H

The Optimal Workforce Staffing Solutions With Random Patient Demand in Healthcare Settings

Alexander Kolker
GE Healthcare, USA

INTRODUCTION

The current demand for more efficient use of healthcare resources, cost reduction, and patient safety improvement stimulates developing the novel operations management solutions. Workforce management has emerged as the one with the biggest impact on cost efficiency and quality of care in the USA. Indeed, labor cost typically absorbs about 54% of total hospital's operating revenue (Herman, 2013). Therefore, an accurate assessment of the required staffing that matches the highly variable patient demand is an integral part of the hospital's budgeting and planning process. Healthcare administrators must accomplish multiple clinical and quality goals while simultaneously developing realistic staffing plans and budgets. Random fluctuations of patient demand present staffing planning challenges to many hospitals. There is a growing trend for using data analytics to address these challenges.

The objective of this chapter is providing an overview and examples of application of the data analytics methodology called the "newsvendor" framework. This methodology helps to determine the optimal staffing solutions for the specified time periods for hospital units with randomly fluctuating daily patient census.

BACKGROUND

The newsvendor model is the widely used analytic model in which the optimal inventory level is determined for a specified time period. Historically, it originates from the problem in which a newsvendor has to decide on the optimal stocking quantity of the newspaper (a single product) to be ordered from the publisher in some defined ahead time period; hence it is called the newsvendor problem. If too many issues are ordered there will be some financial loss due to unsold inventory. If not enough issues are ordered there will also be some financial loss due to unmet customer demand. The problem is determining the optimal quantity order that will minimize the total financial loss due to both over- and understock during some time period.

The newsvendor framework has been widely applied to problems in which decisions should be made on the fixed supply level with an uncertain (random) demand. Such problems are often occurring in supply chain management, retail, transportation, manufacturing, banking, and many other industries (Choi, 2012; Arikan, 2011; Porteus, 2002). Motivated by the importance of various practical applications of the newsvendor model, the entire special issue of the Decision Sciences journal (Chen et al., 2016), and the review paper (Qin et al., 2011) were dedicated to its novel advances and applications.

DOI: 10.4018/978-1-5225-2255-3.ch322

At the same time, the use of the newsvendor framework was rather limited in healthcare management for planning and budgeting the hospital units' staffing while patient demand is uncertain.

For example, in the handbook of newsvendor problems, which is the first handbook dedicated exclusively to the state of the art in this area (Choi, 2012), the optimal nursing staffing problem with uncertain patient demand was not presented at all. However, this is a fruitful area of application of the newsvendor framework. The long-term nursing staffing plans should be developed on the annual basis. The medium-term staffing plans should usually be developed for a 4-6 weeks period, and be posted 1-2 weeks before the start of the planned period. Because of inevitable occurrences of unforeseen deviations from the planned staffing level, some short-term staffing adjustments should be made shortly before each shift to determine whether overtime, pooled or agency nurses are needed, or if the unit is overstaffed and some nurses are not currently needed. There is a cost associated with flexing staff up or down, along with issues of staff dissatisfaction with the erratic unpredictable schedules. There is an empirical evidence that the frequent staffing adjustments costs are accumulated to significant amounts that were not previously budgeted for. The optimal staffing level determined by the newsvendor model minimizes these accumulated costs, thus making nursing staffing plans and budgets more realistic.

One of a few publications that mention the use of the newsvendor framework for determining the optimal nursing staffing level is Hopp and Lovejoy (2013). These authors included the newsvendor framework as one of the management principles: in a single time period (month, quarter, or year) with uncertain staffing demand, the staffing level which corresponds to the minimal (optimal) possible total cost of under- and overstaffing is given by the solution, S, of equation

$$F(S)=Cu/(Cu+Co) \quad (1)$$

where $F(S)$ is the cumulative distribution function of staffing demand, Cu and Co are the hourly costs of under- and overstaffing per nurse, respectively. Derivation of Equation 1 is given in Appendix.

These authors assumed that staffing demand in any single time period is normally distributed with the known mean, m, and standard deviation, σ. Therefore, the optimal staffing level S is given by $S=m+Z*\sigma$, where Z is the inverse standard cumulative normal distribution function, i.e. $Z=\Phi^{-1}[Cu/(Cu+Co)]$.

At the same time, the assumption of normal staffing demand distribution is rarely true (if ever). Staffing demand is usually a skewed distribution function that poorly fits any theoretical distribution. This is pointed out by Davis et al. (2014) in which the newsvendor framework is applied for analyzing nursing staffing under demand uncertainty. The authors propose the use of distributional robust formulations of the newsvendor problem suggested by Perakis et al. (2008). In this formulation, it is sufficient to know only the moments of the demand distribution. However, the closed-form solutions to these models are not available. The authors propose to solve those using linear programming for sub-problems.

One important condition for application of the classic newsvendor framework is that the staffing distribution function must be stable and applicable both for the current and for the future time periods. This requires forecasting the demand which is itself a separate challenging problem. Usually, the demand forecast generated, for example, by a time series analysis can be reasonably accurate only for about a week or so. Beyond that time horizon, the forecasting errors are similar to that coming simply from the historical demand distributions (Davis et al., 2014). It is quite restrictive to assume that the future demand distribution is well known. Therefore, there have been some efforts to relax this assumption. One direction has been the nonparametric (data-driven) approach. In this approach, independent past demand data are used to estimate the minimal number of ob-