Automatic Aircraft Cargo Load Planning with Pick-up and Delivery

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1 Motivation

During last years, some major changes occurred in the airline industry. The removal of barriers to entry for new and existing companies led to the entry and growth of Low Cost Companies, with as direct consequence, an increase of competition in the sector. This accrued competition was accompanied by an important change in mentality. Since the beginning of the 2000s, airlines, traditionally seen as little conscious of their spendings, have gradually introduced programs to reduce costs and improve efficiency. The volatility and increasing trend in the oil prices, combined with the market pressure for more focus on environmental concern has pushed companies to pay more attention to fuel consumption and more broadly to all kinds of costs. The loading activity in the cargo airline sector remains a process highly manual and consequently there exists some major potential gains in terms of time and money. This double objective fits perfectly into programs cost reductions currently undertaken by the airlines. [1, 10]

2 Positioning, objectives and method

The objective of this research is the development of a new mixed integer linear programming (MILP) model designed for optimally loading a set of *unit load devices (ULDs)* into a cargo aircraft. The main contribution is to consider sequences of destinations with pick-up and delivery and to minimize the cost and environmental impacts. We take into account two major costs on which the loading activity can intervene : the cost of time (that includes wages of employees used for loading, fees to the airline for usage of the runway,...) and the cost of fuel as the fuel consumption depends on the way ULDs are loaded in the aircraft. Therefore, the challenge is to find the optimal assignment of ULDs into the aircraft so that the locations of the centers of gravity (CG) for each route induces minimal fuel consumption and simultaneously, the loading time at each destination is as short as possible. This weight and balance problem therefore belongs to the family of assignment problems.

In the scientific literature, there exists already a number of mathematical models and heuristics on aircraft cargo load planning [2, 3, 5, 8, 9]. The starting point of our work is the model developed by S. Limbourg, M. Schyns and G. Laporte (2012)[4], which aims to optimize the loading of a cargo aircraft by minimizing the moment of inertia as main objective. We developed a new objective function that takes into account the two costs. For the first part, we search to obtain the centers of gravity as much as possible to the aft since, as suggested by scientific literature [6, 7], such a result decreases the fuel consumption. In addition, we try to measure the economic impact of this displacement of CG to the aft. We also keep in mind that the CG must lie in a specified area (feasibility envelop) to ensure aircraft stability. Consequently, the first part of our objective will be to minimize the difference between the obtained CG and the furthest feasible CG. For the second part of our objective function, as the loading time depends on the number of operations that employees have to do, we will search to minimize the number of ULDS to unload at each destination.

Our model works with three main components. The roads, which are the different parts of trip separating two successively visited airports, the ULDs to be transported and the different positions in the aircraft. Based on those components, we search the best way in terms of fuel consumption and loading time to assign each ULD at one position on each of the road. For that, our model uses binary variables x_{ijk} as in S. Limbourg, M. Schyns and G. Laporte (2012)[4]. We consider also the same weight and CG constraints but we will adapt them to consider multiple destinations. We also have to add some new constraints to model the number of ULDs to load and unload at each destination. Finally, we plan to expand our current model in order to introduce hazard constraints (for special shipments) and constraints for larger ULDs that are observed in practice and that seriously complicate the problem.

We will test this model on a set of real-world instances provided by an industrial partner, using first exact methods (branch and cuts). So, we will try to quantify the economical and environmental impacts.

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