l_{ij} = number\ of\ days\ until\ associate\ i\ begins\ leave\ \forall\ j.$$

$$d_{ij} = number\ of\ days\ until\ shift\ j\ ends\ \forall\ i.$$

$$w_{ij} = wages\ cost\ of\ associate\ i\ working\ shift\ j.$$

$$t_{ij} = travel\ cost\ of\ associate\ i\ to\ shift\ j.$$

$s_{ij} = seniority\ of\ associate\ i\ \forall\ j.$

$$x_{ij} = \begin{cases} 1, if\ associate\ i\ is\ assigned\ to\ shift\ j \\ 0, if\ not \end{cases}$$

minimize $z = (\beta(\sum_{i,j}(w_{ij} + \alpha\, t_{ij})) + (1-\beta)\sum_{i,j} -s_{ij})\, x_{ij}$

(1)

Subject to

$\sum_i x_{i,j} \leq 1\ \forall\ j$

(2)

$\sum_j x_{i,j} \leq 1\ \forall\ i$

(3)

$\sum_j l_{ij}\, x_{ij} \leq d_{ij}\ \forall\ i$

(4)

$\sum_k w_{kj} = 1\ \forall\ j$

(5)

$x_{ij} = 0\ or\ 1, \forall i, j$

(6)

Equation 1 is the objective function to be minimized. Beta is the linearly combining parameter instructing the solver to place a proportion of effort at solving for minimum cost, or, 1-beta, exercising effort to maximize seniority.

Equation 2 is a special ordered set to guarantee that an associate will work no more than one shift.

Equation 3 is a special ordered set to guarantee that each set will be covered.

Equation 4 assures that an associate will not be assigned to a shift that overlaps their leave time.

Equation 5 assures that associates who are indicated to work no matter their objective function contribution be placed onto the assignment schedule.

Equation 6 guarantees the binary nature of the decision variables.

Technique

The program was written in R which called the LPsolve mixed integer linear programming API.

Solution

Table 5 displays the solution to the problem presented in Tables 3 and 4.

Table 5, Solution

Associate ID	Associate Name	associate travel area	Shift	shift travel area
775497	Charlesetta	Broad Ripple	Academy 1 a630/p430 5	Washington & Emerson
518528	Pat	Broad Ripple	Academy 2 a630/p430 4	Broad Ripple
151384	Sedara	Decatur Twp	Academy 2 a7/p330 1	Broad Ripple
749056	Pamela	Washington & Emerson	Academy 2 p4 1	Broad Ripple
116229	Shieasha	Speedway	Camp A a6 1	Butler
261528	Tavell	Butler	Camp A a6 3	Butler
115334	Kristina	Broad Ripple	Camp A a630/p430 1	Butler
435937	Whitney	Butler	Camp A a630/p430 3	Carmel
175922	Michelle	Broad Ripple	Camp B a6 2	Broad Ripple
940464	Gail	Carmel	Private School 1 a7/p330 3	Washington & Emerson
782965	Tasha	Carmel	Private School 1 p4 3	Washington & Emerson

The reader will note that Shieasha is assigned a shift as requested in the input data and that Nicholas and Shyanna are not assigned shifts since their leave times could not be accommodated in the schedule.

Conclusion

This mathematical programming problem and solution using open source software is approachable by a medium sized organization needing to schedule associates against shifts. It easily can be deployed on a laptop. Organizations previously reluctant to use such a tool due to complexity of use or cost of solution should be encouraged to use this tool for planning and scheduling.

References

[1]. Gottlieb, E.S., Rao, M.R., (1990), "The Generalized Assignment Problem: Valid Inequalities and Facets." *Mathematical Programming*, 46, 31-52.

[2]. King, B. E.,(2010), "Time Constrained Workforce Scheduling as a Multiple Knapsack Problem." *AIMS International Journal of Management*, January, 4 (1), 1-8.

[3]. King, B. E., Leach, A., Platt, M., & White, D. L., (2017). "Scheduling Surgical Operations and the Post-Anesthesia Care Unit Using Work Tours and Binary Programming."*AIMS International Journal of Management*, 11(1), 101-109.

[4]. Nauss, R. M., (2003), "Solving the Generalized Assignment Problem: An Optimizing and Heuristic Approach." *INFORMS Journal on Computing*, 15(3):249-266.