DYNAMIC TURNAROUND MANAGEMENT IN A HIGHLY AUTOMATED AIRPORT ENVIRONMENT

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Abstract

The aircraft turnaround is a time-critical process linking flight legs with various potential disruptions far beyond those appearing during flight. This is often caused due to the lack of substantial automation and limited standardization in aircraft ground handling ranging from human resource skills to equipment types. Whenever a disturbance occurs (e.g. while boarding or fueling) as part of the so-called critical path, these effects immediately cause a disruption propagation resulting in accumulating delay through the whole air traffic network. To allow for an efficient process control and prediction, the turnaround management will have to be systematically standardized ensuring the compatibility to the expected increase of the automation level. Our proposed turnaround model is using closed-loop stochastic dynamic process optimization considering input and state constraints to bridging the efficiency gap between ground and airborne operations. It will also use stochastic models to describe every turnaround sub-process, to be shaped according to expected behavior resulting from increased automation which is based on previous research results.

1 Introduction

The Aircraft Turnaround has been identified to be crucial for airline schedule adherence, for high customer satisfaction, and economic productivity. Productivity is further measured not only by the airline but also by the airport operator, the ground handling companies and the air navigation service provider since all of them have to handle carefully scarce staff and tool resources. Consequently, the aircraft turnaround is complex in terms of both the amount of involved parties and the given process dependencies covering technical, legal and operational aspects. Due to the close dependencies of the turnaround (sub) processes disruptions/disturbances of one single process may result in significant system turbulences.

The aim of our research is to provide optimum time and place of intervention (using control theory approaches) in quite likely case of plan deviations. Nowadays this gap is filled by the experience of ground handling or airline companies, which is not more than a best guess of operators than an objective and valid process strategy granting the propagated target times. The proposed stochastic model allows an efficient transition from common buffer strategies to automated environments with regards to given arrival delays on one hand, and acceptable interface requirements between the turnaround processes on the other hand by using intelligent prediction and controlling strategies. All aircraft handling processes covered by the aircraft turnaround are being scheduled against the *scheduled time of arrival* (STA) and scheduled against the on block times at the assigned aircraft stand (assuming a dedicated taxi-in time). Deviations to the STA will increase the criticality of the underlying requirements regarding to reliability, high service quality, and punctuality.

Over the past years, our research group at the Department of Air Traffic Technology and Logistics at TU Dresden studied various influences on aircraft ground operations. A study in cooperation with an aircraft manufacturer was conducted to understand turnaround reliability enhancements on a long time period on different German airports. Several technical deficiencies in aircraft design were observed, which contributed to uncertainty in turnaround operations. Also, based on representative interviews with ground handling experts, individual impact effects were linked to detailed aspects showing significant potential for improvement on the turnaround reliability for future aircraft design [1].

Analysis of field data gathered as part of our previous research activities has indicated that the delay of incoming aircraft (arrival delay) has a significant influence on the turnaround time. It has also been previously observed that airlines established dynamic buffers strategies to mitigate the disruptive impact of significant TTT deviations and so ensure the integrity of their flight schedule. However, no systematic pattern of buffer introduction was found and the efficiency of the buffer strategies mostly relies on the operator's experience and available information [2].

A detailed analysis regarding to the influence of airport categories (regular hub, non-hub, and supply-base) points out additional variations of turnaround processes [3]. Finally, the varying level of staff skills due to different training principles and expertise was identified as a further major reason for distinct process characteristic [4]. Beside these major findings, several studies focused on our stochastic approach aiming at the detailed characteristics of the turnaround sub-processes such as boarding, fuelling and cleaning [5-7].

2 Ground Handling Processes

The turnaround is a generic term for the aircraft ground processes. Following Airbus' definition of the turnaround (fig. 1), the turnaround time is defined as the aircraft parking time, between on-block and off-block. While the aircraft is at its gate or apron position the ground processes (un)loading, catering, cleaning, refueling, and (de)boarding are executed. Due to safety regulations and logistic requirements some processes run parallel to others and some processes have to be sequentially executed. Consequently, the overall turnaround time is reached with the termination of the last ground process. According to fig. 1 the moving of passenger bridges, the boarding and the refueling are part of the critical turnaround path. Shortening the processes on the critical path implies a decrease of the overall turnaround process time.

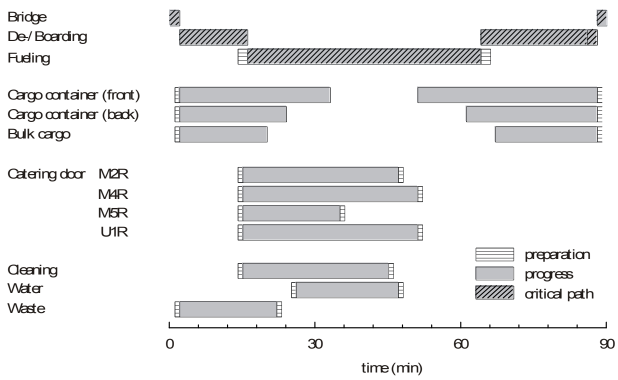

Fig. 1. Turnaround time schedule of A380 (90 min, baseline [8]).

Keeping the focus on the boarding process, it is quite evident that the efficiency of boarding could directly influence the overall turnaround progress. The next sections contain the background to model the turnaround sub-processes.

2.1 Boarding / Deboarding

The ability to improve the baseline turnaround is obviously linked with a (technological) reduction of the fueling process and with a logistical optimization of the deboarding/ boarding of the passengers (processes on the critical path). Though, to achieve reliable improvements to the turnaround, optimizations have to ensure both a reduced expected value and variance of the process duration (accompanied with an increased level of standardization). Despite the variance of the process duration is often neglected, we used this important value as an additional measurement for process quality. Regarding to the stochastic nature of real processes, reliable investigations aiming on serious performance enhancements seriously have to cope with the variance. Numerous research studies were performed on the field of efficient boarding procedures [9-15], by means of finding minimum boarding times, but we focus also on practicability, sensitivity against disturbances and stability [1, 16].

Reflecting the nature of the boarding as process of human interactions, we developed a stochastic transition model, which allows for considering the individual movement speed, amount of baggage, and reaction times. As our detailed investigations points out, particularly the single-aisle layout significantly benefits from the improvements of the boarding procedures [17]. The major achievements of the developed boarding model are shown in tab. I.

Tab. I. Efficiency of boarding procedures

	Boarding procedure	Efficiency	
		boarding time (%)	standard deviation (%)
1 door	random	0%	0%
	block	3%	4%
	outside-in	19%	21%
2 door	random	26%	34%
	block	14%	17%
	ouside-in	36%	57%

Regarding to the selected boarding procedures (random, block, and outside-in) an increased efficiency against the random boarding using one door, by means of smaller boarding times and time deviations can be observed [1, 16]. We could validate our achieved simulation results with recorded data at Berlin Tegel Airport (TXL) in close cooperation with Air Berlin.

The cleaning, catering and fuelling processes are commonly contract out by airlines to service companies. We are in close cooperation with ground service providers, to gain specific insights in the process characteristics. Until these investigations are not finished, the cleaning, catering, and fuelling processes are not modeled in detail by reproducing the internal interactions but the process duration will be described by analytical equations. Our evaluations points out the Weibull distribution as a valid candidate to analytically describe the nature of the observed processes. The cumulative distribution function of the Weibull distribution is:

$$F(t, \Delta t, \alpha, \beta)=1-e^{-((t-\Delta t)/\beta)^{\alpha}} \qquad (1)$$

with β as scaling factor, α as shape parameter and Δt as minimum time value [1].

2.2 Cleaning

Commonly, the cleaning services can be divided into basic sub tasks: seat cleaning, seat pocket cleaning, ashtray cleaning, galley cleaning, toilet cleaning and replenishment, floor cleaning, blanket management and additional services: floor vacuuming, window cleaning, stowage cleaning, and cleaning of the cabin crew resting area [cf. 18]. Considering different stages of cleaning these sub tasks will be combined to one cleaning service product, considering the individual demands of the airlines (low cost vs. full service) and the operational requirements (minimum turnaround vs. overnight).

To cover all these single tasks at a given cleaning progress (attending layout, timeframes, or chronological progress), specific durations of the cleaning processes are recorded. Assuming the proposed Weibull distribution, the cleaning duration is defined by the parameter α=2.16, β=6.76 min, and Δt=5 min (fig. 2).

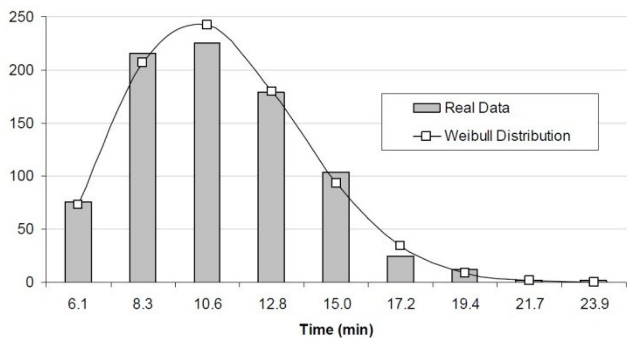

Fig. 2. Process time distribution of cleaning process [2]

2.3 Catering

Catering process included all handling activates to supply a flight with meals drinks and service utilities for passenger supplied by the airline. Supplying the outgoing flight leg with catering stock is one of the main processes on the critical path. Furthermore the catering process is divided in unstocking the used equipment, replenishment for the next leg(s) and controlling by the aircraft crew. Due to the location of galleys near to the exits, the accessibility is only given, if passengers vacate this area. While galleys are located on narrow body aircraft at the front and rear exits, on widebody aircrafts they can be located also next to center exits. Therefore the overall catering process can only be started when the de-boarding process is finished. Also independencies with the cleaning process can be observed, due to the need to clean the galley equipment. Depending of the amount of catering containers one or more catering vehicles on one or more exits can be used. Not for every turnaround the process catering need to be considered. While for short and medium flight durations the catering process provides stock for several legs, the catering for long distance flights is proceeded before every leg. So called low costs airline intend to cater only once a flight day before the first flight leg. Assuming the proposed Weibull distribution, the catering duration is defined by the parameter α=2.18, β=17.37 min, and Δt=0 min (fig. 3).

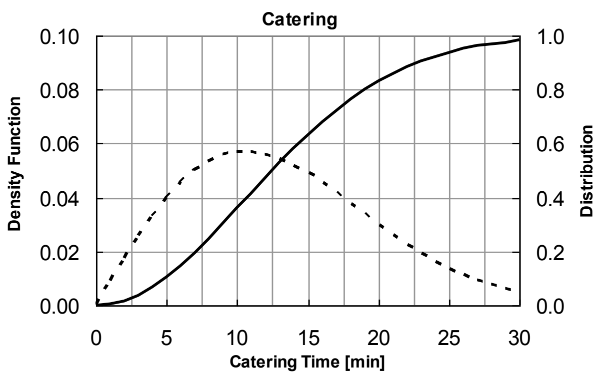

Fig. 3. Process time distribution of catering process [8]

2.4 Fueling

The process of fuelling includes all activities on the ramp to refuel the aircraft with jet fuel. The amount of fuel directly correlates with the flight distance to the destination airport and additional extra fuel plus a safety margin to cope with e.g. detours, holdings, and alternate airport. There are two possibilities to transport the fuel to the aircraft: a) with fuelling vehicles or b) using a under floor transport system in combination with local dispensing devices. The fuelling process itself points out no significant differences using method a) or b). Commonly the process consists of three steps: connection to the wing valves (on one or both sides), the fuelling transfer process and the final unplugging. One major point is the direct communication with the pilots. There are no standardized operating procedures. We observed to best practices: 1) the fuelling service operator starts to fuel a default amount of jet fuel immediately and ask the pilots for the final amount after finishing this prephase, and 2) the operator ask before the fuelling starts and fill the tanks at one step [5]. Due to the fact, that the maximum transfer rate is limited by design, the demanded fuel capacity can be directly transferred to the minimum fueling time. Due to safety concerns it is prohibited to fuelling the aircraft if passengers are on board. In exceptional cases fire brigades have to observe the fuelling process if there is a need to embark passengers in a parallel process [19]. Further on, the use of fuelling vehicles results in additional emergency procedures, by means of an unoccupied maneuver area, which gets very important against the background of the small available place in the vicinity of the aircraft during the turnaround. The assumed Weibull distribution fails the χ^2-test, so we used the Gamma distribution (also two parameters, continuous, direct generalization of exponential distribution). The probability distribution function of the Gamma distribution is given by the following eq. (2).

$$f_{GAMMA}(t,\Delta t,\alpha,\beta)=\frac{1}{\beta^{\alpha}\Gamma(\alpha)}(t-\Delta t)^{\alpha-1}\ e^{-((t-\Delta t)/\beta)} \qquad (2)$$

The parameterized Gamma distribution shows a comparable shape to the Weibull distribution, with an increased probability of the mode value (number that appears most often in a set of numbers), which results in better fitting regarding to processes with smaller deviations. The parameters are α=1.64, β=9.12 min, and Δt=2 min.

2.5 Additional Processes

Beside the common definition of the turnaround we will also include the following procedures to our turnaround prediction process.

2.5.1 Unloading/Loading

The unloading and loading process includes all activities to unload bags, cargo and mail from the incoming leg and load this stuff for the outgoing leg. The loading follows on the unloading process in standard turnarounds. Bags cargo and mail can be loaded bulked, that means piece by piece or containerized. There the bag, cargo or mail is repacked in special container. Depending on the individual aircraft that is used one of these two ways is possible.

While the processes on the main passenger deck are in most cases on the critical path, the unloading and loading processes appear only in special cases when the loading process is disrupted. This is the case if a bag needs to be unloaded when the passenger is not on board, due to security concerns (ICAO ANNEX 17). Disruptions occur if special cargo is (un)loaded or the technical infrastructure for container is curious. Due to the dependencies which are based on special loading instructions by load control, delays are usually expected within the loading process (parameter sets are defined in [3]).

2.5.2 Anti-Icing, De-Icing

Winter conditions crucially result in de-icing/anti-icing processes. Following the Airport CDM Implementation Manual [21], several process requirements are directly impact the turnaround, e.g.:

- There is an increase in communication and coordination between parties and the de-icing companies involved.
- Because of extra de-icing operations, there may be a reduction in staff and equipment availability.
- Turnaround times are increased, affecting pushback times and airline fleet schedules

At these winter conditions the surfaces of the aircraft need to be free of ice or solid water. The conditions are at temperatures below 4°C and narrows to the dew point and/or solid precipitation. The process can be separated to de-icing (removing of ice and snow etc.) and anti-icing, where a special liquid is used to prevent the development of a new coat of ice for a certain time (*hold over time*, HOT). These two processes can be conduct in one or two steps. The liquids have to be applied with special vehicles either on stand or remote on special deicing pads. The anti-icing, de-icing process significantly holds potential of process interference on the apron (e.g. taxi, push back, or gate occupancy times).

2.5.3 Push Back

Evaluating potential bottlenecks at the apron, limited capacities can be identified regarding to aircraft parking stands, apron space, or taxiway layout. To cope with the final take-off sequence planning and to ensure a high reliability of the planned chronological sequence, one significant optimization strategy will most probably be applied to the push-back planning [21]. Even if the push-back defined as subsequent following process of the turnaround, we will include the push-back in our future turnaround model to consider crucial interdependencies and to ensure valid optimization strategies. Therefore, one of the research targets of our Department of Logistics and Aviation focus on safe and reliable pushback strategies for future turnaround procedures [22, 23].

An aircraft pushback is required if an aircraft is unable to leave its aircraft stand by its own power because of the stand design at an apron. Then the aircraft is pushed out by a tug from the stand to a position on the taxiway or to a safe area at the apron. According to the actual standard procedure and used technologies, the pushback process of an aircraft inevitably holds potentials of optimization, and so far is executed with very limited automation support. We are convinced that our detailed pushback analyzes ensure both a significant process optimization and a reliable risk mitigation methodology (adequate collision prevention system for the tug operator [22]). As an example for the push-back process time modeling, fig. 4 shows the classified, empirical times for pushback operations, collected at the German airport Dresden (DRS). The pushback operation time is defined here from start of the manoeuver to the moment of visual confirmation of the ground given hand signal by the cockpit crew. On average a pushback at DRS needs 3 minutes for the operation, the disconnection of the tug/towbar, clearing the aircraft (final check, disconnect communication) and the final hand signal [23].

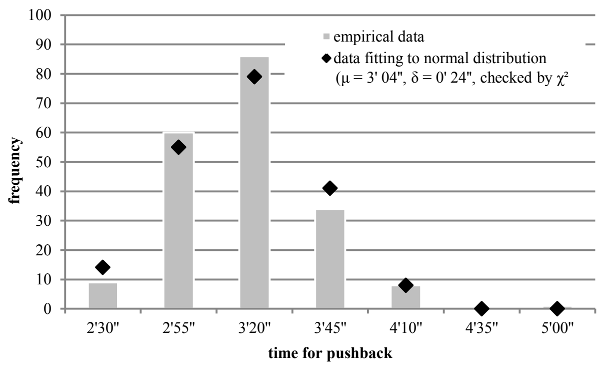

Fig. 4. Standard pushback process at Airport Dresden [23]

2.6 Delay Compensation

To evaluate the potential of delay compensation strategies, we transferred the empirical findings to stochastic model and analyzed the starting time of each handling process [2]. Contrary to the common understanding that all processes start immediately after de-boarding, our analysis clearly showed that in most cases a time shift (buffer) is found between the end of the boarding and the beginning of the following ground processes. We assume that this is the airline and ground handler current strategy to claim for the demanding punctuality standards. Comparing the parallel run processes catering, cleaning, and fueling, different variances for the starting times are observed (see fig. 5). Whereas the turnaround is normally restricted by the fueling processes [cf. 8], our analysis shows a further time restrictions imposed by the catering process. As a result of all preceding process characteristics, the final de-boarding accumulates all uncertainties and so possesses a significant higher variance for the starting time.

As fig. 5 shows, the ground handling processes tend to start earlier with increasing inbound (arrival) delay. Consequently, the overall turnaround time should also decrease compared to the scheduled figures. Looking for a correlation of inbound and outbound delay, a nearly linear characteristic is found. Assuming the linear dependency, ground processes can cover up 33% of the delay at average, with decreasing tendency [2]. This effect is primary caused by the observed (planned) time buffer. Using empirical data as an input for our stochastic model, the Monte-Carlo simulation approach allows for a detailed analysis of the turnaround.

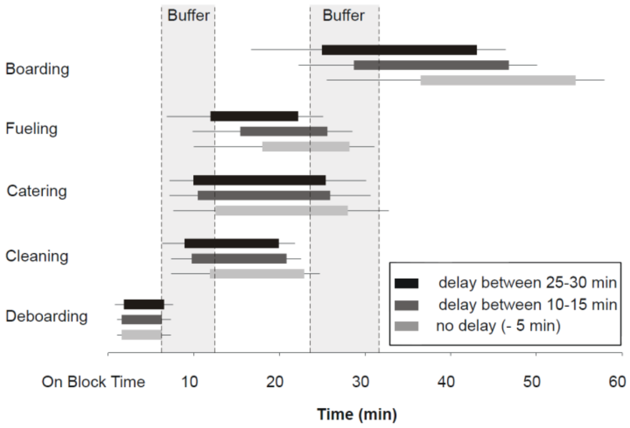

Fig. 5. Delay compensation due to shift of specific process starting time [2]

To understand how a single ground process can influence the overall turnaround performance, its individual contribution to the critical path is needed to be known. Due to the fact that the boarding process is always at the critical path, only the remaining handling processes need to be analyzed consequently. As shown in the following fig. 6 the catering and the fueling process have a significantly higher influence onto the turnaround compared to all other processes.

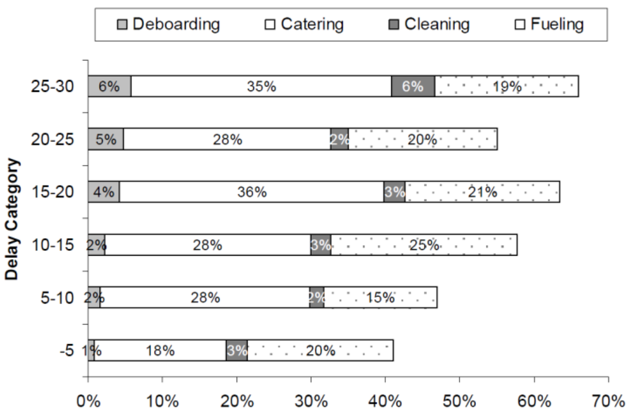

Fig. 6. Increasing inbound delay (measured in minutes) results in different distribution of critical processes [2]

To extend our developed stochastic ground handling model, we additionally include to the turnaround the handling processes as mentioned above: unloading/loading, de-icing/anti-icing, and pushback. Our ground handling model now covers are significant ground movements, except transfers and taxiing. This will be covered in our approach by deterministic look up tables, which holds the average transfer times at a given traffic scenario.

3 Stochastic Turnaround Model

The turnaround time is calculated by summation of the simulated sub-process durations considering both the individual process start times and the observed dependencies on the delayed arrival [2]. Further on, the interactions between the single turnaround processes are covered in the modal by the fact, that a process can start not until the prior process is finished. The chronological order of the processes is determined by the airline procedures and follows the common turnaround scheme as mentioned in fig. 1. This procedure ensures a clear identification of the processes on the critical path (a process is on the critical path, if the change of the process related times are directly influences the turnaround time). Each of the sub-processes is stochastically defined with respect to their start time and process duration based on prior described characteristics [cf. 2].

The start time of the first sub-process can be used as an initial condition and directly taken as the *in block time* (IBT). But our model is also able to consider specific IBTs, e.g. derived from the underlying flight plan (scheduled times) or taken from the current flight plan (actual or target times). As the finishing time of the preceding sub-process constrains the start time of the next sub-process, the turnaround time will finally computed by stepwise calculation of all necessary turnaround processes. Our model also takes into account, that different turnaround procedures are defined by airlines regarding to delays (e.g. speed turnaround) or special purposes (e.g. no fueling). As we use the Monte-Carlo method to simulate the turnaround time, the turnaround sub processes are sequently calculated to derive the total turnaround time and this procedure will be done 10^n times to ensure a valid simulation result.

The stochastic nature of all sub-processes results in a varying total turnaround time, which is hardly manageable in today's operating and controlling procedures. There are various alternatives of sampling this turnaround time distribution, e.g. using mean, mode, median values, or quantiles (see fig. 7). As a consequence, our current research focus on a harmonized concept considering both a clear summarized statistical data set (descriptive statistics) and the controller needs for an adequate representation of the real turnaround progress.

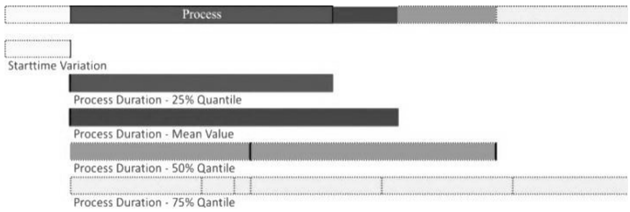

Fig. 7. Example of possible process presentation covering the stochastic nature of the developed model [3]

Our ground management tool (GMAN) is designed to allow the use of a wide range of stochastic input/output distributions. In the case, that there are no statistically reliable distributions available, we fall back to a descriptive statistics method (five-number summary, box plot [24]). If the data set is still unsuitable to be described with this method (e.g. no empirical data is available), the deterministic planned progress of the turnaround by e.g. the airport operator, the airline, or aircraft manufacturers have to be used as a final fall back level (see Airport Handling Manual, Ground Operation Manual, Service Level Agreements). To ensure reliable model results the influence of the following parameters on the turnaround process are captured as well:

- airline
- aircraft type
- airport inbound and outbound
- current airport
- flight distance to destination
- flight type, e.g. low cost
- incoming delay (on gate)
- number of passengers in-/outbound
- type of aircraft stand

For each of these parameters, the influence on turnaround process is defined by finding the correlation to process specific function fitting. The turnaround process distribution is also augmented by tags such as e.g. a connecting flight into a hub airport, where the tolerance level for a delay is expected to be lower than on other airports.

3.3 Prediction Considering Look-ahead Time

To reflect the realistic change of available data quality, we introduce four prediction levels for the turnaround time. These levels are associated with the corresponding time horizons (see fig. 8):

- Basic - more than six months in advance of estimated IBT,
- Strategic - between seven days and six months of estimated IBT,
- Tactical - up to seven days ahead of estimated IBT), and
- Actual - after actual IBT.

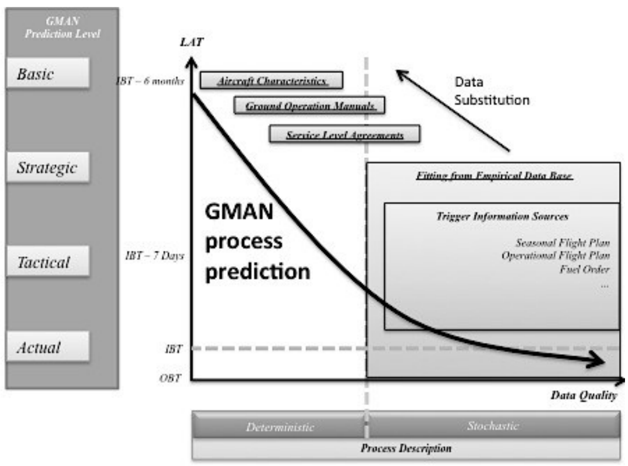

Fig. 8: Sources for process description and Trigger Information for GMAN process prediction [25]

A higher prediction accuracy level requires more reliable information. The basic level of prediction only requires the aircraft characteristics defined by the aircraft manufacturers, and represents the lowest input quality for the turnaround planning. Along with the decreasing time horizon both the amount and the quality of the available data increases. However the prediction at the actual level requires all essential characteristics to be known (e.g. aircraft state downlink). Where the basic turnaround is roughly calculated by using information from standard documents, the actual calculations copes with all specific operational figures.

3.4 Delay Modeling

Prior research results points out the high influence of flight delays to the turnaround process [2]. If the estimated arrival time of the aircraft is not available, the following attributes are found to be significant for the arrival delay:

- Arrival and destination airport,
- Airport category (network function, e.g. hub, non-hub, supply base),
- Time of day, week, month, season, and
- Airline.

To derive a valid arrival delay distribution we use empirical data sets and identify characteristic delay patterns. This analysis is done for four different airports; representing different airport categories. Observation of specific patterns over time, e.g. high delay at peaks at hub airports, is also accounted for in the delay modeling. In close cooperation with the Center for Air Transportation Research at George Mason University, we extend our database of turnaround process times (based on European airport operations) with delay data from American airports focusing our airport categorization. Due to the lack of data for European airports until now, we use the US data source for our GMAN proof of concept [cf. 25], furthermore these are more suitable for testing since delay peaks are higher in the US as in Europe. We are aware of potential conflicts caused by different operational constrains (e.g. slot coordination, ground delay programs, or penalty box concept) which will be analyzed subsequently in our current research. From our point of view, this fact is however no critical condition for the GMAN concept testing as discussed in this paper.

To allow for a comparison to our existing data, we extracted data from the *Aviation System Performance Metrics* (ASPM) of four relevant airports (Atlanta (ATL), New York (JFK), San Jose (SJC), and Buffalo (BUF)) for the time period starting at 00:00 am on 23rd July 2007 to 23:59 pm on 27th July 2007 (Monday to Friday) [20]. The period of summer 2007 was chosen because it represents a period of historical high air traffic demand. The sample histogram in fig. 9 shows the distribution of gate arrival delay with respect to scheduled (blue) and flight plan predicted (red) gate arrival times for Atlanta airport as an example. The dotted vertical lines of the corresponding colors represent the mean for both the cases, i.e. 12.16 minutes and 8.59 minutes respectively.

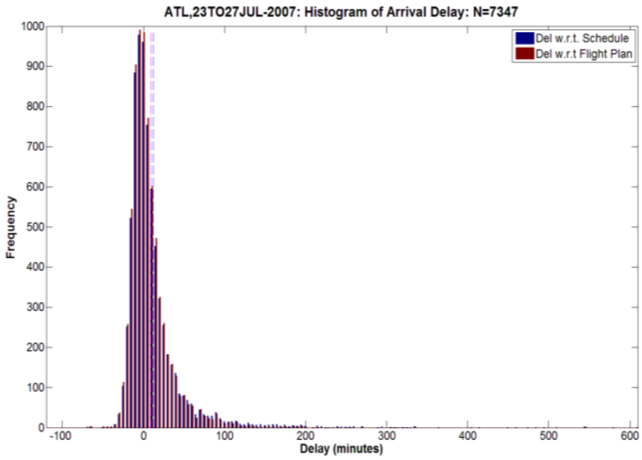

Fig. 9. Distribution of Arrival Delay at ATL [25, 20]

The arrival delay data showed asymmetrical distribution about its mean value. Also, the positive and the negative delays (early arrivals) shows different pattern with the delayed flights having fatter tails as compared to the early arrivals. The same pattern is observed for the other three airports. After isolating the positive and negative values into separate sets, distributions were fitted to the data. In order to identify the relationship of arrival delays with the time of day, the ASPM data for a 24 hour period was filtered for the four airports used in our separate delay pattern study [25]. The objective of this research was to test the hypothesis that delays at hub airports peaks with the increase in the number of active aircraft on the airport surface according to queuing theory. For both the non-hub airports, SJC and BUF, the number of active aircraft throughout the day fluctuates considerably with multiple peaks and troughs. The arrival delay also doesn't follow any distinct pattern. This may also be attributed to the fewer number of flights in one day worth of data presented here. In order to be used in the GMAN environment, this analysis will be repeated with data from more than one day, i.e. over several weeks to gather meaningful peak trends in the data.

5 Outlook

A first step to improve turnaround management to be compliant to future requirements has been achieved, considering the presented stochastic model. However, in a future automated environment, it will not only be required to predict a turnaround with high accuracy, but also to control certain processes in case of plan deviations. This shall be achieved by introducing control theory into the turnaround management and advice airline operators or ground handlers how and when to intervene into the ground operations if a delay occurs (see fig. 10) [26].

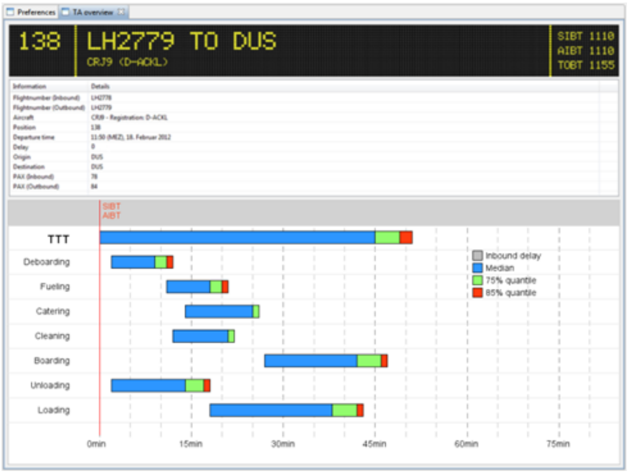

Fig. 10. GMAN as a Decision Support Tool in an Operational Turnaround Control Environment

Turnaround processes will need to be monitored either by sensor technology (e.g. radio-frequency identification) where possible (e.g. fuelling, loading) or by introducing progress checkpoints to achieve this level of automation. Since resources at the airport are limited, may it be human or technical resources, additional planning for ground handling based on the available resources is being considered as an important factor. Further work will be conducted to include basic resource management and airport state information (e.g. gate availability) into the turnaround model. Further research will also investigate how a possible *human machine interface* (HMI) of a decision support tool should be implemented to provide the model output in an understandable way to the ground operator or handling agent. Different user interfaces will be created for each group, matching their requirements based on staff interviews planned during the next year.

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References

[1] Schultz M and Fricke H. *Improving aircraft turn around reliability*. Proceedings of International Conference on Research in Air Transportation, 2008

[2] Fricke H and Schultz M. *Delay Impacts onto Turnaround Performance*, Air Traffic Management Research and Development Seminar, Napa, 2009

[3] Oreschko B, Schultz M, Elflein J, and Fricke H. *Significant Turnaround Process Variations due to Airport Characteristics*, Proc. ATOS, Delft, 2010

[4] Oreschko B, Schultz M, and Fricke H. *Skill Analysis of Ground Handling Staff and Delay Impacts for Turnaround Modeling*, Proc. Of ATOS, Delft, 2011

[5] Graupner S. *Modeling and Simulation of Fuelling Process as Part of the Reliable Turnaround Management* (in German), Student Thesis, TU-Dresden, 2011

[6] Nowak P. *Methods to Control Turnaround Sub-Processes using the Cleaning as an Example*,(in German), Diploma Thesis, TU-Dresden, 2011

[7] Heilmann T. *Modeling and Simulation of Deboarding and Boarding for Reliable Prediction of Turnaround Target Times* (in German), Student Thesis, TU-Dresden, 2011

[8] Airbus. *A380-Airplane Characteristics for Airport Planning*, 2012.

[9] Bachmat E, Berend D, Sapir L, Skiena S, and Stolyarov N. *Analysis of aeroplane boarding via spacetime geometry and random matrix theory*. Journal of Physics A 39, 453–459, 2006

[10] Bazargan M. *A linear programming approach for aircraft boarding strategy*. European Journal of Operational Research 183, 394–411, 2006

[11] van den Briel M, Villalobos J, Hogg G, Lindemann T, and Mul A. *America west develops efficient boarding strategies*. Interfaces 35, 191–201, 2005

[12] Ferrari, P and Nagel K. *Robustness of efficient passenger boarding in airplanes*. Transportation Research Board Annual Meeting, 2005

[13] Kirchner A, Klüpfel H, Nishinari K, Schadschneider A, and Schreckenberg M. *Simulation of competitive egress behavior: comparison with aircraft evacuation data*. Physica A 324, 689–697, 2003

[14] van Landeghem H and Beuselinck A. *Reducing passenger boarding time in airplanes: A simulation approach*. European Journal of Operations Research 142, 294–308, 2002

[15] Marelli S, Mattocks G, and Merry R. *The role of computer simulation in reducing airplane turn time*. Boeing Aero Magazine 1, 1998

[16] Schultz M. *An individual-based model for passenger movement behavior in airport terminals* (in German), PhD thesis, TU Dresden, 2010, http://nbn-resolving.de/urn:nbn:de:bsz:14-qucosa-85592

[17] Schultz M. *Scenario Evaluations of Airplane Boarding Procedures*, to be published

[18] Yeung S S M, Yu I T S, and Hui K Y L. *World at work: Aircraft cabin cleaning*, in: Occupational and environmental medicine, Vol. 62(1), 2005

[19] IATA. *Airport Handling Manual* (AHM), 29th Edition, International Air Transport Association, 2008

[20] Data source: Individual Flights Database, 23rd July 2007 to 27th July 2007, Aviation System Performance Metrics (ASPM), FAA

[21] Eurocontrol, ACI, IATA, *The European Airport CDM Manual*, Brussels, 2012

[22] Dieke-Meier F and Fricke H. *The need for a collision prevention system for the pushback of aircraft*. 28th International Congress of the Aeronautical Sciences (ICAS), Brisbane, 2012

[23] Dieke-Meier F and Fricke H. *Expectations from a steering control transfer to cockpit crews for aircraft pushback*. International Conference on Application and Theory of Automation in Command and Control Systems (ATACCS), London, 2012

[24] Frigge M, Hoaglin D C, and Iglewicz B. *Some Implementations of the Boxplot*. The American Statistician 43 (1), pp. 50-54, 1989

[25] Oreschko B, Kunze T, Schultz M, Fricke H, Kumar V, and Sherry L. *Turnaround Prediction with Stochastic Process Times and Airport specific Delay Pattern*, International Conference on Research in Airport Transportation (ICRAT), Berkeley, 2012

[26] Kunze T, Oreschko B, and Fricke H. *A stochastic turnaround model for predicting aircraft turnaround times*, International Conference on Application and Theory of Automation in Command and Control Systems (ATACCS'12), London, 2012

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