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From sales data to workforce schedules

Forecasting, workload modeling, shift scheduling and shift rostering

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Abstract We discuss a commercially implemented workforce scheduling approach by going through a real-life application in retail stores. This approach takes as input historical 15-minute sales data and translates this into optimized workforce schedules by going through a number of steps. The approach starts by forecasting future sales from the historical sales. After that, the forecasted sales data is translated into staffing requirements, expressing the number of persons that need to be scheduled in each 15 minute time slot of a specified horizon. This is then input to generate a set of shifts that covers these staffing requirements, and finally a workforce schedule is generated by assigning employees to these shifts.

Keywords Forecasting · Workload modeling · Shift scheduling · Shift rostering

1 Context

In supermarkets, the work that has to be performed is mainly driven by grocery sales. Products can be sold only if the cash desks are staffed, and if shelves are stocked at the right moment and time. To make sure the right person is available at the right time, we have developed a scheduling approach that uses historical sales data as input and converts this to optimized workforce schedules. Our scheduling approach consists of multiple stages, which we describe in the next section.

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2 Approach

Our approach consists of five stages: forecasting, workload modeling, capacity planning, shift scheduling and shift rostering. The capacity planning step is an optional step in this approach and can thus be skipped. Comparable decompositions are found in Burke et al (2004), Ernst et al (2004) and Thompson (1997).

1. Forecasting First, we sum the 15-minute historical sales to daily totals. From the day totals future day total sales are forecasted. To convert the forecasted day totals to 15-minute sales data, we use 'day patterns' that specify how sales are distributed throughout the day. The motivation for this decomposition is that sales patterns throughout the day may differ substantially, whereas day totals tend to be more stable, thereby allowing for more accurate day totals forecasts. Forecasts are calculated using various forecasting algorithms that are combined in a regression model. The forecasting algorithms we use are, among others, Holt-Winters and Exponential Smoothening, see, e.g., Gelper et al (2010).

2. Workload modeling This stage determines the staffing requirements, which express the number of people that should be staffed on a certain activity in a specific 15-minute time slot. Using productivity figures, sales forecasts are translated into staffing requirements. For example, if 500 euros is forecasted for some 15-minute time slot, and the productivity at the cash desk is 250 euros per cashier per 15 minutes, then 2 cashiers have to be staffed.

Depending on the level of detail, various forecasts can be calculated to determine staffing requirements for various activities. For example, to determine the number of cashiers, a forecast on the total sales is applicable, but to determine the number of people stocking the dairy products, a forecast for the dairy sales should be available.

3. Capacity planning From the staffing requirements, a mid-term capacity plan can be made, describing target working hours per employee per week. This is useful, since in practice one week may be busier than the other. Therefore, it makes sense to let people work more hours in one week than in the other. This makes it possible to do more with the same people, since in slow weeks there is less over-capacity and in busy weeks there is less under-capacity, reducing the need to hire (expensive) subcontractors. Using lower and upper bounds on the working hours of individual employees combined with absence information of employees, working hour targets are determined per week per employee, such that the workforce capacity is distributed optimally over the weeks. The modeling details are found in Van der Veen et al (2012). Note that in our approach, the capacity planning step is optional and can be skipped.

4. Shift scheduling After staffing requirements have been determined, shifts are scheduled. Shift scheduling is subject to constraints on, e.g., shift lengths, shift starting times, shift ending times, break rules, and allowed activity combinations. Using staffing requirements and shift generation rules as input, a set of shifts is determined, such that the staffing requirements are covered efficiently, hard constraints are respected and violations of soft constraints are minimized. The set of shifts is optimized by a metaheuristic framework that combines various re-start heuristics with variable neighborhood search.

5. Shift rostering After shift scheduling is complete, employees have to be assigned to the shifts. Shift rostering is subject to labor legislation constraints on, e.g., allowed sequences and combinations of shifts. Moreover, unavailability of employees, employees preferences and working hour targets (as determined in the capacity planning step) are considered in shift rostering. Our shift rostering algorithm aims to assign all shifts to employees, while minimizing violations of soft constraints. Of course, hard constraints, such as labor legislation, may not be violated by the algorithm.

In short, this algorithm employs a hybrid heuristic ordering method to construct multiple initial shift schedules, which are improved by a genetic algorithm. Next, the best schedule found by the genetic algorithm is improved using a variable neighborhood search. Mathematical details of this algorithm are found in Burke et al (2008) and Post and Veltman (2004).

3 Conclusions

We have designed a process that creates demand driven workforce schedules using historical sales data. Hereby, the aim is to have people available if needed and when needed. The next steps in our research and implementation are to analyze the effects on cost reduction, profit increases, and service level improvements. Moreover, there are interesting future research questions such as combining the shift scheduling and rostering steps, and assessing the feasibility of our approach for other industries.

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