Runway Operations Scheduling
using Airline Preferences

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Summary
The purpose of the research discussed in this thesis was to assess the effects of considering airline preferences in runway operations scheduling. This was motivated by the congestion and delays that regularly occur in the air traffic system. Delays cause both cost and inconvenience to airlines and their passengers. Airborne delays increase fuel cost. Delays can cause infeasibility to crew and aircraft assignments for subsequent flights. In this way, delays are propagated. This results in additional cost, such as crew overtime payments. Delays can cause passengers to miss connecting flights and these passengers have to be rebooked. This also brings additional cost.

However, the impact of a delay will differ from flight to flight, depending, among others, on the number of (transfer) passengers. An airline will often prefer a delay for a flight without any transfer passengers over a delay for a flight full of time-critical transfer passengers. It is expected that by considering these preferences in air traffic control decisions, the impact of delay on the airlines and their passengers can be reduced. This will lead to cost savings for airlines and fewer frustrations for passengers.

Runway operations scheduling involves assigning a landing or take-off time and runway to each flight in such a way that the required separation between flights is respected. The separation required between two flights at the runway depends on the weight categories and sequence of the aircraft. A light aircraft landing behind a heavy aircraft requires more separation than the reverse order. This means that the capacity can be enlarged by actively sequencing the flights. This is important because runways form a major bottleneck of the air traffic system. However, currently flights are not actively sequenced in practice. This means there is an opportunity to improve the efficiency at this bottleneck and with that the efficiency of the total air traffic system.

In this research, possible increases in runway throughput obtained by sequencing the flights are considered. However, the primary objective is to incorporate airline preferences in the runway operation schedule in order to reduce the impact of delays on airline and their passengers. The consideration of both airline preferences and efficiency fills the gap between the two approaches currently considered in the literature to allocate runway capacity to flights.

A novel approach to represent airline preferences and incorporate these in a fair manner in the scheduling process was presented. In this approach, airline preferences are represented using cost functions. These cost functions represent the cost related to runway operations times of flights and connection times between flights. We want to allow the airlines as much flexibility as possible in representing these cost functions. At the same time, these cost functions must be applicable to establish a fair and efficient runway schedule. Therefore, it must be possible to compare the cost functions from competing airlines in a fair manner. Additionally, it should not be possible for airlines to conduct strategic behavior. To achieve this, a combination of centralized decision making and restrictions on the cost functions were proposed. Additional measures of fairness were also defined and evaluated throughout the research.
Two runway operations scheduling problems were studied. First, the single runway aircraft landing problem was considered. Next, the scheduling of arrivals and departures at a hub airport was considered. For both problems, mathematical programming formulations are given and local search heuristics to obtain good solutions using short computation times were introduced. These heuristics has shown to give solutions of good quality for realistically sized instances.

The scheduling of landing flights at a single runway (aircraft landing problem) was tested in computational experiments. For this a large number of problem instances, created using schedule data from a major European hub, were used. The results show tremendous cost savings for the airlines compared to a schedule that resembles current practice, especially at times when runway congestion is expected.

The results also show that schedules with different distributions of cost over the airlines can be obtained, by considering different objectives. There is a trade-off between minimum total cost (over all airlines) and a more equal distribution of cost (savings) and delays over the airlines. However, it was shown that schedules with a more equal cost distribution over the airlines but at the same time considerable total cost savings compared to current practice, can be obtained.

The scheduling of landings and take-offs at multiple runways provided the possibility to explicitly consider hub airline operations. In this way, the costs related to flight connections can be modeled more realistically. Computational experiments for this problem were also performed using data from a large European hub. The results showed that additional cost savings can be obtained by integrally scheduling the runway operations of arrivals and (connected) departures. In this way, for example, the number of missed transfers can be (further) reduced.

We can conclude that the results of our research show that considering airline preferences in runway operations scheduling indeed leads to a reduction of the negative impact of delays to airlines and their passengers. Considerable cost reductions can be obtained for the airlines. Furthermore, passenger frustrations related to delays and missed transfers can be reduced.

Now that the potential gains are established, further research is necessary to allow for the practical application of the approach. In an operational environment runway operation schedules must be calculated almost instantaneously. Fast (real-time) algorithms must be developed to achieve this.

Another interesting subject for future research is whether a similar approach can be used for related air traffic problems, such as air traffic flow control or airport gate assignment.