TITAN

Turnaround **I**ntegration in **T**rajectory **A**nd **N**etwork

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Report on Exercise Results. Simulations

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EXECUTIVE SUMMARY

The Turnaround Integration in Trajectory and Network (TITAN) project directly addresses the airport operations focusing on the turnaround process. Concept Validation assesses the operational feasibility of TITAN Operational Concept and its effect on predictability, efficiency, flexibility and cost-effectiveness of airlines and airport operations. The validation methodology applied is the European Operational Concept Validation Methodology (E-OCVM). According to E-OCVM, TITAN Operational Concept was stated at V1 maturity level at the beginning of the Validation activity and was planned to achieve late V2 maturity level. Several Validation exercises, using different Validation techniques, have been carried out to cover the different validation objectives at the different stages of the Validation Activity. At V1 maturity level, Expert groups and gaming techniques were used, while Simulation exercises were designed and carried out to cover V2 maturity goals. These simulation exercises have used the TITAN model developed previously in the project.

The main objective of this deliverable is to describe the simulation exercises carried out in the project by executing the validation exercises as defined in the Validation Exercise Plan, the methodology used to perform the exercises and to summarize the results assessing that the validation objectives are met and the scenario parameter configuration is used.

The results of the simulations are presented and attached to the document in Annexes. Simulation results consist of a folder containing all data output files provided by TITAN model after each simulation run. They are grouped into Validation scenarios and Simulation scenarios.

1 INTRODUCTION

1.1 PURPOSE

The aim of this document is to describe the TITAN validation exercises performed within TITAN Operational Concept Validation Activity and to present their results. These simulation results will facilitate the validation of the TITAN Operational Concept at V2 maturity level according to the validation objectives defined in the Validation Exercise Plan [5].

Validation simulation exercises are identified and defined in the Validation Exercise Plan [5]. They comprise simulations conducted by implementing the software model developed in WP2. These exercises mainly consist of measuring a set of established indicators when simulating different Validation scenarios. Exercise results are synthesised in this report which will serve as an input to D3.4 for their analysis.

1.2 DOCUMENT STRUCTURE

The document is divided in the following chapters:

- Chapter 1 gives a brief description of the document.
- Chapter 2 explains the methodology used for the exercise conduction.
- Chapter 3 presents the exercise results content and organization.
- Annex 1 specifies all Simulation scenarios parameters.
- Annex 2 describes the TITAN Services implemented in TITAN model.
- Annex 3 describes the decisions made during the TITAN Simulation scenarios.
- Annex 4 contains the folder with all data output files produced during the simulation exercises.

1.3 INTENDED AUDIENCE

This document is public and may be distributed freely, both within and outside the TITAN consortium.

1.4 ASSOCIATED DOCUMENTATION

[1] The European Operational Concept Validation Methodology (E-OCVM), EUROCONTROL, version 3, February 2010

[2] TITAN D2.2 Single Aircraft Turnaround Model Software Design Document, Version 0.4, March 2012

[3] TITAN D2.4 Single Aircraft Turnaround executable model, version 0.0.450

[4] TITAN D2.7 TITAN executable model, version 0.0.490

[5] TITAN D3.2 Validation Exercise Plan, version 0.7, November 2011

[6] TITAN D3.1 Validation Strategy, version 1.0, July 2011

[7] TITAN D1.3 “Performance Framework”, Version 1.0, October 2010

[8] TITAN_WP3_CRI_INT_01_PU_v0.4_ Guidelines for the configuration of the Validation scenarios, March 2012

[9] TITAN_WP2_Interaction points for the Model, version 0.3, March 2012

[10] TITAN D2.5 TITAN Model Software Design Document, 0.1, April 2012

[11] TITAN D1.4 TITAN Operational Concept Document – Issue 1, v1.0, October 2010

1.5 ABREVIATIONS AND ACRONYMS

ACT	Actual Completion Time
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
AIRS	Airport Information Report Service
ANE	ICAO airline short code: AIR NOSTRUM
AOBT	Actual Off Block Time
AS	Airside
AST	Actual Start Time
ASRS	Aircraft Status Report Service
ATTT	Actual Target Turnaround Time
BER	ICAO airline short code: AIR BERLIN
BFIS	Baggage Flow Information System
CMFIS	Cargo/Mail Flow Information Service
ECT	Estimated Completion Time
EOBT	Estimated Off Block Time
E-OCVM	European Operational Concept Validation Methodology
EST	Estimated Start Time
ETTT	Estimated Target Turnaround Time
EU	European Union
ICAO	International Civil Aviation Organization
KPI	Key Performance Indicator
PC	Passport Control
PFIS	Passenger Flow Information System
PCT	Planned Completion Time
PST	Planned Start Time
PRM	Passengers with Reduced Mobility
SC	Security Control
SIBT	Scheduled In-Block Time
SOBT	Scheduled Off-Block Time
TITAN	Turnaround Integration in Trajectory and Network
UM	Unaccompanied Minor

VIP	Very Important People
WP	Work Package

2 EXERCISE CONDUCTION METHODOLOGY

2.1 Introduction to the model

TITAN model [4] is a flexible model to simulate the turnaround process at an airport taking into account all the sub-processes and actors involved. TITAN model allows configuring different turnaround processes, different resource management principles, several airport scenario parameters and the implementation of TITAN Services. After a simulation, TITAN model produces a set of data output files registering what happened during the simulation. TITAN model data output mainly deal with start/end time of processes and the resources used.

Model functionalities and architecture are described in full detail in TITAN Single Aircraft Model design document [2] and in TITAN Model Software Design Document [10]. Model functionalities have been designed according to the validation objectives and the Validation scenarios defined in the Validation Exercise Plan [4]. TITAN simulation exercises are based on comparing turnaround operation in a generic large airport by using different Validation scenarios (TITAN and non-TITAN Validation scenarios), allowing TITAN model to be configured in order to simulate all of them.

TITAN Services are modelled by means of windows displayed when a measured performance has a value that is beyond a pre-established value range. These windows provide the user with useful information regarding the status of the simulated processes and support him by decision-making. These decisions constitute in choosing to act based on a set of pre-defined actions that would change the course of the simulated processes.

2.2 Exercises definition

2.2.1 Validation Exercises nature

Simulation validation exercises correspond to V2 phase in E-OCVM. Those exercises are characterised by the validation objective that they address and the Validation scenarios that they use:

- Validation objectives are mainly oriented to assess whether TITAN performance meets the targets defined in the Performance Framework [7]. They determine the Validation scenarios to be used and the measurements that will be taken during the exercises.
- The Validation scenarios are designed to reproduce all the turnaround processes at an airport according to the current turnaround concept of operations or to the TITAN Concept of operations [11]. Moreover, they can also take into account any disruption or unexpected event with different severities. Validation scenarios are defined in TITAN Validation Exercise Plan [5]. Exercise analysis will be mainly based on the comparison of the performance obtained in TITAN and non TITAN Simulation scenarios and will be reported in part B of deliverable D3.4

TITAN Validation Exercise Plan [5] identifies four validation exercises. They are organised according to the high-level validation objectives defined in the Validation Strategy [6] that they address. Table 1 lists the four validation exercises performed and their associated high-level objectives:

Exercise ID	Validation Objectives
V2-01	Assess whether the TITAN concept meets the targeted performance levels for predictability, efficiency and flexibility.
	Assess the influence of passenger and baggage processes, especially under several unexpected situations (e.g. late passenger arrival or lost baggage).
V2-02	Assess the effect of disruptions on the performance levels for predictability, efficiency and flexibility.
V2-03	Validate the application of the TITAN services described in the Operational Concept (BFIS, PFIS, CMFIS, AIRS, ASRS).
V2-04	Assess whether the TITAN concept meets the targeted performance levels for cost effectiveness.

Table 1: Validation Objectives and Simulation Validation Exercises

Table 2 identifies the Validation scenarios that have been used in the exercises as defined in TITAN Validation Exercise Plan [5]. There are two generic Validation scenarios and four specific ones, representing several interesting situations (*late passenger, increasing demand, late arrival* and *lack of resources*). All of these situations are reproduced for current turnaround concept and TITAN operational concept. This structure is repeated including different disruptions in the turnaround process. A disruption in TITAN Validation scenarios is understood as a forced delay introduced at the end of a turnaround sub-process.

		Generic Validation scenarios	Specific Validation scenarios			
			Late Passenger	Increasing demand	Late arrival	Lack of resources
Normal Airport Operation	Current situation	GEN-1a	SPEC-1a	SPEC-2a	SPEC-3a	SPEC-4a
	TITAN concept	GEN-1b	SPEC-1b	SPEC-2b	SPEC-3b	SPEC-4b
Disruption	Current situation	GEN-2a	SPEC-1c	SPEC-2c	SPEC-3c	SPEC-4c
	TITAN concept	GEN-2b	SPEC-1d	SPEC-2d	SPEC-3d	SPEC-4d

Table 2: Validation scenarios

2.2.2 Validation Exercises definition

To define each Validation exercise, the high-level validation objectives are specified into exercise objectives. Exercise objectives are lower-level validation objectives which describe the goal of the exercise and the required measurement. Each exercise objective can be achieved by simulating one or several Validation scenarios. Validation Exercise Plan, section 2.5 [5], describes the exercise objectives and the Validation scenarios to be used to assess the level of achievement of each validation exercise objective. Exercise objectives and their associated indicators can be found in 2.4.2.

Once Validation scenarios to be run for each exercise objective have been identified, a number of simulations (Simulation scenarios) are required to be run for each Simulation scenario varying several parameters (e.g. number or resources, number of flights delayed, etc.). Variation of the parameter value ensures the validation of a wide operational context and allows trend analysis of the results. Annex 4 of the Validation Exercise Plan [5] describes the Simulation scenario

configuration of all simulations that have been run and Annex 1 of this document contains an update of this annex.

Figure 1 shows the elements that compose an exercise. According to it, to conduct one validation exercise[1] it is required to perform a number of simulation runs determined by N, M, P and Q values. For a specific exercise:

- N is the number of Validation scenarios[2] that are involved in the exercise.
- P is the number of parameters that are required to vary in a Validation scenario to ensure operational context represents reality (e.g. vary airline policies regarding the parameter "wait or not for missed passengers").
- M is the number of different values introduced for a specific parameter (e.g. M=2 if two different policies are modelled; policy A is to wait for max. 30 minutes, policy B is not to wait for missed passengers).
- One Validation scenario with all possible values of its parameters determined constitutes a Simulation scenario that has a unique configuration in the TITAN Model (set of data inputs). For a Simulation scenario, Q is the number of simulations runs required to ensure reliability of the results obtained and is determined by statistical methods explained in §2.5.
-

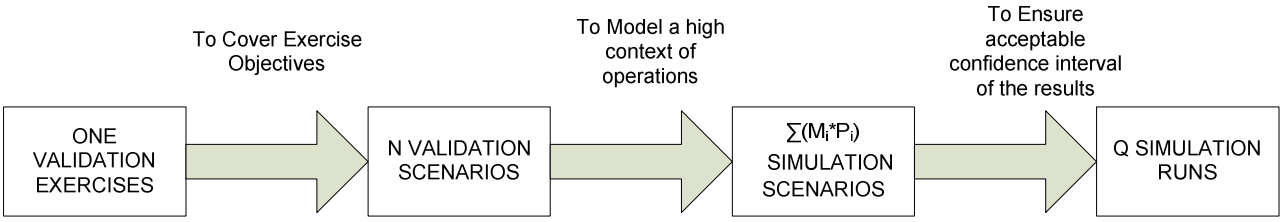

Figure 1: Validation Exercise Definition Process

[1] An activity intended to improve understanding of the concept and/ or demonstrate the fitness for purpose of some elements of the concept.

[2] A specific description of how the concept will operate, developed for the purposes of undertaking validation activities (i.e. exercises) and to gather evidence relevant to the validation objectives.

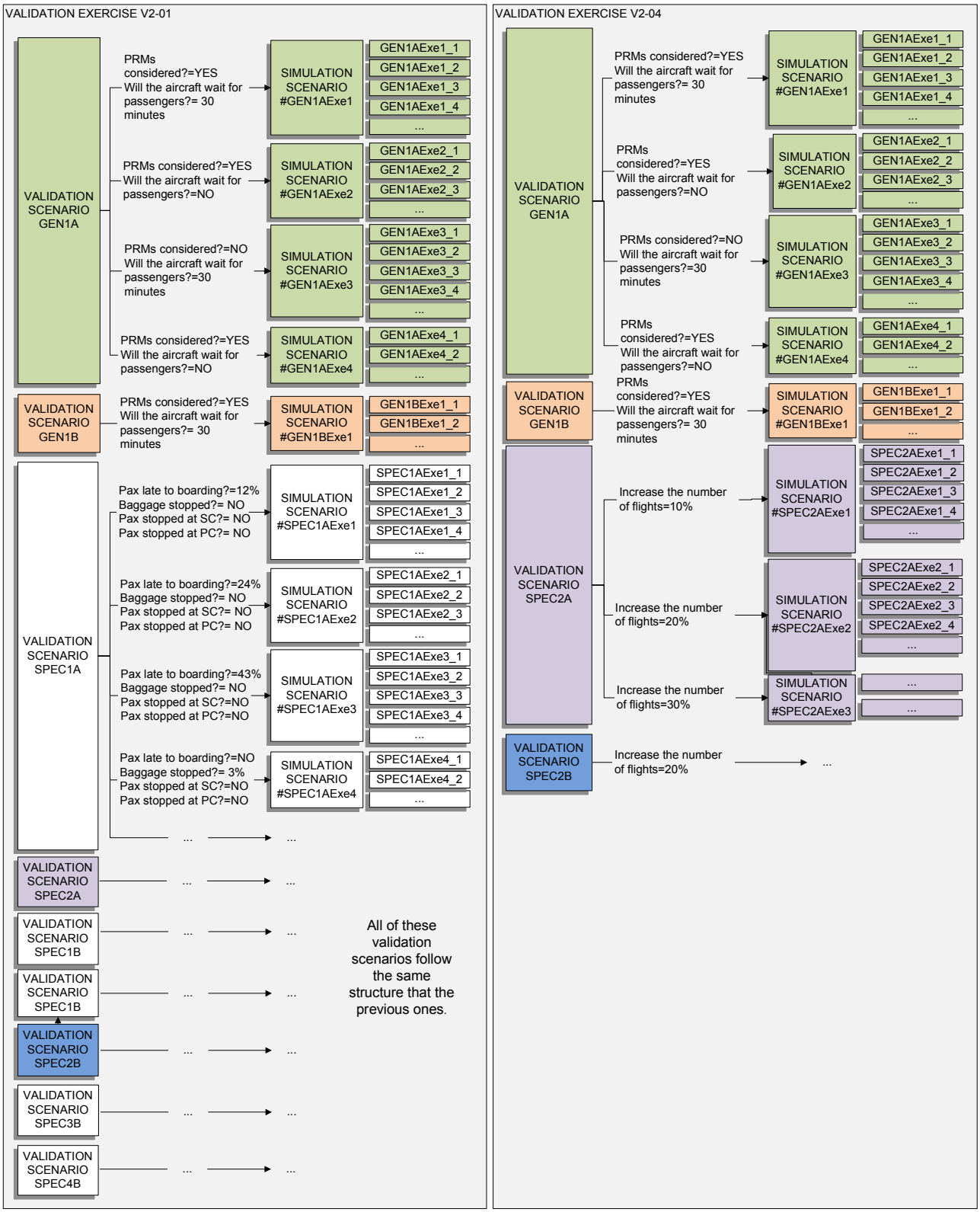

Figure 2Figure 2 reproduces the process of identification of the simulation runs that are needed to assess a validation exercise. It shows the Validation scenarios needed for the exercises V2-01 and V2-04 according to the Validation Exercise Plan [5]. Each Validation scenario comprises a variable

number of Simulation scenarios with different parameters values and therefore implies the run of a certain number of simulations depending on N, M, P and Q.

It must be noted that the same simulation runs serve to evaluate different validation exercises (e.g. simulation runs composing the Validation scenario GEN1A are used in V2-01 and in V2-04).

Having this structure in mind, it seems reasonable to order exercise results by Simulation scenarios, instead of ordering them by exercises.

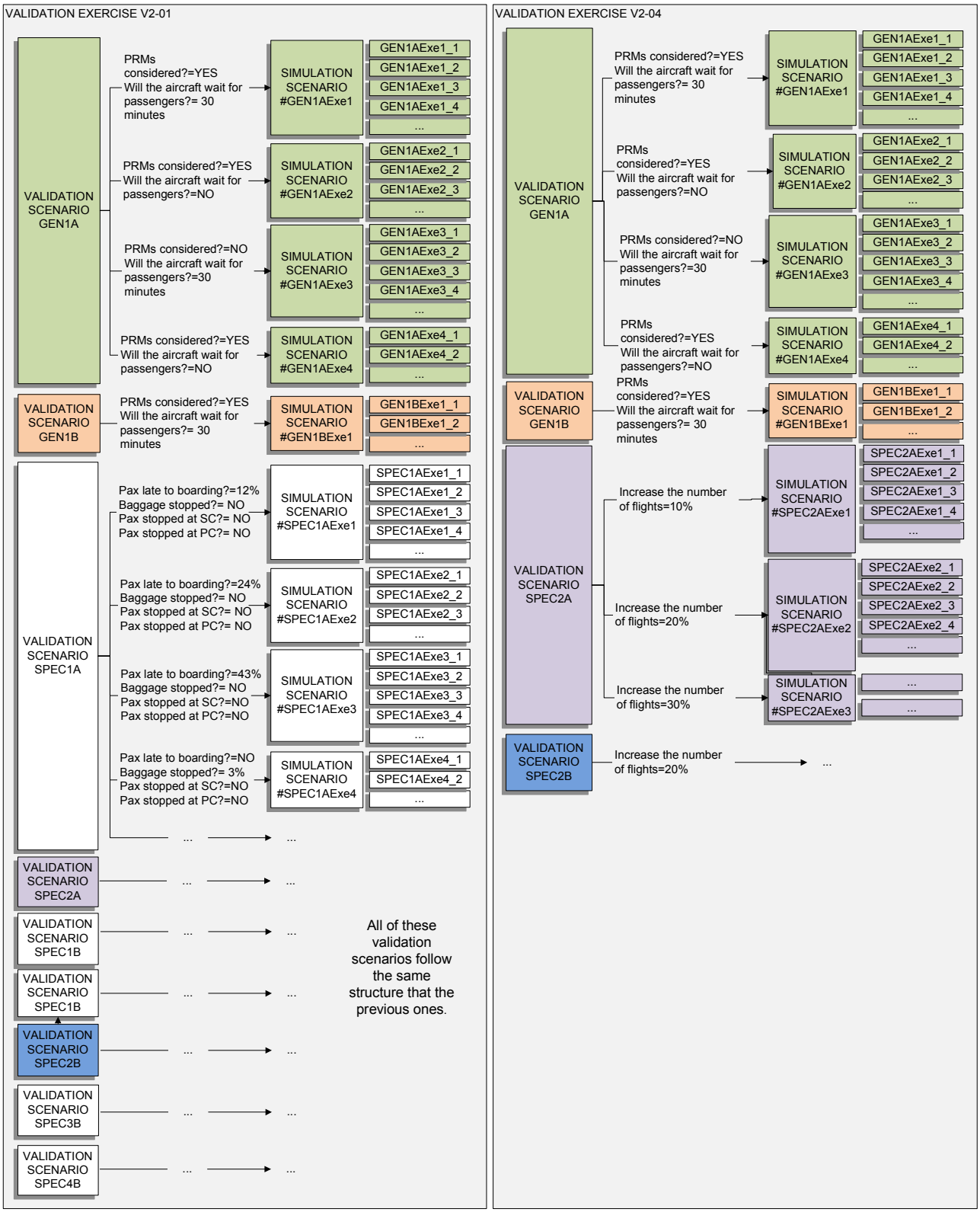

Figure 2: Validation Exercise Structure of V2-01 and V2-04

A high number of simulation runs has been needed to cope with all exercise objectives. *
Each scenario choice is justified in section 2.3

Table 3 lists the Simulation scenarios corresponding to each Validation scenario. A detailed description of the Simulation scenario parameters used is included in Annex 1.

VALIDATION SCENARIO	NUMBER OF SIMULATION SCENARIO	SIMULATION SCENARIO DESCRIPTION	Simulation scenario Id.[3]
GEN-1A	4	Baseline scenario with different combinations of the values of the most generic parameters: - PRMs/No PRMs - Aircraft waiting time for late passengers boarding.	GEN1AExe1 GEN1AExe2 GEN1AExe3 GEN1AExe4
GEN-1B	1	GEN1AExe1 with TITAN Services enabled.	GEN1BExe1*
GEN-2A	9	Baseline scenarios with PRMs (GEN1AExe1 or GEN1AExe3) introducing disruptions in different turnaround sub-processes.	GEN2AExe2 GEN2AExe3 GEN2AExe5 GEN2AExe6 GEN2AExe7 GEN2AExe8 GEN2AExe9 GEN2AExe10 GEN2AExe12
GEN-2B	1	GEN2AExe5 and GEN2AExe8 with TITAN Services enabled.	GEN2BExe5* GEN2BExe8*
SPEC-1A	15	Specific scenarios 'late passenger' varying in one of the late passenger specific parameters (% of passengers arriving late to boarding, Baggage stopped for security issues, Passenger stopped at security control, Passenger stopped at Passport Control).	SPEC1AExe1 SPEC1AExe2 SPEC1AExe3 SPEC1AExe5 SPEC1AExe6 SPEC1AExe7 SPEC1AExe8 SPEC1AExe9 SPEC1AExe11 SPEC1AExe12 SPEC1AExe14 SPEC1AExe15
SPEC-1B	3	SPEC1AExe11 with TITAN Services enabled varying in the number of the enabled services each time (All, PFIS&BFIS or ASRS&AIRS).	SPEC1BExe11* SPEC1BExe11_sub-scenario 1* SPEC1BExe11_sub-scenario 2*

[3] Simulation scenario naming follows the parameterization specified in the Validation Exercise Plan [5]. However, some Simulation scenarios were finally removed from the initial list, but the original terminology was maintained. For that reason, '"gaps" in Simulation scenarios Id. numbering may be observed.

VALIDATION SCENARIO	NUMBER OF SIMULATION SCENARIO	SIMULATION SCENARIO DESCRIPTION	Simulation scenario Id.[3]
SPEC-1C	42	Specific scenarios 'late passenger' introducing disruptions in different turnaround sub-processes.	SPEC1CExe1 SPEC1CExe2 SPEC1CExe3 SPEC1CExe4 SPEC1CExe5 SPEC1CExe6 SPEC1CExe7 SPEC1CExe8 SPEC1CExe9 SPEC1CExe10 SPEC1CExe11 SPEC1CExe12 SPEC1CExe13 SPEC1CExe14 SPEC1CExe15 SPEC1CExe16 SPEC1CExe17 SPEC1CExe18 SPEC1CExe19 SPEC1CExe20 SPEC1CExe21 SPEC1CExe22 SPEC1CExe23 SPEC1CExe24 SPEC1CExe25 SPEC1CExe26 SPEC1CExe27 SPEC1CExe28 SPEC1CExe29 SPEC1CExe30 SPEC1CExe31 SPEC1CExe32 SPEC1CExe33 SPEC1CExe34 SPEC1CExe35 SPEC1CExe36 SPEC1CExe38 SPEC1CExe39 SPEC1CExe41 SPEC1CExe42 SPEC1CExe44 SPEC1CExe45
SPEC-1D	1	SPEC1CExe11 with TITAN Services enabled.	SPEC1DExe33*
SPEC-2A	3	Specific scenarios 'increasing demand' varying in the % of the increment of the number of flights.	SPEC2AExe1 SPEC2AExe2 SPEC2AExe3
SPEC-2B	1	SPEC2AExe2 with TITAN Services enabled.	SPEC2BExe2*

VALIDATION SCENARIO	NUMBER OF SIMULATION SCENARIO	SIMULATION SCENARIO DESCRIPTION	Simulation scenario Id.[3]
SPEC-2C	21	Specific scenarios 'increasing demand' introducing disruptions in different turnaround sub-processes.	SPEC2CExe2 SPEC2CExe3 SPEC2CExe5 SPEC2CExe6 SPEC2CExe7 SPEC2CExe8 SPEC2CExe9 SPEC2CExe11 SPEC2CExe12 SPEC2CExe14 SPEC2CExe15 SPEC2CExe16 SPEC2CExe17 SPEC2CExe18 SPEC2CExe20 SPEC2CExe21 SPEC2CExe23 SPEC2CExe24 SPEC2CExe25 SPEC2CExe26 SPEC2CExe27
SPEC-2D	0		None*
SPEC-3A	3	Specific scenarios 'late arrival' varying in the % of the flights arriving late.	SPEC3AExe1 SPEC3AExe2 SPEC3AExe3
SPEC-3B	1	SPEC3AExe2 with TITAN Services enabled.	SPEC3BExe2*
SPEC-3C	21	Specific scenarios 'late arrival' introducing disruptions in different turnaround sub-processes.	SPEC3CExe2 SPEC3CExe3 SPEC3CExe5 SPEC3CExe6 SPEC3CExe7 SPEC3CExe8 SPEC3CExe9 SPEC3CExe11 SPEC3CExe12 SPEC3CExe14 SPEC3CExe15 SPEC3CExe16 SPEC3CExe17 SPEC3CExe18 SPEC3CExe20 SPEC3CExe21 SPEC3CExe23 SPEC3CExe24 SPEC3CExe25 SPEC3CExe26 SPEC3CExe27

VALIDATION SCENARIO	NUMBER OF SIMULATION SCENARIO	SIMULATION SCENARIO DESCRIPTION	Simulation scenario Id.[3]
SPEC-3D	0		None*
SPEC-4A	3	Specific scenarios 'lack of resources' varying in the % of lack of turnaround mobile resources.	SPEC4AExe1 SPEC4AExe2 SPEC4AExe3
SPEC-4B	1	SPEC4AExe2 with TITAN Services enabled.	SPEC4BExe2*
SPEC-4C	21	Specific scenarios 'lack of resources' introducing disruptions in different turnaround sub-processes.	SPEC4CExe2 SPEC4CExe3 SPEC4CExe5 SPEC4CExe6 SPEC4CExe7 SPEC4CExe8 SPEC4CExe9 SPEC4CExe11 SPEC4CExe12 SPEC4CExe14 SPEC4CExe15 SPEC4CExe16 SPEC4CExe17 SPEC4CExe18 SPEC4CExe20 SPEC4CExe21 SPEC4CExe23 SPEC4CExe24 SPEC4CExe25 SPEC4CExe26 SPEC4CExe27
SPEC-4D	0		None*

*** Each scenario choice is justified in section 2.3**

Table 3: List of Simulation scenarios performed.

According to the Validation Exercise Plan [5], the framework of the TITAN validation exercises is a generic large airport, corresponding to community (EU) or heavy (ICAO) airport categories.

The validation traffic sample is a twenty four hours traffic data corresponding to a representative day in the airport consisting of 339 operations.

Each flight has a different turnaround associated depending on their features. Four different turnarounds have been defined:

- Schengen/ National: For those flights which ADES or ADEP is Schengen.
- Interisland: For those flights which ADES or ADEP belongs to an isle.
- NonSchengen/ International: For those flights which ADES or ADEP is non Schengen.
- Disruption: For those flights whose ADES or ADEP is Schengen but disruptions are introduced in the process editor for those scenarios that need them.

Differences between each turnaround definition are, mainly, about opening/closing scheduled times, passengers arriving rate and distances.

Following paragraphs briefly describe how the Validation scenarios have been modelled. There is a detailed description of the Simulation scenario parameters in Annex 1.

- GEN1 Validation scenarios reproduce a normal operation situation at an airport. They are used as baseline Simulation scenarios. There are four different Simulation scenarios corresponding to GEN1A where the parameters 'special passengers' and 'will the aircraft wait for passengers?' have different values.
- GEN2 Validation scenarios include a forced delay in one turnaround sub-process using GEN1A Simulation scenario as baseline. GEN2B Simulation scenarios are based on GEN2A including TITAN interactions.
- SPEC1 Validation scenarios simulate situations where passengers or bags are stopped for security reasons. They include resources which allow stopping bags and passengers in a security control/check room (interrogation room in the model [4]). Specific parameters linked to them are:
    - % of passengers arriving late to check-in: Passengers arriving late to check-in were simulated by changing the passenger arrival rate distribution and check-in schedule time parameters. Passenger arrival rate is provided by a normal distribution, so the percentage of late passengers is modified by changing the mean value in each turnaround.
    - % of passengers arriving late to boarding: Passengers arriving late to boarding are simulated by introducing a delay of 30 minutes at the end of security process in an increasing number of turnarounds for each exercise.
    - Baggage stopped for security issues: If a bag does not pass through a manual baggage scan it is sent to a scanner room and it can be removed from the flow. For each exercise a 5% of the baggage will be sent to the scanner room in an increasing number of turnarounds for each exercise.
    - Passenger stopped at security control: Passenger stopped at security or passport control works in a similar way. A 5% of passengers will be sent to an interrogation room in an increasing number of turnarounds. In this case, an increasing percentage of passengers will be stopped in each Simulation scenario.
- SPEC2 Validation scenarios have an increase in the traffic sample in comparison with the rest of the Validation scenarios. In particular, an increment of a 10, 20 and 30% of flights were considered. Flights and their associated properties were added randomly.
- SPEC3 Validation scenarios include a percentage of flights delayed with respect to their scheduled arrival time In particular, 10, 20 and 30% of the scheduled flights were delayed. The delay imposed follows a normal distribution between 20 and 40 minutes.
- SPEC4 Validation scenarios consider a lack of mobile resources in the airport operation. In particular, a lack of 10, 20 and 30% of the following mobile resources was considered:
    - Ambulift
    - Baggage Load Belt
    - Baggage Scanner
    - Baggage Security Agent
    - Baggage Truck
    - Boarding Agent
    - Bus
    - Catering Truck
    - Cleaning Truck
    - De-icing Truck
    - Fuel Truck
    - In/Off-block Agent
    - RMP Personnel

- o Pushback Vehicle
- o Stairs

2.3 TITAN Simulation scenarios conduction

While a non TITAN simulation and its corresponding data processing take an average of eighteen minutes, a TITAN simulation and its corresponding data processing take an average of one hour and twenty minutes requiring full time commitment by the user during the simulation. So, once all non TITAN simulations were run and analysed, only those Simulation scenarios that were most impacted by the disruptions or parameters introduced were chosen for the application of the TITAN services.

For the reasons stated below, the following non TITAN Simulation scenarios were chosen to enable TITAN services on them:

- GEN1A: GEN1AExe1 was the most comprehensive Simulation scenario from GEN1A, considering PMRs and waiting for passengers in boarding.
- GEN2A: GEN2AExe5 and GEN2AExe8, disruption in fuelling and baggage un-loading respectively, were the disruptions with the highest impact on the global results.
- SPEC1A: To analyse the impact of enabling and disabling different TITAN services, SPEC1AExe11 (passenger stopped for security issues) was chosen because when a passenger is stopped for security issues his/her baggage can be located by knowing the last sub-process to which it went through and removed by using TITAN services (e.g. PFIS, BFIS, etc.) while the rest of the SPEC1A scenario parameters depend on airlines policies or only affect a certain type of flights (e.g. passport control).
- SPEC1C: SPEC1CExe11 was chosen in order to be coherent with the disruptions chosen from GEN2A.
- SPEC2A/ SPEC3A/ SPEC4A: SPEC2AExe2/ SPEC3AExe2 / SPEC4AExe2 were showing the most stable results. Higher values in the parameters showed higher variability of data results.
- SPEC2C/ SPEC3C/ SPEC4C. Due to lack of resources and time, these Validation scenarios were decided not to be run. It was considered that enough conclusions may be obtained from all previous results.

2.4 Data Outputs obtained

2.4.1 Model data outputs

As described in the Single Aircraft Turnaround Model Software Design Document [2] each turnaround is composed of several processes. TITAN Model [4] defines a process as a network of nodes that entities (passengers, aircraft and baggage) pass through during the simulation. Each process starts when the first entity flows across it and ends when the last entity leaves the last node of the process. TITAN saves automatically an output file containing single time consumption in each node for each entity and process.

Registering all this information could not be useful for analysis purposes; therefore TITAN model includes an entity filter that allows the selection of the needed output parameters. An output file containing only these parameters can be obtained to analyse the results.

For validation purposes, six different time data per sub-process have been selected as most suitable:

- PST: Planned Start Time, according to schedule input data and sub-process definition.
- EST: Estimated –by the model- Start Time, according to estimated and updated durations of the previous sub-processes.
- AST: Actual Start Time, real start time of a sub-process.
- PCT: Planned Completion Time, according to schedule input data and sub-process definition.
- ECT: Estimated –by the model- Completion Time, according to estimated and updated durations of the previous sub-processes.
- ACT: Actual Completion Time, real completion time of a sub-process.

An output file is provided for each simulation. It contains these data (PST, EST, AST, PCT, ECT, ACT) for each turnaround process of the traffic sample.

The data output file presents the time data of a single sub-process in the same line and separated by semicolons. **¡Error! No se encuentra el origen de la referencia.** shows the content of each field and the type of data it may contain:

- First field of each line refers to the Flight code or to the turnaround sub-process name.
- Second field refers to the last status update for the concerned flight or turnaround sub-process.
- The rest of the fields are the data times exposed.

Flight code / Turnaround sub-process	Flight / sub-process Status	PST	EST	AST	PCT	ECT	ACT
Flight code according to traffic sample	Initializing: The turnaround of this flight could not start. On gate: The turnaround of this flight started but could not finish. Off gate: The turnaround finished.	time format: hh:mm:ss					
Baggage Loading/ Check-In, …etc.	Initializing: the sub-process could not start. Running: the sub-process started but could not finish. Completed: the process finished.						

Table 4: Data output file structure

Figure 3 shows an example of the data provided for a flight.

```
SWT150 -> SWT151;Off gate;00:54:00;00:54:00;00:54:00;02:11:00;02:11:00;02:10:49
Baggage Loading;Completed;00:11:00;00:11:00;00:11:00;02:11:00;02:11:00;01:30:43
Baggage Loading
AS;Completed;01:36:00;01:36:00;01:36:00;02:06:00;02:06:00;01:39:30
Baggage Unloading;Completed;00:57:00;00:57:00;00:57:00;01:12:00;01:12:00;01:02:06
Boarding;Completed;01:46:00;01:46:00;01:46:00;02:09:00;02:09:00;02:07:06
Catering;Completed;01:41:00;01:41:00;01:41:00;01:51:00;01:51:00;01:49:41
CheckIn;Completed;00:11:00;00:11:00;00:11:00;01:41:00;01:41:00;01:32:02
Cleaning;Completed;01:41:00;01:41:00;01:41:00;01:46:00;01:46:00;01:45:38
DeBoarding;Completed;00:57:00;00:57:00;00:57:00;01:12:00;01:12:00;01:03:12
InBlocks;Completed;00:54:00;00:54:00;00:54:00;00:56:00;00:56:00;00:55:44
OffBlocks;Completed;02:09:00;02:09:00;02:09:00;02:11:00;02:11:00;02:10:49
PushBack;Completed;02:11:00;02:11:00;02:11:00;02:14:00;02:14:00;02:11:00
Refueling;Completed;01:36:00;01:36:00;01:36:00;01:46:00;01:46:00;01:45:13
Security;Completed;00:11:00;00:11:00;00:11:00;02:11:00;02:11:00;01:37:27
```

* Even though the concept does not consider InBlocks and OffBlocks as sub-processes, for model purposes they are modelled as such.

Figure 3: Data output example for one flight

2.4.2 Exercise Objectives coverage

Using these data outputs, the following parameters are calculated to assess the achievement of the exercise objectives:

- ACT-PCT: Delay of the sub-process with regards to the schedule.
- ACT-ECT: Delay of the sub-process with regards to the model estimation.
- ACT-AST: Real duration of the sub-process.
- PCT-PST: Scheduled duration of the sub-process.
- (ACT-AST) – (PCT-PST): Difference between the real duration and the scheduled one
- Number of (ACT-PCT)>15min.

The following tables describe the relationship between the output data and the Exercise Objectives as extracted from Validation Exercise Plan [5].

2.4.2.1 Exercise V2-01

Exercise Objective	Measurement	Sub-process
Check whether standard deviation of off-block time (AOBT-SOBT) with TITAN is reduced to 3 minutes.	ACT-PCT	Off blocks
Check whether deviation between the estimated and actual end times of processes decreases with TITAN with respect to Non TITAN.	ACT-ECT	All
Check whether deviation between the scheduled and actual duration of processes decreases with TITAN with respect to Non TITAN.	(ACT-AST) - (PCT-PST)	All
Check whether variability of process duration decreases with TITAN with respect to Non TITAN.	ACT-AST	All
Check whether TOBT stability/variability decreases with TITAN with respect to Non TITAN.	Not assessed*	
Check whether number of delayed flights [(AOBT-SOBT)>15min] decreases by 9% with TITAN with respect to Non TITAN.	Percentage of processes in which ACT-PCT>15 min	Off blocks
Check whether delay of every process and the number of processes delayed decrease with TITAN with respect to Non TITAN.	ACT-PCT	All
Check whether turnaround durations decrease with TITAN with respect to non-TITAN.	ACT-AST	Turnaround process
Check whether efficiency and predictability performances are maintained under unexpected events. (This assessment evaluates the flexibility of TITAN with respect to unexpected events).	ACT-PCT ACT-ECT	All
Check the effect of an unexpected event on efficiency and predictability performances (This assessment evaluates the flexibility of TITAN for each unexpected event).	ACT-PCT ACT-ECT	All

*TOBT and number of TOBT updates is not a model output.

Table 5: V2-01 Measurements

2.4.2.2 Exercise V2-02

Exercise Objective	Measurement	Sub-process
Check whether standard deviation of off-block time (AOBT-SOBT) with TITAN is reduced to 3 minutes.	ACT-PCT	Off blocks
Check whether deviation between the estimated and actual end times of processes decreases with TITAN with respect to Non TITAN.	ACT-ECT	All
Check whether deviation between the scheduled and actual duration of processes decreases with TITAN with respect to Non TITAN.	(ACT-AST) - (PCT-PST)	All
Check whether variability of process duration decreases with TITAN with respect to Non TITAN.	ACT-AST	All
Check if TOBT stability/variability decreases with TITAN with respect to Non TITAN.	Not assessed	
Check if number of delayed flights [(AOBT-SOBT)>15min] decreases by 9% with TITAN with respect to Non TITAN.	Percentage of processes in which ACT-PCT>15 min	Off blocks
Check if delay of every process and the number of processes delayed decrease with TITAN with respect to Non TITAN.	ACT-PCT	All
Check if turnaround durations decrease with TITAN with respect to non-TITAN.	ACT-AST	Turnaround process
Check whether efficiency and predictability performances are maintained under unexpected events. (This assessment evaluates the flexibility of TITAN with respect to unexpected events, when the process is already disturbed).	ACT-PCT ACT-ECT	All
Check the effect of an unexpected event on efficiency and predictability performances (This assessment evaluates the flexibility of TITAN for each unexpected event when the process is already disturbed).	ACT-PCT ACT-ECT	All
Check the isolated effect of a disruption in the TITAN concept when an unexpected event occurs.	ACT-AST ACT-PCT Percentage of processes in which ACT-PCT>15 min	All

Table 6: V2-02 Measurements

2.4.2.3 Exercise V2-03

Exercise Objective	Measurement	Sub-process
Check the feasibility and usefulness of different combinations of TITAN Services under normal airport operation and under disrupted airport operation.	ACT-PCT ACT-AST Percentage of processes in which ACT-PCT>15 min	All

Exercise Objective	Measurement	Sub-process
Check whether all turnaround processes adjust their actual end times to the scheduled ones.	ACT-PCT	All
Check whether turnaround duration variability decrease with TITAN with respect to non-TITAN.	(ACT-AST) - (PCT-PST) ACT-AST	Turnaround process

Table 7: V2-03 Measurements

2.4.2.4 Exercise V2-04

Exercise Objective	Measurement	Sub-process
Check whether certain level of turnaround efficiency (assessed through delays) can be maintained under normal airport operation while reducing the number of resources.	ACT-PCT	All
Check whether certain level of turnaround efficiency (assessed through delays) can be maintained under increasing demand while reducing the number of resources.	ACT-PCT	All

Table 8: V2-04 Measurements

2.4.3 Performance framework indicators and data outputs

TITAN Performance Framework [7] defines the Key Performance Indicators (KPI) that *identify **what** information must be obtained to achieve TITAN performance objectives. These indicators quantitatively describe the performance of the turnaround process* [7]. Processing of the measurement data will be performed when analysing the validation results, but identification of the measurements needed to calculate each metric has already been done.

Table 9 shows the KPIs that directly cover TITAN performance targets according to the Validation Plan [5] and the identification of the exercise measurements that will allow obtaining them.

KPI	Metric	Calculation of Metric	Measurement
Variability of ETTT	Time	Standard deviation of ATTT-ETTT	(ACT-AST) - (ECT-EST)
Off Block punctuality	Percentage	% of flights compliant with AOBT-SOBT <15 minutes	Percentage of processes in which ACT-PCT<15 min
Number of flights	Number	Total Number of departure flights per day in the airport	Number of Aircraft whose status is 'Off gate'
Total Delay (Off-Block)	Time	Delay time in minutes per flight (AOBT-SOBT)	ACT-PCT

KPI	Metric	Calculation of Metric	Measurement
Cost reductions (resources used)	Number	Resources used/ number of operated flights	Resources used*/Number of Aircraft whose status is 'Off gate'
Accommodate scheduled changes without increasing delays	Time	AOBT-EOBT for a determined number of Estimated times updates with a difference with the previous one bigger than 15 minutes	ACT-ECT
Recovery delay factor	Percentage	Recovery delay factor = ((possible forced delay in a turnaround process) - (AOBT-SOBT))100/ (AOBT-SOBT)	(Forced delayed**-(ACT-PCT))*100/ ACT-PCT)
Recovery delay factor upon gate reallocation	Percentage***	Recovery delay factor = (delay in the affected process - (AOBT-SOBT))100/ (AOBT-SOBT)	$((ACT\text{-}PCT)_{process\ A}$-$(ACT\text{-}PCT)_{turnaround})100/ ACT\text{-}PCT)_{turnaround}$
Recovery delay factor when lost passenger	Percentage***	Recovery delay factor = ((Delay of the boarding processes) – (Total delay of the turnaround process))100/ (AOBT-SOBT) Recovery delay factor = ((Delay of the loading processes) – (Total delay of the turnaround process))100/ (AOBT-SOBT)	$((ACT\text{-}PCT)_{boarding}$ - $(ACT\text{-}PCT)_{turnaround})100/ ACT\text{-}PCT)_{turnaround}$ $((ACT\text{-}PCT)_{loading}$ - $(ACT\text{-}PCT)_{turnaround})100/ ACT\text{-}PCT)_{turnaround}$
Recovery delay factor when unavailability of a service is detected	Percentage***	Recovery delay factor = ((Delay in the affected process) – (AOBT-SOBT))100/ (AOBT-SOBT)	$((ACT\text{-}PCT)_{processA}$ - $(ACT\text{-}PCT)_{turnaround})100/ ACT\text{-}PCT)_{turnaround}$

*Resources used are defined as part of the Simulation scenario data inputs.
**Forced delays are defined as part of the Simulation scenario data inputs.
***These metrics and their corresponding calculation have been slightly modified from D3.2 to reach units coherency.

Table 9: Performance Framework KPIs and measurements

2.5 Statistical methods

To assess data outputs reliability a statistical analysis of data output was carried out. Statistical analysis has been performed over the post-processed measurements used to assess the level of achievement of the exercise objectives;

- ACT-PCT
- ACT-ECT
- ACT-AST
- (ACT-AST) – (PCT-PST)
- Percentage of processes in which (ACT-PCT) >15min

The statistical parameters obtained are:

- Mean of each measurement of every turnaround sub-process: It is used to estimate the central trend of the sub-process measurement (sub-process delay or sub-process duration average).
- Standard deviation (σ) of each measurement of every turnaround sub-process: It is used to estimate the dispersion of the data measurement (dispersion of the sub-processes delays or sub-processes durations).

- Confidence interval (C.I.) of the off-block sub-process delay: It ensures reliability of the data measurement by calculating the interval that contains an established percentage (Confidence level, α) of the data measurement.

Figure 4 shows the definition of these three statistical parameters.

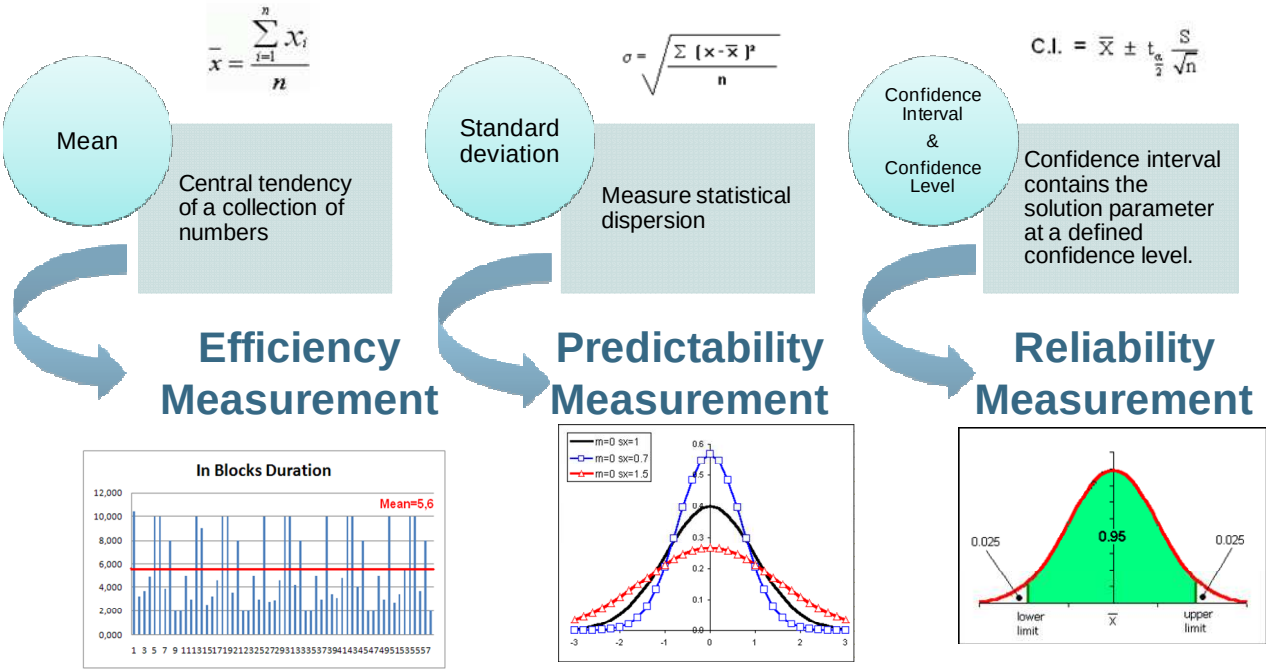

Figure 4: Statistical parameters

Each Simulation scenario was run until the data outputs reached a confidence level of 0.95 for the off-block sub-process delay and a confidence interval of 0.33 minutes (20 seconds). That means that 95% of the flights of the simulation scenario had an off-block sub-process delay within the interval of ±20 seconds around the Mean value of all off block process delays assuming a normal distribution. Confidence interval is directly proportional to the standard deviation and inversely proportional to the number of data. For this reason, when the dispersion of the data is very high (there are flights with very high delays and flights with very low delays), much more simulation runs are necessary in order to achieve the desired confidence interval.

In some Simulation scenarios delay results are narrowly dispersed among a small group of flights and therefore standard deviation is very high. It was observed that after five simulation runs, mean and standard deviation of all measurements becomes stable. Therefore, it was decided to establish a maximum number of five simulations even though the interval confidence was greater than 20 seconds. In any case, confidence interval data are provided for consideration in the exercise analysis.

Following tables show the Statistical data obtained for each simulation run:

Firstly, the mean of each one of the indirect model outputs was obtained. This way, these mean values can be easily compared and analysed.

Sub-process	ACT-PCT Average	ACT-ECT Average	ACT-AST Average (duration average)	(ACT-AST) – (PCT-PST) Average (duration deviation average)	Number of sub-processes in which (ACT-PCT)>15min	Percentage of sub-processes in which (ACT-PCT)>15min
Baggage Loading*	-29,10	-28,83	31,20	-88,80	0	0 %
Baggage Loading AS*	-16,94	-19,20	9,67	-19,96	9	1 %
Baggage Unloading	-2,21	-3,67	10,64	-5,23	74	4 %
Boarding	0,31	-1,94	21,80	-1,20	135	8 %
Catering	0,15	-1,45	8,99	-1,01	43	3 %
Check-In	-5,80	-5,60	84,06	-5,80	0	0 %
Cleaning	1,09	-0,76	4,49	-0,51	56	3 %
De-Boarding	-2,90	-4,36	9,99	-4,64	90	5 %
In-Block	1,47	0,01	1,75	-0,25	66	4 %
Off-Block	3,44	1,18	1,76	-0,24	134	8 %
Pushback	2,32	0,06	1,75	-1,25	119	7 %
Re-Fuelling	0,64	-1,62	8,99	-1,01	57	3 %
Security Control	-31,60	-30,84	88,40	-31,60	0	0 %

* TITAN Operational concept [11] considers the sub-process Baggage Loading; however the model has divided it into two sub-processes (Baggage Loading and Baggage Loading AS) for modelling purposes.

Table 10: GEN1AExe1 Calculated Means

Secondly, the standard deviation of each value (excepting the number of sub-processes with a delay bigger than 15 minutes) was calculated. This will serve as a measurement of the variability in each sub-process.

Sub-process	ACT-PCT Standard deviation	ACT-ECT Standard deviation	ACT-AST Standard deviation (duration standard deviation)	(ACT-AST) – (PCT-PST) Standard deviation (duration deviation standard deviation)
Baggage Loading	7,07	8,15	24,34	24,34
Baggage Loading AS	7,12	6,36	4,61	4,72
Baggage Unloading	8,62	5,62	2,42	3,04
Boarding	10,52	10,00	7,66	7,66
Catering	5,09	4,52	0,33	0,33

Sub-process	ACT-PCT Standard deviation	ACT-ECT Standard deviation	ACT-AST Standard deviation (duration standard deviation)	(ACT-AST) – (PCT-PST) Standard deviation (duration deviation standard deviation)
Check-In	6,15	6,18	6,82	6,15
Cleaning	5,63	4,33	0,17	0,17
De-Boarding	9,54	7,05	6,20	6,04
In-Block	6,72	2,71	0,08	0,08
Off-Block	8,09	8,00	0,09	0,09
Pushback	7,62	7,49	1,15	1,15
Re-fuelling	5,89	4,95	0,34	0,34
Security Control	6,38	7,85	6,38	6,38

Table 11: GEN1AExe1 Calculated Standard deviations

Finally, the confidence interval is calculated according to the number of measurements, e.g. for the presented simulation scenario (GEN1AExe1) five fast time simulations (24h each one) were run (each simulation contains 339 flights), and therefore the results correspond to 339*5=1695 off-block delay measurements. The mean of the off-block delay is 3.44 minutes, with a standard deviation of 8.09 minutes and a confidence interval of 23 seconds. In other words, off-block delay of 95% of all flights falls within the interval 3.44 ± 0.39 minutes (03:05 minutes, 03:50 minutes) assuming a normal distribution of the off-block delay.

2.6 Exercise conduction methodology

2.6.1 Simulation Scenario configuration

Before conducting the simulation exercises all scenarios were configured in the model. Simulation scenario parameters were provided in Annex 4 of the Validation Exercise Plan [5]. However, the value of some parameters was not fixed in this deliverable. While running the simulations a pre-analysis of the obtained results was performed to fix the best suitable value for these parameters. Moreover, refinement of the values of some of the initial parameters was needed to ensure the feasibility of assessing the validation objectives according to the model features or to optimise the validation exercise conduction activity. The final parameters are presented in:

- Annex 1: It describes all TITAN Simulation scenario parameters configured for the validation exercises.
- Annex 2: It describes how TITAN Services are implemented in the model.
- Annex 3: It describes the decisions made during TITAN validation exercises.

TITAN_WP3_CRI_INT_01_PU_v0.4_ Guidelines for the configuration of the Validation scenarios [8] was elaborated as part of the training material for the users conducting the exercises. It contains the steps to be followed to configure each parameter in TITAN model.

2.6.2 Exercise conduction

Validation activities were performed by the simulation team provided with guidelines [8] containing detailed instructions for the execution of the simulation exercises. Before the conduction of the exercises, two training sessions were carried out to explain how to use the model, how to conduct the exercises and how to check results reliability before storing the data output files.

Two Simulation scenarios were used as baseline simulation scenarios. Each further Simulation scenario was configured by changing different parameters in those two baseline scenarios. The user guidelines [8] provided detailed information about which parameters had to be changed in each specific case and how they should be changed. After configuring each Simulation scenario they were asked to save and name them according to a pre-established coding. Therefore, all Simulation scenarios were stored and could be used in case that new runs were needed later on.

While simulations were running, the simulation team performed checks to:

- Ensure that there were no simulation errors. If an error occurred during the simulation, the model wouldn't show any values of the process time parameters but empty data outputs instead. At the end of each simulation, technicians checked that all data outputs had been provided by the model.
- Ensure that the simulation time was coherent with the Simulation scenario definition. The most critical the Simulation scenario was, the largest the amount of the delayed processes would be. It was expected that the model would need more time to complete a 24-hour schedule for Simulation scenarios with a high number of delayed processes (e.g, if a baseline Simulation scenario was completed in 24 hours and some minutes, a simulation scenario with severe disruptions in critical processes could need 27 hours approximately).
- Observe which types of delays occurred during the simulation. Whenever the model was confronted with delayed sub-processes, it showed them in red. Technicians could randomly check if the disruption introduced in a turnaround process, the lack of a resource or any other value input parameter was causing flight delays.

Figure 5 shows the HMI of the model where the simulation team can check this information. The example shows a Simulation scenario with a forced delay in refuelling. It results in a delay in other sub-processes such as boarding, off-block or pushback which seems logical.

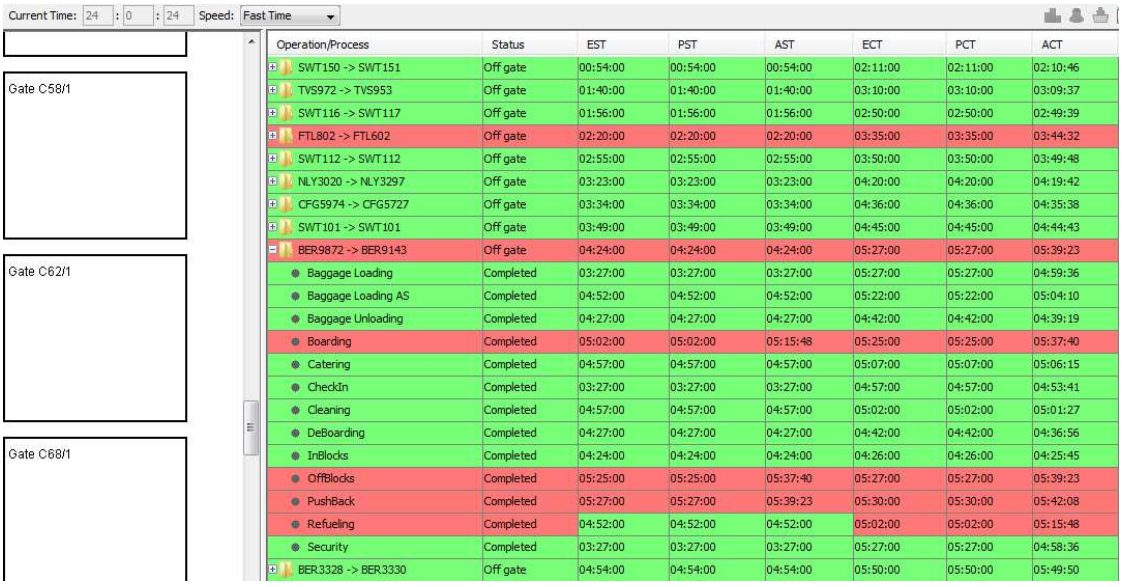

Figure 5: TITAN model screenshot during a simulation.

2.6.3 Assessment of the results quality/ Quality checks performed

Once the reliability of the data output file for each Simulation scenario had been ensured (the achieved confidence interval was adequate), a pre-analysis of the output data was carried out in order to detect possible mistakes made during the Simulation scenario configuration.

This analysis was based on indirect data outputs obtained as described in section 2.4.2. and can be summarised as follows:

- Comparing data outputs with baseline Simulation scenarios: All Simulation scenarios reproduce a situation more critical than the one of the baseline scenario, so general parameters should not show any improvement compared to the baseline (except for TITAN Simulation scenarios).
- Comparing with similar Simulation scenarios: Some Simulation scenarios differ only in one parameter (e.g. simulation scenarios where 5%, 10% or 15% of all passengers are stopped at security control. In these Simulation scenarios, the delay in the security control process should increase progressively. The number and the percentage of flights with a delay greater than 15 minutes in that process should also increase).
- Comparing with “no disruption” Simulation scenario: All Simulation scenarios with a forced delay are based on a Simulation scenario without the particular disruption. Results from a Simulation scenario with a forced delay in a certain sub-process should show an increase of the mean of the delays in that sub-process (and it may affect other sub-processes too) and an increase of the standard deviation of it. The number and the percentage of flights with a delay greater than 15 minutes in that sub-process should also increase.
- Checking that the confidence interval decreases: Each time a new data output file is added to the pre-analysis data document (an excel file) the confidence interval is reduced progressively. See section 2.5 for detailed information about the process followed to ensure an adequate confidence interval.

2.7 Assumptions

Following assumptions where made during the simulation exercises:

- As described in Single Aircraft Turnaround Model Software Design Document [2], TITAN model manages two different types of resources (Fixed resources and Mobile resources). Fixed resources are associated with a specific airline or handling company (e.g. baggage drops or check-in desks). However, in order to simplify Simulation scenario configuration, mobile resources (such as buses or baggage trucks) are shared between all aircrafts at the airport. This assumption results in an optimistic efficiency of the resource management.
- The refuelling cannot be performed during passenger boarding.
- The passenger boarding sub-process can be extended maximum 30 minutes for late passengers in non TITAN scenarios.
- TITAN services have been modelled via a set of standardized decisions taken during the TITAN Simulation scenarios. They are presented below in Annex 4.

3 EXERCISE RESULTS

3.1 Data Output Files

Data output obtained was described in detail in 2.4. TITAN model produces a text file for each simulation. Data output text files were named following the convention:

- File names follow the structure: SCENXAExeY_Z.
- First six letters 'SCENXA' identify the Validation scenario (e.g. SPEC1A, GEN2B, etc.)
- 'ExeY' identifies the Simulation scenario.
- 'Z' is a number to identify each simulation run of the same Simulation scenario (having the same value parameters).

This way, text file *SPEC4AExe3_2* contains the results of the second simulation of the Simulation scenario SPEC4AExe3.

3.2 EXERCISE RESULTS

Exercise results are organised by Validation scenarios in a data output file package (Annex 4). Data output files are organised in six folders:

- GEN1: contains GEN1A and GEN1B Simulation scenarios.
- GEN2: contains GEN2A and GEN2B Simulation scenarios.
- SPEC1: contains Simulation scenarios SPEC1A, SPEC1B, SPEC1C and SPEC1D.
- SPEC2: contains Simulation scenarios SPEC2A, SPEC2B, SPEC2C and SPEC2D.
- SPEC3: contains Simulation scenarios SPEC3A, SPEC3B, SPEC3C and SPEC3D.
- SPEC4: contains Simulation scenarios SPEC4A, SPEC4B, SPEC4C and SPEC4D.
-

Each folder contains the data output files of all simulation runs, correctly identified according to the naming convention explained in section 3.1

ANNEX 1: SIMULATION SCENARIO PARAMETER IDENTIFICATION

This annex comprises the tables that identify the Simulation scenario parameters. Annex 4 of the Validation Exercise Plan (Exercise configuration) [5] has been used as a baseline and has been updated according to the final parameters configured in the Simulation scenarios.

The aim of this annex is to register parameter configuration in the Validation scenarios as well as to justify respective changes serving as baseline material for both, technicians running the exercises and the personnel conducting the simulation data analysis.

Following general criteria applied to the parameter configuration for all Validation scenarios:

- 'Refuelling during boarding' was not allowed in any Validation scenario. This parameter was initially defined as a variable parameter. However, it was fixed in order to reduce the number of simulation runs. The most restrictive condition was further considered.
- Connecting passengers were not modelled despite the fact that this feature is implemented in the TITAN model. There is no specific validation objective or TITAN Service involving connecting passengers; therefore it was decided not to model them to avoid adding more complexity to the Simulation scenarios.
- Baggage and Passenger monitoring points are not considered as parameters in the Simulation scenario configuration. They indirectly depend on the TITAN Services implementation described in Annex 2.
- The same 'Airline Policy' applies to all Simulation scenarios, concerning the time that an aircraft waits for missing passengers, being established as a maximum of 30 minutes in non TITAN Simulation scenarios. In TITAN Simulation scenarios this time varies depending on where the entities are located at closing time.

There are some parameters that have different values depending on the Simulation scenario. They are described below:

- 'Will the aircraft wait for passengers?': During non TITAN simulations the model does not inform about how many passengers are not on board. If there is a high delay, the aircraft departs leaving behind a large number of passengers without having a high impact on the turnaround performance though (off-block time delay). Therefore, in order to obtain comparable results with TITAN Simulation scenarios, non TITAN Simulation scenarios were configured to wait for passengers. It was decided that if at estimated closing time not all passengers were on board, boarding gate would remain open for another 30 minutes.
- 'TITAN Services Availability?': If TITAN Services are enabled, the interaction points described in Annex 2 are activated during the simulation.
- 'Disruption (forced delay in…)': Some Simulation scenarios have a forced delay in one or several sub-processes. This feature was modelled by including a delay of 15 minutes at the end of a turnaround process. This delay affects up to 30% of the scheduled flights.
- 'UM and/or PRMs passengers': Passenger definition is included in arrival and departure manifest files. These files describe the number of passengers for each flight and some of their characteristics such as number of bags, if the passenger is VIP or not and if there are special passengers. A normal distribution is used to introduce the amount of special passengers in the traffic sample. TITAN Model generates a different number of special passengers in each simulation. Two different arrival/departure manifest files were created including or not special passengers.

Additionally to these parameters there are some other specific ones that vary only in the related specific Validation scenarios:

- % of passengers arriving late to check-in

- % of passengers arriving late to boarding
- Baggage stopped for security issues
- Passenger stopped at security control
- Passenger stopped at Passport Control
- % of increment of the number of flights
- % of the flights arriving late
- % of lack of turnaround mobile resources

1. GEN1A

Runs	4				
Generic Parameters	Will the aircraft wait for passengers?	YES		NO	
	TITAN Services Availability	NO			
	Disruption (forced delay in…)	NO			
	UMs and/or PRMs	YES	NO	YES	NO
Simulation scenario Id.		GEN1AExe1	GEN1AExe2	GEN1AExe3	GEN1AExe4

Table 12: GEN1A

2. GEN1B

Runs	1	
Generic Parameters	Will the aircraft wait for passengers?	Depending on the estimated time on passenger arrival to boarding (see Annex 3)
	TITAN Services Availability	YES
	Disruption (forced delay in…)	NO
	UMs and/or PRMs	YES
Simulation scenario Id.		GEN1BExe1

Table 13: GEN1B

3. GEN2A

Runs	9								
Generic Parameters	Will the aircraft wait for passengers?	YES							NO
	TITAN Services Availability	NO							
	Disruption (forced delay in…)	Check-in	SC	Fuelling	De-boarding	Loading	Un-loading	Start-up	SC	Check-in
	UMs and/or PRMs	YES								
Simulation scenario Id.		GEN2AExe2	GEN2AExe3	GEN2AExe5	GEN2AExe6	GEN2AExe7	GEN2AExe8	GEN2AExe9	GEN2AExe10	GEN2AExe12

Table 14: GEN2A

4. GEN2B

Runs	2		
Generic Parameters	Will the aircraft wait for passengers?	Depending on the estimated time on passenger arrival to boarding	
	TITAN Services Availability	YES	
	Disruption (forced delay in…)	Fuelling	Un-Loading
	UMs and/or PRMs	YES	
Simulation scenario Id.		GEN2BExe5	GEN2BExe8

Table 15: GEN2B

5. SPEC1A

Runs	15														
Generic Parameters	TITAN Services Availability	NO													
	Disruption (forced delay in…)	NO													
	UMs and/or PRMs	YES													
Specific Parameters	% of passenger arriving late to check-in/ Mean value	12%/ 0.6	24%/ 0.65	43%/ 0.7	NO			NO			NO			NO	
	% of passengers arriving late to boarding (checked in)/ Turnaround affected/ Delay	NO			10%./D/ 30 min	10%/D+I/ 30 min	10%/D+I+S+NS/30mi	NO			NO			NO	
	% of baggage stopped for security issue / Turnaround affected	NO			NO			5%/D	5%/D+I	5%/D+I+NS	NO			NO	
	% of passenger stopped at security control / Turnaround affected	NO			NO			NO			5%/D	5%/D+I	5%/D+I+NS	NO	
	% of passenger stopped at PC/ Turnaround affected	NO			NO			NO			NO			5%/NS	10%/NS	15%/NS
Simulation scenario Id.		SPEC1AExe1	SPEC1AExe2	SPEC1AExe3	SPEC1AExe4	SPEC1AExe5	SPEC1AExe6	SPEC1AExe7	SPEC1AExe8	SPEC1AExe9	SPEC1AExe10	SPEC1AExe11	SPEC1AExe12	SPEC1AExe13	SPEC1AExe14	SPEC1AExe15

D: Turnaround Disruption/ I: Turnaround Interisland/ S: Turnaround Schengen/ NS: Turnaround NonSchengen.

Table 16: SPEC1A

6. SPEC1B

Run	3			
Generic Parameters	Will the aircraft wait for passengers?	Depending on the estimated time on passenger arrival to boarding		
	TITAN Services Availability	YES		
	Disruption (forced delay in…)	NO		
	UMs and/or PRMs	YES		
Specific Parameters	% of passenger stopped at security control/ Turnaround affected	5%/ D+I	5%/ D+I	5%/ D+I
Simulation scenario Id.		SPEC1BExe11	SPEC1BExe11 Sub-scenario 1 (only PFIS, BFIS enabled)	SPEC1BExe11 Sub-scenario 2 (only ASRS, AIRS enabled)

Table 17: SPEC1B

7. SPEC1C

Runs	42																											
Generic Parameters	TITAN Services Availability	NO																										
	Disruption (forced delay in…)	Check-in	De-Boarding	Fuelling	Check-in	De-Boarding	Fuelling	Check-in	De-Boarding	Fuelling	Boarding	De-Boarding	Fuelling	Boarding	De-Boarding	Fuelling	Boarding	De-Boarding	Fuelling	De-Boarding	Fuelling	Loading	De-Boarding	Fuelling	Loading	De-Boarding	Fuelling	Loading
	UMs /PRM	YES																										
Specific Parameters	% of passenger arriving late to check-in/ Mean value	12% / 0.6			24% / 0.65			43% / 0.7			NO									NO								
	% of passengers arriving late to boarding (checked in)/ Turnaround affected/ Delay	NO									10%. / D / 30 min			10% / D+I/ 30 min			/ D+I+S+NS / 30min			NO								
	% of baggage stopped for security issue / Turnaround affected	NO									NO									5% / D			5% / D+I			5%/ D+I+NS		
	% of passenger stopped at security control / Turnaround affected	NO									NO									NO								
	% of passenger stopped at PC/ Turnaround affected	NO									NO									NO								
Simulation scenario Id.		SPEC1CExe1	SPEC1CExe2	SPEC1CExe3	SPEC1CExe4	SPEC1CExe5	SPEC1CExe6	SPEC1CExe7	SPEC1CExe8	SPEC1CExe9	SPEC1CExe10	SPEC1CExe11	SPEC1CExe12	SPEC1CExe13	SPEC1CExe14	SPEC1CExe15	SPEC1CExe16	SPEC1CExe17	SPEC1CExe18	SPEC1CExe19	SPEC1CExe20	SPEC1CExe21	SPEC1CExe22	SPEC1CExe23	SPEC1CExe24	SPEC1CExe25	SPEC1CExe26	SPEC1CExe27

Generic Parameters	TITAN Services Availability	NO														
	Disruption (forced delay in…)	SC	De-Boarding	Fuelling	SC	De-Boarding	Fuelling	SC	De-Boarding	Fuelling	De-Boarding	Fuelling	De-Boarding	Fuelling	De-Boarding	Fuelling
	UMs /PRM	YES														
Specific Parameters	% of passenger arriving late to check-in/ Mean value	NO									NO					
	% of passengers arriving late to boarding (checked in)/ Turnaround affected/ Delay	NO									NO					
	% of baggage stopped for security issue / Turnaround affected	NO									NO					
	% of passenger stopped at security control / Turnaround affected	5%/D			5%/D+I			5%/D+I+NS			NO					
	% of passenger stopped at PC/ Turnaround affected	NO									5%/NS		10%/NS		15%/NS	
Simulation scenario Id.		SPEC1CExe28	SPEC1CExe29	SPEC1CExe30	SPEC1CExe31	SPEC1CExe32	SPEC1CExe33	SPEC1CExe34	SPEC1CExe35	SPEC1CExe36	SPEC1CExe38	SPEC1CExe39	SPEC1CExe41	SPEC1CExe42	SPEC1CExe44	SPEC1CExe45

Table 18: SPEC1C

8. SPEC1D

Runs	1	
Generic Parameters	Will aircraft wait for passengers?	Depends on estimated time of arrival to the gate
	TITAN Services Availability	YES
	Disruption (forced delay in…)	Fuelling
	UMs and/or PRMs	YES
Specific Parameters	% of passenger stopped at security control / Turnaround affected	5%/D+I
Simulation scenario Id.		SPEC1DExe33

Table 19: SPEC1D

9. SPEC2A

Runs	3			
Generic Parameters	TITAN Services Availability	NO		
	Disruption (forced delay in…)	NO		
Specific Parameters	UMs and/or PRMs	YES		
	Increase the number of flights	10%	20%	30%
Simulation scenario Id.		SPEC2AExe1	SPEC2AExe2	SPEC2AExe3

Table 20: SPEC2A

10. SPEC2B

Runs	3	
Generic Parameters	TITAN Services Availability	YES
	Disruption (forced delay in…)	NO
	UMs and/or PRMs	YES
Specific Parameters	Increase the number of flights	20%
Simulation scenario Id.		SPEC2BExe2

Table 21: SPEC2B

11. SPEC2C

Runs	21																							
Generic Parameters	TITAN Services Availability	NO																						
	Disruption (forced delay in…)	Check-in	SC	Fuelling	De-boarding	loading	Un-loading	Start-up	Check-in	SC	Fuelling	De-boarding	loading	Un-loading	Start-up	Check-in	SC	Fuelling	De-boarding	loading	Un-loading	Start-up		
	UMs and/or PRMs	YES																						
Specific Parameters	Increase the number of flights	10%							20%							30%								
Simulation scenario Id.		SPEC2CExe2	SPEC2CExe3	SPEC2CExe5	SPEC2CExe6	SPEC2CExe7	SPEC2CExe8	SPEC2CExe9	SPEC2CExe11	SPEC2CExe12	SPEC2CExe14	SPEC2CExe15	SPEC2CExe16	SPEC2CExe17	SPEC2CExe18	SPEC2CExe20	SPEC2CExe21	SPEC2CExe23	SPEC2CExe24	SPEC2CExe25	SPEC2CExe26	SPEC2CExe27		

Table 22: SPEC2C

12. SPEC3A

Runs	3			
Generic Parameters	TITAN Services Availability	NO		
	Disruption (forced delay in…)	NO		
	UMs and/or PRMs	YES		
Specific Parameters	Flights arriving late	10%	20%	30%
Simulation scenario Id.		SPEC3AExe1	SPEC3AExe2	SPEC3AExe3

Table 23: SPEC3A

13. SPEC3B

Runs	1	
Generic Parameters	Will the aircraft wait for passengers?	Depending on the estimated time on passenger arrival to boarding
	TITAN Services Availability	YES
	Disruption (forced delay in…)	NO
	UMs and/or PRMs	YES
Specific Parameters	Flights arriving late	20%
Simulation scenario Id.		SPEC3BExe2

Table 24: SPEC3B

14. SPEC3C

Runs	21																							
Generic Parameters	TITAN Services Availability	NO																						
	Disruption (forced delay in…)	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up		
	UMs and/or PRMs	YES																						
Specific Parameters	Flights arriving late	10%							20%							30%								
Simulation scenario Id.		SPEC3CExe2	SPEC3CExe3	SPEC3CExe5	SPEC3CExe6	SPEC3CExe7	SPEC3CExe8	SPEC3CExe9	SPEC3CExe11	SPEC3CExe12	SPEC3CExe14	SPEC3CExe15	SPEC3CExe16	SPEC3CExe17	SPEC3CExe18	SPEC3CExe20	SPEC3CExe21	SPEC3CExe23	SPEC3CExe24	SPEC3CExe25	SPEC3CExe26	SPEC3CExe27		

Table 25: SPEC3C

15. SPEC4A

Runs	3			
Generic Parameters	TITAN Services Availability	NO		
	Disruption (forced delay in…)	NO		
	UMs and/or PRMs	YES		
Specific Parameters	Lack of turnaround resources	YES		
	Required turnaround resources different from planned	Lack of 10% mobile resources	Lack of 20% mobile resources	Lack of 30% mobile resources
Simulation scenario Id.		SPEC4AExe1	SPEC4AExe2	SPEC4AExe3

Table 26: SPEC4A

16. SPEC4B

Runs	1	
Generic Parameters	Will the aircraft wait for passengers?	Depending on the estimated time on passenger arrival to boarding
	TITAN Services Availability	YES
	Disruption (forced delay in…)	NO
	UMs and/or PRMs	YES
Specific Parameters	Lack of turnaround resources	YES
	Required turnaround resources different from planned	Lack of 20% mobile resources
Simulation scenario Id.		SPEC4BExe2

Table 27: SPEC4B

17. SPEC4C

Runs	21																							
Generic Parameters	TITAN Services Availability	NO																						
	Disruption (forced delay in…)	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up	check-in	SC	Fuelling	De-boarding	loading	un-loading	Start-up		
	UMs and/or PRMs	YES																						
Specific Parameters	Lack of turnaround resources	YES																						
	Required turnaround resources different from planned	Lack of 10% mobile resources							Lack of 20% mobile resources							Lack of 30% mobile resources								
Simulation scenario Id.		SPEC4CExe2	SPEC4CExe3	SPEC4CExe5	SPEC4CExe6	SPEC4CExe7	SPEC4CExe8	SPEC4CExe9	SPEC4CExe11	SPEC4CExe12	SPEC4CExe14	SPEC4CExe15	SPEC4CExe16	SPEC4CExe17	SPEC4CExe18	SPEC4CExe20	SPEC4CExe21	SPEC4CExe23	SPEC4CExe24	SPEC4CExe25	SPEC4CExe26	SPEC4CExe27		

Table 28: SPEC4C

ANNEX 2: TITAN Services Modelling

Table 29 summarises the interaction points defined according to internal document Interaction points for the Model *[9].* The meaning of the following fields is:

- Milestone ID: Milestone identity defined for each interaction point.
- Sub-process: Sub-Process of the turnaround the milestone is referring to.
- Type: Time stamp in the sub-process that the milestone is associated to regarding scheduled time, sub-process late to start or sub-process late to complete.
- Description: Short description to clarify the meaning of the milestone.
- Trigger: Reason for the interaction point to appear (gate not available, lack of resources, process not completed…).

Milestone ID	Sub-process	Type	Description	Trigger
M7	In-block	Process late to start	EIBT is going to be missed	Original gate not available
M8	Ground Handling (Baggage Unloading Baggage Loading Catering Cleaning De-icing Power Supply Refuelling)	Process late to start	Start of Ground Handling is going to be missed	Ground handling cannot start due to lack of resources for 1st process
M11A	Boarding	Process late to start	Start of Boarding is going to be missed	Process cannot start due to lack of resources
M11B	Boarding	Process late to complete	End of Boarding is going to be missed	Process not completed at scheduled time
M15	Off block	Process late to complete	SOBT is going to be missed	Processes not completed at scheduled time
M17	Check-In	Process late to complete	End of Check-In is going to be missed	Process not completed at scheduled time

Milestone ID	Sub-process	Type	Description	Trigger
M18	Security	Process late to complete	End of Security Control is going to be missed	Process not completed at scheduled time
M19	Passport	Process late to complete	End of Passport Control is going to be missed	Process not completed at scheduled time
M20	De-boarding	Process late to start	Start of De-boarding is going to be missed	Process cannot start due to lack of resources
M21	Baggage loading	Process late to complete	End of Baggage Loading is going to be missed	Process not completed at scheduled time
M22	Baggage Unloading	Process late to start	Start of Baggage Unloading is going to be missed	Process cannot start due to lack of resources
M23	Baggage loading AS	Process late to start	Start of Baggage Loading AS is going to be missed	Process cannot start due to lack of resources
M24	Refuelling	Process late to start	Start of Refuelling is going to be missed	Process cannot start due to lack of resources
M25	Pushback	Process late to start	Start of Pushback is going to be missed	Process cannot start due to lack of resources
M26	De-icing	Process late to start	Start of De-icing is going to be missed	Process cannot start due to lack of resources

Table 29: Interaction Points for the TITAN Model

ANNEX 3: Decisions followed on TITAN Simulation Scenarios

Table 30 summarizes the common decisions taken during the validation activities (in TITAN Simulation scenarios) for each interaction point. The meaning of the following fields is:

- Milestone ID: Milestone identity defined for each interaction point. It is shadowed in blue if it appeared in all TITAN Simulation scenarios, in grey if it never appeared and in pink if it appeared in some of them.
- Options Available: Options defined in the internal document Interaction Points for the TITAN Model [9] for each interaction point.
- Option Chosen: Common decisions chosen in the validation activities.
- Simulation scenario: Simulation scenario where the interaction point was shown.

Milestone ID	Options Available	Option Chosen	Simulation scenario
M7	1. Wait for gate to become available 2. Choose a random gate * 3. Choose an alternate gate manually * *from a subset of gates estimated to be free for the next X minutes	Option 2 (X= 01:30:00)	All***
M8	1. Prioritise this process in resource acquisitions 2. Start a different process 3. Cancel process 4. Wait for period x 5. Do nothing	Option 2 (Start Refuelling)	All***
M11A	1. Do nothing (wait for process to start) 2. Prioritise process in resource acquisitions 3. Start process immediately 4. Extend for duration X	- If the company code is different from BER or ANE: Option 1 - If the company code is BER or ANE: Option 2	None

Milestone ID	Options Available	Option Chosen	Simulation scenario
M11B	1. Wait for process to be completed 2. Extend for duration X 3. Close process	PFIS Checking: - If at least one passenger is "Past boarding gate" or "At boarding gate or queue": Option 1 ** - If at least one passenger is "Past passport desk"/ "Past passport interrogation room" for NonSchengen/International turnaround or "Past security desk" / "Past security interrogation room" for the other turnarounds: Option 2 (X=10 minutes) - If at least one passenger is "At passport desk or queue" for NonSchengen/International turnaround or "At security desk or queue" for the other turnarounds: Option 2 (X=15 minutes) - If at least one passenger is "Past security desk" for NonSchengen/International turnaround or "Past check-in desk" for the other turnarounds: Option 2 (X=20 minutes) - If at least one passenger is "Past check-in desk" NonSchengen/International turnaround: Option 2 (X=25 minutes) - If passengers is only "At passport or security interrogation room" : Option 3 ** "Standard passengers missed check-in" are never considered in the flow.	All***
M15	1. Do nothing (wait for processes to be completed) 2. Prioritise flight (and its processes) in resource acquisitions 3. Leave immediately (close all processes) 4. Close processes (from list)	- If Security is running, check PFIS. If passengers are only "At security interrogation room": Option 4 (Close Security) - If Passport is running, check PFIS. If passengers are only "At passport interrogation room": Option 4 (Close Passport) - If Baggage Loading is running, check BFIS. If bags are only "At baggage interrogation room": Option 4 (Close Baggage Loading) - If any other: Option 1	All***
M17	1. Extend for duration X 2. Close process 3. Open new desk (to remain open for X at most)	Option 2	All***

Milestone ID	Options Available	Option Chosen	Simulation scenario
M18	1. Do nothing (either use defined extension period or close process) 2. Search for entities to move 3. Open new desk (to remain open for X at most)	- If passengers are only "At security interrogation room or queue": Option 2 - If any other: Option 1	SPEC1BExe11 SPEC1BExe11 sub-scenario1 SPEC1BExe11 sub-scenario2 SPEC1DExe33
M19	1. Do nothing (either use defined extension period or close process) 2. Search for entities to move 3. Open new desk (to remain open for X at most)	- If passengers are only "At passport interrogation room or queue": Option 2 - If any other: Option 1	None
M20	1. Do nothing (wait for process to start) 2. Prioritise process in resource acquisitions 3. Start process immediately 4. Extend for duration X	- If the company code is different from BER or ANE: Option 1 - If the company code is BER or ANE: Option 2	All***
M21	1. Wait for process to complete 2. Do nothing (either use defined extension period or close process)	Option 2	All***
M22	1. Do nothing (wait for process to start) 2. Prioritise resources for this process 3. Start process immediately	M22 coincides with M8 in all the Simulation scenarios. The decision is done according to M8	None

Milestone ID	Options Available	Option Chosen	Simulation scenario
M23	1. Do nothing (wait for process to start) 2. Prioritise resources for this process 3. Start process immediately	- If the company code is different from BER or ANE: Option 1 - If the company code is BER or ANE: Option 2	All***
M24	1. Do nothing (wait for process to start) 2. Prioritise resources for this process 3. Start process immediately	- If the company code is different from BER or ANE: Option 1 - If the company code is BER or ANE: Option 2	None
M25	1. Do nothing (wait for process to start) 2. Prioritise resources for this process 3. Start process immediately	- If the company code is different from BER or ANE: Option 1 - If the company code is BER or ANE: Option 2	None
M26	1. Do nothing (wait for process to start) 2. Prioritise resources for this process 3. Start process immediately	De-icing is disabled in all the Simulation scenarios	None

***Simulation scenarios with TITAN: GEN1B, GEB2BExe5, GEN2BExe8, SPEC1BExe11, SPEC1BExe11 sub-scenario1, SPEC1BExe11 sub-scenario2, SPEC1DExe33, SPEC2BExe2, SPEC3BExe2, SPEC4BExe2

Table 30: Decisions taken during validation activities

ANNEX 4: Exercise results