OPTIMUM TOUR SCHEDULING OF IT HELP DESK AGENTS

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ABSTRACT

This paper reports the results of a workforce staffing and scheduling project accomplished at the IT Help Desk of a large local company. The objective is to reduce the labor cost by determining the best staffing level and employee weekly schedules required to meet the demand that varies over a 24-hours operating period. Extensive data is collected and analyzed to translate the number of incoming calls into hourly staffing requirements. An integer programming model is used to determine the number of IT help agents and their associated schedules. Weekly tour schedules are constructed which define for each employee the starting and finishing times, the lunch (dinner) breaks times, and the off days.

KEYWORDS

Tour scheduling, Staffing, Stochastic labor demands, Call center scheduling, Integer programming.

1 INTRODUCTION

The modeling and solution of an actual tour scheduling problem at the Information Technology Help Desk (ITHD) of a large company are described. The objective is to minimize the labor cost and to determine the adequate number of agents and their schedules required to meet the demand that varies over a 24-hour operating period. ITHD agents provide services and support 24 hours a day, 7 days a week to all the company employees. They receive customers' technical problems and complaints and try to resolve them immediately. ITHD has 47 agents, who belong to three groups with different pay scales and different scheduling arrangements.

ITHD management notices callers' frustration with being placed on hold for several minutes during peak periods, although ITHD uses the first-come, first-served (FIFO) rule to queue incoming calls. Because of long delays, many calls are lost and many users complain. Another problem for ITHD is unscheduled one-hour breaks; any agent who deserves a one-hour break is allowed take it randomly any time during a predetermined two-hour interval. This policy gives the agents the flexibility to go whenever they want to go but, on the other hand, it makes it too difficult to constantly maintain an adequate staffing level.

Currently, hourly labor demands are estimated and employees are assigned to different schedules based only on management observations and the shifts leaders' opinions; no systematic or scientific methods are used. In order to systematically determine the optimum tour schedule, several steps were taken. First, extensive data on the number of and duration of incoming calls for each hour of the day and each day of the week was collected and analyzed. This data was converted into hourly labor demands for a typical work week. Next, an integer programming model that represents the various restrictions and alternative schedules was formulated and solved. Finally, detailed weekly tour schedules were constructed which define the starting and finishing times for shifts, the lunch (dinner) breaks times, and the off days for each employee.

2 LITERATURE SURVEY

Telephone operator scheduling techniques reported in the literature include forecasting, queuing models, regression, heuristics, integer linear programming (LP), network flows, and genetic algorithms. Van Oudheusden and Wu (1982) used an integer LP model to determine the optimum assignment of tours to a limited number of available operators. Wilson and Willis (1983) formulated an LP model to staff and schedule telephone betting operators. Willis and Huxford (1991) applied integer programming to generate telephone operator rosters for Telecom Australia.

Andrews and Parsons (1989) combined forecasting, cost/benefit analysis, queueing theory, and regression to schedule telephone agents for L.L. Beans, a large catalog mail-order company. Later, Andrews and Parsons (1993) used economic optimization instead of service-level criteria for determining staffing levels, thus balancing the costs of overstaffing and understaffing. Agnihothri and Taylor (1991) determined hourly staffing requirements by the (*M/M/c*) queueing model and rearranged the work shifts to schedule a hospital phone appointment workforce. Fromm (1997) discusses the use of Erlang queueing formulas several software packages for determining hourly staffing demands and constructing operator schedules.

Thompson (1997) used a goal programming-like heuristic to assign New Brunswick Telephone Company operators to shifts, with the objectives of meeting all demands and satisfying employee preferences in the order of seniority. Yamada, et al. (1999) utilize a genetic algorithm approach to schedule a variable number of operators in a telephone information center, aiming to maintain service quality and reduce labor costs. Lin, et al. (2000) combine regression, simulation, and mixed integer programming models to determine staffing levels and operator schedules for a 24-hour hotline service. Çezik at al. (2001) developed an integer programming model to schedule agents in a call center by combining days-off and shift scheduling constraints into a network flow structure.

3 THE PROBLEM AND CONTEXT

IT Help Desk (ITHD) function is to provide high quality, timely, cost effective services and support delivered with a customer focus. The ITHD Help Desk is staffed by agents 24 hours a day, 7 days a week. Agents receive customers' questions and complaints and try to solve them immediately as much as they can. All the employees of this large company (several thousand employees) will call IT Help Desk (ITHD) for IT related services and support. Since ITHD was created to assist users, courtesy and good communications skills are necessary to keep the help desk running well, no matter how busy the day is or how many problems have arisen.

The IT Help Desk currently has 47 employees, classified into three categories whose tour schedules are shown in Table 1 and described below. The total monthly cost per employee, including benefits and overhead, is given each employee category as:

1. Shift employee: $5,781.39
2. Non-shift (day) employee: $4,680.19
3. Contractor on any shift: $7,978.31

1. Company employees on shift schedules

This employee category has 19 agents divided into four groups. Group A consists of 5 agents, group B has 5 agents, group C has 4 agents, and group D consists of 5 agents. They work in three different eight-hour shifts without meal breaks: (1) from 7:00 am to 3:00 pm, (2) from 3:00 pm to 11:00 pm, and (3) from 11:00 pm to 7:00 am. Over a 4-week cycle, four groups of employees rotate on the three work shifts, using the days on/days off pattern 7/2-7/2-7/3.

2. Company employees on day schedule

Currently, there is only one agent on the regular day schedule who works 5 days a week, Saturday to Wednesday, taking the weekend off on Thursday and Friday. This agent begins at 7:00 a.m. and finishes at 4:00 p.m., with one hour as a lunch break from 12:00 noon to 1:00 pm.

3. Contractors

Currently, there are 27 contractors divided into 3 work times as follows:

(a) 6:00 am to 3:00 pm
In this shift, 16 contractors work from Saturday to Wednesday and have one-hour lunch breaks any time from 11:00 am to 1:00 pm. Their off days are Thursday and Friday.

(b) 9:00 am to 6:00 pm
In this shift, there are only 4 contractors. They work from Thursday to Monday and their off days are Tuesday and Wednesday. Each agent can take a one-hour lunch break anytime from 12:00 noon to 2:00 pm.

(c) 3:00 pm to 12:00 midnight
There are seven different tours for seven contractors working in this time period, differing only in the pair of consecutive off days. All of the seven contractors can go for one-hour dinner breaks any time between 7:00 pm and 9:00 pm.

No.	Agent Type	Shift Time	Agents	Break	Off Days
1	Employees on shifts	3 shifts, 24 hours	19	None	Different: 7/2-7/2-7/3
2	Day employees	7:00 am-4:00 pm	1	12:00 pm-1:00 pm	Thursday-Friday
3	Contractors	6:00 am-3:00 pm	16	11:00am-1:00 pm	Thursday-Friday
4	Contractors	9:00 am-6:00 pm	4	12:00 pm-2:00 pm	Tuesday-Wednesday
5	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Monday-Tuesday
6	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Wednesday-Thursday
7	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Friday-Saturday
8	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Tuesday-Wednesday
9	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Sunday-Monday
10	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Thursday-Friday
11	Contractors	3:00pm-12:00 pm	1	7:00 pm-9:00 pm	Saturday-Sunday

Table 1 The current assignment of 47 employees to 11 tours

The ITHD management notices frustration with long waiting times during peak periods, although incoming calls are handled on a first-come, first-serve (FIFO) basis. Management's initial response to the complaints was to specify a minimum number of agents needed to meet the demand over different intervals. In estimating these demands, management depended only on its observations and the shifts leaders' opinions. They did not use any systematic or scientific method to estimate the demand for agents. Therefore, although working with these values had decreased the number of lost calls and users' complains, the problems still persisted. Another problem with the current schedule is unscheduled one-hour breaks, which can be taken randomly any time during predetermined two-hour intervals as shown in Table 1. This policy makes it too difficult to the shift leader to satisfy the varying workload.

Based on the above problem description, the IT Help Desk management aims to scientifically find the minimum-cost tour schedule of the agents subject to meeting the labor demands in each work period. For managerial reasons, the number of company employees on shift schedules must be between 5 and 20 agents in any proposed schedule. In order to achieve these objectives, the work was divided into the following stages: data collection and analysis, determining hourly labor requirements, model formulation and solution, and finally schedule construction.

4 DATA ANALYSIS TO ESTIMATE LABOR DEMANDS

In order to determine the proper number of agents for short-term staffing, ITHD management needs to forecast the workload on an hourly basis. Therefore, the first step involved building up a reliable history on the pattern of the workload (number of calls). To find the arrival pattern of calls, historical data of the number of calls arriving during each hour for five typical months was collected. The data was used to calculate the average number of arriving calls for every hour of the day and every day of the week.

The call arrival rate depends on both the time of the day and the day of the week. The weekdays have a higher number of calls than the weekend. This is especially true during the official work hours of the company (7:00 am to 4:00 pm). The call arrival patterns for the workdays differ significantly from those of the weekend. All the workdays (Saturday to Wednesday) have very similar patterns. We could also say the same thing about the weekends. Therefore, the average number of hourly calls was calculated separately for workdays and weekends.

Service time is defined as the time duration of each successfully-completed call to the IT Help Desk. The service time has a mean of 4.03 minutes and a standard deviation of 1.741 minutes. It is interesting to note that the actual mean of 4.033 minutes is much smaller than the 10-minute service-time standard the ITHD management was arbitrarily using. During workdays, the IT Help Desk receives an average of 79.21 calls per hour. During weekends, the average drops to 29.10 calls per hour.

A Markovian queuing model was used to determine the hourly labor demands. Since queuing models are robust to the assumptions made, the *M/M/c* queuing model is commonly used in the literature without checking the actual distributions. For example, Agnihothri and Taylor (1991) and Andrews and Parsons (1989); (1993) simply assumed Poisson arrival distribution and exponential service time distribution. Therefore, an (*M/M/c*) : (*GD*/∞/∞) queuing model is used here as an approximation, based on the following assumptions:

1. The arrival rate of the daily number of calls depends on both the time of day and the type of day, i.e., workday or weekend.
2. The inter-arrival time of calls within each time period has an exponential distribution.
3. The service time distribution has an exponential distribution.

First in, first served (FIFS) rule is applied in answering incoming calls as a policy of the IT help desk. Calls that cannot be answered immediately because all agents are busy will join a queue and wait for agents to be available. For workdays and weekends, the intervals with similar arrival rates were grouped and analyzed together using a separate queuing model with the same arrival rate.

An exponentially distributed service time with a mean $\mu = 1/Y$ was used for every day of the week. This mean represents the service rate as the number of calls processed per minute. In order to covert to hourly units to match the arrival rate, we must multiply with the number of work minutes per hour. Out of each eight-hour work shift, approximately one hour is lost for unscheduled breaks personal needs, and so on. Therefore, the net work time averages 52.5 minutes per hour, and the hourly service rate is given by:

$$\mu = \frac{52.5}{Y} \text{ calls per hour} \quad (1)$$

According to Taha (2003, p. 612), the number of servers c_i required in hour i for the (*M/M/c*) : (*GD*/∞/∞) queue must satisfy ($\lambda_i/\mu c_i < 1$), or:

$$c_i > \frac{\lambda_i}{\mu} \quad (2)$$

Thus, the minimum number of the agents needed for each hour i is calculated by:

$$c_i = \left\lceil \frac{\lambda_i Y}{52.5} \right\rceil \quad \text{agents per hour} \qquad (3)$$

Where

λ_i = arrival rate (number of calls received during hour i)
μ = service rate (number of calls processed per hour)
c_i = number of operators required for the given hour
Y = call duration in minutes
$\lceil a \rceil$ = smallest integer $\geq a$.

In equation (3), the maximum value of arrival rate λ_i for each hour i and the mean values of call duration Y were used. Using the maximum λ_i is specified by ITHD management, who aim to have adequate staffing to satisfy the highest demand. The days of the week were divided into two groups (workdays and weekends), and the days in each group were divided into intervals with similar arrival rates λ_i. The results are shown in Table 2.

Time Interval	Range of hours i	*Workdays*	Weekends
12:00 midnight-6:00 am	1, .., 6	3	2
6:00 am-10:00 am	7, …, 10	16	7
10:00 am-12:00 noon	11, …, 12	9	7
12:00 noon-3:00 pm	13, …, 15	14	7
3:00 pm-8:00 am	16, …, 20	10	6
8 pm-12:00 midnight	21, …, 24	6	6

Table 2 Minimum number of agents for each hour as a function of λ_i and Y

5 NEW SCHEDULING OPTIONS

In addition to the 11 tour types described in Table 1, new tours introduced to provide more flexibility in order to better match the varying demand pattern. Following management instructions, only the tours which cause minimum disruption to the current work practices were considered. New tours were created by considering the following combinations of days off, shift start/finish times, and lunch (dinner) hours.

1. Non-shift (day) employees work hours will be from 6:00 am to 3:00 pm instead of 7:00 am to 4:00 pm. It is better to start at 6:00 am because the peak period starts at 6:00 am. The one-hour lunch break is still taken from 12:00 noon to 1:00 pm.

2. For contractors who work from 6:00 am to 3:00 pm with Thursday and Friday off, 14 variations were introduced by considering all 7 pairs of consecutive days-off and 2 possible lunch hours (either 11:00 am-12:00 noon or 12:00 noon-1:00 pm).

3. For contractors who work from 9:00 am to 6:00 pm with Tuesday and Wednesday off, the work hours were delayed to 10:00 am-7:00 pm in order to

avoid overlapping their lunch hours with those of the 6:00 am shift. The lunch break will be 1:00-3:00 pm instead of 11:00 am to 1:00 pm. Moreover, 14 variations were introduced by considering all 7 pairs of consecutive days-off and 2 possible lunch hours (either 1:00-2:00 pm or 2:00-3:00 pm).

4. For contractors who work from 3:00 pm to 12:00 midnight with different pairs of days off, 14 variations were introduced by considering all 7 pairs of consecutive days-off and 2 possible dinner hours (either 7:00-8:00 pm or 8:00-9:00 pm).

6 MODEL CONSTRUCTION AND SOLUTION

After determining labor requirements for each hour of the week and developing new tours to better match these requirements, an integer programming (IP) model is constructed to optimize employee tour schedules. There are 44 decision variables used in building the integer program corresponding to 44 different weekly work tours. The objective of the IP model is to minimize the labor cost, subject to meeting the hourly labor demands and satisfying all applicable scheduling rules and constraints. The model is formulated as follows.

$$\text{Minimize } W = \sum_{j=1}^{44} k_j x_j \tag{4}$$

subject to

$$\sum_{j=1}^{44} a_{ij} x_j \geq c_i, \qquad i = 1, 2, ..., 168 \tag{5}$$

$$1 \leq x_1 \leq 5 \tag{6}$$

$$x_j \geq 0 \text{ and integer}, \qquad j = 1, 2, ..., 44 \tag{7}$$

where

W = workforce size, i.e., total number of employees assigned to all 44 tours
x_j = number of employees assigned to weekly tour j
a_{ij} = 1 if hour i is a work period for tour j, 0 otherwise
c_i = minimum number of employees required in hour i
k_j = cost of weekly tour j

6.1 Alternative solution

Using the above inputs and assumptions, the integer program was solved for the calculated values of the right hand side vector c_i corresponding to max. λ_i and mean Y. Using LINDO to solve the resulting problem, an alternative solution was obtained. Table 3 compares the features of the proposed solution with the current schedule.

Schedule property	Current Schedule	Proposed schedule
Shift employees: $4x_1$	19	20
Non-shift employees: x_2	1	1
Contractors: $x_3 + x_4 + \ldots + x_{44}$	27	21
Total workforce	47	42
Total monthly cost ($)	329,941	287,853
Workforce utilization (%)	69.8	77.8

Table 3 Comparison of the current and proposed schedules

6.2. Comparing solutions

The choice among the two alternative solutions will depend primarily on the total cost and the total number of agents needed. The choice will also be affected by the advantages and disadvantages of each schedule, and the preferences of the IT help desk management.

By assuming maximum number of calls λ_i, the new solution provides a very good level of customer service. This solution keeps the agents' utilization high (78%) and reduces the cost by $42,089 per month and the number of agents by 5. It must be noted that workforce utilization is defined as the ratio of required to assigned man-hours per week. After evaluating and comparing the two alternative solutions, IT Help Desk management made the decision to choose the new solution, which assigns 42 agents to 13 different tours as described in Table 4.

No.	Agent Type	Shift Time	Agents	Break	Off Days
1	Employees on shifts	3 shifts, 24 hours	20	None	Different: 7/2-7/2-7/3
2	Day employees	6:00 am-3:00pm	1	12:00 pm-1:00 pm	Thursday-Friday
3	Contractors	6:00 am-3:00 pm	1	12:00am-1:00 pm	Saturday-Sunday
4	Contractors	6:00 am-3:00 pm	1	11:00am-12:00 pm	Tuesday-Wednesday
5	Contractors	6:00 am-3:00 pm	7	11:00am-12:00 pm	Thursday-Friday
6	Contractors	6:00 am-3:00 pm	2	12:00am-1:00 pm	Thursday-Friday
7	Contractors	10:00 am-7:00 pm	1	2:00 pm-3:00 pm	Friday-Saturday
8	Contractors	10:00 am-7:00 pm	1	2:00 pm-3:00 pm	Sunday-Monday
9	Contractors	3:00pm-12:00 pm	1	7:00 pm-8:00 pm	Monday-Tuesday
10	Contractors	3:00pm-12:00 pm	1	8:00 pm-9:00 pm	Monday-Tuesday
11	Contractors	3:00pm-12:00 pm	1	7:00 pm-8:00 pm	Friday-Saturday
12	Contractors	3:00pm-12:00 pm	1	8:00 pm-9:00 pm	Friday-Saturday
13	Contractors	3:00pm-12:00 pm	4	12:00 pm-1:00 pm	Thursday-Friday

Table 4 Details of tour assignments obtained from the new solution

7 CONCLUSIONS

This paper described an employee tour scheduling project accomplished in the Information Technology Help Desk (ITHD) of a large company. Extensive data on the number of calls and call durations was collected and analyzed to determine the minimum number of agents required for each hour of the week. New tours were proposed to provide more flexibility to better meet labor demands, while minimizing the disruption to the current scheduling system. An integer programming model was used to find the optimum employee tour schedules that satisfy labor requirements with the minimum number and cost of employees.

The proposed tour schedule defines for every employee the starting and finishing work hours, the lunch or dinner break hour (if applicable), and the off days. The new solutions were compared in order for the management to choose the best schedule. The chosen solution will save $505,066 a year while satisfying customer demands and management objectives.

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