Automatic Cargo Load Planning: Special shipments

Sabine Limbourg[1]
Michael Schyns[2]

Abstract: *The aircraft loading problem is a real-world combinatorial optimisation problem highly constrained. Indeed, loading the aircraft so the gross weight is less than the maximum allowable is not enough. This weight must be distributed to keep the centre of gravity (CG) 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 (ULDs) and bulk into an aircraft. Experimental results for real data sets show that the model achieves better balanced solutions in only a few seconds compared to the solution obtained by load masters.*

Keywords: Aircraft loading, weight and balance, transport, dangerous, perishable, animals.

1. <u>Introduction</u>

This paper is concerned with the incorporation of constraints related to special shipments in a mixed integer linear program for 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.
Several papers consider how to optimise the location of ULDs in an aircraft and their impact on the Centre of Gravity (CG): Mongeau and Bès, 2003; Souffriau et al. 2008, and Limbourg et al., 2011. Mongeau and Bès, 2003 optimise the mass of goods loaded while Souffriau et al., 2008 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 the International Air Transport Association (IATA), 2010. In these cases, we have to ensure that the loading should be concentrated or "packed" around the CG. That's why Limbourg at al., 2011 propose an approach based on the moment of inertia to tackle this problem.
The rapidity of air transport can be very useful for cargo such as perishable goods or live animals. However, none of these papers takes into account the special requirements apply to this special cargo and to hazardous material. That is precisely the aim of this paper.
According to the US Department of Transportation, a hazardous material (hazmats) is defined as any substance or material capable of causing harm to people, property, and the environment. On the one hand, the United Nations sorts hazardous materials into nine classes according to their physical, chemical, and nuclear properties (UN, 2001). Each hazard class is divided into several hazards divisions and specific labels are applied to each one of these classes or divisions. On the other hand The IATA Dangerous Goods Regulations considers three types of dangerous goods: goods too dangerous to be transported by air, goods transported with cargo aircraft only (called CAO shipments) and goods transported both with cargo and passenger aircraft.
The transportation of hazmats can be classified according to the mode of transport, namely: road, rail, water, air, and pipeline. A literature review about Hazardous Materials Transportation can be found in Erkut at al. (2007). Due to the large number of papers in this

[1] QuantOM, HEC Management School, University of Liège, Rue Louvrex 14 (N1), 4000 Liège, Belgium. Sabine.Limbourg@ulg.ac.be
[2] QuantOM, HEC Management School, University of Liège, Rue Louvrex 14 (N1), 4000 Liège, Belgium. m.schyns@ulg.ac.be

area, the authors propose a classification in four categories: risk assessment, routing, combined facility location and routing, network design.
Finally, some goods may react dangerously with others. To avoid any interaction, a segregation table from IATA sums up the incompatibilities between different shipment types. 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. It has been studied by several authors: Shilfer and Naor (1961) introduced a formulation of SPP. White and Francis (1971) and, Dannenbring and Khumawala (1973) investigated a branch and bound procedure. Neebe and Rao (1976) proposed a column-generation procedure for a linear version of the problem and, Evans and Cullen (1977) introduced a mixed integer formulation of the problem.
Barbucha (2004) introduced and formally defined a new problem called the generalized segregated storage problem (GSSP). It involves the allocation of a certain number of goods to available compartments subject to segregation (physical separation) constraints. The subject of this paper was motivated by practical problems arising in maritime transportation of goods including dangerous goods. Because of the fact that both problems are computationally difficult (a proof of NP-completeness of SSP was presented in Barbucha, 2004) it is possible to obtain in reasonable time exact solutions only for instances of relatively small sizes.
The first part of the paper gives an overview of the air cargo flows and briefly presents a mathematical model designed for optimally loading a set of containers and pallets into a compartmentalised cargo aircraft. This is followed by a summary of the incompatibilities between different shipment types and by the incorporation of these segregation constraints into the model. The paper ends with case studies and conclusions.

2. Air cargo flows

Airports Council International publishes annual Worldwide Airport Traffic Report (abbreviated as WATR reports) (2009), based on the data from a number of airports, representing approximately 98 percent of global airport traffic. Distinction is made between domestic cargo accounting for 37% of total cargo volume and international cargo accounted for 63% of the total cargo volume. The three main regions according to the cargo volume are: Asia-Pacific (35%), North America (32%) and Europe (19%), Table 2.

Regions	Number of airports	Total Cargo (tons)
Africa	176	1 944 332
Asia-Pacific	185	27 700 660
Europe	459	15 445 874
Latin America-Caribbean	269	4 178 973
Middle East	53	5 144 183
North America	212	25 403 389
Total	1354	79 817 412

Table 1. Cargo volume by regions (Source WATR reports 2009)

A few main commodities govern air commerce between the major trading partners. According to Boeing World Air Cargo Forecast (WACF), 2010, industrial products and miscellaneous manufactured goods are major components of both eastbound and westbound flows between Europe and North America.
71% of eastbound air cargo traffic between Asia–North America is made up by office machines and computers, apparel, telecommunication equipment, electrical equipment, general industrial equipment, and specialized and scientific equipment; while 47% of the westbound traffic is made up by general industrial equipment, documents and small packages, electrical machinery, scientific and specialized equipment, and chemical materials (5%).

For 72.6% and in descending order, the Asia-to-Europe flow consists of general industrial machinery, electrical machinery and apparatus, express packages, pharmaceutical products (8.8%), automobile parts and accessories, and miscellaneous manufactured goods; while the Europe-to-Asia flow is primarily manufactured goods.
Europe represents 66% of Africa's market for international air cargo. Principal northbound commodities are perishables. Southbound commodities are far more varied and include pharmaceuticals, machinery and transport equipment, oil-related supplies, and manufactured goods. The same trends are observed between Latin America and North America where 69% of total northbound traffic is perishable, while southbound flows included small packages and documents, industrial machinery and parts, computers, office machines, and specialized equipment.
A closer look on hazardous goods can be obtained in the 2007 Commodity Flow Survey (CFS). This survey provides data on the movement of freight by type of commodity shipped and by mode of transportation. More than 90% of goods transported by air for the United States are nonhazardous, and main hazard goods transported in terms of weight are perfumery products with flammable solvents and radioactive materials.

3. Mathematical model

The aim is to find the optimal allocation into a compartmentalised cargo aircraft of a set of ULDs of different types, contours and weights. Our model is based on the mixed integer programming CargoOpt model presented in Limbourg et al (2011). They optimise the moment of inertia under CG constraints.
Let's $\boldsymbol{U}$ be the set of ULDs, w_i the weight of the i^{th} ULD (U_i) and $\boldsymbol{P}$ the set of predefined positions (P_j) in the aircraft. We denote by P_L (resp. P_R) the set of positions on the left (resp. right) side. The longitudinal location of each position is expressed in inches as the distance from a virtual point called datum, this distance is denoted as the arm. We also define the central arm value a_j of P_j as the point where the ULD weight will be concentrated, L denotes the total length of the aircraft in inches, ID is the index datum value representing the requested CG and the total weight of the load is $W = \sum_{i \in U} w_i$.

Decision variables

x_{ij} = 1 if the ULD U_i is allocated to the position P_j
0 otherwise
y = 0 if constraint (10) is applied
1 if not

Objective function

$$\min \sum_{i \in U} \sum_{j \in P} w_i (a_j - ID)^2 x_{ij} + L^2 W y$$

Subject to

$$x_{ij} = 0 \qquad \forall\, i \in \mathbf{U}, j \in \mathbf{P} \mid U_i \text{ does not fit in } P_j \qquad (1)$$

$$\sum_{i \in U} x_{ij} \le 1 \qquad \forall\, j \in \mathbf{P} \qquad (2)$$

$$x_{ij} + x_{i'j'} \le 1 \qquad \forall\, i, i' \in \mathbf{U}, j \in \mathbf{P}, \forall j' \in \mathbf{O_J} \qquad (3)$$

$$\sum_{j \in P} x_{ij} = 1 \qquad \forall\, i \in \mathbf{U} \qquad (4)$$

$$-\varepsilon \le \frac{\sum_{i\in U}\sum_{j\in P} w_i(a_j - ID)x_{ij}}{W} \le \varepsilon \tag{5}$$

$$-\overline{D} \le \sum_{i\in U} w_i\Big(\sum_{j\in P_R} x_{ij} - \sum_{j\in P_L} x_{ij}\Big) \le \overline{D} \tag{6}$$

$$\sum_{i\in U} \sum_{j\in P \mid P_j \cap O_k^D \ne \phi} x_{ij} o_{ijk}^D \le \overline{O}_k^D \qquad \forall D\in \mathbf{D} \, \forall\, k\in \mathbf{O^D} \tag{7}$$

$$\sum_{i\in U} \sum_{j\in P \mid P_j \cap \bigcup_{c=1}^{k} F_c \ne \phi} \sum_{l=1}^{k} x_{ij} f_{ijl} \le \overline{F}_k \qquad \forall\, k \in \mathbf{F} \tag{8}$$

$$\sum_{i\in U} \sum_{j\in P \mid P_j \cap \bigcup_{c=1}^{k} T_c \ne \phi} \sum_{l=1}^{k} x_{ij} t_{ijl} \le \overline{T}_k \qquad \forall\, k \in \mathbf{T} \tag{9}$$

$$\sum_{i\in U} \sum_{j\in P \mid P_j \cap \bigcup_{c=1}^{k} T_c \ne \phi} \sum_{l=1}^{k} x_{ij} t_{ijl} - Wy \le \overline{R}_k \qquad \forall\, k \in \mathbf{T} \tag{10}$$

$$x_{ij} \in \{0,1\} \qquad \forall\, i \in \mathrm{U},\ \forall\, j \in \mathrm{P} \tag{11}$$

$$y \in \{0,1\}$$

Due to their dimensions, all the ULDs do not fit in all the positions, i.e. each position accepts only some ULD types; this leads to the set of constraints (1). A second set of constraints (2) ensures that one position can accept at most one ULD. The third set of constraints is related to the fact that it is possible to load larger ULDs in some special positions overlaying several smaller ones. When an ULD is loaded in such a position, the underlying positions must remain free and, conversely, when an ULD is loaded in a basic position, the overlaying position is no longer available. In (3), O_j denotes the set of position indices underlying position P_j. Constraints (4) ensure that each ULD is loaded, while constraint (5) ensures that the deviation of the CG from ID is very small. Constraint (6) warrants that the lateral imbalance is less than a threshold ($\overline{D}$). The combined load limits constraints (7) guarantee that there is not too much weight on given sections of the aircraft. This is done for the main deck, the lower deck and both decks together, and hence we distinguish the three cases by the index D. For deck D, the k^{th} area is denoted by O_k^D, the maximal weight of this area is $\overline{O}_k^D$ and o_{ijk}^D is the proportion of w_i falling in $\{O_k^D \cap P_j\}$. Constraints (8) stipulate that the cumulative weight distribution from the nose to the centre of the aircraft must lie below a forward piecewise linear limit function and constraints (9) that the cumulative weight distribution from the tail to the centre of the aircraft must lie below an aft piecewise linear limit function. We denote by F_k (resp. T_k) the consecutive forward (resp. aft) areas, f_{ijk} (resp. t_{ijk}) is the proportion of w_i falling in $\{F_k \cap P_j\}$ (resp. $\{T_k \cap P_j\}$) and $\overline{F_k}$ (resp. $\overline{T_k}$) the maximal cumulative allowable weight for the section starting at the nose (resp. the tail) and ending with F_k (resp. T_k). For the Boeing 747, it is preferable to load the aft section so as to satisfy a more restrictive cumulative aft limit. We define the new limit values by $\overline{R_k}$ instead of $\overline{T_k}$ (with $\overline{R_k} \leq \overline{T_k}$). These constraints should not be applied if they make the problem infeasible. That's why a new binary variable *y* expressing whether or not constraint (10) is applied for each area *k*. Finally, to guarantee that *y* takes the value zero whenever possible, the penalty term L^2Wy is added in the objective function.

4. Incompatibilities between different shipment types

Whenever dangerous goods are loaded onto a mean of transport, the segregation requirements must be fully satisfied. There may be variations between the land, air and maritime regulations, the minimum distances between ULDs denote particular requirements related to types of aircraft, types of stowage (vertical or horizontal), types of packing (open or closed), place to store packages (on main deck or lower deck), etc.

Table 1 regarding the separation requirements for dangerous goods and other cargo is related to the IATA Dangerous Goods Regulations. Segregation can be achieved by either separating tie-down of the ULDs or by locating ordinary compatible cargo ULDs between incompatible ULDs.

Here are general rules that can be extracted from this document:

- Dangerous goods from classes 2, 3, 4, 5 and 8 shall not be loaded in close proximity of dangerous goods from class 1
- Dangerous goods from class 7 must be separated from animals, hatching eggs and unexposed films. Moreover, during the flight, minimum horizontal and vertical distances must separate these radioactive packages from each other and from passengers.
- Live animals must be loaded in close proximity of neither foodstuffs nor human remains
- Live animals and hatching eggs must not be loaded in close proximity of dry ice. Note that dry ice is used as a refrigerant for perishable goods transportation.
- Live animals should be separated from laboratory animals
- Animals that are natural enemies such as cats and dogs should not be loaded insight, sound, smell or reach of each other
- Foodstuffs must not be loaded in close proximity of human remains.

Live animals and perishable goods are particularly restricting shipments to transport, they can't be directly loaded on the floor of the aircraft; in addition to the temperature, several other factors must be considered: on the one hand, animals and perishable goods need a relatively fresh air, but on the other hand they give off substances which can be harmful.

When transporting live animals and perishable goods, the basic rule is "Last in – First out". For the cargo to arrive in the best condition, it must be loaded as near as possible to the aircraft departure time and collected as soon as possible at the destination airport. That means that it must be loaded close to the cargo door.

Moreover, for goods emitting radiations such as magnetized or radioactive materials, the separation distances depend on the level of radiations. Magnetized materials must not be loaded in such a position that they will have a significant effect on the direct-reading magnetic compasses or on the master compass detector sections of the aircraft. The separation distances from packages of radioactive materials to passengers are based on a reference dose. If more than one ULD containing radioactive materials is placed in the aircraft, the minimum separation distance for each individual ULD must be determined on the basis of the sum of the reference doses.

IMP code	RCX	RGX	RXB	RXC	RXD	RXE	RXG	RXS	RFG	RNG	RCL	RPG	RFL	RFS	RSC	RFW	ROX	ROP	RPB	RIS	RRW	RRY	RCM	ICE	FIL	HUM	EAT	HEG	AVI	AVI
	Explosive	Explosive	Explosive	Explosive	Explosive	Explosive	Explosive	Explosive	Flammable Gas	Non-flammable Gas	Cryogenic Liquid	Toxic Gas	Flammable Liquid	Flammable Solid	Combustible	Dangerous when Wet	Oxidiser	Organic Peroxide	Toxic Substance	Infectious Substance	Radioactive	Radioactive	Corrosive	Dry Ice	Undeveloped Film	Human remains in coffin	Foodstuffs	Hatching Eggs	Live Animals	Laboratory animals
RCX		1	1		1	1	1																							
RGX	1		1	1	1	1																								
RXB	1	1		1	1	1	1																							
RXC		1	1		1	1	1																							
RXD	1	1	1	1		1	1																							
RXE	1	1	1	1	1		1																							
RXG	1		1	1	1	1																								
RXS																														
RFG																														
RNG																														
RCL																														
RPG																														
RFL																														
RFS																														
RSC																														
RFW																														
ROX																														
ROP																														
RPB																											2		2	2
RIS																											2		2	2
RRW																														
RRY																									X		X	X	X	X
RCM																														
ICE																														
FIL																						X								
HUM																														
EAT																			2	2		X								
HEG																						X								
AVI																			2	2		X							3	
AVI																			2	2		X								

This table must be read and used in conjunction with the IATA Dangerous Goods Regulations

Source: adaptation of DGP-WG/11-IP/4 CIAO

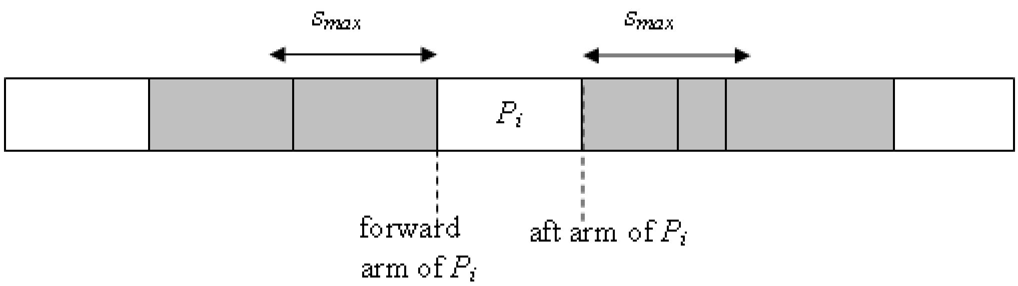
X	Minimum separation distance as specified by IATA Regulations
	Shall not be loaded in close proximity of one another
1	Refer to IATA Dangerous Goods Regulations 9.3.2.2
2	Must not be stowed in the same compartment, unless loaded in ULD's not adjacent to one another or in closed ULD's
3	This segregation requirement applies only to laboratory animals and to animals which are natural enemies

Table 2. Separation requirements for dangerous goods and other cargo

5. Incorporation of segregation constraints into the model

To incorporate the segregation constraints into the model described in section 3, we use lazy constraints which are constraints not specified in the constraint matrix of the MIP problem but integrated when violated. They represent simply one portion of the constraint set, they are only checked when an integer-feasible solution candidate has been identified, and of course, any of these constraints that turn out to be violated will then be applied to the full model. Using lazy constraints makes sense when there are a large number of constraints that must be satisfied at a solution, here representing each incompatibility, but are unlikely to be violated if they are left out. The latter is the case of instances suggested by our partner, CHAMP Cargosystems, where there are less than 15% of ULDs that need specific requirements.
Let m be the number of special load and let n be the number of available positions. Let S be the segregation matrix. Element $s_{ik} \in Z^+$ of matrix S (i; k = 1,…, m) defines required segregation distance in inch between goods: s_{ik} equal 0 if and only if good i can be loaded together with good k without any restrictions, and element s_{ik} is greater than 0 if some segregation conditions between goods i and k are required. Let s_{max} be the maximum of s_{ik} (i; k = 1,…, m). Note that S is symmetrical and elements of main diagonal are equal to zero.
Each position of the aircraft is defined by two values: the forward arm and the aft arm. To each position a neighbour list (NL) is added. For each deck, a position P_j is in the NL of a position P_i, ($i \neq j$) if the forward arm of P_j is less than the aft arm of P_i plus s_{max} or if the aft arm of P_j is greater than the forward arm of P_j minus s_{max} . The shaded positions in Figure 1 are the neighbour positions of P_i.

Figure 1. Neighbour positions



To deal with segregation constraints we propose the following algorithm.

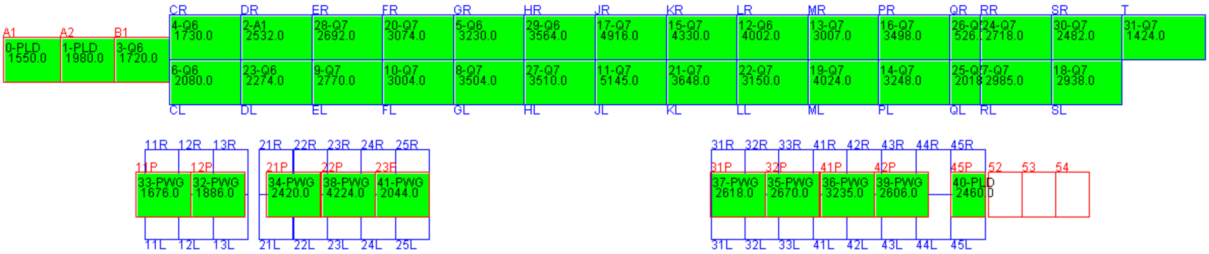
For each U_i to load ($i \in$ **U**)
    For j=i+1 to the number of ULDs to load
        If s_{ij}>0 then
        For each position possible $P_{i'}$ for U_i,
            For each position possible $P_{j'}$ for U_j
                For each $n \in$ NL of $P_{i'}$
                    if (n=j')
                        $x_{in}+x_{jj'} \leq 1$

Moreover, the general rules described in section 4 must be complete by a lot of specific rules such as those for magnetic or radioactive materials. That's why we modified the software such that, the load master can lock some ULDs in specific positions and a optimal solution for the other ULDs is found.

6. Case studies:

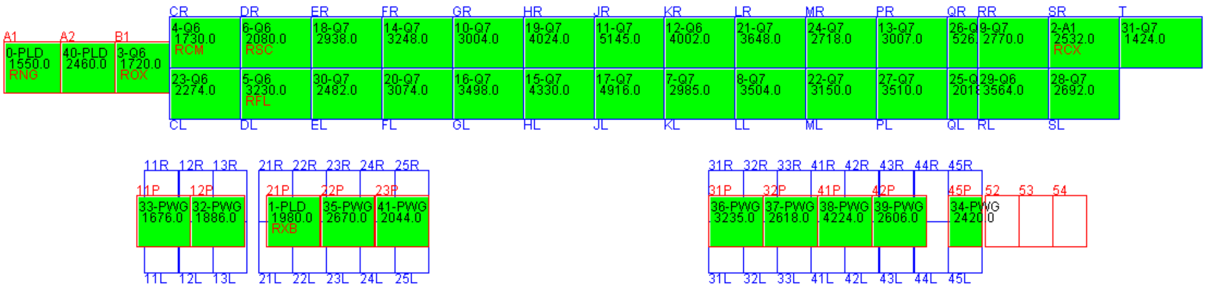
In order to generate these results, we have written a software in Java. The role of this software is to prepare the data, to call the professional optimisation library IBM ILOG CPLEX and to analyse the results. It has been compiled and tested under Windows XP and under Linux (Ubuntu 10.04). The optimisation steps were performed on a personal laptop computer (Windows XP, Dual-Core 2.5GHz, 2.8GB of RAM) and with CPLEX 12. Since we must solve a mixed integer linear program, we have used the classical branch-and-cut CPLEX solver with the default parameters.
The case study contains a large number of ULDs (42) and, a high capacity and largely operated aircraft, i.e. a Boeing 747. A Boeing 747 is divided into 67 basic positions, plus 10 larger ones overlaying some of the basic positions. We know the exact location and dimensions of each position, as well as the list of ULD types that each may contain. The positions are represented by boxes in Figure 2. Some positions are on the main deck (first row) and others are on the lower deck (second row). Each position is identified by a code on the side of the box.
Figure 2 also illustrates the solution obtained by the software. Each shaded box is a ULD with its type and weight. All constraints of the model presented in section 3 are satisfied.
Concerning the quality of the solution, we may measure the deviation between the CG obtained and its ideal position. In this case, the location of the requested CG is expressed as a percentage of the mean aerodynamic chord (MAC) value and equals 28 with a precision required of 0.01. With a result of 27.997, the goal is achieved. Finally, less than two seconds were required to solve this instance.

Figure 2 : Loading without incompatibly constraints



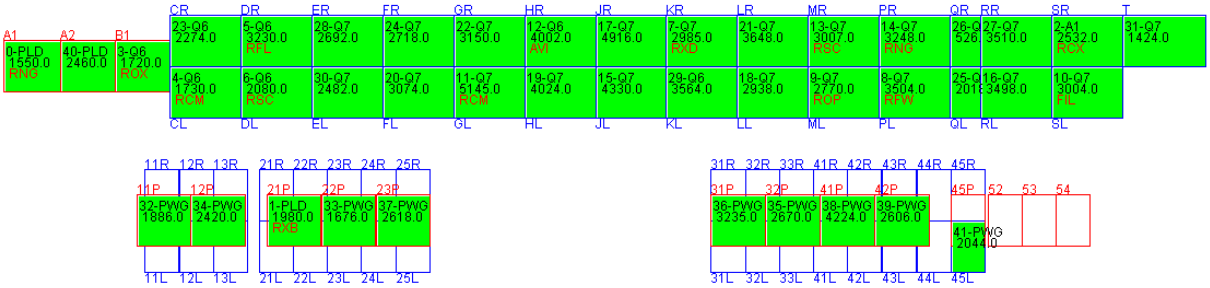
Several tests with a number of special ULDs less than 15%, have been performed. Figure 3 represents a case with seven ULD having separation requirements, solved in 4.9 s. The cargo-Interchange Message Procedures (IMP) code of these ULDs is in red in the shaded box. The time needed to solve is less than 7 s.

Figure 3 : Loading with 7 special ULDs



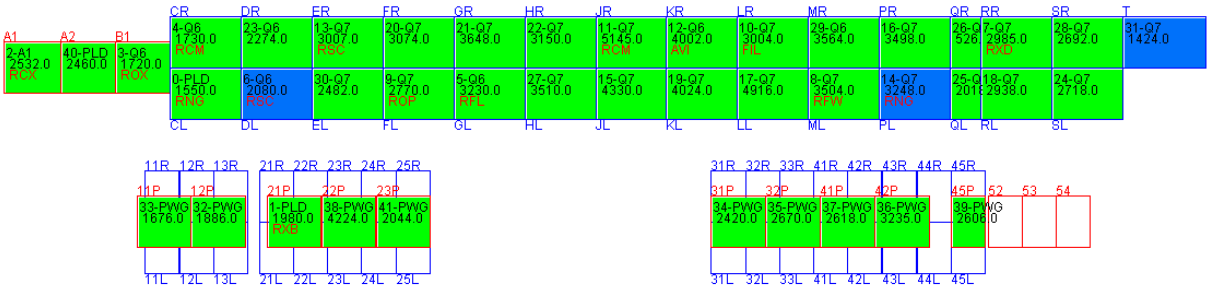
To test our model, we also present a case with 15 special ULDs solved in 6.1 s (Figure 4)

Figure 4 : Loading with 15 special ULDs



Finally, let's assume that in the case represented in Figure 3, we have three additional constraints: the ULDs 6 and 14 must be located near the doors and that the ULD 31 contains magnetic component that must be located far from electronic equipments. These ULDs can be positioned before the optimisation process, represented in blue in Figure 5. Starting from this configuration, it takes 3.2 s to obtain the optimal solution.

Figure 5 : Fixed positions for 3 ULDs



7. <u>Conclusion</u>

Our goal was to take the segregation constraints into account in a mixed integer linear program for the optimal loading of a set of containers and pallets into a compartmentalised cargo aircraft. In our knowledge and according to the commodity flow data, the number of incompatibilities between ULDs by flight is not too important. That's why our first approach, presented in this paper, was to used lazy constraints which are constraints not specified in the constraint matrix of the MIP problem but integrated when violated. This approach provides an optimal solution within less than seven seconds when there are about 15% of special ULDs to load.
Moreover, we modified the software such that, the load master can lock some ULDs in specific positions to satisfy additional rules such as those for magnetic or radioactive materials before the optimisation process.
The results obtained are encouraging but must still be validated by other tests.

Bibliography

Airports Council International (2009), Worldwide Airport Traffic Report http://www.airports.org/aci/aci/file/Press%20Releases/2010/PR_WATR2009_050810_FINAL.pdf

Barbucha, D (2004) *Three approximation algorithms for solving the generalized segregated storage problem*, **European Journal of Operational Research** 156(1): 54-72.

Boeing World Air Cargo Forecast (WACF), 2010, www.lb.boeing.com/commercial/cargo/wacf.pdf

Commodity Flow Survey, Hazardous Materials (2010), http://www.bts.gov/publications/commodity_flow_survey/2007/hazardous_materials/

Dannenbring, D.G. Khumawala, B.M. (1973) *An investigation of branch and bound methods for solving segregated storage problem*, **AIIE Transactions** 5 (3) 265–274.

Evans, J.R. Cullen, F.H. (1977) *The segregated storage problem: Some properties and an effective heuristic*, **AIIE Transactions** 9 (4) 409–413.

Erkut. E., S. Tjandra and V. Verter (2007), *Hazardous Materials Transportation*, Chapter 9 in Transportation, C. Barnhart and G. Laporte (editors), **Handbooks in Operations Research and Management Science** *vol 14, Elsevier. Pages 539-621*

IATA [International Air Transport Association] (2010). Cargo e-Chartbook. Quarterly Report, http://www.iata.org/whatwedo/Documents/economics/eChartbook-Q4-2010.pdf.

Limbourg, S. Schyns M, Laporte, G. (2011) *Automatic Aircraft Cargo Load Planning,* submitted to Journal **of the Operational Research Society**

Mongeau, M. and Bès, C. (2002). *Optimization of Aircraft Container Loading*, **IEEE Transactions on Aerospace and Electronic Systems**, Vol. 39, pp. 140–150.

Neebe, A.W. Rao, M.R. (1976) *An algorithm for the segregated storage problem*, **Naval Research Logistics** 23 406–420.

Shilfer, E. Naor, P. (1961) Elementary *theory of the optimal silo storage problem*, **Operational Research Quarterly** 12 54–65.

Souffriau, W., Demeester, P. and Vanden Berghe, G. and De Causmaecker,P. (2008). *The Aircraft Weight and Balance Problem,* Proceedings of ORBEL 22, Brussels, pp. 44–45.

UN (2001). UN recommendation on the transport of dangerous goods, model regulations. United Nations Economic and Social Council's Committee of Experts on the Transport of Dangerous Goods.

White, J.A. Francis, R.L. (1971*) Solving a segregated storage problem using branch-and-bound and extreme point ranking methods,* **AIIE Transactions** 3 (1) 37–44.