An Integer Programming model for air transport of hazardous and special shipments

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Abstract

The aircraft loading problem is a real-world combinatorial optimisation problem highly constrained. This weight must be distributed to keep the centre of gravity within specified limits. Moreover, an aircraft has usually several cargo compartments with specific contours and structural limitations such as floor loading, combined load limits and cumulative load limitations. Finally, some shipments are particularly restrictive to transport, like dangerous goods, live animals and perishable goods. This paper is concerned with the incorporation of these latter constraints in a mixed integer linear program for the problem of loading a set of Unit Loading Devices and bulk into an aircraft. Experimental results show that our method achieves optimal solutions within only few seconds.

Keywords: Aircraft loading, weight and balance, hazardous, special shipments

Several papers deal with the problem of loading a set of Unit Loading Devices (ULDs) and bulk into a cargo aircraft. An ULD is an assembly of components consisting of a container or a pallet with a net. [4, 5, 6] consider how to optimise the location of ULDs in an aircraft and their impact on the Centre of Gravity (CG). [5] optimise the mass of goods loaded while [6] maximize the total cargo value. This implies that the aircraft is nearly always loaded at full capacity. However, there are often far fewer ULDs to load than what the aircraft is capable to carry, see [3]. In these cases, we have to ensure that the loading should be concentrated or "packed" around the CG. That's why [4] propose an approach based on the moment of inertia to tackle this problem.

According to [3], the airlines have sent 40 million tons of cargo, which corresponds to 35% of the world of trade by value. Indeed, the rapidity of air transport can be very important for high value product or for time sensitive cargo such as perishable goods or live animals. However, none of these papers takes into account the special requirements that apply to these special shipments and to hazardous material. That is precisely the aim of this paper.

A literature review about hazardous materials transportation can be found in [2]. The authors propose a classification in four categories: risk assessment, routing, combined facility location and routing, network design. The literature on marine, air, and pipeline transport of dangerous goods is in its beginnings.

A hazardous materials transportation must take into account that some goods may react dangerously with others. To avoid any interaction, a segregation table sums up the incompatibilities between different shipment types. Other materials, as such perishable goods, living animals, can be treated in the same way. The *segregated storage problem* (SSP) consists of determining an optimal distribution of products among existing storage compartments such that at most one product may be stored in a given compartment. A new problem, called the *generalized segregated storage problem* (GSSP), is introduced in [1]. It involves the allocation of a certain number of goods to available compartments subject to segregation (physical separation) constraints. A proof of NP-completeness of SSP was presented in [1].

Our work is an extension of [4] where we add extremely important constraints in air transport. It originality is in its ability to deal with the problem of loading a set of ULDs into a cargo aircraft, ensuring that the loading is concentrated around the required CG and taking into account the specificities of the goods, this includes hazardous products but also some special shipments like oversized ULD. This new model will be presented during the conference. Besides, we have created a JAVA software that use the library IBM ILOG CPLEX with its classic branch-and-bound solver to test our model. Data is given to us by our industrial partners and the first results is very encouraging. A demonstration video of the software is available on our website *http://www.quantom.hec.ulg.ac.be*.

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