SENSITIVITY ANALYSIS TO DETERMINE THE OPTIMISATION POTENTIAL OF AIRPORT TURNAROUND PROCESSES FOR SHORT-HAUL AIRCRAFTS

L. Christoffels, O. Gluchshenko,
Institute of Flight Guidance, German Aerospace Center (DLR), Germany

Abstract

In comparison to the flight time, the turnaround time at the airport has a higher percentage for short-haul flights than for medium and long-haul flights. Shortening the time for a short-haul aircraft staying on the ground offers a high potential for optimisation, which reduces both the travel time for passengers and the fleet expenditure of the airlines. It is assumed that the time for the turnaround solely on the land side, i.e. the time between in-block and off-block, can be shortened by at least 10% compared to the today's reference turnaround process with specially designed processes for short distance flights and a respectively adapted aircraft configuration.

This paper describes an initial sensitivity analysis of a turnaround model based on the reference turnaround process chain of the A320 aircraft family, which is frequently used on short distance routes. The sensitivity analysis explores relational level between input data represented by demand and available resources and output data represented by utilisation of resources and turnaround time. The main goal is to determine the processes with the most significant influence on the land side turnaround time of a short-haul aircraft. The investigation methodology and the input parameters are explained in detail. The reference process chain for the analysis of the optimisation potential is described. On the basis of the presented results upper and lower bound of resources limitation for the next step of the investigations are derived.

1. INTRODUCTION

Airlines are interested in a high productivity of their fleet, which implies achieving a high haul capacity of cargo or passengers by flying planes instead having them bound on the ground. Therefore it is beneficial to reduce the processing time for an aircraft at the airport. This is particularly important for short-haul flights which have the most unfavourable share of ground and airborne time compared to flights on longer distances. In order to balance this disadvantage, the objective is to shorten the landside turnaround time for short-haul flights by 10% compared to the reference turnaround time [1] by utilising specially designed processes at the airport in conjunction with a respectively adapted short-haul aircraft. The emphasis of this investigation is to reveal the most significant turnaround processes for short-haul flights in order to have a solid base for optimisations regarding relevant processes and aircraft configuration.

2. METHODS AND SETUP

For a simulation of ground handling processes of an exemplary short-haul aircraft type the relevant procedures at the airport are modelled. The characteristics of the involved processes and their dependencies have been implemented in a discrete eventful simulation environment. Results of numerous simulation runs with traffic scenarios of different densities are examined by a sensitivity analysis for achieving a deeper knowledge of the interdependencies of process durations and resource utilisation.

2.1. Sensitivity Analysis

Sensitivity analysis evaluates relation between input parameters and output parameters of a simulation model. The aim of the analysis is to investigate the impact of the input parameters variation on the model output. There are local and global quantitative methods of the sensitivity analysis. The local methods vary only one input parameter at the same time. The other parameters are retained. The local methods are computationally efficient, but they do not evaluate interactions between parameters. The global methods include variation of all input parameters at the same time and thus the sensitivity for the whole parameter pool is specified. These methods are intensive in terms of computing time and additionally no ranking of parameters is possible. One of the global methods is Monte-Carlo method on the basis of repeated random sampling. Sensitivity analysis is applied to investigate effects of resource pool changes on turnaround process on the base of a simulation model.

2.2. Simulation

The simulation of turnaround processes at the airport is performed by TASim (TurnAround Simulator), a discrete eventful simulation environment developed by DLR [2][3]. Provided with a configuration including process durations (as constants or statistical distributions), resource pool (aviobridge, service vehicles, etc.), process dependencies and a scenario (flight plans with scheduled in- and off-block times, aircraft characteristics) the processes are simulated in fast time by TASim. The results of a simulation run are buffer times and the earliest, latest and actual start and finish times of each process. Furthermore the utilised amount of each resource type is reported for any time of a change. A statistical report by analysing the recorded data is derived by a post processing step which provides information about the achieved actual ground handling time and the peaks of resource utilisation.

2.2.1. Modelled ground handling processes

The dependencies of ground handling processes at the airport are represented by the modelled process chain. Some of the processes are divided into parts – preparation, main process, post processing -- due to the different characteristics of fixed and amount dependent durations. Each ground handling process can allocate different devices and vehicles from a pool of resources. The available number of each resource type can be unlimited for investigating their utilisation without any interferences, or limited to analyse the temporal impact on the process chain. Only processes that are performed between in-block and off-block, are taken into account, which complies with the definition by IATA, who specifies the turnaround time is as the time period when an aircraft occupies a stand or a gate at the airport [4]. The ground handling processes and resources which are modelled in the simulation are briefly summarised in the following subchapters.

2.2.1.1. Opening and Closing doors

The first and last processes of ground handling are the opening and closing of passenger and cargo doors.

2.2.1.2. Unloading and Loading

Offloading of baggage and cargo is done by utilising a belt loader and a cargo loader which can already start while passengers are deboarding. The loading process can start immediately after unloading has been finished.

2.2.1.3. Deboarding and Boarding

Passengers leave and enter the aircraft via an aviobridge. The aviobridge is allocated for the whole duration between in- and off-block. Head counting is considered as a part of boarding process.

2.2.1.4. Cleaning

The aircraft interior has to be cleaned in preparation for the next flight. The cabin cleaning can start after deboarding and has to be finished before boarding. In our model this process will be finished not later than refuelling and catering have been finished. Therefore this process is theoretically not on the critical path.

2.2.1.5. Catering

The catering service uses galley trucks to deliver meals and beverages for the passengers. The process can start after deboarding and has to be finished before boarding.

2.2.1.6. Refuelling

Refuelling of the aircraft is provided by a fuelling vehicle which pumps kerosene from a hydrant or bulk container. Passengers are not allowed to be present in the aircraft during this process. Exceptions are possible in case of availability of firefighters and functional emergency chutes.

2.2.1.7. Lavatory and Water Services

The lavatory service uses a truck to take care for the drainage of used water and toilet disposal. Fresh potable water is provided by a water truck.

2.2.2. Modelled turnaround process chains

An aircraft can arrive or depart as a short-haul, medium-haul or long-haul flight. It can leave the over-night parking position before becoming in-block for ground handling or stay over-night after becoming off-block. Due to the different possible turnaround combinations it is necessary to model dedicated process chains for each situation. Since the turnaround of flights with at least one short-haul part is considered, there are five process chains possible. They are described in Subchapters 2.2.2.1 - 2.2.2.3.

The standard turnaround time of A320 short haul flights specified by Airbus [1] with deboarding and boarding via an aviobridge is 44 minutes. We take as a base the turnaround time of 35 minutes for aircraft that have arrived and depart as a short haul flight, which tends to the standard turnaround time by lowcoster airlines.

2.2.2.1. Inbound and outbound process chains

The passenger and cargo doors can be opened as soon as the aircraft is in-block. Water and lavatory services and unloading of baggage and cargo start in parallel with the deboarding of passengers. Cleaning, catering and refuelling will be processed between deboarding and boarding. After finishing boarding, water and lavatory services, loading of baggage and cargo the doors will be closed and the the aircraft is ready for becoming off-block.

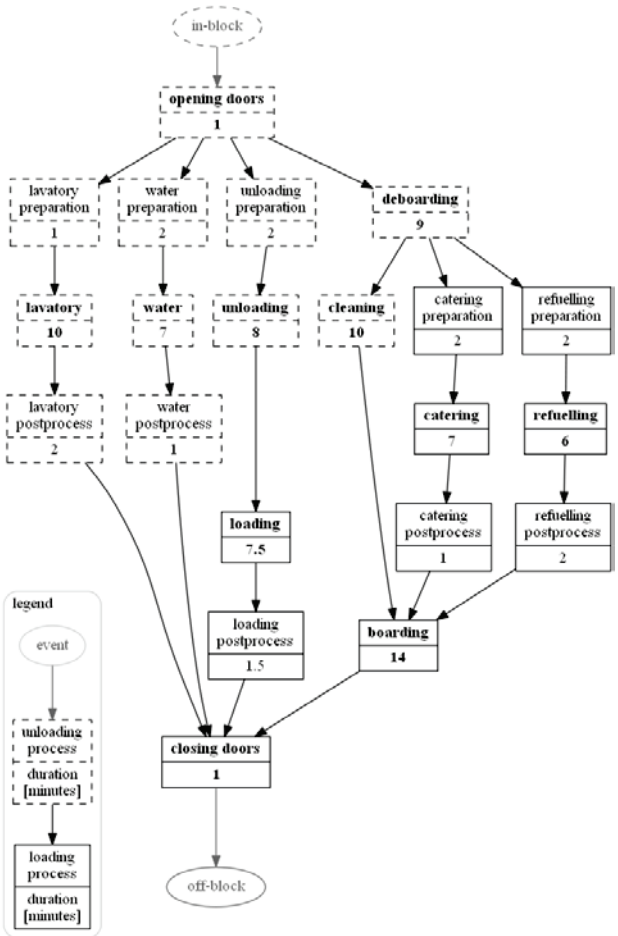

Figure 1. Process chain of aircrafts which have arrived and depart as a short haul flight

The process types and their dependencies (see Figure 2) are similar for all combinations where the aircraft is scheduled as an inbound and outbound flight. Merely the expected durations for some processes differ as shown in TAB 1 where process durations for flights with at least one short-haul part are listed. Obviously a longer processing time must be expected especially for catering, refuelling, unloading and loading when flights include a non short-haul in- or out-bound component.

in-block as off-block as	short-haul short-haul	short-haul long-haul	long-haul short-haul	short-haul off-duty	in-duty short-haul
deboarding	9	9	9	9	n/a
boarding	14	14	14	n/a	14
water	7	7	7	7	n/a
lavatory	10	10	10	10	n/a
cleaning	10	19	15	19	n/a
catering	7	17	7	n/a	7
refuelling	6	16	6	n/a	6
unloading	8	8	10	8	n/a
loading	7.5	9.5	7.5	n/a	7.5

TAB 1. Process durations (without preparation and post-processing) in minutes depending on operational status of the aircraft

Sequential processes which consume the maximum accumulated duration belong to the critical path. For short-haul flights this affects boarding, catering, refuelling and deboarding. Although cleaning looks like to be critical, it is common practice to finish this process not later than both, catering and refuelling have been finished.

2.2.2.2. Inbound only process chain

Aircrafts which will be set off-duty after arriving have their own assigned process chain (see Figure 3). Processes like catering, refuelling and loading are related to departing flights and therefore omitted. In absence of a loading process the unloading is followed by a subsequent post processing. Regarding process durations there is a remarkable increase of cleaning time for tidying up the aircraft.

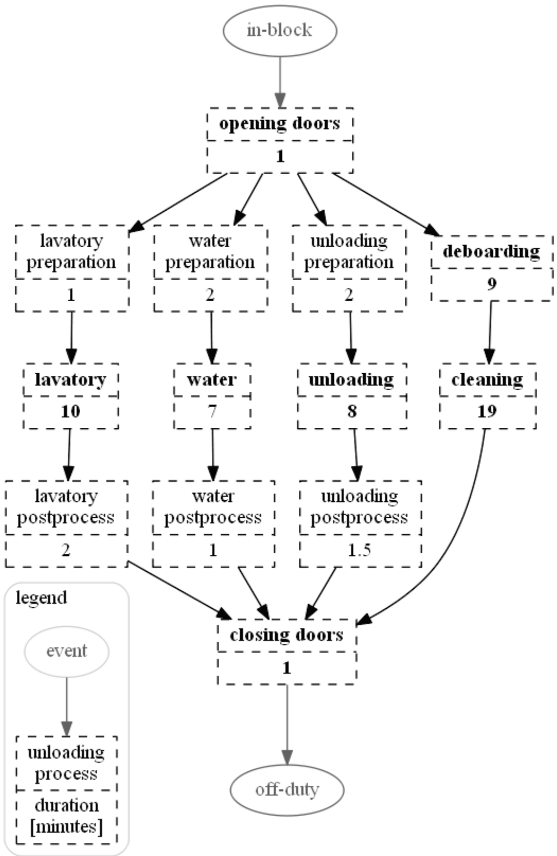

Figure 2. Process chain of arrivals which stay over-night

2.2.2.3. Outbound only process chain

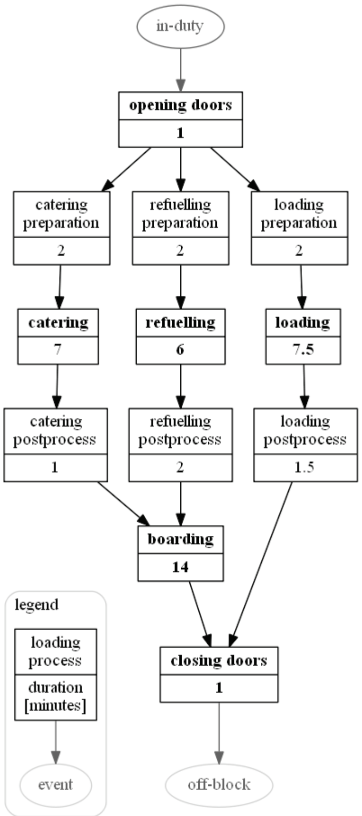

Figure 3. Process chain of departures which have stayed over-night

Aircrafts which will be set in-duty before departing have also their own assigned process chain (see Figure 3). Processes like water and lavatory services and unloading are related to arriving flights and therefore omitted. In absence of an unloading process there is an additional preparation preceding the loading of baggage and cargo.

2.3. Deployed Scenarios

We consider three scenarios based on the real operational data from a German airport. The scenarios are specified as original scenario, 2-times compressed scenario and 3,5-times compressed scenario.
The original data include 433 flight movements per this day. There are 221 departures and 212 arrivals. Aircraft of the A320 – family encounter 109 times in arrivals and 107 times in departures. There are 82 arrivals and 82 departures as a short haul flight (flight distance is under 500 NM). The mentioned 164 short haul flights consist of

- 60 aircraft that have arrived and depart as a short haul flight,
- 5 aircraft that have arrived as a short haul flight and depart as medium haul or long haul flight
- 7 aircraft that have arrived as a not short haul flight and depart as a short haul flight,
- 15 departures that have stayed over-night,
- 17 arrivals that stay over-night.

Therefore, the turnarounds of 104 independent aircraft take place, when the turnaround of one physical machine is considered as a completed process between its arrival and departure at the studied airport. The selected demand on turnaround of aircrafts of A320 family executing/executed a short haul flight generates the original scenario. It consists of 87 departures and 17 arrivals that stay over-night. The planning period takes 18 hours. Since we are interested in determining of resource pool sufficient for smooth processing and in finding out of critical paths operating with limited resources, the following turnaround times are specified:

- 35 minutes for aircraft that have arrived and depart as a short haul flight (Figure 1),
- 45 minutes for aircraft that have arrived as a short haul flight and depart as medium haul or long haul flight
- 40 minutes for aircraft that have arrived as a not short haul flight and depart as a short haul flight,
- 26 minutes for departures that have stayed over-night (Figure 2),
- 30 minutes for arrivals that stay over-night (Figure 3).

As a scheduled off-block time (SOBT) for departures is taken the original scheduled time. As a scheduled off-block time for the staying over-night arrivals is used the original scheduled time increased on turnaround time of 30 minutes. The number of obtained in such a way SOBTs per half an hour is illustrated in Figure 4.
Since our goal is to estimate the impact of demand variations on the duration of turnaround process, there is no buffer in the corresponding turnaround time to compensate deviations from the scheduled in block time (SIBT) and SOBT. Therefore, the associated SIBT is equal to SOBT minus the specified above corresponding turnaround time. The number of SIBTs and SOBTs in the original scenario is shown in Figure 4.

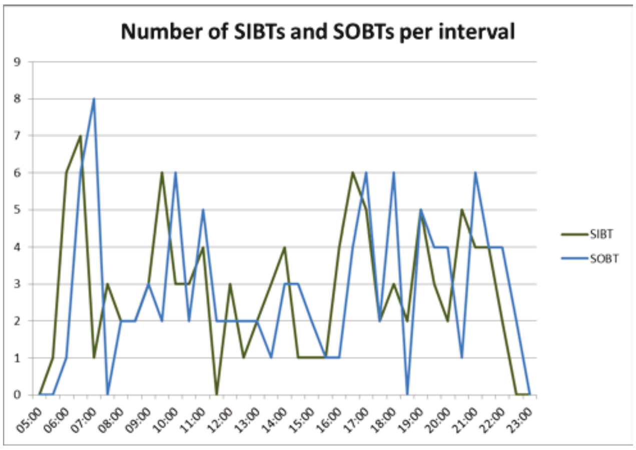

Figure 4. SIBTs and SOBTs in original scenario per half an hour

The difference of accumulated SIBTs and SOBTs illustrates, that the scheduled turnaround of the short haul flights in the original scenario consists of three periods. Each period ends with the completed turnaround for all flights with SIBTs within of this period.

Since the original scenario has relative small demand density – average of approx. three short haul flights per a half an hour – the original demand of the 104 aircraft executing/executed short haul flight has been compressed so that the turnaround times of the original scenario stay valid. There are two compressed scenarios: 2-times compressed with the duration of approx. 9,5 hours and the density of approx. 5,5 short haul flights per a half an hour (SOBTs, AIBTs are shown in Figure 5) and 3,5-times compressed with the duration of 5,5 hours and the density of approximate 9,5 short haul flights per a half an hour (Figure 6).

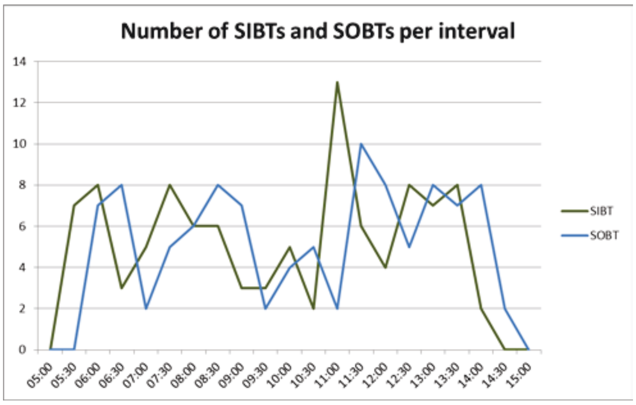

Figure 5. SIBTs and SOBTs in 2-times compressed scenario per half an hour

The scheduled turnaround of the short haul flights in 2-times and 3,5-times compressed scenarios consists of one period without phases with the completed turnaround for all flights with SIBTs within of this period.

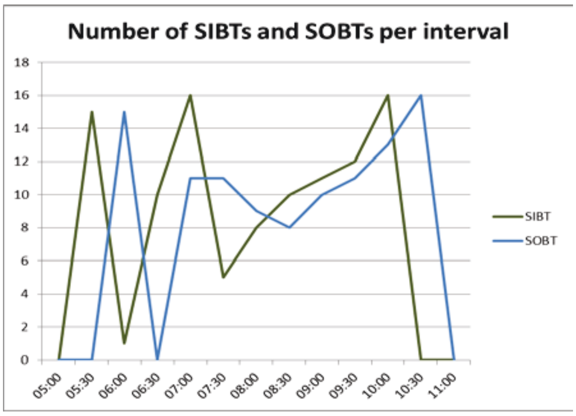

Figure 6. SIBTs and SOBTs in 3,5-times compressed scenario per half an hour

3. RESULTS OF THE SENSITIVITY ANALYSIS

As a first step is assumed, there is unlimited resource pool for the turnaround process provided and actual in-block time corresponds to the scheduled in-block time of the considered demand. This "best case" baseline helps us to estimate the minimum of resources we need to get the best makespan. The simulation period is divided into intervals by the beginnings and endings of involved turnaround processes and the corresponding resource requirement per interval is calculated. After that actual in-block time is varied by triangle distribution relating to scheduled in-block time with parameters: minimal value 15 minutes for scheduled in-block time, maximal value 30 minutes after scheduled in-block time and mode equal to scheduled in-block time. Simulations with varied in-block times are performed to estimate resource requirements for the same physical demand of 104 aircrafts coming to different in-block times. The obtained findings will be used for a selective limitation of resources to estimate the impact of this limitation on the turnaround process and its makespan and to find out the corresponding critical paths. As a next step the duration of the involved turnaround processes will be stochastic varied relating to their standard duration to estimate caused delays.

3.1. Reference simulation

One simulation run for all three scenarios was performed under unlimited resources and actual in-block time equal to scheduled in-block time to get the corresponding to each scenario reference utilisation of resources. The calculated utilization is illustrated in Sections 3.1.1-3.1.3. The vertical axis of each graph represents the number of utilized resources. The ressource aviobridge is occuped the whole time from opening till closing of aircraft doors. Therefore, its utilisation can be seen as actual demand.

3.1.1. Scenario 1 with fixed in-block times

The actual demand of the original scenario is illustrated in Figure 7. There is one peak at the morning with the maximum of 10 aircraft for turnaround of a short haul flight. The rest of the day has relatively smooth demand.

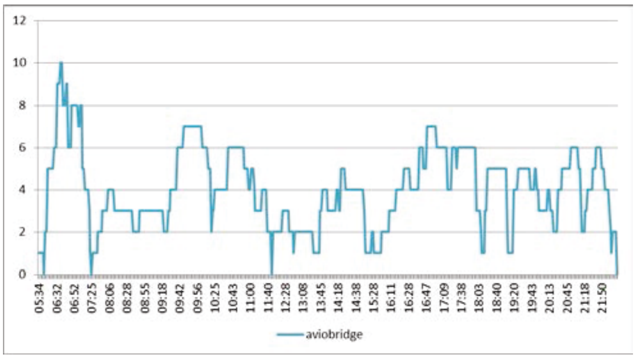

Figure 7. Resource aviobridge: utilisation rate

There is a correlation in utilisation of resources belt loader and cargo loader (Figure 8) used for unloading and loading, since each process requires 2 cargo loaders and one belt loader and the simulation was done with unlimited ressources.

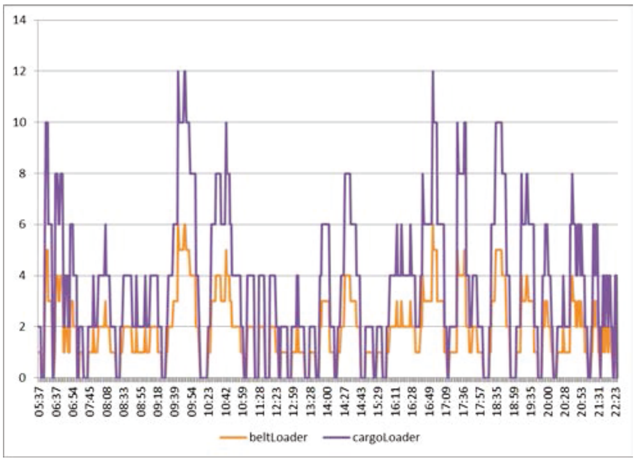

Figure 8. Resources belt loader and cargo loader: utilisation rate

Figure 9 illustrates utilisation of resources galley truck and tank truck required for catering and fuelling processes. They are contraposed on one graph, since both belong to the critical paths (Figure 1). The processes have approximately equal duration (TAB 1) and require respectively one truck for a short haul flight turnaround. In the case of a not short haul departure two galley trucks are required.

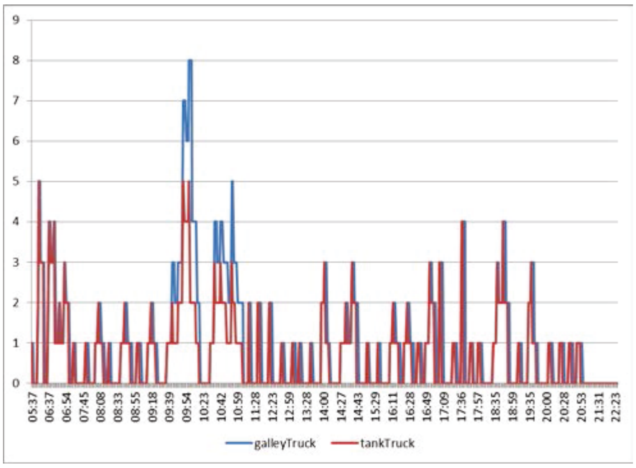

Figure 9. Resources galley truck and tank truck: utilisation rate

There are 5 aircraft that have arrived as a short haul flight and depart as medium haul or long haul flight in the demand. They have a noticeable effect in the resources utilization between 9 and 11 o'clock (Figure 9).

3.1.2. Scenario 2 with fixed in-block times

Two-times compressed scenario has the actual demand shown in Figure 10. There are peaks both in the morning hours and in the interval between 11 and 12 o'clock.

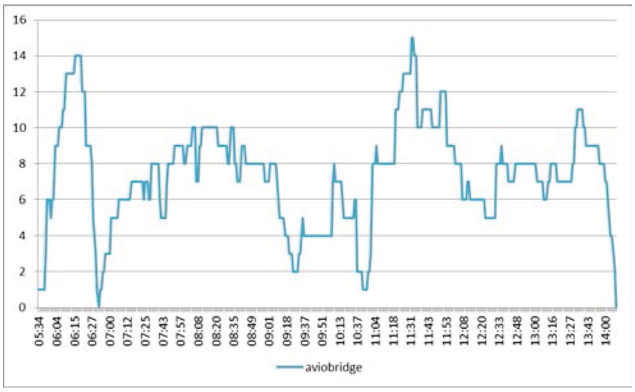

Figure 10. Resource aviobridge: utilisation rate

Utilisation rates with effects described in Section 3.1.1 for ressources belt loader, cargo loader and galley truck, tank truck are illustrated in Figure 11 and Figure 12, respectively.

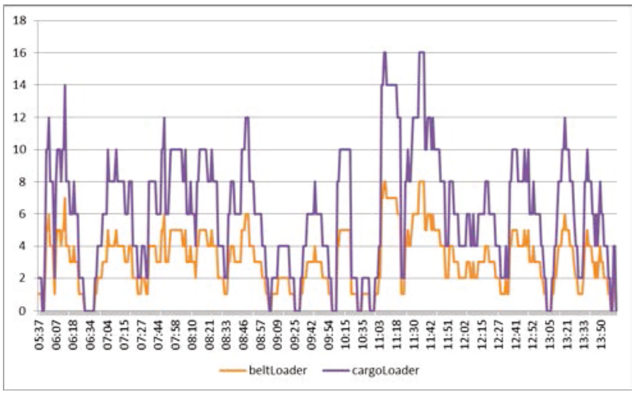

Figure 11. Resources belt loader and cargo loader: utilisation rate

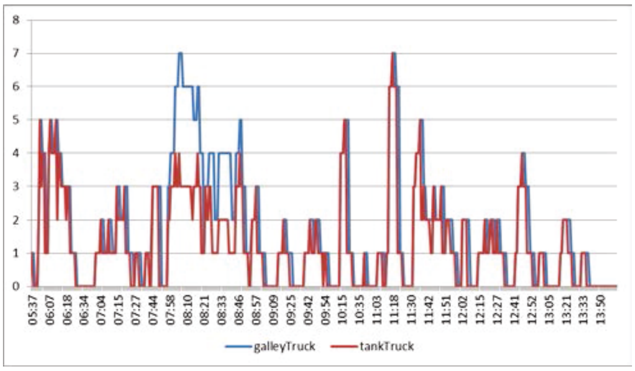

Figure 12. Resources galley truck and tank truck: utilisation rate

3.1.3. Scenario 3 with fixed in-block times

Utilisation of aerobridge and, as follows, the actual demand of 3,5-times compressed scenario is illustrated in Figure 13. There are vour significant peaks during the simulation period.

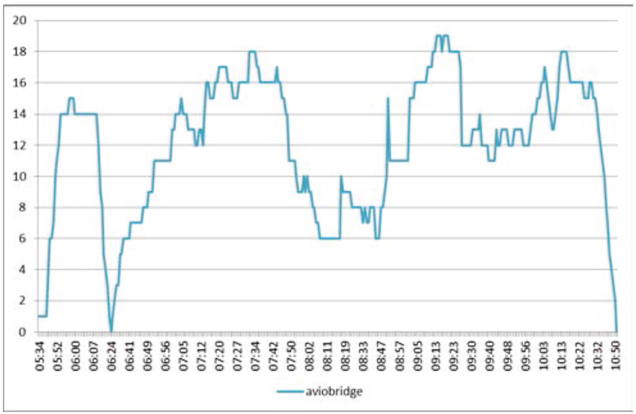

Figure 13. Resource aviobridge: utilisation rate

There is again, in common with the previous two cases, a correlation in utilisation of resources belt loader and cargo loader (Figure 14). Compared to scenario 2 utilization of resources galley truck and tank truck has an additional significant deviation that arises from the different duration of these processes (Figure 15).

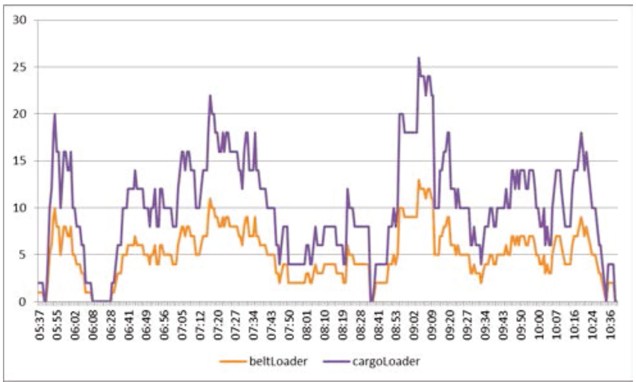

Figure 14. Resources belt loader and cargo loader: utilisation rate

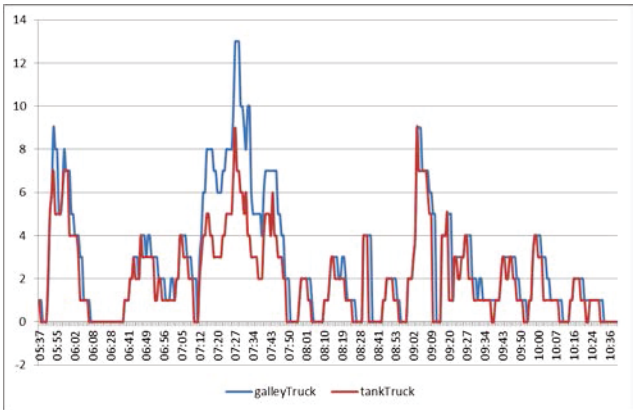

Figure 15. Resources galley truck and tank truck: utilisation rate

3.2. Simulations with variations of in-block times

In order to estimate resource requirements for the same physical demand of 104 aircrafts coming to different in-block times 30 simulation per scenario were performed. The actual in-block times in each scenario are varied by triangle distribution with parameters: minimal value 15 minutes for scheduled in-block time, maximal value 30 minutes after scheduled in-block time and mode equal to scheduled in-block time. It is performed for all not stayed over-night flights. The following indicators for each resource per simulation were calculated: minimum, maximum, mean value, standard deviation and mean value of utilisation per time. The utilisation of resources aviobridge, galley truck and tank truck, which belong to the critical path processes, per simulation is summarised and illustrated in Subsections 3.2.1 - 3.2.3.

3.2.1. Scenario 1 with variated in-block times

Considering utilisation of resource aviobridge (Figure 16) and compare it with the actual demand in Figure 7, one can notice that the maximum of 10 does not exceed the other local maxima at each simulation run. It shows, that the considered variation do not form demand peaks overcoming the peak at the beginning of the simulation period. It can be explained with the fact, that the demand of scenario 1 has relative small density. There are also almost equal courses of the mean values and of the standard deviation over simulations (Figure 16).

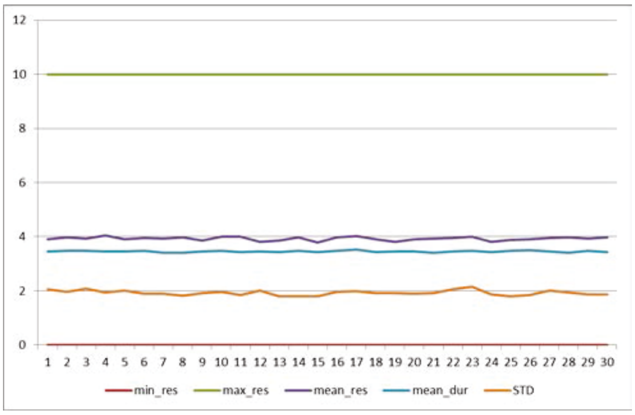

Figure 16. Resource aviobridge: utilisation indicators per simulation

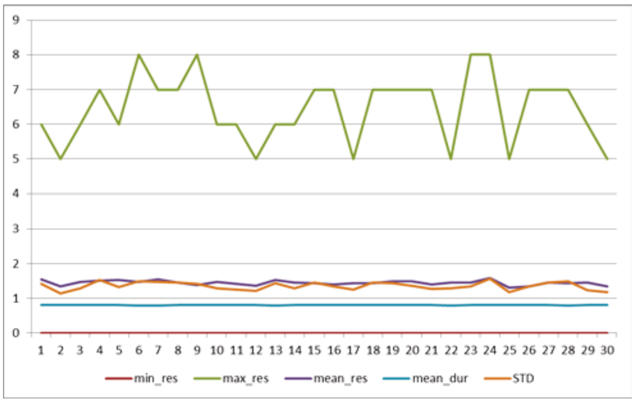

Figure 17. Resource galley truck: utilisation indicators per simulation

The utilisation of resources galley truck and tank truck is summarised in Figure 17 and Figure 18. The maximal values of 8 and 5 units do not exceed the corresponding values of the reference simulation (Figure 9). The performed perturbation of the demand by triangle distribution has resulted in such composition of demand, that the maximal utilization of resource galley truck is equal to 5 units (Figure 17). It can be seen, for instance, in the run #12.

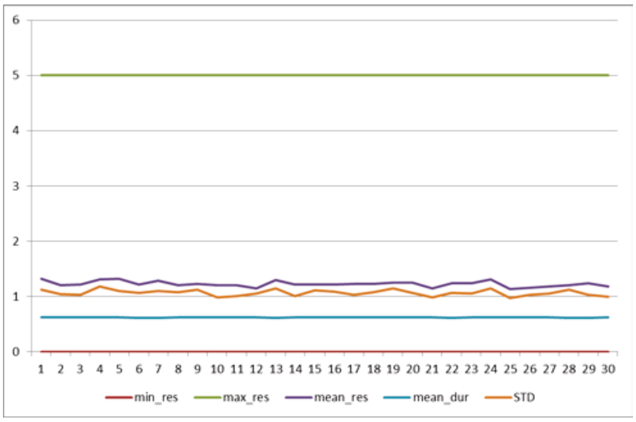

Figure 18. Resource tank truck: utilisation indicators per simulation

The courses of the resources utilization in the run #6 with maximal utilization of 8 units for galley truck and 5 units for tank truck and in the run #12 with 5 units for both trucks are illustrated in Figure 19 and Figure 20, respectively. Since the resources are unlimited, the utilization of ressource aviobridge corresponds to the actual demand in each simulation run. There are less peaks (and they are smaller) at the periods of accumulation of the actual demand in the run #12 compare to the run #6 (blue curve in Figure 19 and Figure 20). It explanes together with a little wider distribution of in-block times of 5 aircraft with a not short haul departure the more uniform utilization of resources.

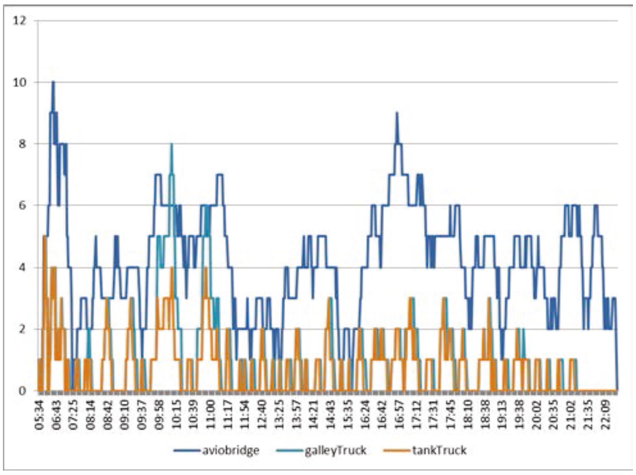

Figure 19. Resources aviobridge, galley truck und tank truck: utilisation in run #6

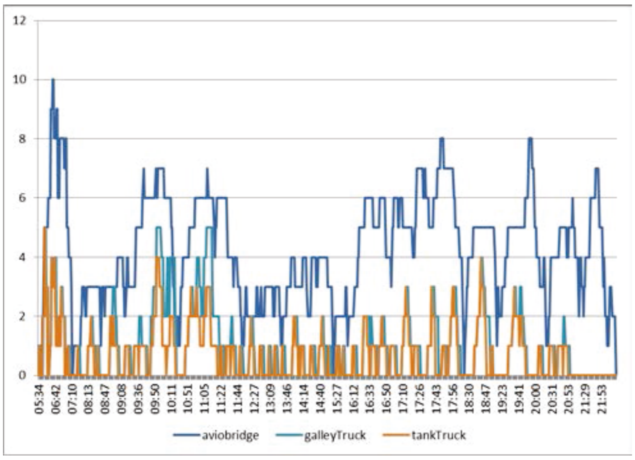

Figure 20. Resources aviobridge, galley truck und tank truck: utilisation in run #12

3.2.2. Scenario 2 with variated in-block times

Since this demand is denser in relation to the previous scenario (see Figure 10) and it has comparable peaks, the perturbation of this demand involves more variation in the resource utilization for performed simulation runs. The maximal utilization of resources galley truck and tank truck is equal to 7 units in the reference scenario (Figure 12). The perturbed demand requires predominant maximal 7 or more galley trucks and always not more than 6 tank trucks (Figure 22 and Figure 23).

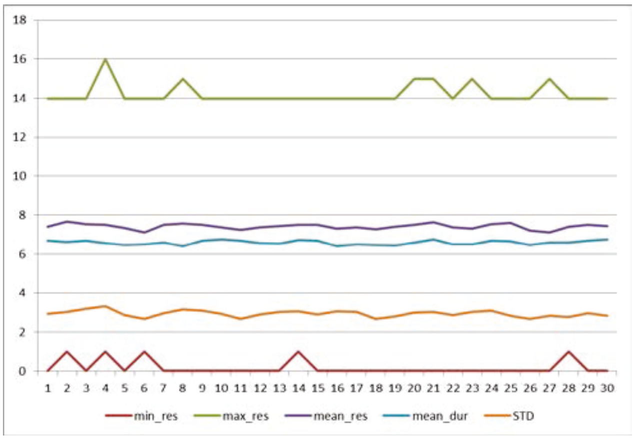

Figure 21. Resource aviobridge: utilisation indicators per simulation

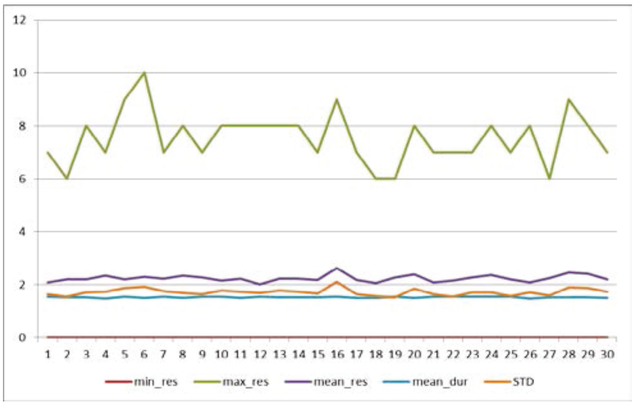

Figure 22. Resource galley truck: utilisation indicators per simulation

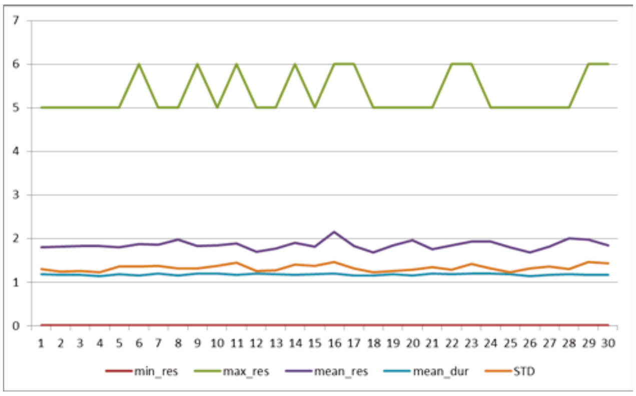

Figure 23. Resource tank truck: utilisation indicators per simulation

3.2.3. Scenario 3 with variated in-block times

The actual demand of the reference scenario is illustrated in Figure 13. It has four comparable peaks. The maximal utilization of resources galley truck and tank truck is equal to 13 and 9 units in the reference scenario (Figure 15). The perturbed demand requires maximal between 9 and 14 galley trucks and predominant less than 9 tank trucks (Figure 25 and Figure 26).

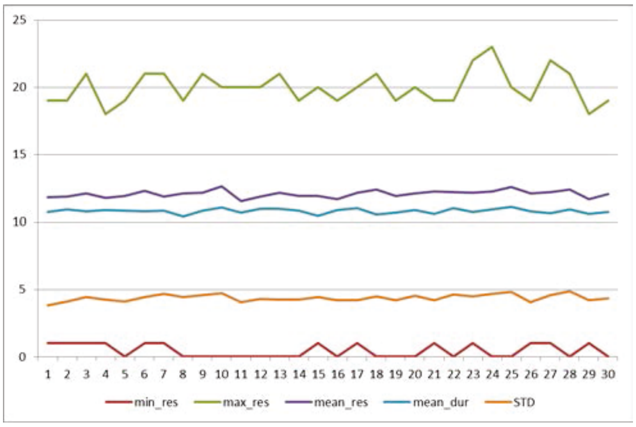

Figure 24. Resource aviobridge: utilisation indicators per simulation

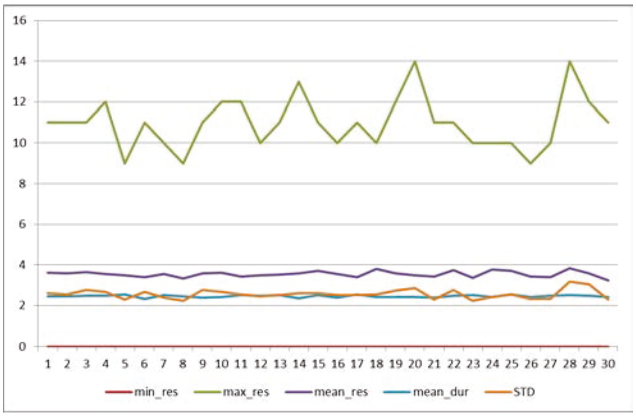

Figure 25. Resource galley truck: utilisation indicators per simulation

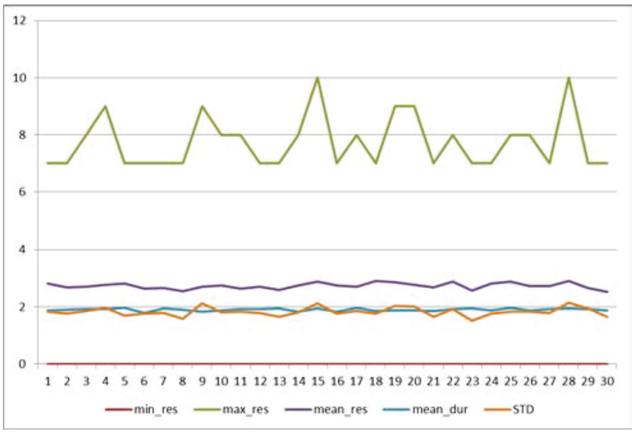

Figure 26. Resource tank truck: utilisation indicators per simulation

4. DISCUSSION OF THE RESULTS

Several conclusions can be derived from the results of these simulation runs. As expected, there is in general a strong correlation of the demand induced by each of the particular traffic scenarios and the utilised amount of ground handling resources. Due to the fact, that an aviobridge is not solely blocked by deboarding and boarding itself but for the whole time period at the gate, this is especially valid for the number in use of this resource during the elapsed time. One of the most noticeable observations is the increase of deviations regarding resource utilisation while augmenting an uncertainty for the actual in-block times. Uncertainty effects caused by variations of processing times were not in focus for this research and are subject for future analyses.

The obtained results on resource utilisation provide upper and lower bounds for the limitation of resources planned as the next step of sensitivity analysis. These bounds can be calculated using maximal and mean values with corresponding standard deviations. The results of the simulation point out, that the needed number of resources does not increase with the same factor as the demand which is shown in Figure 27 and Figure 28.

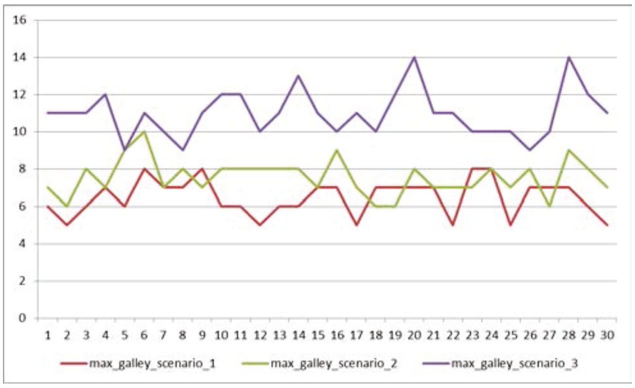

Figure 27. Resource galley truck: maximal utilisation per simulation and per scenario

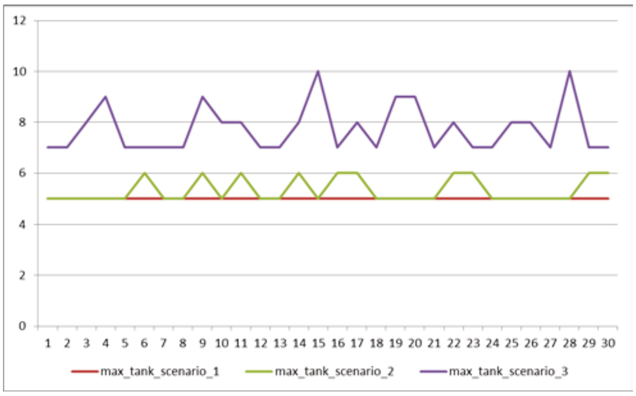

Figure 28. Resource tank truck: maximal utilisation per simulation and per scenario

Based on the achieved results, the next step is to extend the modelling of the relevant ground handling processes with dedicated variations which reflect the distribution of uncertainty effects.

5. ACKNOWLEDGEMENT

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6. LITERATURE

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