Ground staff shift planning under delay uncertainty at Air France

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\section*{Context}

Ground staff agents of airlines operate many jobs at airports such as passengers check-in, planes cleaning, etc. Shift planning aims at building the sequences of jobs operated by ground staff agents, and have been widely studied given its impact on operating costs.

During the last decades, the rise of global air traffic has been followed by an increase in flights delays. More than 20\% of European flights are delayed by more than fifteen minutes in 2005 \cite{5}. Disruption of passenger connections, crews, and ground operations is a major source of cost for airlines \cite{1}. More specifically, disruptions of ground operations have two negative consequences. First, ground operations contribute to delay propagation: as a flight cannot take-off if mandatory jobs have not been performed by ground staff, a ground staff agent that is delayed on a given job propagates this delay to the flights corresponding to its next jobs. Second, avoiding this propagation of delay requires additional staff to perform ground operations. Building ground staff schedules that are resilient with respect to delay is therefore growing challenge for airlines.

Our work is the result of a project initiated by Air France, the main French airline, to build such schedules.

\section*{Literature}

Deterministic ground staff scheduling problems have been less studied than airplane and crew scheduling problems as they are not specific to airline and can be treated using standard approaches of the personnel scheduling literature \cite{6}. However, this last assertion becomes false when delay is taken into account. Indeed, personnel scheduling literature focuses on uncertainty about demand volume, demand arrival time, and manpower availability \cite{6}, but not on the propagation of delay. On the contrary, the construction of sequences of flight legs that do not propagate delay has been extensively studied for airplanes and crews – see e.g. \cite{3, 7, 2}. But to the best of our knowledge, the problem of building sequences of tasks for ground staff agents that do not propagate delay has not been considered yet.

\section*{Contributions}

Our first contribution is a \textit{stochastic ground staff shift planning problem} that can deal with Air France specific context. Uncertainty holds on flight legs delay. The framework is flexible
enough to deal with the different kinds of jobs operated by ground agents of the company. The way delay is propagated along shifts, the online management of delay, and the resulting costs for the airline have been modeled with care. We notably introduce a modeling hypothesis on delay propagation that fits the way the airline handles delay and simplifies optimization. We provide solution methods (see next contributions) for scenario based distributions, which enables to work with any distribution through sampling.

Second, we provide compact integer formulation for the deterministic task-level shift planning and generalize it to the stochastic task-level shift planning. If similar formulations of the deterministic problem have been considered in the literature, our formulation is tailored for Air France specific problem, and off-the-shelf solvers are able to solve to optimality instances with hundreds of jobs in a few seconds. The stochastic version can solve heuristically instances with a few dozens of jobs, and highlights the difficulty of the stochastic shift scheduling problem.

Our third and main contribution is a column generation approach to the stochastic shift planning problem that can solve to optimality instances with up to 210 jobs and 200 scenarios in a few minutes, and instances with up to 250 jobs and 200 scenarios in at most a few hours on a standard computer. To the best of our knowledge, this is the first practically efficient algorithm for shift planning with delay propagation. The pricing subproblem of the column generation build interesting shifts, and the master problem selects the shifts that will be operated. As delay propagates along shifts, stochasticity is handled in the pricing subproblem. The performance of our approach lies in the efficiency of the pricing subproblem algorithm. We solve this pricing subproblem using a framework for resource constrained shortest path recently introduced by the second author [4]. We emphasize that the framework does not explain how to model a concrete problem in practice. Indeed, to successfully apply the framework, we had to introduce a non-trivial algebraic structure to model delay propagation. This algebraic structure provides insights on delay propagation and is a contribution on its own. Furthermore, the framework had never been applied to a concrete stochastic industrial problem, and our work demonstrates the relevance of such an approach.

Finally, we demonstrate the practical relevance of a stochastic approach including the cost of delay. On industrial instances, using a few hundred scenarios, moving from the deterministic problem to the stochastic one enables to reduce the total operating costs by 3% to 5%.

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