Labor Planning and Shift Scheduling in Retail Stores using Customer Traffic Data

Labor operating costs are among the largest expense in the retail sector, and one of the main sources of employment in developing countries. Whereas retail operations management has made significant progress in improving inventory management (the largest operating expense in retail), labor management has now become critical to improve operational efficiency, in part enhanced by new technologies that provide real-time data on customer traffic and employees. These data has propelled empirical research in retail labor management, starting with the seminal work by Fisher et al. (2006) that studies how changes in the staffed labor affects the sales of retail stores. This study and other that follow show that labor is an important driver of revenues. This work builds over this important stream of work to combine empirical analysis with optimization methods to build a decision support tool that can be used by managers to plan labor allocation and schedule working shifts to maximize store profitability, balancing gross margins with labor costs.

Following Fisher et al. (2006), Perdikaki et al. (2012) studies the relationship between labor and sales, but account for customer traffic as an additional factor. Chuang et al. (2016) expands this work to develop a decision model to plan labor hours at a weekly level by store, accounting also for heterogeneity across stores in a chain. Although this is similar to our work, our goal is to provide a more detailed plan of labor staffing in an hour-by-hour, day-today basis, including working shifts of full-time and parti-time employees. Our work is related to Mani et al. (2015), that seeks to measure over and under staffing of stores. Their approach uses structural estimation to uncover the gross margin and costs of labor, assuming that the retail store staffs optimally at the weekly aggregate level. We use a different methodology that does not assume that the store staffs optimally, and we also consider labor regulatory restrictions and worker’s scheduling preferences to jointly optimize the staffing hours and shift scheduling.

The Operations Research literature has a long history in developing models to optimize shift schedules in service delivery systems using tools from mathematical programming (e.g. Thompson (1995)). However, these models typically take the labor requirements as a fixed input, finding a feasible schedule that achieves these requirements at minimum costs. In our work, the desired labor requirements is one of the key decisions, which accounts for the trade-off between costs (wages) and margins (sales).
Our methodology is separated into two steps. First, an econometric model is developed to estimate the effect of labor on sales in an hourly basis. This model provides an input to mathematical program that seeks to find the best feasible schedule (with several regulatory and practical constraints) to maximize store profitability.

At an hourly level, it is quite common to observe zero sales, which can complicate the specification of the econometric model. To account for this, we decompose the effect of labor on sales into two parts: (1) conversion, which is modeled through a Poisson regression or other similar models for count data that can account for zero transactions during the time interval; and (2) ticket value, which is always positive and can be modeled through a log-linear regression.

The recent work by Fisher et al. (2017) shows that identifying a causal effect of labor on sales is challenging because staffing levels are endogenous: a positive correlation between staffing and sales can be generated by omitted variables in the regression model which are observed and accounted for by the store managers in the labor planning process. To identify the causal effect of labor on sales, we follow the same strategy as Fisher et al. (2017), using deviations between the planned and actual staffing level of the store as exogenous variation. However, our deviations are measured at a more granular level using hourly planned and actual schedules, which were collected from the stores archival data (Fisher et al. (2017) uses weekly labor hours).

Our identification strategy is based on the presumption that deviations from the planned labor are exogenous and are unrelated to demand shocks that may affect conversion and ticket value. It is therefore important to control for factors that can potentially affect customer behavior and deviations from the planned staffing level. Most of the deviations from the working schedule are due to factors unrelated to demand: requests from employees to adapt the working schedule, unexpected absenteeism, among others. However, one common factor that can affect both (customers and working schedule deviations) are disruptions that affect transportation: access to the physical stores can affect demand and staffing simultaneously. Our models include control for weather events and other disruptions in the transport system that were publicly reported.

This econometric model was used to predict sales as a function of customer traffic and staffing levels. As in Chuang et al. (2016) and Perdikaki et al. (2012), we find a non-linear effect of traffic and staffing levels on sales, where most of the effect is through conversion. The magnitude of the effect is comparable to the results of Fisher et al. (2017): increasing labor in under-staffed stores can increase sales in the order of 2-5% (depending on the level of traffic of the store).

The results suggest that, conditional on traffic, expected sales is an increasing concave function of labor. Without any constraints, the optimal staffing decision can be decoupled hour-by-hour, increasing the staff
in each hour period until the marginal increase in gross margin equals the employee salary. In practice this is not feasible because regulation requires compliance with minimum hours per working shifts, hours per week, rest days, among others. This complicates the optimization of working schedules that combines full and part time employees, but we show it can be effectively modeled and solved to optimality with a mixed integer program using data from real instances.

In summary, our work integrates several features of previous work, combining hourly customer traffic, planned and actual staffing levels and optimization methods to develop a decision support tool that can be used by store managers to optimize the labor plan together with a detailed shift schedule that complies with labor regulations and other real-world constraints. We effectively test this methodology in a children apparel retail chain in South America. We also use the model to quantify the economic impact of labor regulatory restrictions on store profitability, which are relevant in the context of our application due to ongoing changes in the regulatory environment.

References


