Schedule of Sorting Warehouses in Charles de Gaulle Airport

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1 Introduction

A study led by the Air France's Operations Research Departement gave birth to a project aiming at rescheduling the sorting warehouses on the connection platform of Charles de Gaulle airport.

During this study, it actually occured to us that a small optimization tool, quickly designed, would help to realize great savings and improvement at a logistics management level.

This quite simple but very efficient approach, with the associated mathematical model, is presented here with a complete description of the problem, from a real airline point of view. This approach will also be compared with the previous manual solution, in order to underline significant improvements. Finally, some computational results will be discussed.

2 Description of the problem

2.1 The Sorting Warehouses in Charles de Gaulle Airport

In the highly modern Charles de Gaulle airport, baggage of passengers in connection are automatically treated, with no-need for another check-in. Connecting baggage containers are redirected to two big automated sorting warehouses. Baggage are dispatched towards predefined positions on the baggage carousels, positions that are associated to the flights. These sorted baggage are then put into containers, and delivered under the appropriate aircraft.

This is therefore a 3 steps procedure: 1. redirection of connecting baggage containers and lifting inside the sorting warehouse, 2. dispatch of the baggage in the warehouse, 3. delivery in a position associated with the outgoing aircraft.

The objective of the scheduling project is to optimize the position of the flights on the carousels, in a warehouse.

2.2 Definitions

Timing Charts: each flight has, in addition to the opened position, a timing chart associated. A timing chart is an amount of time, which gives us an opening and closing time for the flight. Between these two times, baggage in connection to this flight can be delivered on the assigned position.

Anticipated baggage: a baggage is called anticipated when it arrives on the carousel before the opening of the flight on its associated position. These pieces are latter put back on their original carousel, which means a special treatment, with extra costs.

2.3 Problem Formulation

The main sorting warehouse is composed of P carousels. Each of them has a capacity of 11 to 17 positions, depending of its size. Let $C = C_1, ..., C_P$ be the set of carousels and P_i the number of positions of the the carousel C_i. Let $E = e_1, ..., e_n$ be the set of n flights that must be assigned on the positions. The flights can be classified into 5 different groups: long-haul flights (LH), heavy flights (L), very heavy flights (XL), multi legs flights (ML), and regular flights (R). The flights classified in (XL) and (ML) must be assigned to 2 positions, whereas only 1 is required for the others. The flights can be opened on carousels with different duration. For instance, a flight e_i scheduled to take of at H, can have its associated position opened from H-03:00 to H-00:30. With each possible duration is associated a timing chart f_i. Let $F = f_1, ..., f_m$ be the set of existing timing charts. The number of elements in this set must not be over 10 due to limitations imposed by the sorting system. One of the objectives of the optimization tool is to reduce the number of the redundant treatments associated to anticipated baggage, in maximizing the time during which the flights are openened.

The optimization tool must respect the following constraints: 1. assignement of all the flights, following the required positions, 2. respect of the number of positions available on the carousels, 3. no more simultaneous flights opened on a same carousel than allowed for the categories (LH), (L) and (XL), 4. the simultaneous opening of 2 flights for the same destination should be avoided (this could be confusing and lead to baggage assigned to the wrong flight), but tolerated for a short period of time if no other solution exists.

As a result, the tool gives the position assigned to each flight, for which length (i.e which timing chart). The main objective is to minimize the number of flights simultaneously opened on a same position (overlap). The second one is to reduce the number of anticipated baggage. Finally, the third one is to smooth the load on the different carousel. This is a very important goal from an operationnal point of view: the stake is to avoid concentrating in a same place the whole activity, which could lead to an operational breakdown of the system. In order to introduce working habits, we were asked to handle one more goal: to ensure a stability in the assignements over the week, from one day to another one. If a flight is scheduled several days in a week, it would be better to assign the same position each day.

3 Resolution

Problem's size would prevent from a global resolution over a whole week. Thus it was decided to adopt a day by day approach, trying to have programmation each day as close as possible from the first day. For each day, resolution was decomposed into 2 steps, each of them solved by Mixed Integer Linear Program. The first MIP aims at assigning a carousel and timing chart to each flight; in the second one we try to assign, on each carousel, the flights to the available positions.

4 Mathematical Programming Model

In order to remain clear, the model presented here is only a simplified version: some of the constraints and objective are not represented.

4.1 Notations

We need to introduce some others notations:

- $PA(c)$ returns the number of available positions on the carousel c,
- $PU(e)$ returns the number of positions needed by the flight e,
- $HPA(c)$ returns the number of positions available for "heavy" flights on a carousel c,
- $OT(e, f)$ returns the opening time of flight e if its associated timing chart is f,
- $CT(e, f)$ returns the closing time of flight e if its associated timing chart is f,
- $Intersection(e_1, e_2)$ returns the number of minutes when both flights e_1 and e_2 are opened.

4.2 First MIP

We use the following variable: $x_{e,c,f}$ is a binary variable indicating wether the flight e is opened on the carousel c with the timing chart f.

The objective is to

$$Min \sum_{e,c,f} NbAnticipatedBag(e,f) \times x_{e,c,f}$$

subject to:

$$\forall e,\ \sum_{c,f} x_{e,c,f} = 1 \quad (1)$$

$$\forall c,\ \forall t,\ \sum_{(e,f)/OT(e,f) \leq t \leq CT(e,f)} PU(e) \times x_{e,c,f} \leq PA(c) \quad (2)$$

$$\forall c,\ \forall t,\ \sum_{\substack{(e,f)/OT(e,f) \leq t \leq CT(e,f) \\ and\ e \in L}} PU(e) \times x_{e,c,f} \leq HPA(c) \quad (3)$$

$$\forall (e_1,f_1),\ \forall (e_2,f_2)\ such\ as\ Destination(e_1) = Destination(e_2)$$
$$and\ Intersection(e_1,f_1,e_2,f_2) \neq 0,\ \forall c,$$
$$x_{e_1,c,f_1} + x_{e_2,c,f_2} \leq 1 \quad (4)$$
$$\forall (e,c,f),\ x_{e,c,f} \in \{0,1\}$$

Constraints (1) impose that each flight must be affected to a carousel with only one timing chart; (2) count the positions available on a carousel; (3) limit the positions available for heavy flights (same constraints for other types of flights); (4) ensure that 2 flights going to the same destination won't be opened simultaneously on a same carousel.

4.3 Second MIP

We use the following variables:

- $x_{e,p}$ is a binary variable indicating wether the flight e is opened on the position p.
- $u_{e_1,e_2,p}$ is a binary variable indicating wether the flights e_1 and e_2 are opened simultaneously on p.

The objective is to

$$Min \sum_{e_1,e_2,p} Intersection(e_1,e_2) \times u_{e_1,e_2,p}$$

subject to:

$$\forall e, \sum_{p} x_{e,p} = 1 \quad (5)$$

$$\forall (e_1,e_2,p)\ such\ as\ Intersection(e_1,e_2) > 0,$$
$$x_{e_1,p} + x_{e_2,p} \leq 1 + u_{e_1,e_2,p} \quad (6)$$
$$\forall (e,p),\ x_{e,p} \in \{0,1\}$$

Constraints (5) ensure that only one main position is reserved for each flight, while with (6) we try to avoid two flights opened simultaneously on a same position.

5 Results

We quickly had some highly interesting results, which helped to industrialize our optimization tool. We managed to cut off more than 50% of anticipated baggage and to significantly smooth the load between the carousels. Our approach (decomposition into two MIP), allows us to have results in a few hours for a complete patern week. Though designed originally for only one sorting warehouse, it has been adapted and used to schedule the two main warehouses in use in Charles de Gaulle, for now almost two years.