A multi-objective optimization approach for hub connections. Application to the insertion of new flight in airline schedule

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1 Introduction

Airline schedulers face the difficult and intricate task to build high quality schedules that maximise the airlines profitability in highly competitive and continuously changing markets. The construction of an airline schedule requires numerous mutually interacting decisions to be made that influence the profitability of the schedule and its operational performance.The final schedule will impose numerous requirements on the airlines operating environment,including airspace, airport, runways and maintenance facilities. Moreover, it could significantly influence the operations of other airlines, especially in case the selected schedule has a hub-and-spoke structure.The operational performance of an airline schedule is the result of a complex interaction between the schedule and its operating environment [1].

In this work, we introduce the quality of service index (QSI), as a duel parameter for the profitability of the new opened destination, this decision-making aspect would be expressed by the repercussions test of the new insertion in a pre-set flight Schedule, taking in count the generated delays and then see the impact of this decision on the quality of service offered to a target customers. These delays generated as well as other costs will be the subject of a multi-objective optimization with financial earn through the insertion of this new market.

2 Proposed approach

A general formulation of multi-objective optimization problems is given by,

$$\begin{cases} \min_x f_i(x) \quad (i = 1, \ldots, N) \\ s.t \; g_j(x) \leq 0 \quad (i = 1, \ldots, M) \\ x_l \leq x \leq x_u \end{cases} \tag{1}$$

where $(f_i)_{i=1}^N$ are the objective functions, x is the design variable vector, x_l and x_u are respectively the lower and upper bounds of x,and the functions $(g_i)_{i=1}^M$ are the constraints. The optimization problem (1) has generally more than one solution which satisfy the trade-offs among the N objective functions. The set of those solutions is called the Pareto set [2].

Our problem can be formulated as a multi-objective problem by using two objective functions f_1 and f_2. The first one aims to increase the financial earn through the insertion of this new market using P_k, the passenger potentials recorded for an airport k, as a weighting in the objective function, and subsequently, the new market will encourage the connection of airports with high potentials. The second one consists to improve the quality of service index (QSI) affected by disruptions, delays, and it's related costs.

The mathematical formulation can be written as follows

$$\begin{cases} f_1(x) = \sum_{kij} P_k Y_{ki} Y_{kj} \\ f_2(x) = QSI \end{cases}$$

where

$$Y_{ki} = \begin{cases} 1 & \text{if an Outbound connection is realized for } a_{ki} \\ 0 & \text{otherwise} \end{cases}$$

and

$$Y_{kj} = \begin{cases} 1 & \text{if an Inbound connection is realized for } d_{kj} \\ 0 & \text{otherwise} \end{cases}$$

Outbound connection is realized when a given value a_{ki} comes inside the arrival time window $[h - t_{max}, h - t_{min}]$, and the inbound one is realized when a given value d_{kj} comes inside departure time window $[h + t + t_{min}\ ,\ h + t + t_{max}]$, where a_{ki} and d_{kj} are respectively the sets of weekly hub arrivals and Departures to the targeted Airport k (figure 1). The new opened line is characterized by it's hub departure time h ,and the arrival time h+t , where t is the round trip duration, t_{min} and t_{max} are the minimal and maximal hub stop-time. This process is illustrated by (figure 1).

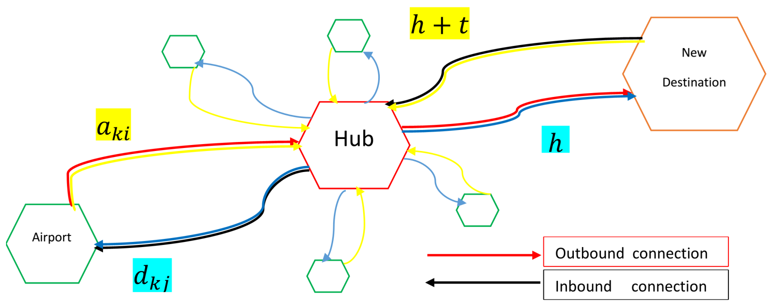

figure 1: Outbound/Inbound connections through the hub

3 Conclusion

We have introduced a new multi-objective optimization approach for the insertion of new flights in the airline schedule problem. The implementation was carried out using the jMetal Framework [3]. The pareto set is generated using SMPSO [4] and NSGA-II [5] Algorithms. Numerical results based on real fight schedules of Royal Air Maroc in the hub of Casablanca, demonstrates the efficiency of this work, and as perspective, we include the disruption model in order to construct a robustness approach.

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