Turnaround prediction concept: proofing and control options by microsocopic process modelling

GMAN proof of concept & possiblities to use microscopic process scenarios as control options

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*Abstract***— For most flight phases, automated and reliable target time predictions for efficient resource management are common, but during the turnaround on ground best-guessing by staff is still standard. The turnaround prediction concept of TU-Dresden, called GMAN, is an approach to predict the Total Turnaround Time and the appropriate Target Off Block Time. With suitable adjustments to the local information environment, the proof of concept in a real airport environment shows its ability to work reliably in an automated ATM-system. Furthermore, this paper also offers control options by illustrating an approach with the microscopic process definition..**

Keywords: turnaround, predcition, A-CDM, processes

I. Motivation

While many approaches for the airborne phase of flight exist - precise predictions of target times up to 30 seconds can be made - the ground phase, including the Total Turnaround Time (TTT), is still rather ambivalent for making reliable automated time predictions. Currently, instead of connecting with the automated ATM environment with the help of decision support tools, ground staff solves possible conflicts using a best-guess behavior. The aircraft operators and manufacturers derive the TTT from deterministic subprocess durations (deboarding, fueling, etc.) and their simple summations. Since each of these subprocesses has a stochastic nature, this is not an accurate representation of reality. This becomes especially evident in non-standard situations, e.g. delays or extended process durations. [1][3][9][10][11]

II. Research Aim and Review

The scope of turnaround (TA) research at TU Dresden is to predict and control the turnaround of aircrafts and the turnaround processes by profound knowledge of all necessary activities and its dependencies. The core of the prediction is the so-called GMAN concept an application based on several research activities (which will be later described) where the main idea of stochastic process description and stochastic time prediction function in conjunction with the microscopic process definition.

Together with the main ideas of Airport Collaborative Decision Making (A-CDM) the GMAN concept can be used to optimize the use of airport infrastructure and capacity as well as the individual processes themselves.

A. A-CDM prediction gaps

Within the A-CDM concept, the main ideas are information sharing and the so-called milestone approach, which establishes standard timestamps throughout every stage of ground operations with the Target Off Block Time (TOBT) and Target Startup Approval Time (TSAT) as the most important timestamps for a TA. While the TSAT is reversely calculated from the Take Off Time (TOT) by well-known principals, the TOBT has no reliable calculating method. The most common way for issuing the TOBT is by operational staff's best-guess knowledge. This, however, is not in accordance with the A-CDM goal for a consistently reliable milestone definition. [5][8]

B. Previous Turnaround Research activities at TUD

To understand turnaround reliability enhancements on a long time basis, fundamental knowledge for detailed process understanding was gathered during a study in cooperation with an aircraft manufacturer. [1] Significant factors regarding uncertainty within the TA arose, and it became evident that there is potential for improving future aircraft design with respect to TA reliability. One major impact factor contributing to uncertainties and non-standard process execution is the arrival delay, as shown in our study covering several German airports. It was also observed that airlines introduce dynamic scheduling buffers to mitigate the impact of disturbances in ground operation leading to TTT on their schedule integrity. [2]

A following study focused on the processes themselves, analyzing effects on the execution due to airport type. As shown in [3] beside the well-known airport categories hub and non-hub, at least one additional classification called *supply basis* can be found in the process execution. It was identified that the supply basis is a major reason for the different observed process characteristics, including the varying levels of the staff's skills due to different training principles and expertise. [4]

1) The Turnaround Time Prediction concept GMAN[6][13]

Furthermore, we consolidated the TA process knowledge into a concept called GMAN with the output of a stochastic TTT for a single TA. Together with a given In Block Time (IBT) it was possible to issue predictions on durations of the stochastically TOBT (Target Off Block Time) and single stochastical processes. This output can be used in ramp operations control or to schedule planning in favor of the usual best-guess behavior of ground staff in an A-CDM environment. The output of the stochastical time covers the non-deterministic behavior of a turnaround and gives evidence for the quality od the prediction.

The TTT within the GMAN concept is calculated (at least 10,000 times) by the summation of the stochastically simulated process durations and start times for each run, considering the dependencies of the longest process within the critical path of parallel and subsequent processes. Monte Carlo simulations are used to gather a single data set out of the stochastic descriptions. The following basic processes are considered: deboarding, catering, fuelling, cleaning, and boarding, though others can be added. The stochastic behavior of the process is described by empirical data gathered from several analyses and categorized by different trigger parameters (e.g. airport type, delay and aircraft type). Finally, probability distribution functions or value arrays (when no sufficient function can be fitted) are used to sample the dataset.

Depending on the available information for the process description (stochastic start times and durations), different trigger parameters are defined. Correlating with the decreasing Look Ahead Time (LAT), a more accurate prediction should be available over different prediction levels. As the LAT decreases, more accurate trigger information is expected to become available out of operational sources; and therefore, a more specific stochastic process description is available, see [6]. In cases where no empirical data is available, the deterministic process descriptions from aircraft operators or manufacturers is used.

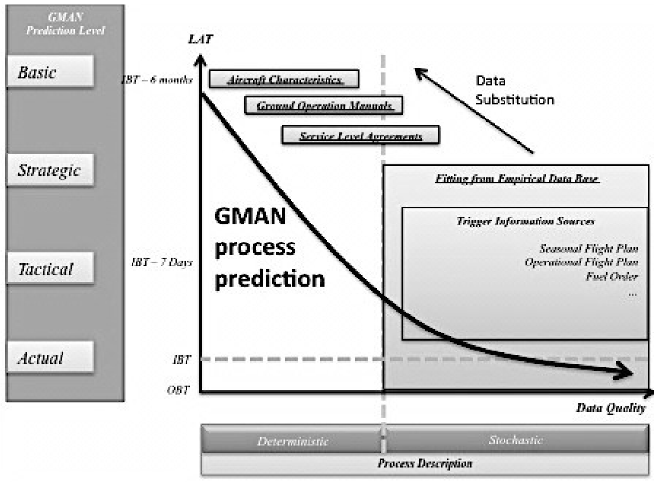

Figure 1: Sources for process description and Trigger Information for GMAN process prediction [6]

2) Microscopic Process Modelling [7]

The possibility to modify the planned schedule exists basically for every process. This allows for the opportunity to vary single processes in advance (open-loop control) or during execution (closed-loop control) in case a specific TA target time has to be achieved. Possible control options comprise of a change in used equipment and staff, or a change in the conducting of process parts, e.g. stopping single tasks.

As shown in the latest publication [7], based on an extended process chain, see Figure 2, all main TA processes were analyzed down to their single tasks in order to reveal possible control options. Therefore, each process is separated into subprocesses representing individual tasks on a microscopic level; these can be regrouped again to match different process scenarios, see Figure 3 for cleaning process as an example.

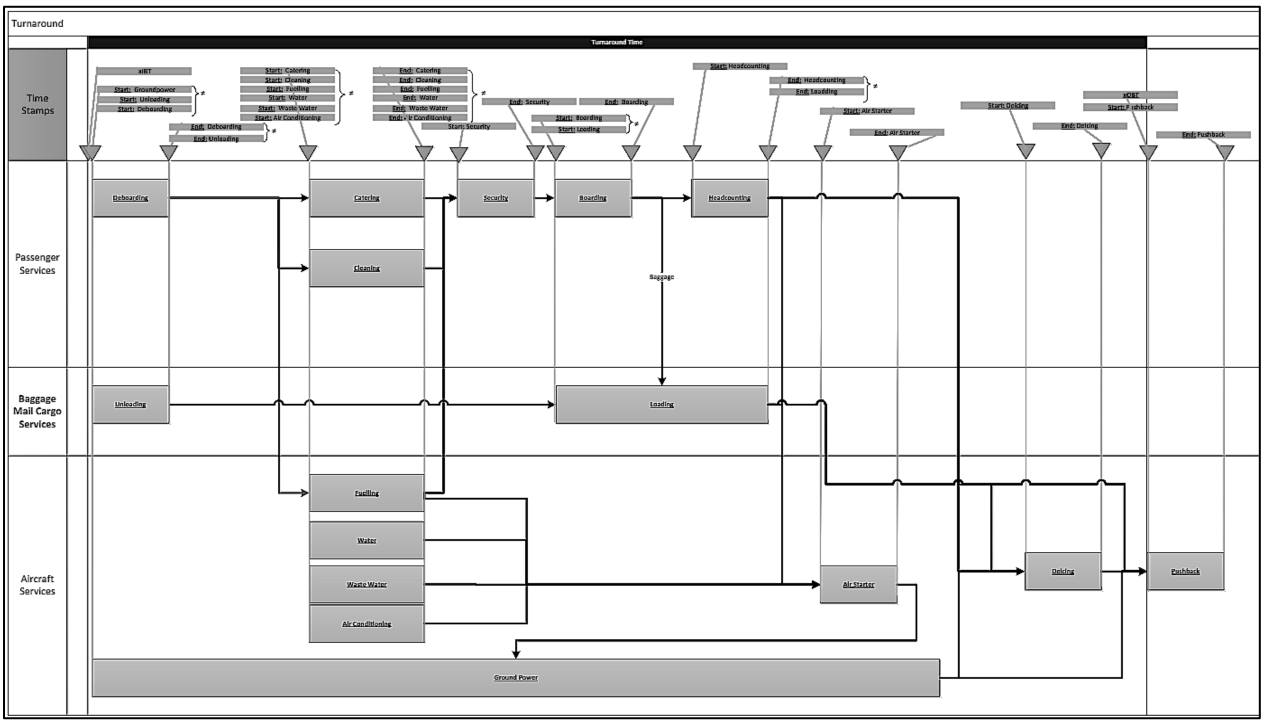

Figure 2: Detailed and extended process chain

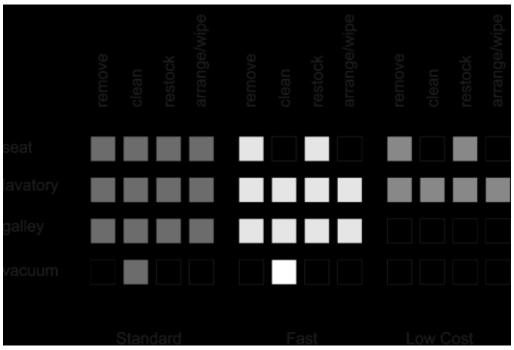

Figure 3: tasks in different scenarios for cleaning process[7]

To stochastically model the process, two ways to calculate the process duration were studied: an analytical approach and a numerical calculation model with the use of Normal-distribution N (μ, σ) of tasks execution, with the expected value μ and standard deviation σ for single tasks steps, e.g. cleaning a single seat or galley. Depending on the task's connection and scenarios in the microscopic process description, specific process readiness distributions can be simulated with interaction points and break up points.

III. GMAN Proof of concept

To proof the principle idea of the GMAN – the prediction of TTT and TOBT – empiric data were used in cooperation with the airport authority (AA) of Leipzig-Halle Airport (LEJ), Germany. LEJ is a medium sized airport with mainly domestic and European flight connections. In addition, the hub of a large cargo integrator is situated at the airport. Except for the proof of concept (POC), only data from passenger turnarounds, excluding general aviation, was used; however, the GMAN concept could also be adapted to cargo operations.

A. GMAN Adjustments to LEJ

For the POC, in order to have to have a sufficient pool of empiric data, the turnaround model within the GMAN had to be modified, because limited processes automatic timestamps are available in LEJ. Since some timestamps in LEJ were not gathered directly on the aircraft, as considered in the original GMAN concept, start and end times of deboarding, fuelling, unloading, loading and boarding were adjusted to an adopted GMAN model. The exclusion of catering and cleaning process for this POC is acceptable because prior analysis of the process data showed only a minimum amount of occurrences of these processes on the critical path in LEJ. For a detailed quality analysis of the GMAN output, an alternative data source or another airport environment with sufficient data quality should have been made available for further analysis.

B. Compilation of stochastic process descriptions

To compile the stochastic process descriptions as basis for the GMAN prediction, all TA in LEJ from the year 2012 were available in a database with the following timestamps for every TA in accordance to the LEJ-modified GMAN model:

- Scheduled & Actual In-Block Time (S/AIBT)
- Scheduled & Actual Off-Block Time (S/AOBT)
- Start and end times:
  - Deboarding
  - Boarding
  - Unloading
  - Loading
  - Fuelling

Additionally, the following trigger information (see II.B.1) completed the database for every TA:

- Aircraft type
- Airline type
- Departure and destination airport
- Passenger number inbound and outbound

In a first step, all TA with a scheduled TTT (SOBT-SIBT) above 2 hours were skipped, so that night stops and long TA, which are not of the focus of the GMAN, were not analyzed. The remaining 8,150 datasets were available for the analysis. In a second step, some of the trigger information was clustered with the aim to decrease the number of data classes. While the trigger *airline* were clustered into *main, charter and low-cost* classes, the trigger *aircraft type* was clustered into groups of similar sizes by the maximum seats available:

- *ac100*- up to 100 seats
- *ac156* - 101 up to 156 seats
- in the same order, the classes *ac189*, *ac224, ac305* and *ac3xx* (with more than 306 seats).

The trigger information of *passenger numbers inbound* and *outbound* were clustered into classes of 25 and 50: *Pax25* represents a class where 0 up to 25 passengers were counted and *pax50* represents a flight where 26-50 passengers arrived or departed. The cluster size in 25s is in accordance to our boarding simulation [12] and the available information from the aircraft manufacturer, which shows this size is suitable for the indented prediction quality. In a third step, the durations for the single processes and the start times out of the individual AIBT were calculated.

The last step was the creation of classes for the start times and durations of every process regarding the trigger information. While boarding, deboarding, loading and unloading were first clustered regarding the aircraft type and secondly to the corresponding passenger number class (deboarding and unloading to inbound passenger number and loading and boarding to outbound passenger number), fuelling was first clustered regarding the aircraft type and secondly to the destination airport. That duration values were put in a corresponding array, a fitting to separate functions was not made. TABLE 1 shows a short example of the duration in seconds for the process of unloading with the classes *ac305* and *pax175 while most other arrays have obviously more data.*

TABLE I. EXAMPLE ARRAY OF TIMESTAMPS: UNLOADING DURATION, AC305, PAX175, IN [SECONDS]

295	703	1050	1116	1165	1179	1195

C. Analysis of prediction quality

The prediction quality of the adjusted GMAN was measured after the local empiric database was compiled. Therefore, the GMAN was connected to the local airport information network while the predicted TTT/TOBT was compared to the actual TTT/AOBT. Because the GMAN gives out a stochastic prediction, the calculated TTT/TOBT is not an exact value but a compilation of several stochastic values, e.g. mean, median or other different quantiles. The proposed increased prediction quality over a decreasing LAT (see II.1.) could not be monitored because the local information network only includes the final trigger information and no intermediate steps. However, this will be checked in the following test environment.

For the POC, a total of 596 datasets from all applicable turnarounds in September 2013 in LEJ were available. The GMAN calculated the TTT, and based on the individual AIBT, the stochastic TOBT, with the values of mean, median, σ and 2σ, displays a spectrum of possible target times that can be plotted for every TA. Considering that for every TA the distribution is different, the appropriate given AOBT value was then calculated in accordance (percentage) to the predicted TOBT spectrum, showing the quality of the prediction. When the AOBT was above the highest predicted/calculated TOBT value, it was put into 100% of the predicted TOBT spectrum. Figure 4 shows the plotted AOBT values as described. It can be observed that a huge share of the AOBTs is in the range of 60% to 90%. The accumulation of many values at or over 100% needs to be determined. Most properly an improper adjustment of the boarding process timestamps - the last TA process within the critical path - compared to the original GMAN model is the reason. Actually, a slab of the curve was expected with a peak below the 100% quantile. Therefore, further adjustments and analysis with LEJ will need to be done. Regarding the LAT, this should be achievable by using the trigger information clustering to pool similar turnarounds.

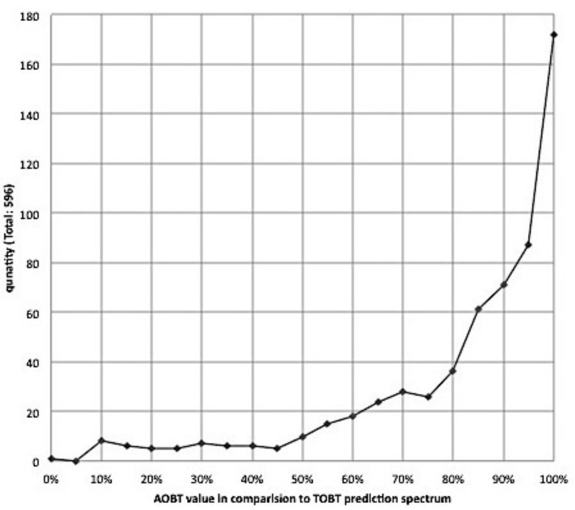

Figure 4: Turnaround AOBT values compared to the appropriate GMAN TOBT prediction spectrum, LEJ, September 2013

IV. MICROSOPIC PROCESS SCENARIOS FOR TURNAROUND CONTROL

The GMAN concept as described above not only helps to predict a stochastic TTT/TOBT for various scenarios and choose the most suitable option for a dedicated situation to control the TA process as a whole, but also on a single task level. This applies when a specific OBT has to be achieved (e.g. due to an earlier TSAT in an A-CDM environment); but the predictions show a high possibility that this cannot be achieved with the standard scenario and that a single process is likely to be delayed or disturbed (due to missing equipment or staff for example). Technically, the GMAN idea of dividing the TA into subprocesses could be continued to the point of single process tasks, with a similar stochastic task description of start times and durations through empiric data of start and end times for each task. But this timestamp data are not likely to be available in a sufficient quality for all individual tasks or for a specific airport environment. As shown in the POC at LEJ, even the first breakdown of the TA into standard processes cannot be lodged by corresponding timestamp data in a real airport environment for a proper GMAN prediction. Therefore, the approach of microscopic process description [7] offers the opportunity to sufficiently control the TA as an advanced mechanism after the TTT/TOBT prediction has shown that a given TTT/TOBT cannot be meet with the standard TA procedure.

The mechanism for turnaround control consists of mainly two steps. In a first step, the TTT is predicted, as shown above. If the result is in non-conformance with target times (e.g. TOBT vs. TSAT or calculated vs. scheduled TTT), then the second step has to be done. The calculation of different predefined process scenario alternatives for the turnaround are performed and are evaluated against each other. Therefore, it is guaranteed that different scenarios are defined for every process (e.g. short, medium and standard duration/quality), illustrating different control options. By recalculating the TTT using a set of different process scenarios, the effect of the possible control options (selectable scenarios) can be examined, evaluated, and finally, the scenario with the best performance under prevailing conditions can be identified.

The possible different process scenarios have to be defined in advance. For the development of an advanced prototype of the GMAN including the mentioned control options, different analyses of standard process executions were and will be conducted and implemented. For example, the boarding process can be divided into the individual task *boarding PAX* and *boarding UM* (“passengers with reduced mobility” and “unaccompanied minors”) and different boarding strategies (e.g. random, back-to-front). Each task is defined by stochastic parameter, e.g. by three Normal-distribution parameters as assumption: the expected value μ, standard deviation σ, and the correlating quantity of (normal or UM) passengers n. It is assumed that *boarding UM* always takes place before *boarding PAX*, and one or two doors for boarding can be used. Hence, four different scenarios with different strategies are possible as shown in Figure 5. Depending on the prediction time and LAT, all or only some of the scenarios are possible, e.g. if it is too late to relocate stairs at the 2nd door, these scenarios cannot be considered for TA control.

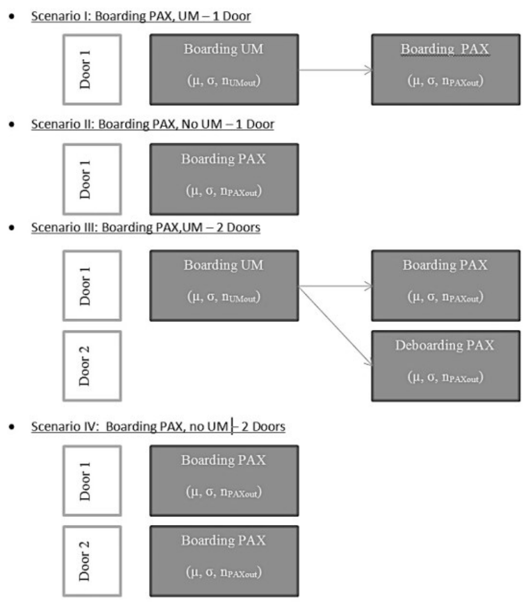

Figure 5: 4microscopic process scenarios for boarding

V. FUTURE WORK

To further advance the GMAN concept, the next step is to implement the microscopic processes and proof the principle concept at LEJ. Furthermore, the focus is to improve the prediction quality with better adjustments to the local characteristics and by analyzing the stochastic TTT/TOBT output leading to the correct prediction values. As shown with the POC, the necessary information (empiric timestamp) for the GMAN prediction is not always available in a sufficient quality; hence, alternative approaches need to be considered. The issue that should also be analyzed further is the effect of the LAT, especially the trigger information development over the decreasing LAT and the resulting behavior of the TTT/TOBT prediction quality.

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