



Discrete Optimization

Retail store scheduling for profit

Nicolas Chapados^a, Marc Joliveau^b, Pierre L'Ecuyer^{a,c}, Louis-Martin Rousseau^{b,*}^a Université de Montréal, Montréal, Canada^b École Polytechnique de Montréal, Montréal, Canada^c Inria–Rennes, Rennes, France

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ABSTRACT

In spite of its tremendous economic significance, the problem of sales staff schedule optimization for retail stores has received relatively scant attention. Current approaches typically attempt to minimize payroll costs by closely fitting a staffing curve derived from exogenous sales forecasts, oblivious to the ability of additional staff to (sometimes) positively impact sales. In contrast, this paper frames the retail scheduling problem in terms of operating profit maximization, explicitly recognizing the dual role of sales employees as sources of revenues as well as generators of operating costs. We introduce a flexible stochastic model of retail store sales, estimated from store-specific historical data, that can account for the impact of all known sales drivers, including the number of scheduled staff, and provide an accurate sales forecast at a high intra-day resolution. We also present solution techniques based on mixed-integer (MIP) and constraint programming (CP) to efficiently solve the complex mixed integer non-linear scheduling (MINLP) problem with a profit-maximization objective. The proposed approach allows solving full weekly schedules to optimality, or near-optimality with a very small gap. On a case-study with a medium-sized retail chain, this integrated forecasting–scheduling methodology yields significant projected net profit increases on the order of 2–3% compared to baseline schedules.

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1. Introduction

The retail sector accounts for a major fraction of the world's developed economies. In the United States, retail sales represented about \$3.9 trillion in 2010, over 25% of GDP, employing more than 14 M people at some \$300B annual payroll costs (U.S. Census Bureau, 2011). Given these figures, it stands to reason that effective sales staff scheduling should be of critical importance to the profitable operations of a retail store, since staffing costs typically represent the second largest expense after the cost of goods sold (Ton, 2009): as a result, all efficiencies coming from better workforce deployment translate into an implicit margin expansion for the retailer, which immediately accrues to the bottom line.

The best retailers today rely on a staff schedule construction process that involves a decomposition into three steps (Netessine, Fisher, & Krishnan, 2010). First, the future sales over the planning horizon are forecasted, usually a few weeks to one month ahead at a 15- to 60-minutes resolution. Second, this forecast is converted into labor requirements using so-called

“labor standards” established by the business (e.g., every \$100 in predicted sales during a given 15-minutes period requires an additional salesperson that should be working during that period). Finally, work schedules are optimized in a way that attempts to match those labor requirements as snugly as possible, while meeting other business and regulatory constraints (e.g., one may have that an employee cannot be asked to come to work for less than three consecutive hours or for more than eight hours in total, must have breaks that follow certain rules, etc.).

It may be somewhat unsettling that nowhere does this process acknowledge, explicitly or tacitly, that in many retail circumstances, salespeople *actively contribute to revenue* by doing their job well—advising an extra belt with those trousers, or these lovely earrings with that necklace—and not only represent a salary cost item to store operations. In other words, the presence of an additional staff working at the right time drives up expected sales, a crucial dynamics ignored when sales forecast tranquilly descends “from above”.

This paper, in contrast, formalizes the retail staff scheduling problem by formulating it as one of *expected net operating profit maximization*. It introduces a modeling decomposition that allows representing the expected sales during a time period as a function of the number of salespersons working, thereby capturing the impact of varying staffing hypotheses on the expected sales. The

* Corresponding author. Tel.: +1 514 343 7442; fax: +1 514 343 7121.

E-mail addresses: chapados@iro.umontreal.ca (N. Chapados), marc.joliveau@gmail.com (M. Joliveau), lecuyer@iro.umontreal.ca (P. L'Ecuyer), louis-martin.rousseau@polymtl.ca (L.-M. Rousseau).

profit-maximizing labor requirements are obtained, for a given time period, as the number of employees beyond which the marginal payroll cost exceed the marginal revenue gain from having an additional staff working. Finally, it introduces new solution techniques that are able to capture the profit maximization aspects of the problem. On a case-study with a medium-sized Canadian clothing and apparel chain, this integrated forecasting–scheduling methodology yields significant projected net profit increases on the order of 2–3% with respect to baseline schedules.

The literature on schedule optimization is quite vast; see Ernst, Jiang, Krishnamoorthy, Owens, and Sier (2004); Ernst, Jiang, Krishnamoorthy, Sier (2004) and Van den Bergh, Beliën, De Bruecker, Demeulemeester, and De Boeck (2013) for comprehensive reviews. Given the retail industry’s overall economic significance, the impact of staffing decisions has received some attention in the literature, albeit perhaps not any commensurate with the gains that are to be expected from improved planning. Thompson (1995) proposed a scheduling model that takes into account a linear estimate of the marginal benefit of having additional employees, but not accounting for understaffing costs. Lam, Vandenbosch, and Pearce (1998) and Perdikaki, Kesavan, and Swaminathan (2012) have shown that store revenues are causally and positively related to staffing levels, opening the door to staffing rules based on sales forecasts. Moreover, using data from a large retailer, Ton (2009) finds that increasing the amount of labor at a store is associated with an increase in profitability through its impact on conformance quality but, surprisingly, not its impact on service quality. Mani, Kesavan, and Swaminathan (2011) find systematic understaffing during peak hours in a study with a large retail chain, using a structural estimation technique to estimate the contribution of labor to sales. Additionally, in what is probably the most potent case to date for improving scheduling practices, Netessine et al. (2010) find—with another large retailer—strong cross-sectional association between labor practices at different stores and basket values, and observe in their examples that small improvements in employee scheduling and schedule execution can result in a 3% sales increase for a moderate (or zero) cost.

Perhaps the contribution closest in flavor to what we suggest in this paper comes from the work of Kabak, Ülengin, Aktas, Önsel, and Topcu (2008): similarly to the present paper, these authors introduce a two-stage approach to retail workforce scheduling based on a statistical forecasting model of sales incorporating an explicit labor effect. The profit-maximizing number of salespeople under this model is then computed to obtain the desired hourly staffing levels in the store, assuming workforce cost homogeneity. This is followed by an optimization phase, which assigns individual employees to a set of pre-existing shifts. The approach is then validated through simulation to demonstrate its effectiveness on a Turkish apparel store.

As we show later, our paper extends this approach by suggesting the use of complete *sales curves* within the schedule optimization stage, better reflecting the uncertainty surrounding the sales response model (which often exhibits a rather flat shape around the optimal number of salespeople), and easily allows optimizing schedules with non-homogenous staff costs. To achieve this goal, we first propose a stochastic model of retail store sales in terms of a revenue decomposition that is particularly amenable to robust and modular modeling. This decomposition allows to obtain an accurate 15-minutes-resolution forecast of sales, conditional on any desired determinant, opening the path to operating profit maximization.

Furthermore, in contrast to Kabak et al. (2008), the proposed schedule optimization does not use a set of predefined shifts, but rather builds those that, while meeting labor and union regulations, allow to maximize profit. The main difficulty is to efficiently

combine two distinct sets of objectives and constraints: those of the retailer, defined in terms of the number of working employees in each time period, and those of the workers, defined in terms of the “friendliness” of the working shifts assigned to them. We formulate the profit-maximization problem as a mixed integer non-linear problem (MINLP) where the decision variables specify the work status (working, break, lunch, rest) of each employee, and we examine two ways of solving this problem. The first approach linearizes the problem and turns it into a mixed integer program (MIP), which is then solved either directly or approximately using piecewise linear functions. The second approach expresses the original MINLP as a constraint program (CP), which is solved directly. It provides better performance, especially on larger problems. The proposed problem formulations are based on the use of a regular language to specify the admissibility of shifts with respect to union agreements. Schedules are constructed both over a day and a week.

The rest is organized as follows. In Section 2 we formulate the problem, setting forth overall schedule construction objectives. In Section 3, we explain the stochastic models we developed for sub-hour sales forecasts, and we evaluate the forecasting ability of these models on out-of-sample sales at several locations of a mid-sized clothing and apparel chain of retail stores. We continue in Section 4 with two scheduling problem formulations, one as a MIP and the other as a CP, whose solutions are employee schedules that maximize expected profits, over a day and over a week (as shown in Section 5). Section 6 concludes. A preliminary and summarized version of this work was previously presented in Chapados, Joliveau, and Rousseau (2011).

2. Problem formulation

Here we present an overview of the proposed approaches. The global schedule construction process has two main steps, summarized in Fig. 1:

1. Analyzing the historical workforce sales performance to construct a stochastic model of store behavior and to build *sales curves*, which give the expected sales at each store for each time period, as a function of the number of staffs assigned to sales during that period.
2. Using these sales curves to construct admissible work schedules, for the employees, that maximize the expected profit.

2.1. Forecasting sales as a function of staffing

Each sales curve provides a functional characterization of how the expected sales at a given store and time period are impacted by varying the staffing. A classical staffing *demand curve*, in

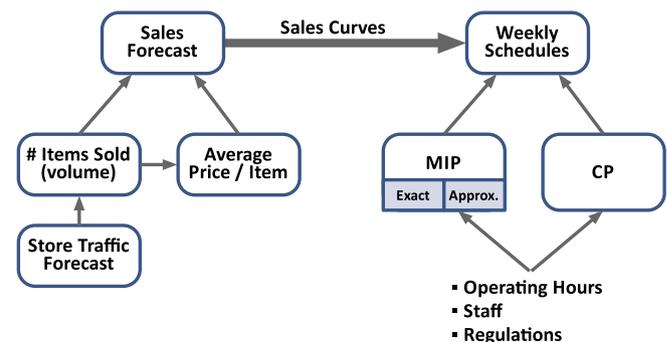


Fig. 1. Overview of the proposed methodology to address the problem of retail scheduling for profit.

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