Shift scheduling with autonomous agents

Sara Mattia[1], Fabrizio Rossi[2], and Stefano Smriglio[2]

[1] Istituto di Analisi dei Sistemi ed Informatica, Consiglio Nazionale delle Ricerche (Italy)
[2] Dipartimento di Ingegneria e Scienze dell'Informazione e Matematica, Università di L'Aquila (Italy)

The classical *shift scheduling* problem in workforce management is stated as follows. We look at a discrete planning horizon T and, for each time slot $t \in T$, we are given a *staffing level* $b_t \in \mathbb{Z}$, that is, the number of agents which are needed to be on duty at interval t in order to guarantee the expected Level of Service (LoS) provided by a service system to customers. We are also given a set J of work shifts which comes from the labor contracts, e.g. part-time or full-time, chosen by the organization. A *work shift* $j \in J$ corresponds to a sequence of consecutive time slots $T_j = \{t_s^j, \ldots, t_f^j\}$ and is assigned with cost c_j, representing the salary cost falling on the company when such a shift is covered by some agent. The *shift scheduling problem* consists of deciding how many agents must be assigned to each work shift in order to cover the demand at minimum cost. Since the first mathematical formulations have been introduced [7,9], this problem has been extensively studied in several application contexts, as it represents one major stage of the workforce management process [1,6]. In practice, work shifts include *rest breaks*, which are particularly important to reduce workers stress. Their placement is tightly regulated by National regulations as well as collective agreements, which results in a given collection $\mathcal{B}^j = \{B_i^j | B_i^j \subseteq T_j, i = 1, \ldots, r(j)\}$ of feasible break allocation patterns for shift j [5].

Two types of mathematical models have been developed to address the shift scheduling problem with breaks. *Explicit* models associate a decision variable to each pair shift-break [7,9]. *Implicit* models consider, instead, separate assignment variables for shifts and breaks, whose compatibility is enforced by linking constraints, which require a posteriori algorithm to build the schedule [2,4,8]. Examples of these formulations, along with a comparison of the two approaches, can be found in [3]. Both explicit and implicit models share the same decision-making point of view: a *manager* chooses the shifts along with the breaks, whereas the agents play little or no role. This centralized process is supported by the managers, who are concerned with the performance impairment due to the rest breaks. On the other hand, such a rigid enforcement of breaks remarkably affects agents' well-being, as discussed, e.g., in [10]. Indeed, this conflict is often getting critical in large organizations and requires negotiation between management and trade unions.

In this talk we investigate the trade-off between agents' autonomy and personnel cost. This is carried out by comparing two planning options. The first consists of a fully centralized approach, where the manager decides shift and break schedules so that personnel and under/overstaffing costs are minimized. We compute such benchmark schedules by a standard explicit model. Differently, in the sec-

ond option, agents are free to choose their breaks within the legal, union and company restrictions. In this setting, we introduce a model able to determine shift schedules which are robust to agents' unsupervised choices. This is a *two-stage robust* optimization model, where the manager (first stage actor) chooses a shift schedule, while agents (second stage actors) individually choose when to enjoy their rest breaks.
Two-stage robust optimization problems are well-known to be hardly tractable both in theory and practice. Nevertheless, by exploiting the specific structure of our model, we have devised a heuristic algorithm able to compute good feasible solutions of relevant industrial cases. Finally, the practical impact of the resulting methodology is discussed.

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