Airport logistics - A case study of the turn-around process

Anna Norin, Tobias Andersson Granberg, Di Yuan and Peter Värbrand

Linköping University Post Print

N.B.: When citing this work, cite the original article.

Airport Logistics – a case study of the turn-around process

Anna Norin[1,2], Tobias Andersson Granberg[1], Di Yuan[1] and Peter Värbrand[1]*

[1]Division of Communication and Transport Systems, ITN, Linköping University, SE-601 74

Norrköping, Sweden

[2]Swedavia Teknik, Swedish Airports, SE-601 79 Norrköping, Sweden

*Corresponding author. Tel+46-11-363213, Fax +46-11-363270, tobias.andersson@liu.se

Abstract: This paper introduces the concept of airport logistics, along with a proof of concept through a case study where we model and optimize de-icing services at Stockholm Arlanda airport. The optimized schedule is tested using a simulation model of the turn-around process. The results demonstrate that a schedule taking into account the overall airport performance results in less delay than the schedule targeting solely the performance objective of the de-icing company.

Keywords: airport; logistics; simulation; optimization; de-icing, turn-around

1. Introduction

Airport logistics is the planning and control of resources and information that create a value for the customers utilizing the airport. The customers in this study are broadly defined as the passengers, cargo service consumers, as well as airlines, restaurants, shops, and other actors operating at the airport. In the context of collaborative decision making (CDM, www.euro-cdm.org), the goal of airport logistics is to utilize and process the information made available through CDM to achieve efficient resource management.

In this paper, we provide a proof of concept for airport logistics through a case study where we model and optimize de-icing services at Stockholm Arlanda airport. A simulation model is developed to provide a comprehensive picture of the logistic activities involved in the turn-around process. A tool for optimized scheduling of the de-icing vehicles is implemented and integrated into the simulation model. Figure 1 highlights the process: A flight schedule is used as input to the optimization algorithm that produces a schedule for the de-icing vehicles. The flight schedule together with the de-icing schedule provide the input data to the simulation model. Performance is evaluated using indicators such as delay and waiting time. The overall objective is to investigate whether it is possible to obtain more efficient airport logistics by optimizing one of the turn-around services, while taking into account the overall airport performance.
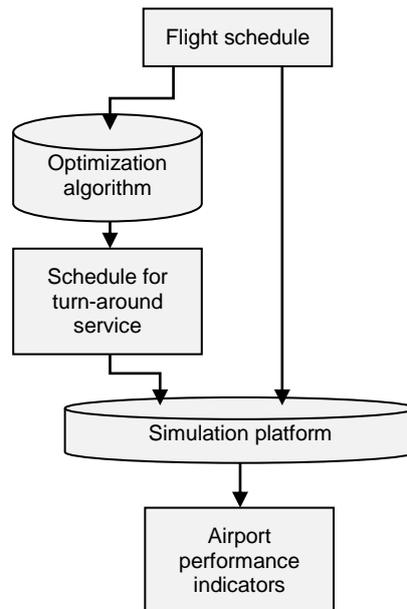
Figure 1   Integration of optimization and simulation in airport logistics.

The study in this paper takes an Operations Research (OR) perspective to approach airport logistics. For previous works of applying OR to air transportation, we refer to the surveys in Barnhart et al. (2003) and Clarke and Smith (2004). The rest of the paper is organized as follows. In Section 2, the turn-around process is modeled conceptually, as well as by means of simulation and optimization. The performance study is presented in Section 3, and conclusions are given in Section 4.

2. Modelling the turn-around process at Stockholma Arlanda airport

Many handling services are performed as part of the turn-around process, including baggage handling, catering, cleaning, fueling, sanitation, water refill, and de-icing. At Stockholm Arlanda airport (SA), fueling is performed using a hydrant system, if that is available at the stand, and otherwise by tankers. Vehicles performing sanitation and water re-filling typically operate on the opposite side of the aircraft body than baggage handling and fueling. Thus, sanitation and water re-filling can be done simultaneously with baggage loading/unloading and fueling.

At SA, the de-icing period is between October and April. The de-icing process consists of two steps. During the first step, frost and ice are removed from the aircraft, usually by a warm, buoyant glycol mix (Type 1 fluid). The next step, called anti-icing, uses a thicker fluid (Type 2 fluid) to prevent new frost and ice from appearing on the aircraft before take-off. The time from anti-icing to take-off (called hold-over time) is bounded, as the effect of the Type 2 fluid wears off after a while. The length of the hold-over time depends on the type of fluid, temperature, and precipitation.

SA has three runways. One has a remote de-icing station, partly because the taxi time from the gates to the runway might compromise the hold-over time. For the other two runways, de-icing is performed on-stand by de-icing vehicles. In this study, we focus on de-icing performed on-stand.

Due to the hold-over time, performing de-icing at the "right" moment is more challenging than planning the other turn-around services. Today, there is no preplanned schedule of de-icing. Thus the drivers do not know in advance which aircraft they are going to de-ice during the day. The de-icing coordinator makes a plan tactically based on weather conditions and the flight schedule, and operationally – when a deicing vehicle is dispatched – based on a request from the pilot. The request from the pilot usually arrives at the beginning of the turn-around process, with the assumption that all activities will be performed on time.

The de-icing procedure is not unique for SA. Other airports performing de-icing on-stand include Heathrow and many other UK airports (HCTC, 2011), and Helsinki airport that also has integrated the de-icing operations into a CDM system (Finavia, 2008).

2.1. *A simulation model of Stockholm Arlanda airport*

We have developed a simulation model for SA. From an aircraft point of view, the model starts with touch down and taxiing into the stand, continues with the turn-around process and ends with taxiing out to the runway and taking off. Since the turn-around process is very complex and contains both discrete and continuous functions, simulation is an appropriate method for performance assessment. In this study, ARENA, which is a generic simulation package, is used. A reason for choosing ARENA is the possibility to integrate pre-generated schedules for various types of resources, particularly those within the turn-around services, into the model. Figure 2 shows the conceptual model, which includes all the activities that are simulated.

The activities must be performed in the order shown by the arrows in Figure 2. If there is no arrow connecting two activities, they do not depend on each other and can be performed simultaneously. In the figure, water refill comes before sanitation, although in the ARENA simulation model (as well as in reality), the order can be reversed depending on resource availability.

The conceptual model has some simplifications in comparison to reality:

- In the model, cleaning and catering can be performed simultaneously, which in reality is not the case for all aircraft types.

- Some airlines do not allow fueling while passengers are on board, i.e., fueling may have to be performed between deboarding and boarding.

- For some (large) aircraft types, fueling can be performed simultaneously as baggage handling.

The amount of resources available to each operator (e.g. catering vehicles), as well as which flights a particular operator has to serve, are specified in the input to the model. All the handling services are modeled as resources, which are split into service pools. An airline has a contract with only one of the service pools for each activity.
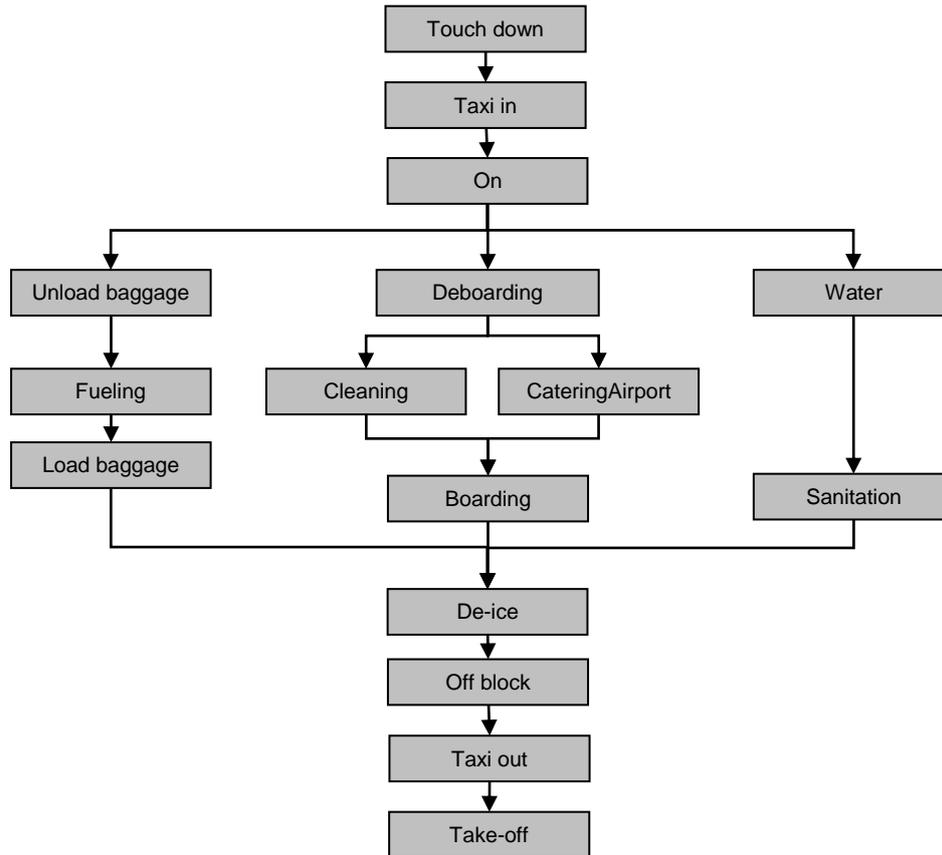
Figure 2   Turn-around activities in the simulation model.

The duration time of the turn-around activities depends on the aircraft type (number of seats, baggage loaded in bulk or containers, one or two escalators, etc.), although it is also possible to specify time for each individual aircraft. The model is validated using a number of techniques, including animation, degenerate and extreme condition testing, and conformation of face validity by conferring with system experts at SA.

2.2. *Optimizing the de-icing process*

The aim of the optimization approach is to efficiently schedule the de-icing vehicles. The planning task includes deciding which vehicle that should serve each individual aircraft, and when a vehicle should visit the refill station. A vehicle starts at a depot, drives to an aircraft to perform de-icing, and then travels directly to the next assigned aircraft until it is time to return to the depot or go to the refill station.

We have applied a GRASP heuristic (Feo and Resende, 1995) for problem solution. Two objectives are considered: accumulated total delay of the flights, weighed by parameter *a*, and the total distance (time) travelled by the de-icing vehicles, weighed by parameter *b*. Changing the values of *a* and *b* alters the performance emphasis. In this paper, $a = 1$ and $b = ½$. These values are selected through computational testing to give a good balance between the two objectives. The GRASP algorithm

4

constructs a number of solutions (de-icing schedules). Solutions dominating in either low delay or short travelling time are considered attractive and explored further.

Table 1 presents the performance of three de-icing solutions. In the GREEDY solution, the closest located vehicle is selected for every assignment, disregarding whether or not the vehicle is available at the moment. This gives a solution with a short (although not necessarily the shortest) accumulated distance, but with an unacceptable amount of delay. The GRASP solutions represent two trade-offs between delay and travel time; GRASP 1 is likely preferred by the de-icing company, whereas GRASP 2 performs better in terms of the overall airport performance. We remark that a solution without any delay is not attainable, since some flights are delayed due to other reasons.

Solution	Traveling time [minutes]	Delay [minutes]
GREEDY	842	340 270
GRASP 1	1063	319
GRASP 2	1127	246

Table 1   Performance of three solutions to the de-icing scheduling problem.

3. Simulation results

3.1. *Scenarios*

Using the simulation model, it is possible to compare the efficiency of turn-around when using an optimized de-icing schedule to that when simple scheduling rules are used. To this end, four scenarios have been created. The first one is a reference scenario with no de-icing. The three other scenarios include de-icing of all departing flights by a total of 18 de-icing vehicles. In Scenario 2, a simple rule of thumb is applied; de-icing is carried out in the order of scheduled time of departure of the flights. De-icing in Scenario 3 is performed according to a schedule from the optimization algorithm, corresponding to solution GRASP 1 in Table 1, to illustrate the overall efficiency when individual actors are sub-optimizing their own processes. Finally, in Scenario 4, the de-icing vehicles follow the schedule that gives the lowest delay for the departing flights, i.e. GRASP 2 in Table 1.

The simulation is run for a 24-hour period of a flight schedule from 2008 including 515 flights with varied airline operators and aircraft types. The number of replications needed for reliable observations from the simulation depends on the amount of diversity in the results between the runs. Examining the output variables for all scenarios, 50 is the highest number of replications required for an allowed deviation from the mean by 10%, with a confidence interval of 99%. Therefore the simulation output is based on 50 replications for all scenarios.

3.2. *Output*

The amount of delay in percentage, as well as the maximum and average of the delays are given in Table 2. The calculation of the average value is restricted to flights with delay.

	Touch down			Stand			Off block		
	Percentage delay	Max delay	Average delay	Percentage delay	Max delay	Average delay	Percentage delay	Max delay	Average delay
Scenario 1	19%	3 min	1 min	1%	7 min	4 min	8%	14 min	5 min
Scenario 2	19%	3 min	1 min	2%	25 min	8 min	27%	48 min	9 min
Scenario 3	19%	3 min	1 min	1%	7 min	3 min	25%	20 min	7 min
Scenario 4	19%	3 min	1 min	1%	7 min	3 min	25%	22 min	6 min

Table 2   Delays for the different scenarios.

A touch down delay is the difference between the scheduled time of arrival (STA) in the flight schedule and the time that the flight touches down in the simulation model. The percentage values are set in relation to the total number of movements on the runway. A stand delay is the difference between the time the flight reaches the stand and the time the turn-around process starts, i.e. the waiting time for the stand if it is occupied by another aircraft. An off block delay is defined as the time difference between the completion of the turn-around process and the scheduled time of departure. A strict definition of delay is used; a delay occurs if any activity fails to begin within one second of the expected start time.

The touch down delays are due to runway capacity. Several flights may be scheduled to touch down at the same time, although in reality some may arrive earlier (or later) than the STA. In the simulation, the arrival times of all flights are set to the respective STA, and then they are separated before touch-down. Hence there is a relatively high percentage of touch down delays but the delay time is short.

The stand delays are a direct result of the off block delays, and increase with the accumulated time that flights are occupying the gates. Consequently, there are more and longer stand delays in Scenario 2 than in Scenarios 3 and 4. The average off block delay does not differ much between Scenarios 2 and 3. However, it turns out that most of the off block delays in Scenario 3 occur in the late evening, giving less impact on stand delays in comparison to Scenario 2.

For the flights with off block delay in Scenario 1, 65% of the cases are contributed by touch down delay, including time for taxi-in. The rest have a turn-around time longer than scheduled, with the unload baggage - fueling - load baggage track (i.e. the left track in Figure 2) being the bottleneck. In Scenarios 2-4, most of the off block delays are due to the de-icing process.

Studying the number of off block delays in Table 2, the result of Scenario 4 is better than that of Scenario 3, which in its turn is better than that of Scenario 2. Similar observations are made for the

stand delays, as well as for the average off block delay times, although the maximum off block delay is larger for Scenario 4 than for Scenario 3.

Waiting time for de-icing is a good performance indicator of the de-icing service. In Table 3, the number of aircraft (in percentage) that have to wait for de-icing is presented. For the waiting aircraft, the maximum, average and total waiting times are given. From the table, the results in waiting time are consistent with those of off block delays. The performance in Scenario 3 is better than that in Scenario 2, and all the performance indicators have the best values in Scenario 4.

	De-icing			
	Percentage waiting	Max waiting time	Average waiting time	Total waiting time
Scenario 1	-	-	-	-
Scenario 2	24%	60 min	14 min	1330 min
Scenario 3	21%	42 min	10 min	812 min
Scenario 4	20%	39 min	10 min	757 min

Table 3   Waiting times for de-icing.

Thus, the results in Table 2 and Table 3 show that the de-icing schedule optimized for the overall airport performance (Scenario 4) gives better results than the schedule optimized for the de-icing company (Scenario 3) or that by the simple rule of thumb (Scenario 2). The finding supports the theory that optimizing the turn-around process with respect to the overall performance is preferable to letting each service actor optimize its own activity only.

4. **Conclusions**

Our study has shown that optimizing the de-icing schedule at Stockholm Arlanda airport, while taking the total airport performance into consideration, enables the reduction of delays and waiting times. For practical implementation, it is necessary for the de-icing companies to obtain accurate and up-to-date information regarding arrival and departure times, e.g., through collaborative decision making. The results also suggest that scheduling tools for other turn-around activities have solid potential of further improving resource efficiency at the airport.

References

Barnhart C, P Belobaba, and A R Odoni, 2003, Applications of Operations Research in the Air Transport Industry, Transportation Science, 37(4), pp. 368-391.

Clarke M, and B Smith, 2004, Impact of Operations Research on the Evolution of the Airline Industry, Journal of Aircraft, 41(1), pp. 62-72.

Feo T A and M G C Resende, 1995 , Greedy Randomized Adaptive Search Procedures, Journal of Global Optimization, 6, pp. 109-133.

Finavia, 2008, Rules for the arrangement of de-icing operations at Helsinki-Vantaa Airport, Manual, v. 1.2.

HCTC, House of Commons Transport Committee, 2011, Keeping the UK moving: The impact on transport of the winter weather in December 2010, House of Commons, London.