

# MODELLING OF GROUND HANDLING OPERATIONS AT AIRPORT

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## Abstract

*In aviation, aircraft ground handling defines the servicing of an aircraft while it is on the ground and (usually) parked at a terminal gate of an airport. Ground handling operations include many activities: passenger handling, ground transport, assistance in blocking the aircraft and delivery of required equipment, loading and unloading of the aircraft, including provision and operation of required equipment, as well as transport of the crew and passengers between the aircraft and the terminal, transport of luggage between the aircraft and the terminal, catering.*

*This paper presents a fragment of an analysis of the elementary operations performed at the apron and presents model of ground handling at the airport and stochastic analyses. The method of solving the problem is based upon an analysis of the actual airport operations. During the investigation different ground handling processes schemes and elementary operations identified at the apron were analyzed. Random parameters of the duration of each action at the apron were identified. The focus was the problem of increase airport capacity for the ground airport operations. Problem of airport capacity is specifying as airside and landside. The authors present short description of method. It is present ground handling model and some of results of simulation.*

**Keywords:** transport, air transport, ground handling, aerodrome traffic, Gantt diagrams

## 1. Introduction

This report presents a fragment of an analysis of the elementary operations performed at the apron. In order to achieve the intended target it was necessary to perform a comprehensive analysis of the traffic of planes, which take off, and land in the ground airplane traffic. The elementary ground handling processes and random parameters of their realization have been identified. The developed ground-handling model reflects the processes that take place in an airport and its compliance with the analyzed system is well verified. The ground handling includes a series of parallel or sequential activities, which are described in detail in the following sections. Appropriate management of such activities influences the ending time of the whole ground handling. An analysis and expectations regarding the ending time of the ground handling permit to evaluate the airplane take-off time.

## 2. Ground handling operations

One of the fundamental activities related to the ground operations of an airplane is to protect the airplane from free taxiing. After the arrival of an airplane its wheels may be protected when:

- the airplane has been parked,
- main engines have been switched off,
- anti-collision lights have been switched off.

Once those actions have been concluded, the air-plane wheels are protected with special blocks. In the case of the airplane departure, the blocks are removed once it has been checked that the doors and hatches are closed and the ground handling equipment and the passenger platform have been removed. Once the blocks have been removed, the captain is informed the airplane is ready to push back.

Certain types of airplanes require during stopping, service and engine starting, that an additional Ground Power Unit be used. The Ground Power Unit operator is present near the apron a couple of minutes before the scheduled landing. What is important among the airplane service operations is to guarantee a safe and free boarding and exit of passengers from the airplane. It may be realized by means of passenger bridge or passenger stairs. In the case the airplane is docked at a contact position, passengers leave the board of the airplane directly to the passenger terminal building. The passenger bridges are placed at the airplane doors, connecting directly the departure lounge and the airplane. In the case of a remote apron or a lack of passenger bridges, it is necessary to use passenger stairs, which are placed within the apron a couple of minutes before the scheduled landing.

While the passengers are leaving the airplane, the ground handling employees commence to unload the airplane. Loading and unloading of the air-plane should be realized in accordance with the loading instructions (load mass distribution). Loading and unloading of luggage is realized by means of special equipment (Ground Handling Equipment – GHE). Unloading of passenger airplanes is performed by means of self-propelled belt conveyors, and in the case of certain types of airplanes by means of palette and container loading machines.

While passengers are leaving the airplane, the plane is being cleaned and catering replenished. Depending on the requirements and contract specifications, cleaning may be realized its basic or extended scope. Regardless of the aforementioned activities, sewage disposal is realized on board. The ground handling employees are also supposed to replenish the potable water supply. During stopover, the airplane is catered by a specialized group.

A dangerous stage of the ground operations is refuelling of the airplane. During refuelling safety regulations must be strictly observed. It is prohibited to use fire or equipment which may generate sparking or fire where the airplane is being refuelled.

The airplane may be refuelled with passengers on board solely when:

- it has been authorized by the ground traffic coordination service,
- it has been approved by the airplane crew,
- the operation is supervised by the fire brigade,
- all doors of the airplane and emergency exits are available and ready for immediate use.

Once the airplane has been refuelled, it is ready for take-off. New passengers are led into the plane. At the same time luggage is loaded into the luggage compartments.

Once all the operations have been concluded under supervision of the flight coordinator, the required documentation is transferred to the air-plane, namely the airplane load distribution and loading document (Load sheet), information regarding special or dangerous shipment, passenger lists, cargo and mail document. Once all the documents have been delivered and all the take-off procedures have been performed, the airplane is ready to commence the procedure of leaving the apron.

The ground handling processes are concluded at the moment the anti-collision lights are turned on by the airplane crew. Then the engine starting procedure commences and the airplane is moved away from the apron.

Engine starting may be realized by means of a special starting unit. During the engine starting there must be communication of the ground handling personnel with the crew by means of a head set or manual signalling. Before a starting unit is applied, it must also be agreed with the captain which engine will be started first. Once these actions have been concluded, the external power source is disconnected.

Push back is moving of the plane away from the starting place is to transfer the airplane by means of a shaftless towing vehicle towards the taxiing route. It is prohibited to use the airplane reverse thrust near passenger brings.

The operation push back may commence provided the following conditions are fulfilled:

- the loading of the airplane has concluded,
- the handling equipment used for loading or other machines have been removed from the area occupied by the airplane,
- the airplane doors and hatches are locked,

- the passenger bridge has been removed,
- the wheel blocks have been removed,
- the towing vehicle driver received a signal to start moving the airplane away from the stopping place.

Once the airplane has been pushed back from the apron, it should be at the yellow line, i.e. the front undercarriage leg of the airplane should be at the yellow line, and the rear undercarriage legs should be placed symmetrically at both sides of the taxiing road.

### 3. General scheme of the ground handling

Skilful planning of the time of commencement and finish of specific elementary operations influences the time of conclusion of the whole ground handling process. Exact scheduling of the time when the ground handling stage is concluded influences correct decisions made by the airport traffic controllers.

Figure 1 presents a general scheme of the flow diagram, which includes all the registered ground handling actions. The time dedicated to the ground handling stage depends on the number of passenger seats in the airplane and the kind of flight.

There are also other flow schemes which have been developed for the elementary ground handling processes for different types of airplanes. Probabilistic time values of duration of the specific elementary operations have been registered and analysed for the ground handling.

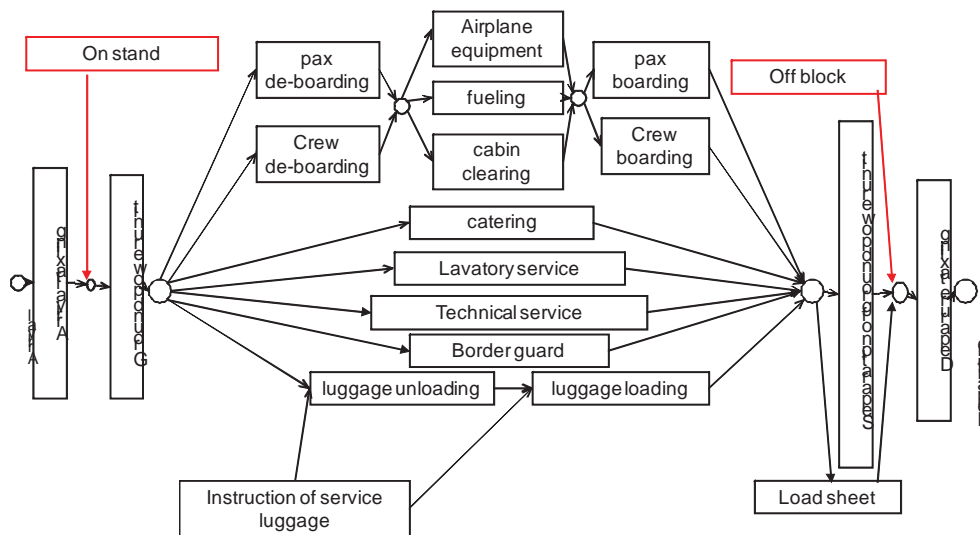


Fig. 1. General ground handling model

For the identified elementary ground handling processes of the airplanes, the times of realisation of the operations for selected types of airplanes have been measured. The results can be presented in the Gantt diagrams, which include the division of specific elementary operations and their planning in time. Fig. 2 presents an example of the Gantt diagram for an ATR/Embraer airplane.

The Gantt diagram is a method of visual description of the project. This is a special diagram applied in the project management. It reflects the division of a project into tasks and their planning in time.

### 4. Modelling of the ground handling

Entry process and air traffic service parameters are identified on the basis of elements of the stochastic processes theory. The first question is an analysis of the airplane entry stream. For the purpose of the stochastic entry process  $N(t)$  the observed realization of the number of entries,

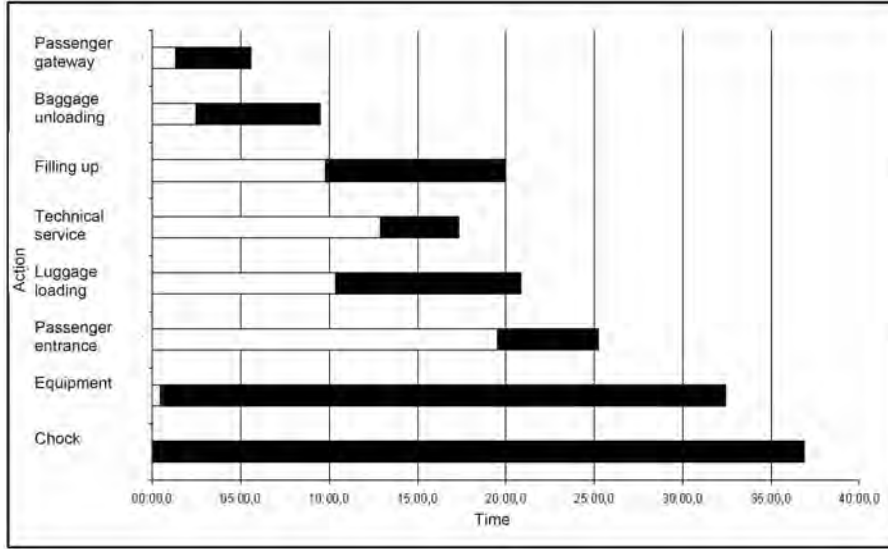


Fig. 2. Diagram Gantt for ATR/EMB

which appeared within the period of time between  $t_0 = 0$  until  $t \geq 0$  are a random variable  $n(t)$ . The number of entries and the number of concluded service operations of airplanes within the period of time  $[t-1, t)$  is equal to the difference  $n(t)-n(t-1)$ . The following moments when entries appear are marked by  $t_1, t_2, \dots, t_m, \dots$ , and the symbols  $x_1, x_2, \dots, x_m, \dots$  refer to the number of entries appearing during that time. Then  $\tau_m = t_{m+1} - t_m$  (for  $m = 0, 1, 2, \dots$ ) is the time between the entries of the groups  $m$   $x_m$  and  $(m+1)$   $x_{m+1}$ .

Identification of the actual streams of entries of airplanes for ground handling processes has allowed identifying solely a partial compliance with the Poisson stream.

In practice we register a series of the observed instants, when the random airplane entry for ground handling processes in question occurred or the analysed elementary service operation concluded:

$$t_0 = 0 \leq t_1 \leq t_2 \leq \dots \leq t_m, \quad (1)$$

Such a notation of a series of instants may be replaced with an equivalent notation of the intervals between subsequent airplane entries (conclusion of service operations):

$$\tau_k = t_{k+1} - t_k. \quad (2)$$

Obviously then the following holds:

$$t_n = \sum_{k=0}^{n-1} \tau_k. \quad (3)$$

The notation  $\tau_k = t_{k+1} - t_k$  is more comfortable for the purpose of description of the event of conclusion of the airplane service operations. For the number of entries  $n(t)$  or intervals of entries of subsequent airplanes  $\tau_n$ , in time  $[0, t)$ , where  $t \geq 0$ , the following holds:

$$n(t) = n_0 \quad \text{for } t_m \leq t < t_{m+1}, \quad \text{for: } m = 0, 1, 2. \quad (4)$$

Adopting the earlier notations  $n(t)$  and  $\Delta n(t, \tau)$  the definition implies the following relations:

$$\Delta n(t, \tau) = n(t + \tau) - n(t) \quad \text{for: } t \geq 0, \tau \geq 0, \quad (5)$$

$$\Delta n (0, \tau) = n (\tau). \quad (6)$$

For the data  $t \geq 0$  and  $\tau \geq 0$ :  $\Delta n(t, \tau)$  is equal to the number of instants  $t_k$  of an event for which the following holds  $t \leq t_k \leq t + \tau$ . Thus for  $m = 1, 2, \dots$ , if  $\Delta n(t, \tau) = m$  then there is a natural number  $k$ , which is such that the following holds:

$$t_{k-1} \leq t < t_k \leq \dots \leq t_{k+m-1} \leq t + \tau < t_{k+m}. \quad (7)$$

Two or more entries for the airplanes in the airport service stage or conclusion of the service operations at the same instant have not been observed in practice. Therefore there are no entries or group service operations.

The following notations have been adopted:

$v_n(t)$  - probability density function for realization of the stochastic process  $N(t)$  defined as follows:

$$v_n(t) = P(n(t) = m), \quad (m = 0, 1, 2 \dots), \quad (8)$$

$v_{\Delta n}(t, \tau)$  – probability density function for realisation of the stochastic process  $\Delta N(t, \tau)$  defined as follows:

$$v_{\Delta n}(t, \tau) = P(\Delta n(t, \tau) = m) \quad (m = 0, 1, 2 \dots). \quad (9)$$

Probability  $v_{\Delta n}(t, \tau)$  concerns predetermined ranges  $(t, t + \tau)$ . The average values of the random variables  $n(t)$  and  $\Delta n(t, \tau)$  which refer to realization of the stochastic processes  $N(t)$  and  $\Delta N(t, \tau)$  (assuming the series are convergent, i.e. the sums in both equations are finite) are expressed in the following dependences:

$$E(n(t)) = \sum_{m=0}^{\infty} m v_n(t), \quad (10)$$

$$E(\Delta n(t, \tau)) = \sum_{m=0}^{\infty} m v_{\Delta n}(t, \tau). \quad (11)$$

The stochastic process  $\Delta N(t, \tau)$  is a uniform process when  $v_{\Delta n}(t, \tau) = v_n(\tau)$  for:  $\tau \geq 0$ .

In the case of realization of a uniform process the following holds:

$$E \Delta n(t + u) = E n(t) + E n(u). \quad (12)$$

It has been concluded that realization of the airplane entry process for the ground handling processes is a uniform process solely for specific ranges.

## 5. Stochastic analyzes of the ground handling processes

The result of the analysis of the measurement data are histograms, cumulative distribution functions and estimators of the parameters of empirical distributions, and the aforementioned results have been achieved on the basis of the highest reliability method. The measured relations were tested using the Statgraphics Centurion XV package.

The model analysis of the complexity of the identified elementary operations is a good and reliable tool of analysis and traffic evaluation in the selected airports. Summary statistics for ground handling are presented in Tab. 1.

Tab. 1. Summary statistic of ground handling operations

	Deboarding	Boarding	Luggage loading	Luggage unloading	Fuel	Catering	Cabin clearing
Count	39	39	39	39	31	22	22
Average	4.0512	5.7435	6.7948	10.359	9.2580	8.13636	12.454
Standard deviation	1.3755	2.3588	2.7547	4.6196	3.8032	2.7307	2.8238
Minimum	2.0	2.0	3.0	4.0	4.0	3.0	7.0
Maximum	8.0	11.0	17.0	25.0	19.0	14.0	20.0
Range	6.0	9.0	14.0	21.0	15.0	11.0	13.0

In Table 1 are presented basic results: count, standard deviation, minimum, maximum and range. Data were analyzed using the Statgraphics Centurion XV package. The software package gives the calculated critical significance level, which is compared to the assumed je z significance level  $\alpha$ . The hypothesis in question must be rejected if the significance level is lower than or equal to  $\alpha$ . Otherwise there are no grounds to reject the hypothesis.

Measurements and analyses of the actual duration of the ground handling processes permitted to identify the probability density functions and cumulative distribution functions for distributions of random variables for duration of specific operations at the stopping places.

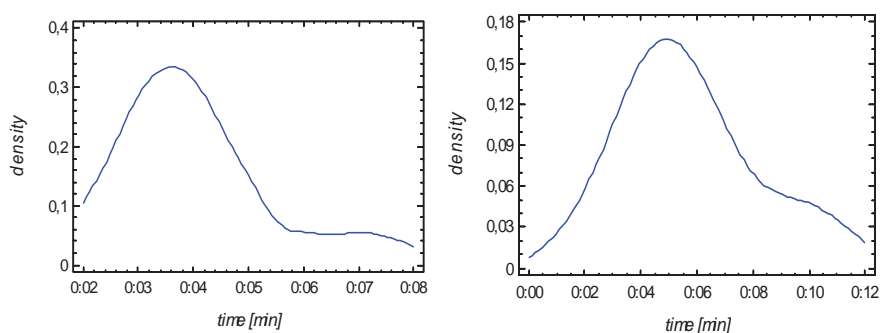


Fig. 3. Function density – deboarding and boarding passengers

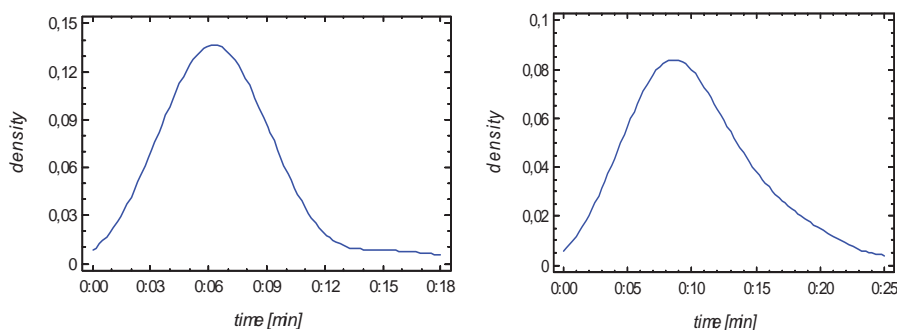


Fig. 4. Function density – unloading and loading luggage

Figures 3 and 4 present examples of probability density functions for de-boarding and boarding passenger, and unloading and loading luggage.

### 6. Simulation model of the ground handling

The model specifies certain paths which include the specified actions. The simulation model developed on the basis of the distribution of the entry times and handling of the individual operations permits to read the actions which determine the whole scope of realization of the ground handling. Such actions are included in the critical path (Fig. 5).

The critical path is a term applied to every longest path  $\mu_{max}(x_p, x_k)$  within the flow chart, and its duration (the sum of duration of the subsequent actions included in the critical path) is equal to the final time. It must be noted the charts may include more than one critical path.

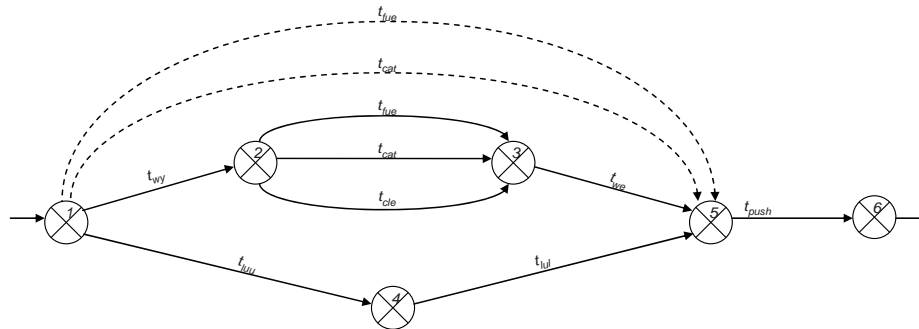


Fig. 5. Model of ground handling

The arrangement of actions within a critical path indicates the sequence of critical actions, which guarantees the shortest possible time of realization of the whole process. Acquaintance with the critical actions facilitates planning, management and coordination of the process, since excessive duration of any critical action implies delays in realization of the whole project.

The system of planning and management of the aprons should allow for the possibility of evaluation of the current state and forecast further tasks, and particularly the possibility of exerting such influence on their realization that guarantees prompt realization of the whole handling process or its shortening. Every modeled elementary operation has been treated as a queuing theory.

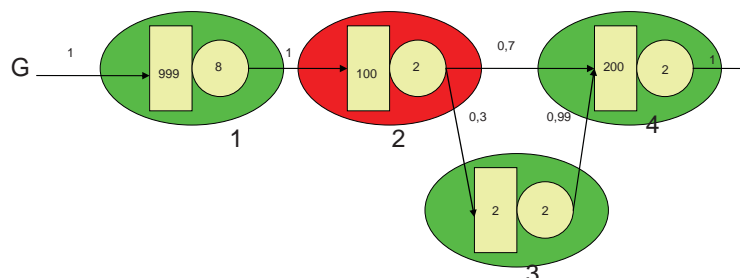


Fig. 6. Queuing model

The simplest form of the queuing model comprises three stages: entry into the handling system, waiting for handling operations and handling. The queuing system is described by means of three properties, namely entry stream, handling process and queue handling method. The entry process and handling described within the queuing theory system are random (Fig. 6).

The data for the simulation model were developed as cumulative distribution functions of random distributions, taking into account all the actions divided in accordance with the categories of airplanes.

The simulation model includes a series of parameters which determine the current conditions. It is possible to determine the number of teams which realize the ground handling processes. Simulation is realized for a specific number of airplanes, which are supposed to be handled. There

is a possibility of calculation of the percentage of the airplanes which are subject to parallel refueling and catering service for each category. The obtained results present the percentage of the critical path or paths. On this basis it is possible to indicate actions that determine the whole realization of the ground handling processes.

The simulation model was developed on the basis of an analysis of the actual processes which take place in the context of the airport traffic. The results obtained on the basis of the aforementioned model were verified.

The simulation model may contain a series of parameters indicating the actual conditions. The displayed results present the total handling times, operations causing delays (waiting for an unoccupied team) and the percentage of the critical paths in the realized simulations. The simulation model offers a lot of possibilities to modify the parameters and adapt to the existent airport infrastructure.

## 7. Conclusions

The method of solving the problem is based upon an analysis of the actual airport operations. During the investigation different ground handling processes schemes and elementary operations identified at the apron were analyzed. The basic investigation methods were the following: stochastic analysis of the ground handling process in the airport, and modeling of airport operations for the purpose of determination of the airside capacity as a queuing network.

A series of simulation experiments were realized. The random flow chart analysis of the ground handling process was realized on the basis of the model, using the critical paths interrelations. The results of the simulation indicated the critical paths for the ground handling process organization charts. It was the basis to define the significant elements of the flow charts which determine the time of realization of the ground handling process for the given type of airplanes. A detailed analysis of the ground handling process served to determine the airside capacity value.

The analysis of the obtained results constitutes the basis for a better organization of airport processes which will lead to an increased airside capacity. It can be useful for a model, which will be a flexible tools that permits to determine the airside capacity. It may also serve to evaluate delays and then eliminate them. Early information will allow for more detailed specification of the commencement of subsequent operations.

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