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Practical scheduling for call center operations

Dennis C. Dietz

Qwest Communications International Inc., 1855 South Flatiron Court, Boulder, CO 80301, USA

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ABSTRACT

A practical spreadsheet-based scheduling method is developed to determine the optimal allocation of service agents to candidate tour types and start times in an inbound call center. A stationary Markovian queueing model with customer abandonment is employed to determine required staffing levels for a sequence of time intervals with varying call volumes, handling times, and relative agent availabilities. These staffing requirements populate a quadratic programming model for determining the distribution of agent tours that will maximize the fraction of offered calls beginning service within a target response time, subject to side constraints on tour type quantities. The optimal distribution is scaled to reflect the total number of scheduled agents, and a near-optimal integer solution is derived using rounding thresholds found by successive one-dimensional searches. This novel approach has been successfully implemented in large service centers at Qwest Communications and could easily be adapted to other operational environments.

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1. Introduction

Many commercial enterprises and public agencies operate centralized call centers to provide effective and responsive service for patrons. Mandelbaum [1] estimates that there are as many as 200,000 separate call centers operating in the United States, employing up to 4% of the national workforce (more than the entire agricultural sector). About 70% of the operating cost of a typical call center is attributable to personnel expense, so the economic efficiency of the operation is determined primarily by the quality of the employee scheduling process. For inbound call centers, the scheduling problem is normally characterized by a highly variable demand pattern and a requirement to assign service agents to “tours” that are constrained by labor rules. The fundamental problem is to schedule tours such that resulting time-varying staff quantities maximize the service level, or achieve a target service level at minimum cost.

Efficient management of a modern call center involves decision making (and supporting modeling and analysis) on three primary time horizons: annual planning, monthly (or quarterly) scheduling, and daily execution. Annual planning deals with strategic concerns such as forecasting long-term call volume trends and associated personnel requirements, managing an employee replacement pipeline, planning for volume seasonality, and conducting an annual vacation bid. Daily execution encompasses tactical matters such as consideration of schedule change requests, monitoring of schedule compliance and center performance metrics, and responding to unpredicted fluctuations in call volume by offering discretionary time-off or overtime to appropriate agents. This article focuses on monthly scheduling, which involves confirming forecast volume and total staff quantities, adjusting for nonproductive activity requirements (estimating agent “availability”), creating a schedule, and then populating the schedule with particular employees based on seniority and preferences. We are specifically concerned with the technical task of creating an optimal schedule, which is derived as an optimal quantification of tours by type and start time.

The importance of the call center scheduling problem is indicated by a large and growing body of relevant literature. Gans et al. [2] present a cogent overview, and Mandelbaum [3] provides a comprehensive bibliography. Reported application areas include retail sales [4], transportation [5], public services [6], and the telecommunications industry [7,8]. Solution approaches have incorporated diverse management science methods such as mathematical programming [9,10], analytical queueing models [11], simulation [12], dynamic programming [13], genetic algorithms [14], and other heuristic procedures [15]. Brigandi et al. [16] document deployment of a call center modeling system that delivered $750 million in increased annual profits for a diverse set of client enterprises. The system relied on simulation as the primary modeling tool, but employed queueing models to calculate staffing requirements and a network flow approach to determine workforce schedules. In this article, we apply queueing theory, quadratic programming, and a one-dimensional search algorithm to derive and evaluate optimal schedules, all within a practical spreadsheet implementation.

2. Determining staffing requirements

A forecast weekly demand profile for a typical call center can be accurately constructed from historical data. Fig. 1a displays an

E-mail address: dennis.dietz@qwest.com

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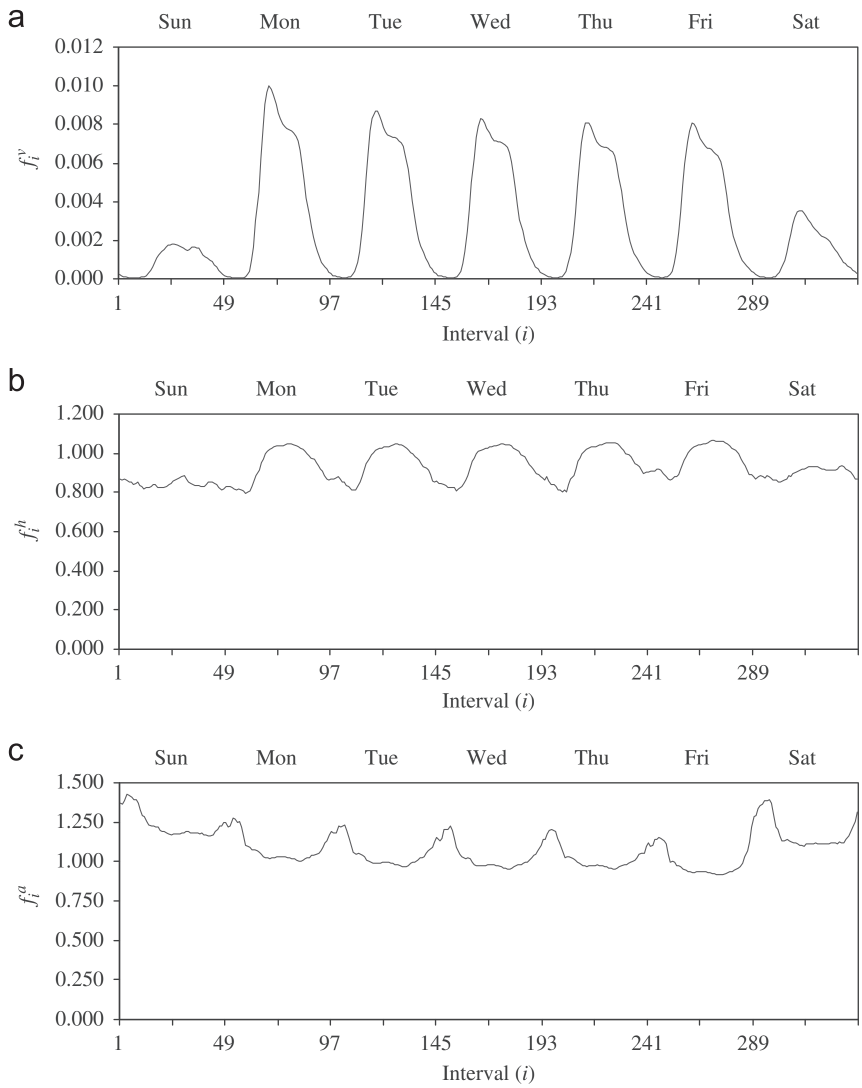

Fig. 1. Typical parameter profiles. (a) Offered call volume, (b) average handling time and (c) staff availability.

expected distribution of offered repair calls for a typical week and product at Qwest Communications. For any future week, the expected call volume v_i for each 30-min operating interval $i \in I \subseteq \{1,\ldots,336\}$ is determined as the product of the associated profile value f_i^v (where $\sum_{i\in I} f_i^v = 1$) and a forecast weekly volume V. For the particular product depicted, the weekly volume varies seasonally by about 30% from its low value in December to its peak value in August. The distribution of call volume among intervals within the week, however, is demonstrably invariant throughout the year. Variability in realized call volume within an interval can be treated as random, so the customer arrival process can be modeled as a nonstationary Poisson process with an expected number of arrivals v_i. A similar approach is pursued to capture interval-dependent variation in handling time. Fig. 1b displays handling time profile values f_i^h which are aggregated from annual interval data and scaled such that $\sum_{i\in I} f_i^v f_i^h = 1$. The profile indicates the presence of recurring patterns including "shift fatigue" (longer service time during high volume intervals), which is commonly discerned [11]. Letting H be a specified average handling time for a given future week, average handling time for each interval i can be computed as $h_i = f_i^h H$ (the scaling of f_i^h ensures that $\sum_{i\in I} f_i^v h_i = H$). Finally, Fig. 1c displays a staff availability profile, which captures interval-dependent variability in the average fraction of time a scheduled agent is actually available to handle calls after accounting for nonproductive activities such as absences, breaks, meetings, training, and other administrative functions. The availability factor for interval i is computed as $a_i = f_i^a A$, where the profile values f_i^a are similarly derived from annual interval data and A is the average availability estimate for the week (A must be a number between 0 and $1/\max_{i\in I}\{f_i^a\}$, so that $0 \le a_i \le 1, i \in I$). Since an efficient schedule will correlate interval staffing levels with corresponding work volumes, the values f_i^a are scaled to ensure that $\sum_{i\in I} f_i^v f_i^h f_i^a = 1$ (so that $\sum_{i\in I} f_i^v f_i^h a_i = A$). By decoupling H and A from their associated profiles, we can conveniently model trends and seasonalities in these factors which do not appreciably affect their relative magnitudes across intervals. We note that all three profiles must be periodically and simultaneously updated due to interaction between call volume, handling time, available staff, and implemented schedules.

When the scheduling objective is to minimize total cost (surrogated by staff size), an optimal schedule must ensure that sufficient agents are assigned on each interval to satisfy a composite service level requirement for each week of the relevant scheduling period. Alternatively, when the staff size is specified, the service level requirement can be iteratively adjusted until the predetermined number of agents is employed in the optimal solution. For scheduling purposes, we narrowly define service level as the probability that a random customer will not wait more than a

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