# A Multi-Objective framework for investigating airport schedule efficiency, fairness, flexibility, and regularity trade-offs

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## 1 Introduction

The IATA Worldwide Slot Guidelines [1] is the prevailing mechanism for allocating slots at congested (Level 3 coordinated) airports. In these airports, airlines should request and obtain slots to operate their flights. According to [1] airlines should place requests for slots or series of slots. "A series of slots is at least five slots allocated for the same *or approximately same time* on the same day-of-the-week'' [1], throughout the requested period. Priority rules for satisfying the slot requests are foreseen in [1], giving higher priority to series of slots over ad-hoc requests, and to historic requests over changes to historic and new entrant requests. Single [2], and multi-objective models [3] have been proposed in literature to optimize slot allocation decisions by considering efficiency [2,3,4,5,6], fairness [4,5], flexibility [6], and schedule regularity criteria [7]. However, the literature currently lacks models that can consider simultaneously efficiency, fairness, flexibility, and schedule regularity criteria. In this paper we introduce a multi-objective framework that supports decision makers to investigate trade-offs among the above identified objectives, and we incorporate the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method [8] coupled with the Shannon's entropy [9], to select among the generated efficient solutions the solution that will be proposed to be implemented.

## 2 Multi-Objective Optimization Framework

The proposed framework considers the optimization of airport schedule efficiency, fairness, and regularity while adhering to airline flexibility constraints. The schedule efficiency objective aims to allocate the slots as close as possible to their requested time by minimizing the total displacement, i.e the sum of the absolute value of the difference between the requested and allocated time [2]. The flexibility associated with the allocation of slots is expressed [6] through a range of acceptable time intervals. The concept of schedule regularity is associated with the requirement to allocate series of slots for the same or approximately the same time and day of the week for all the weeks that the requested series will operate. Given the airport capacity and operational constraints, it is not possible to satisfy all slot requests while adhering to flexibility and regularity requirements. Therefore an issue regarding the fairness of the distribution of the dis-benefits of the scheduling process arises. The proposed framework considers fairness regarding the distribution of the displacement among all airlines [4, 5].

The optimization framework starts with the generation of the base schedule. The scheduling season is segmented into sub-periods [7], and slots are allocated by relaxing the regularity requirement. The base schedule is generated by lexicographically minimizing un-accommodated requests, maximizing the regularity of slots allocated to requested series, and minimizing total schedule displacement. The base schedule is used to calculate the peak periods for the entire scheduling season [4]. The identified peak periods are used to calculate the value of the total displacement fairness index of each airline. The minimization of the maximum difference between the average total displacement and the total displacement-fairness value of each airline is then defined as the displacement-fairness objective [5]. The resulting maximum difference is transformed to an $\epsilon$ value. Please note that smaller $\epsilon$ values represent better schedule performance in terms of fairness. To generate the four-dimensional efficient frontier between the displacement-fairness, total schedule displacement, total number of unaccommodated requests, and regularity, we use the $\epsilon$ −constraint method as illustrated in Figure 1.

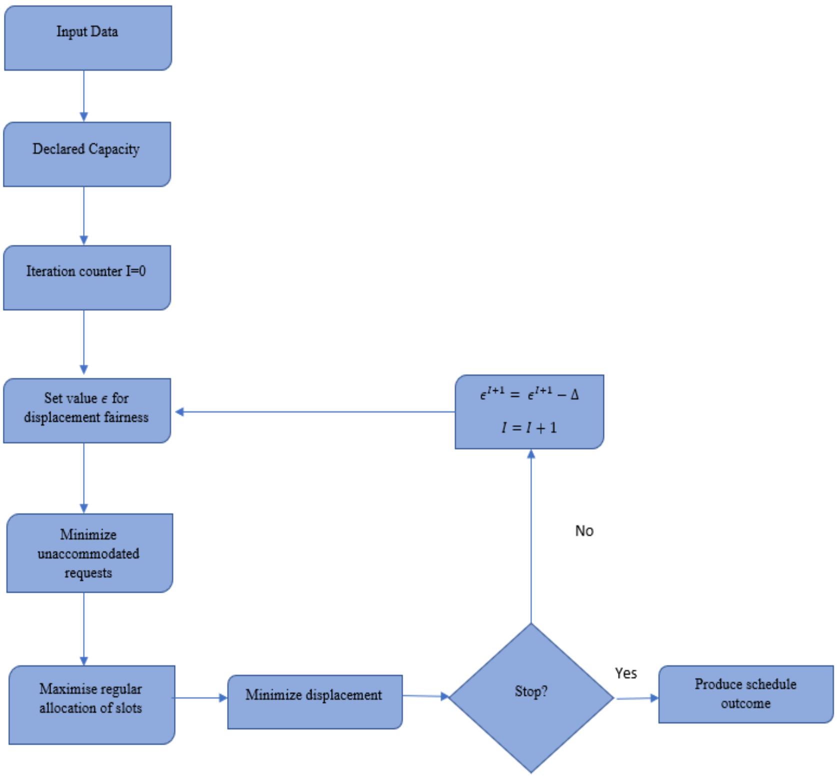


Figure 1: Flow-chart of the solution algorithm

According to the solution algorithm we lexicographically minimize the number of unaccommodated requests while relaxing the regularity requirement, maximize the regular allocation of slots to the requested series, and minimize total schedule displacement for different values of the displacement fairness objective. Therefore, we maximize the regular allocation of series of slots, while adhering to the irregularity scheme only for series requests that cannot be allocated regular and acceptable slots throughout the scheduling season.

In the context of decision making, we use the TOPSIS [8] method to select among the efficient solutions, the final solution (airport schedule). To this end, we incorporate to the TOPSIS method objective weights evaluated by the Shannon's entropy [9] technique for each objective and airline. The incorporated technique is applied for each airline and aims to transform the arising objectives' variability to weights. The proposed framework is illustrated in Figure 2 and applied for each priority class.

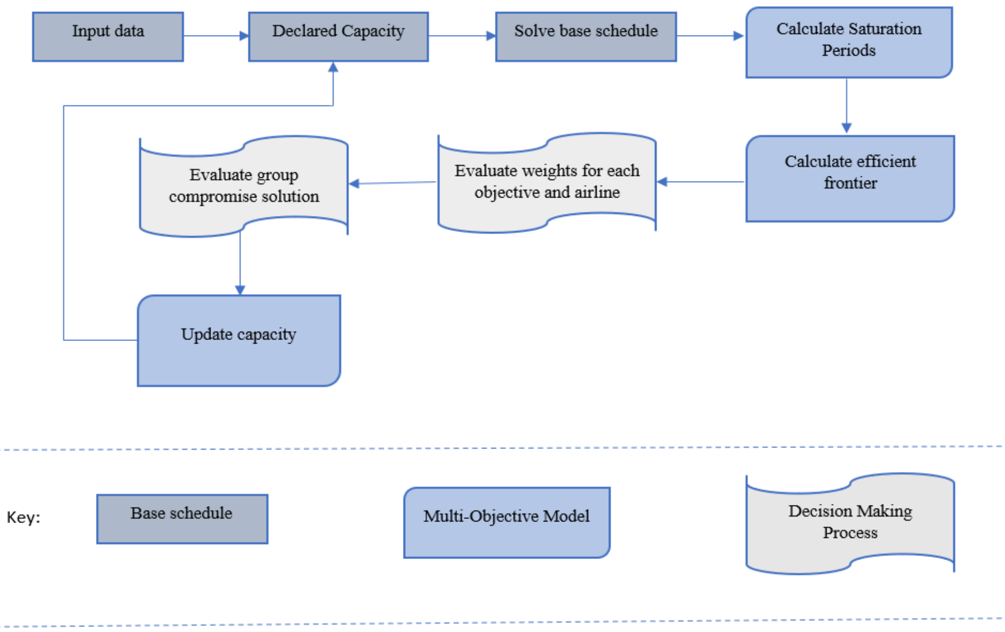


Figure 2: Overall flow-chart of the optimization framework

## 3 Concluding Remarks

Work under way involves the use of the proposed framework for investigating trade-offs between schedule efficiency, fairness, flexibility, and regularity by using slot requests and declared capacity data related to a Level 3 airport, and synthetic data related to airlines' flexibility. In our analysis we consider 596 requested series, including arrivals and departures. The framework will be implemented hierarchically, i.e. firstly for historic and then for the non-historic requested series, by using a commercial integer programming solver. Results obtained so far, indicate that no unaccommodated requests arise when dealing with the historics priority class. However, not all non-historic requested series can be allocated slots by adhering to their schedule flexibility constraints.

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