Turnaround prediction and controling with micrsocopic process modelling

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

Bernd Oreschko, Thomas Kunze, Tobias Gerbothe, and Hartmut Fricke
Chair of Air Transport Technology and Logistic
Technische Universität Dresden, Germany
{oreschko, kunze, gerbothe, fricke}@ifl.tu-dresden.de

***Abstract*— For most flight phases automated and reliable target time predictions for an efficient resource management are common, but during the turnaround on ground best guessing by staff is still the 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. The proof of concept in a real airport environment shows it ability to work reliable in an automated ATM-system, with suitable adjustments to the local information environement. Further an approach with microscopic process definition to offer control options is shown.**

Keywords: turnaround, predcition, A-CDM, processes

I. Motivation

While for the airborne phase of flight, many approaches for a precise prediction of target times up to 30 seconds exist, the ground phase including the total turnaround time (TTT) is still out of the scope for reliable automated time prediction. The aircraft operators and manufacturers derive the TTT from deterministic sub-process (de-boarding, fueling, etc.) durations and their simple summation. This is not an accurate representation of reality as each of these sub-processes has a stochastic nature. This becomes especially evident in non-standard situations, e.g. delays or extended process duration. Nowadays ground staff solves possible conflicts using a best-guess behavior and not with the help of decision support tools to connect with the automated ATM-environment. [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 its processes by profound knowledge of all necessary activities and its dependencies. The core of the prediction is the so-called GMAN concept and application, based on several research activities - as further described - with the main idea of stochastic process description and stochastic time prediction in conjunction with microscopic process definition.

Together with the main ideas of Airport Collaborative Decision Making (A-CDM) it 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 most important timestamps. While the second one is reversely calculated from the Take Off Time (TOT) by well-known principals - for the first one no reliable calculating method is given. The most common way for issuing the TOBT is by operational staff’s best guess knowledge that, however, is not in accordance with the A-CDM goal for an always-reliable milestone definition. [5] [8]

B. Previous Turnaround Research activities at TUD

Fundamental knowledge for detailed process understanding was gathered during a study in cooperation with an aircraft manufacturer while aiming to understand turnaround reliability enhancements on a long time basis.[1] Significant contributions to uncertainty within the TA and potential for improvements in TA-reliability for future aircraft design showed up. 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 to 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 can be found in the process execution – called *supply basis*. It was identified that the supply basis is a major reason for different observed process characteristics due to varying levels of staff skills based on different training principles and expertise [4]

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

Further 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) a stochastically TOBT (Target Off Block Time) and single process durations predictions can be issued. This output can be used in ramp operations control or schedule planning in favor of the usual best guess behavior of ground staff in an A-CDM environment.

The TTT within the GMAN concept is calculated (at least 10.000 times) by 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 dataset out of the stochastic descriptions. The following basic processes are considered: deboarding, catering, fuelling, cleaning, boarding, but other 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 are expected to become available out of operational sources and therefore a more specific stochastic process description, see **Fehler! Verweisquelle konnte nicht gefunden werden.**In cases where no empirical data is available, the deterministic process descriptions from aircraft operators or manufacturers is used.

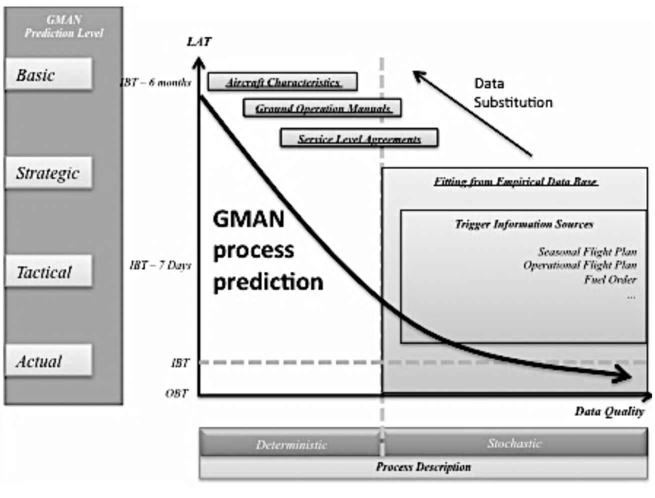

Figure 1: Sources for process description and Trigger Information for GMAN process prediction [6]

2) Microscopic Process Modelling [7]

The possibility to modify the planned schedule exists basically for every process. This gives 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.

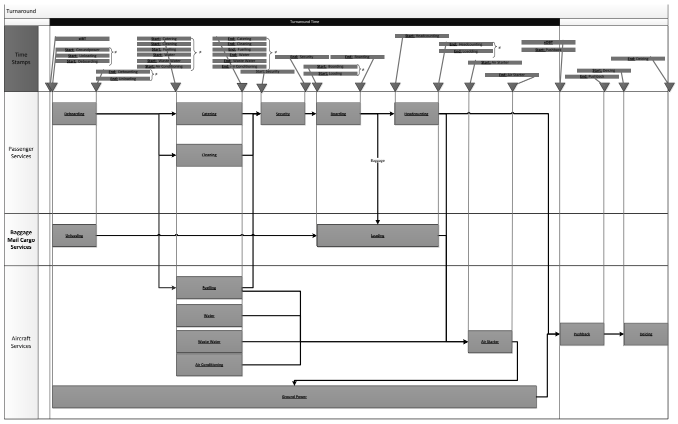

Figure 2: Detailed process chain

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

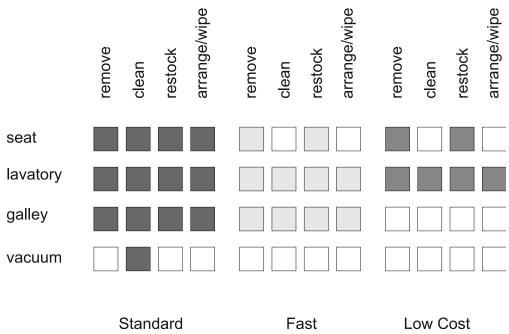

Figure 3: tasks in different scenarios for cleaning process[7]

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. Further a hub of a big cargo integrator is situated at the airport. But for the proof of concept (POC) only data from passenger turnarounds, excluding general aviation was used – although the GMAN concept could also be adapted to cargo operations.

A. GMAN Adjustments to LEJ

For the POC, the turnaround model within the GMAN had to be modified, due to the fact that not for all processes automatic timestamps are available in LEJ to have a sufficient pool of empiric data. Start and end times of deboarding, fuelling, unloading, loading and boarding were available with some adjustments and adoption due to that some timestamps in LEJ are not gathered at the apron direct on the aircraft as considered in the original GMAN idea. 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 an non on the critical path in LEJ. For a detailed quality analysis of the GMAN output, an alternative data source should be accessible or another airport environment with sufficient data quality.

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 following time stamps 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 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 nightstops and long TA that are not in focus of the GMAN were not analyzed. The remaining 8150 datasets were available for the further analysis. In a second step some of the trigger information were 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 regarding into groups of similar sizes by maximum seats available:

- *ac100* - up to 100 seats,
- *ac156* - 101 up to 156 seats,
- and 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 – e.g. *pax25* represents a class where 0 up to 25 passengers were counted, while the next class *pax50* represents a flight were 26 up to 50 passengers arrived or departed. The cluster size in 25s steps is in accordance to our boarding simulation [12] and available information from aircraft manufacturer showing this size is suitable for the indented prediction quality. In a third step the durations for the single processes were calculated and the start times out of the individual AIBT.

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

TABLE I. ARRAY OF TIME STAMPS: UNLOADING DURATION, AC305, PAX175, IN [SECONDS]

295	703	1050	1116	1165	1179	1195

C. Analysis of prediction quality

After the compilation of the local empiric database the prediction quality of the adjusted GMAN was measured. Therefore the GMAN was connected to the local airport information network, while the predicted TTT/TOBT was compared to the actual TTT/AOBT. Due to the fact that the GMAN gives out a stochastically prediction the calculated TTT/TOBT is not an exact value but a compilation of several stochastic values, e.g. mean, median or different other 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 but will be checked in a following test environment.

For the POC data from all applicable turnarounds in September 2013 in LEJ were available, in total 596 datasets. The GMAN calculated the TTT and based on the individual AIBT the stochastic TOBT, with the values of mean, median, σ and 2 σ – giving out a spectrum of possible target times that can be plotted for every TA. The appropriate given AOBT value was then calculated in accordance (percentage) to the predicted TOBT spectrum, showing the quality of the prediction – considering that for every TA the distribution is different. When the AOBT was above the highest predicted/calculated TOBT value it is 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 from 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- to the GMAN model is the reason. Actual a slab of the curve was expected. Therefore further adjustments and analysis with LEJ will be done.

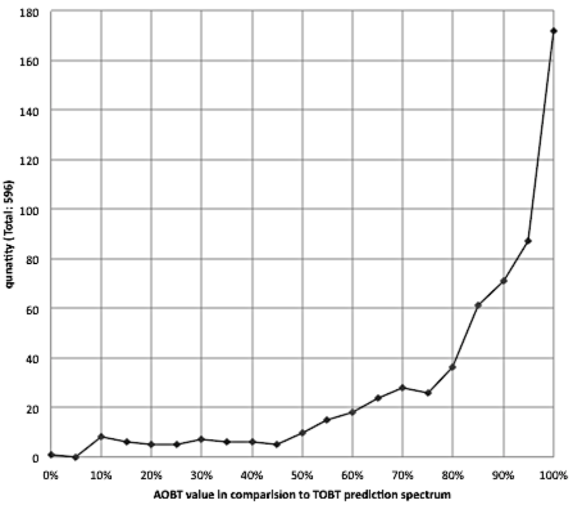

Figure 4: Turnaround AOBT values compared to the appropriate GMAN TOBT prediction spectrum, LEJ, September 2013

IV. MICROSOPIC PROCESS SCENARIOS AS TURNAROUND CONTROL OPTION

The GMAN concept as described above gives the opportunity to predict a stochastic TTT/TOBT. With the application of the microscopic process scenarios process and TA controlling is also possible. This applies when either 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 or a single process is likely to be delayed or disturbed. Technically, the GMAN idea of dividing the TA into sub-processes could be continued to the point of single process tasks, with an similar stochastic description of start times and durations through empiric data of start and end times for each task. But these timestamp data will likely not be available in a sufficient quality for all tasks in general or at 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. Therefore, the theoretic approach of microscopic process description [7] offers the opportunity of sufficient control options as a second step after the TTT/TOBT prediction.

In a first step the TTT for a single TA is predicted as shown above. If the result is in nonconformance with target times (e.g. TOBT vs. TSAT or calculated vs. scheduled TTT) then the second step is done, calculating different predefined process scenarios for one or more processes. If it is guaranted that different scenarios are defined for every process (e.g. short, medium and standard duration/quality) different process predictions are possible, illustrating different control options. By recalculation the TTT using a set of different process scenarios the effect of the possible control options (selectable scenarios) can be examined.

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. As example the boarding process can be divided into the individual task *boarding PAX* and *boarding UM* (“passengers with reduced mobility” and “unaccompanied minors”). Each task is defined by stochastic parameter, e.g by three Normal-distribution parameters: the expected value μ, standard deviation σ and the correlating quantity of (normal or UM) passengers n. It is assumed that *boarding UM* takes always place before *boarding PAX* and one or two doors for boarding can be used. Hence four different scenarios, as shown in Figure 5 are possible. 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, then these scenarios are not possible.

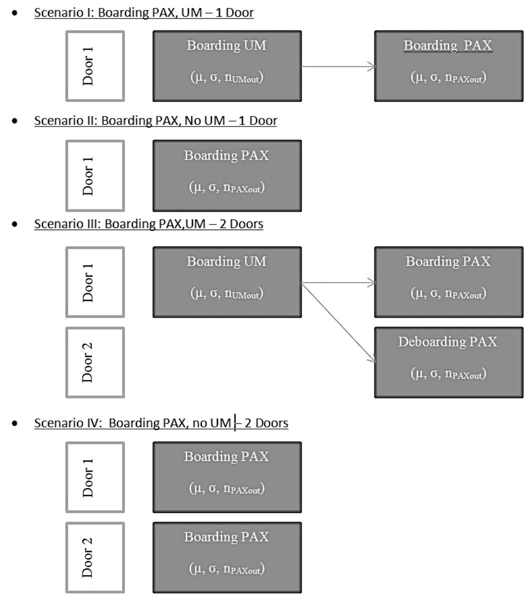

Figure 5: 4 microscopic process scenarios for boarding

V. FUTRE WORK

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