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To cite this version:

Rodrigo Acuna-Agost, Mourad Boudia, Nicolas Jozefowiez, Catherine Mancel, Felix Mora-Camino. Passenger improver - A second phase method for integrated aircraft passenger recovery systems. TRISTAN VII 2010, 7th TRIennal Symposium on Transportation ANalysis, Jun 2010, Tromso, Norway. pp 1-4. hal-00938772

HAL Id: hal-00938772

https://enac.hal.science/hal-00938772v1

Submitted on 22 May 2014

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Passenger Improver - A Second Phase Method for Integrated Aircraft-Passenger Recovery Systems

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1 Introduction

Airlines are permanently confronted to disruptions caused by external or internal factors like extreme weather conditions, unavailability of crew members, unexpected breakdowns of aircraft, or airport capacity shortages. These disruptions prevent the planned execution of the schedule, which either becomes suboptimal or infeasible. In this paper, a solution method to solve "*the simultaneous aircraft and passenger recovery problem*" is developed. This approach minimizes the impact of disruptions by taking into consideration the flight schedule, the fleet and maintenance management requirements and the impact on passengers, all simultaneously. This viewpoint is contrasted with the classical approach found in the literature that reallocates resources according to a common hierarchy: aircraft, crew, and finally passengers.

The literature provides some references to approaches where resources are coordinated by a meta-process. Though, there are very few references proposing integrated approaches where a single solution process addresses the problem globally. In this respect, Bratu and Barnhart have proposed an approach in which the objective is to find the optimal trade-off between airline operating costs and passenger delay costs [2]. More recently, the French Operational Research and Decision

Analysis Society (ROADEF) and AMADEUS S.A.S. organized the ROADEF challenge 2009 on the topic: "Disruption Management for Commercial Aviation" [4]. Several research teams participated with original solution methods solving large-scale instances generated by the organization. The approaches presented by the finalist teams include MIP-based methods, minimum-cost flow models, decomposition techniques, and heuristic approaches based on the use of shortest path methods.

In this paper, a post-optimization method that improves the solutions obtained by current approaches is developed. The method, called *Passenger Improver* (PI), provides an optimal reaccommodation for the still disrupted passengers. The term "reaccommodation" refers to a modified assignment of passengers to flight-cabins such that passenger are re-routed to their destinations in the best possible conditions. The remainder of the paper is organized as follows. Section 2 describes two different approaches from the ROADEF challenge used as a first phase of this method. Section 3 presents PI and a mathematical formulation of the problem. Finally, the conclusions and main results are discussed in Section 4.

2 Integrated Aircraft-Passenger Recovery Systems

The authors of this paper have worked developing two solution methods. These approaches are:

NCF: *New Connection Flights* [3]. This is a heuristic approach that tries to recover a perturbed schedule by adding flight legs to connect infeasible aircraft routings while passengers are reaccommodated at each step of the method. These adjustments are locally optimized by applying an adapted version of Dijkstra's algorithm.

SAPI: *Statistical Analysis of Propagation of Incidents* [1]. This method is based on a mixed-integer programming (MIP) formulation that is solved using a statistical analysis of the propagation of disruptions. This approach provides the third best overall results of the competition and it outperformed NCF on small and middle size instances. Nevertheless, on large instances, the MIP becomes too large to perform in a reasonable amount of time.

NCF and SAPI are based on important approximations. In particular, the schedule changes provide unused passenger reaccomodation opportunities.

3 Passenger Improver (PI)

Passengers are grouped in an so-called *itinerary*. Two passengers of the same "itinerary" have to share at least these common characteristics: flights, type of cabin class, and type of trip. The type of the cabin class can be first, business or economy; and the type of the trip can be inbound or outbound trips. Let K be the set of itineraries indexed by k where an *itinerary* k is composed of n_k passengers. After the execution of one of the recovery procedures described in the previous section, itineraries are classified in two groups: non-disrupted (K_F) and disrupted (K_D). The passengers

belonging to K_F are considered fixed and cannot be reaccommodated. On the other hand, K_D contains passengers that need to be reaccommodated because of missed connections, flight leg cancelations or delays. The problem can be formulated as a variation of the classical minimum-cost multicommodity flow problem. Let $G = (V, E)$ be a directed and connected network, where V is the set of nodes, indexed by i, and E is the set of directed arcs connecting them. To reduce the size of the problem, let V_k be the set of nodes compatible with commodity k. Every itinerary in K_D is considered as a commodity having only one supply node and one sink node. All the remaining nodes, are transshipment nodes representing a pair flight-cabin labeled with R_i, the remaining capacity of the flight-cabin. In general, an arc represents a valid connection for passengers between two flight-cabins. The cost of the flow through each arc is proportional to the amount of that flow, representing delay, cancelation or downgrading costs. These last costs model the inconvenience to passengers when they are reaccommodated to a lower service cabin on all or part of the trip. The objective is then to minimize the total cost of transporting all disrupted passengers to their destinations including the expensive possibility of canceling their trips. Let x_{ij}^k be the decision variables that represent the quantity of flow of commodity (itinerary) k from node i to node j. Thus, the mathematical formulation of this problem is:

$$\text{Minimize}: \sum_{k \in K_D} \sum_{i \in V_k} \sum_{j \in V} c_{ij}^k x_{ij}^k$$

Subject to:

$$\sum_{j \in V_k} x_{ij}^k = n_k \qquad \forall k \in K_D, i \in O_k \tag{1}$$

$$\sum_{j \in V_k} x_{ji}^k - \sum_{j \in V_k} x_{ij}^k = 0 \qquad \forall k \in K_D, i \in V_k \setminus O_k \setminus D_k \tag{2}$$

$$\sum_{i \in V_k} x_{ij}^k = n_k \qquad \forall k \in K_D, j \in D_k \tag{3}$$

$$\sum_{k \in I_D} \sum_{j \in V} x_{ij}^k \leq R_i \qquad \forall i \in V \setminus O_k \setminus D_k \tag{4}$$

$$x_{ij}^k \in \mathbb{N}_0 \qquad \forall k \in K_D, i \in V_k, j \in V_k \tag{5}$$

The classical multi-commodity flow problem is known to be NP-complete for integer flows. Nevertheless, from numerical tests, it seems that the coefficient matrix is totally unimodular and a formal proof is under study. This property implies that the solution to the linear relaxation of the IP model would be integer and the problem would be solved in polynomial time.

The construction of V_k is a key aspect of this method because it permits to reduce the size of the model. An additional function based on the Floyd - Warshall algorithm is used to limit the nodes compatibles with the passengers by allowing a maximal number of connections per passenger.

4 Results, Conclusion, and Perspectives

Two reference solution methods, NCF and SAPI, have been presented to solve *the simultaneous aircraft and passenger recovery problem*. They have their respective strengths, but also show a common weakness, as they do not guarantee an optimal reaccommodation of disrupted passengers. To complement these two approaches, a new method called Passenger Improver (PI) is presented to reaccommodate disrupted passengers based on a particular case of the minimum-cost multicommodity flow problem. The algorithm was tested on a PC Intel Core Duo T5500 1.66 GHz 2 GB RAM over Windows Vista Operation System using ILOG CPLEX 11.1 as a standard MIP solver. The results evidence important improvements to the final solutions of NCF and SAPI over the 32 instances of the ROADEF challenge 2009, some of them with more than 700000 passenger and 6000 flight-legs. Actually, PI decreases the total cost by 18% (NCF) and 5.92% (SAPI) with an average CPU time of 120 [s]. Additionally, to the best of our knowledge, 71.8% of the current best known solutions for these instances have been calculated using NCF, SAPI and PI.

A future research direction is the development of a fully integrated system primarily based on SAPI. First, an adaptation of NCF will be used to calculate an initial solution. The main part of the algorithm will perform improvements by the study of propagation of disruptions (SAPI). Finally, the post-optimization function will be replaced by an adaptation of PI to have a better reaccomodation for still disrupted passengers. We expect that this integration will help to improve the CPU time rather than the quality of solutions.

References

[1] R. Acuna-Agost, D. Feillet, P. Michelon, and S. Gueye; "Rescheduling Flights, Aircraft, and Passengers Simultaneously under Disrupted Operations - A Mathematical Programming Approach based on Statistical Analysis", *AGIFORS*. Anna Valicek Medal 2009, (2009)

[2] S. Bratu and C. Barnhart, "Flight operations recovery: New approaches considering passenger recovery", *Journal of Scheduling* 9, 279298 (2006)

[3] N. Jozefowiez, C. Mancel, and F. Mora-Camino, "Approche heuristique pour la gestion de pertubation dans le domaine aérien (in French)", http://challenge.roadef.org/2009/methodes.en.htm, ROADEF (2009)

[4] M. Palpant, M. Boudia, C.A. Robelin, S. Gabteni, and F. Laburthe. "ROADEF 2009 challenge: Disruption Management for commercial aviation", *Working paper, AMADEUS S.A.S.*, Operations Research Division, Sophia Antipolis, France (2009).