The Calibration of Air Traffic Simulation Model

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Synopsis

The increase of the flight operations and the demand to guarantee a suitable level of service it makes necessary both to foresee what the principals are "bottle necks " of the airport infrastructure, both to hypothesize some future scenarios where the infrastructure can increase his own question. The elevated number of the aleatory variable connected to the phenomenon has pushed to the use of the simulation models to foresee the development of the airport system seeking the maximum number of compatible operations with a scenery of hypothesized intervention. The application in the airport Naples-Capodichino has been performed with the *Simmod*, official simulator of FAA and EEC, defining the characteristics of the aerial traffic simulation system and individualizing the principal subsystems that represent it:

1. approach;
2. landing;
3. take-off;
4. leaving;
5. taxing.

The runways, the taxiways, the airport features and the airport stands have been reproduced analyzing the airport infrastructure.

This model has been inserted in the *Simmod* as initial scenery, inserting all the characteristics of the system. The management of the aircraft movement in arrival and in departure from the airport has been conducted implementing in the software the functions of drawn probcapacity to analyze the official fly schedule. They appears as the aleatory variable and it's important to know the laws of probcapacity. These last ones have been determined through the techniques of the statistic inference.

The statistic function has been implemented in the Simmod and it's used by the simulator to manage the aleatory events that are followed during the simulation.

Since the combination of arrivals and departures on an airport it's a aleatory variable, to get a stable result of simulation, we have performed thirty cycles of run, at the end of which it's drawn the average delay for flight operation. The inferred delays distribution curve and the theoretical function defined to real fly patterns, we have been checked with the statistic test χ^2. With a following validation, the Simmod can implement some statistic functions, characteristics of some real aircraft behaviours, that as default can be used in similar infrastructures.

1.   THE MODEL SIMULATION STUDY

1.1.   Introduction

A model is a representation of the reality gotten with a simplified and generalized formulation of the principal characteristics of a real situation; it's used to understand the behavior of a system in situations where, for technical, economic, political or moral motives, the experimentation is not possible. In the airport sector, the model seems particularly advantageous for the advantages that it offers on the infrastructures project operations, on the verification operations of the Levels of Service of the existing components, on the rationalization and regulation operations of the people and commodities mobility management. The use of the model is justified by three principal motives:

1. The difficulty to foresee the impacts following to the realization of interventions on the components of the transports system;
2. the difficulty to realize experiments on the place for the costs and the organizational problems that they involve;
3. the complexity of the phenomenon that concerning the mobility.

Entering in the specific of present research, it's possible to simulate the phenomenon of the aerial traffic could deducing the capacity that a runway can reach fixing a determined configuration of the system and an acceptable middle delay.

The maximum number of the fly operations that can be sell out by a runway, it isn't easy to determinate, Many States use different relationships to appraise the airport runway capacity, for example the FAA method or the Harris model. Nevertheless, if we would consider all the variables involved, these relationships are analytically onerous, for which the runway performance degree evaluation, particularly that the Naples-Capodichino airport can offer for the traffic flows selling out, it has been conducted with the use of digital micro-simulation techniques.

Among the different models the Simmod (by ATAC-Corporation) dresses particular interest, in fact it's the official simulator of the Federal Aviation Administration and of Eurocontrol. The approach with the Simmod begins with the general characteristics definition of the simulation model and with the individualization of a subsystem series that they are analyzed singularly. These subsystems are identified in the different phases that compose the airport system working scheme, they are the approach, the landing, the take-off, the leaving and the taxiing.

Every one is developed in an ampler way.

• *Approach:*

The procedures of aerial navigation are generally concluded with a long final approaches: this is made possible by the electric and optical apparatuses available that point out the correct trajectory to the pilot. The subsystem "approach" makes reference to the some points that are individualized with the existing approach and leaving charts in any airport. The approach model is realizable through a reticular technique, or it's possible configure the aircraft trajectory through a knots and links system. The knots characterize the airplane passage points: Fix, Intersection, VOR, NDB, DME; the links individualize the connections among the knots. In every links is possible to individualize a distance-function among the aircrafts that it's variable in according to the different classes of airplanes.

The knots can be individualized through the geographical coordinates that are brought in the approach Charts (Standard Terminal Arrival Routes), to which the pilot always owes to make reference. The links represent the distance that the airplane has to complete for passing from a knot to the following one, therefore they are defined through their length and the speed with which the aircraft crosses them and the speed is constant during all distance.

• *Landing:*

The landing procedure begins when the pilot is found in correspondence of the "MAP", after to have received the authorization from the Tower of Control and to have appraised all the conditions to begin the manoeuvre in safety. In the hypothesis that the pilot, approached him to the runway up to be to the height of the Decision Height or the Minimum Descent Height, he's able to establish the visual contact with the ground, the approach proceeds according to a pre-arranged angle of glide-path that it's red on the Approach Chart. Also this second phase is schematized with a system of knots and links; the first ones are divided in "physical", that represent the passage of the airplane in places pre-arranged of the space and "fictitious", that individualize the positions in which the aircraft varies the movement conditions (for example variations of speed, variation of the wait times etc). The links are segments that individualize the run effected by the airplane in the passage from a knot to that following; during the journey it's hypothesized that the airplane deceleration is maintained constant. Every link will have a functions vector: speed, time of routes, time of wait, descent gradient. Since in the reality these parameters change in consequence of different factors as the airplane typology, the pilot capacity, the climatic

conditions, the evaluation of the relative distance among airplanes can be deduced by the experimental analysis that allows to individualize some constant values or aleatory variables.

In this sub-system the real knots are represented by the Decision Height, the Touch Down Zones and the point of gone out from runway; the virtual knots are the points of anterior wheel support and the points of the mechanical brakes driving. Some virtual knots are inserted for individualizing also some distances that the airplane covers with a constant variation of speed.

• *Take-off*

The procedures for the take-off are distinguished for airplanes with helix motors and for airplanes with reaction motor, the object of the application concerns these last. The airplane in departure is brought on the runway and it increases its speed after having received the consent to the take-off, increasing the push of the motors. The necessary space to the take-off takes four factors in account:

- the capacity of the pilot;
- the characteristics of the airplane;
- the climatic factors;
- the environmental conditions.

Also this scheme is brought back to the technical knot reticular and links described in the preceding phases. The knots are reported both to that physical points in ground or in the space as, for example, the point of departure from the runway, the flight high the conventional obstacle or the distances to which the airplane reaches some specific speeds, both to that points that separate two links in which the aircraft has a different behavior as, for example, a different acceleration or a different temporal distance.

• *Leaving*

The aircraft leaving manoeuvre begins from the point where the aircraft exceeds the obstacle conventional placed to a height of 30ft at the end of the clearway and it finishes in correspondence of the last intersection that introduces the airplane in the air-way. Also in this case it's used a scheme with knots and links.

• *Taxiing*

In the phase of taxiing the airplane leaves the runway and it's directed toward the stand assigned to his from the Tower of Control; if the airplane has to take off, it leaves the stand and it's directed toward the runway where begins the following phase of take-off, after being authorized by the Inspector of flight. In both cases the speeds and the distances among the exit-taxiway and the stands are defined; therefore the times employed by every airplane to complete all the operations of taxiing are defined before in function of the taxiways geometric characteristics. The scheme of this phenomenon can happen with knots and links. The first ones represent some physical points in which the airplane finishes an operation and attends to start the following one. These knots are the exit-taxiways from runway, the intersections among taxiways, among the apron-taxiways and between the taxiing and the runway (in case more runways). Also the stands are the knots in which the airplane finishes its run to begin another and some knots are all the necessary structures to the airport operations as, for example, the hangars or the stands where it's effected the maintenance or the restocking. The links are the connections among two knots and they represent those parts of surface that the airplane crosses to pass from a knot to another to constant speed Generally the simulator distinguishes the system airport knots from those of the airspace, in fact the knots of the airport model describe notable positions of the flight field as gate, departure queue, runways, intersections among taxiways, while the knots of the airspace represent characteristic positions what fix of navigation, electric apparatuses, encircled of wait or intersections among the aircrafts different routes. The airport subdivision can represent parts of taxiway, runways and stands. The airspace subdivision represent the crossed routes.

1.2. The input and output parameters

The input parameters are classified in three groups: the site geometric data, the data related to the traffic flows and the simulation data that regulate the program execution. They are:

- the airport data and the possible reported restrictions, for example, to the stands for aircraft model or for the movements on the taxiways;
- the data on the aircrafts and the possible reported restrictions, for example, to the separations in consequence of the wake turbulences;
- the data of the airspace and the possible reported restrictions, for example, to the speeds on the system subdivisions;
- the geographical confinements of the sectors ATC (Air Traffic Control) and the possible reported restrictions, for example, to the maximum capacity of the sectors ATC;
- the O/D matrix;

- the scheduling of the simulation events;
- the meteorological conditions.

The parameters of output are the results related to the principal simulated greatness; they are usually divided for type of operation, for time intervals, for groups selected of airlines, fields of flight or iterations. They are:
- the operations on the airport runways for type of aircraft;
- the operations on the runways, the operations demanded and the accumulated differences;
- the times and the delays on the airport runways;
- the times and the delays separated for iteration;
- the airport operations for gate;
- the airport operations for every airlines;
- the times of taxiing and the delays for gate;
- the times of taxiing and the delays for airlines;
- the flights number with delays that revert in an specific time interval;
- the course in the time of the departure queue;
- the aircrafts total number that has crossed a sector in a specific time interval;
- the maximum number of aircrafts, in every area of sector responsibility, for a specific time interval;
- the flight middle times for sector;
- the aircrafts number of a levelled flight, in slope or in descent for every sector in a specific time interval;
- the intensity of the flow of traffic on a whatever point of the model in the time;
- the number of levelled aircrafts, in slope or in descent on any point of the model for time intervals;
- the number of potential conflicts that will require an ATC intervention;
- the distance middle times for every route;
- the number of aircrafts for every route, for time intervals.

2. ANALYSIS OF THE SIMULATION MODEL OF THE AIR-TRAFFIC: THE SIMMOD

2.1. The Simmod characteristics and the finalities

For the realization of a model that can manage, analyze and improve the aerial traffic in route, in the terminal areas and during the airport operations and the ground handling, has been used the Simmod. This software is an operational tool able to improve, from an operational point of view, the various problems that are introduced in the management of the Air-side, simulating all the operations that are developed in an airport, furnishing the tools to resolve the various present conflicts and improving the characteristics of everything system. The simulation happens with a series of procedures that serve to interpret the real phenomenon that is wanted to reproduce, trying all the phases that concern the flight. Nevertheless it's not possible to keep in consideration all the unforeseen events that can be verified, however the Simmod allows the employer to have a tool of synthesis to individualize those problems that concern the ordinary phases for the carrying out of the aerial traffic and it allows to resolve them without intervening on the place. In this context the Simmod furnishes a multiplicity of functions of probability that simulate the phenomenon offering to the operator the same casualness that is present in the reality. This happens with a continuous and constant control, from the simulator, of the input data correctness inserted. At the end of the trial we can be consulted, in easy way, the output data furnished by the Simmod in two ways: the "visual", that consists in observe as the phenomenon evolves in the time through its simulation on a monitor, or with many printouts that furnish all the connected indications to the event that we are simulating as, for example, the temporal distance among the aircrafts, the hourly practical capacity of the runway or the last capacity of the system.

The phenomenon study is articulated in different phases that can be consulted and managed separately: the preparatory phase is committed by the Simmod to the Network Builder that furnishes the possibility to plan and to visualize the system fact state. This happens with the insertion of the airport characteristic data and with their visualization in a complex database. All news acquired by the simulator are brought in a different phase with the restitution on the video of the places state and the data inserted in the system.

The analysis of the introduced data happens in a processor preceded to this function; everything procedure is visualized in the Animator that represents the real simulation of the airport activities in ground and in the airspace. In such phase it can be realized the possible anomalies that the system introduces in comparison to what is wanted to simulate and it can be entered again the Network Builder and to insert the corrections. This phase requires many iterations because of the complexity that exists for trying to make the virtual coincident with the reality. The last phase consists of entering to the Report that furnishes the synthesis both of the input data

inserted, both those output data that concern the system operation, in according to the parameters inserted in the Network Builder. In this way it's read the simulation process result having to disposition a tool that can furnish all the answers to eventual new aleatory variable that it can be proposed afterwards. The system principal motor (engine) realistically simulates the movement of every airplane and it turns possible conflicts acting as an inspector ATC, testing the times and the delays.

To make comprehensible the simulation process through the calculation results animation, many characteristics of the system, also not essential to the interest variables knowledge, they have been equally included in the model. The system, taken in examination by the Simmod, includes five principal elements blocks:

- the airspace;
- the airport;
- the aircrafts and theirs flight envelops;
- • the flight rules and procedural;
- the events that happen during the simulation.

2.2. The logic process

The Simmod applies to a stochastic model to describe a system. The phenomenon is reproduced with a simulation program so that to have, in phase of execution, an event that is verified only with a probability "p". For this purpose the simulator implements a generator of casual numbers; every execution of a routine assigns to a variable "n" a time casual value in time different, uniformly distributed in an interval, that goes from 0 to 1. The possible condition for which the value of "n" results less of the probability "p", in partnership to the event stochastic real to be simulated, constitutes an event simulated that it's occurred only with probability "p". Every parameter introduced, with the purpose to represent the real movement, it constitutes a "inside event"; if takes over a variation of the trial, the simulator considers it as the addition to the trial of a "external event" (for example: the present dispositions in the documents AIP that introduce additional ties for determine procedures), and it introduces an inspector that regulates the new situation allowing everything system to work respecting the reality that is being simulated.

The variation of the model is possible in many situations, that interfere in the Simmod with a different distribution of the casual variable as:

- in the stands occupation times (for the unloading and loading passengers);
- in the multiplier of the separations in the trace;
- in the distances for the taxiing in the take-off and landing phases;
- in the times of manoeuvre of gone out of the stands;
- in the times of crossing of a runway in a possible intersection with a taxiway;
- in the delays of the flight in route;
- in the times of transfer among flights in operations of hub.

Everything of these variations is determined with a cumulative probability distributions; the Simmod generates a random real number, between 0 and 1, and uses this number to select values from the distribution. Cumulative probability distributions are defined by pairs of numbers. The first number in the pair represent the probability of a value less than or equal to "x" occurring; the second defines the corresponding value "x". Two such pairs, one indicating 0% probability for the lower value in the distribution range and the other 100% probability for the upper value, defines a basic linear function. Additional pairs specify a more detailed distribution.
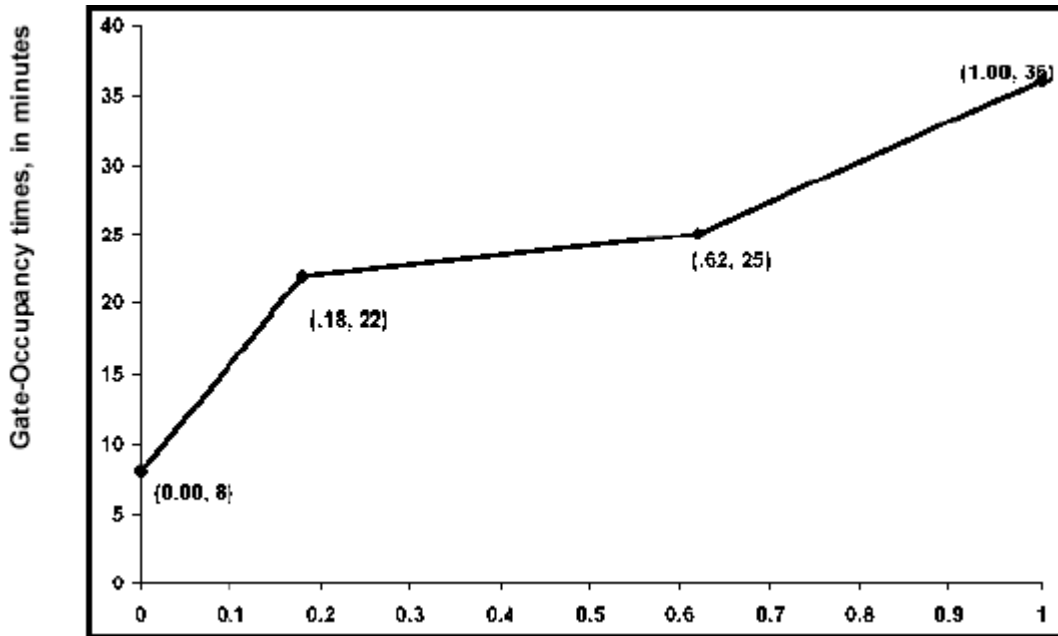
Figure 1 – Cumulative distribution of gate occupancy times for Commuter aircraft

The figure 1 shows a cumulative distribution that defines the range and probabilities for gate-occupancy times for commuter aircraft in Naples-Capodichino; the inspector acts, with a single event logic process, assigning to it the more result "reliable" in probability terms. To do this, the Simmod is served of a series of routines that applies to the process in iterative way to reach a result that reproduces the phenomenon with the same casualness that is had in the reality. The simulator produces a sequence of casual numbers, in every iteration of a series of data, and it assembles them into Simscript II.5, the language in which Simmod is programmed. The first number, that represents the beginning of the event that is wanted to simulate, is called seed and it's the casual variable that is produced the ensuing stream. Starting with the same seed, the simulator will always produce the same sequence of casual numbers (assuming that the simulation is run on a machine with the same processor) and it will allow the process inspector to reproduce the results of the simulation gotten with the same series of data without committing errors. Making reference to the case of Naples-Capodichino in the description of the process we have been distinguished the problems that the airspace concerns from those that concerns the airport.

2.3. The airspace model

The Naples-Capodichino CTR airspace has been modeled departing from its technical description published in AIP–Italy. It's limited, north-western, from the points PEMAR and MOVEL that are found on the axis that connect the electric apparatus of Rome-Fiumicino with the VOR-DME in Pescara (airway UG23). This points, even if rather distant from the Neapolitan area (around 80 NM), have been chosen for guaranteeing a descents suitable control toward the CTR; in fact after these points (situated to around 60 NM from the airport) it begins, generally, the instrumental descent toward AMSOR/BENTO. To East of the CTR, the model has been extended up to the limit of the border between the FIR in Rome and in Brindisi, with the subdivisions of the airways (UA33) that are extended toward the Foggia airport and the Gioia - Tauro military airport. To southeast the model includes lines of airspace up to the point PAOLA, on the border FIR (to around 100 NM from the VOR-DME of Sorrento), and the knots EVINO and ANIBA on the radial 216 from the electric apparatus in Bari; also these points, that limit the model up to over the Cilento, have been individualized to enough distance to allow an accurate modeling of the slopes and descents from and toward the Naples-Capodichino airport. In direction Sicilia, to South, the airspace included in the model is extended up to the point TAGEL, on the airway (UR2), that links Sorrento to the electric apparatus of Cagliari-Carbonara. The islands of Ponza and Ventotene and the area of the airport of Fiumicino are the border of the model to West. The routes have been extended up to the electric apparatus of Ponza and to the point Circeo, almost on the radial one between the airport of Ciampino and the electric apparatus of Latina (LAT). The inside area to the described confinements has been modeled in detail, understanding all the flight levels, the principal routes, the paths of approach and leaving. Also it was been included in the airspace model all the routes that use the radial ones attested on the four principal area electrical apparatuses; they are: Ponza-

Ischia (PON-VOR/DME), Sorrento (SOR-VOR/DME), Teano (TEA-VOR/DME) and Pomigliano (POMVOR/DME); this last represents, in practice, the modeled area center and it's found to around 4,5 NM in axis to the THR 24 of the Naples-Capodichino airport.

In control's zone modeled, that depends on the ENAC-Naples, assistance Centre to the flight, it are been calculated, positioned and included in the model, all the Procedures of Instrumental Approach published for the traffic IFR (Instrumental Flight Rules).

All the SIDs have been reproduced for the two possible directions of take-off (06 and 24) with the addition of the TEANO 5B only for the runway 06; all the routes of exit have been modeled for at least two accruals of slope standard (300 and 600 ft/NMs). The flights VFR has been reproduced including in the model their trajectories esteemed in according to the sequence of the points crossed and of the times employed during the route. The altitudes have been limited in according to how much it's imposed in RAC 4-2-3.4 par.6.

Figure 2 – Sids' procedure in Naples Airport – Capodichino

Figure 3 – Stars' procedure in Naples Airport - Capodichino

2.4. The airport model

The Naples-Capodichino airport has been modeled with an elevated degree of detail both for how much it concerns to its characteristics physics, both for what it concerns the control various logics and the use of the infrastructure. The model includes two separate areas; the first, coincident with the North area of the runway, includes the apron of the *Officine Aeronavali*; in this part of the airport it has been modeled the stand system and the taxiways system that connects to the runway. In the second part of the infrastructure (to RWY24 left) the taxiway has been modeled up to the principal Apron. Runways 06 and 24 was been included in the model with their used rules and their restrictions; the assistance to the instrumental landing system has been simulated; the holdings have been modeled near the two runway thresholds with the wait system. The runways have been submitted to a complete system of procedures control that simulate the traffic control capacity with mechanisms type look-ahead; this procedure provides to stop the simulation in progress if it goes to conflict or it's not separated by other operations that are being developed. The aircrafts speed on the various runway distances has been defined in according to the same airplanes categories that use the infrastructure. The runway thresholds, THR 06 and THR 24, are been simulated comprehensive of their displacement in ahead for the landings; for the take-offs, as it happens in the reality, all length of available runway has been considered; only exception are the Helicopters flights and the General Aviation that can use, also in the model, only part of the runway; for this it was been included in the model further control logics departure queue in every intersection between exit taxiway and runway. Since the only taxiway management to double march sense could become, for elevated traffic volumes, one of the principal necks of bottle of the airport runway capacity, it has been endowed with one logical management over structure denominated Dynamic Single Direction Path (DSP Path).

This facilitation correctly reproduces the mechanism adopted for the control to the airport ground, that allows only the entry in the taxiway only to the aircrafts that have to cross it in the same sense, obliging the others, that have to use it in the opposite verse, to attend. All zones of the apron-stand taxiway (WA, CA, EA, MA1), and those zones reserved to the *Officine Aeronavali*, have been reproduced. In fact the model includes all the available stands that are been simulated complete of their management system. Particularly it has also been inserted in the model a mechanism for the possible precedence among aircrafts that should have find contemporarily in manoeuvre. All the apron-stand taxiways have been modeled in detail, inclusive some distance in curve and the intersections among the taxiways; besides the entrance and exit from the apron-stand taxiway usual rotations are been inserted in the simulation model. The stands numeration on the principal apron, as for the stands at North of the runway, are conforming to the denomination declared by AIP.
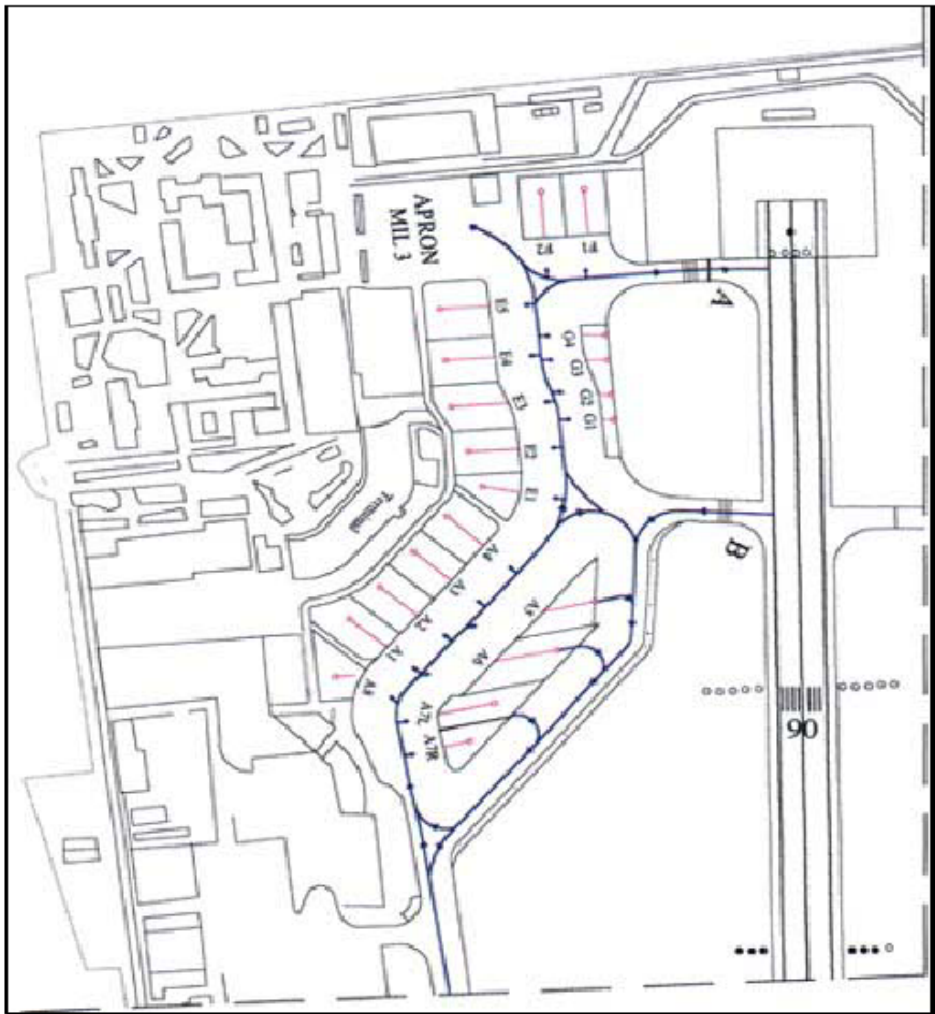
Figure 4 – Stands model in Naples-Capodichino

Simmod uses an aircraft index number to identify the aircraft model of each flight. The number refer to aircraft model definitions in the Integrated Noise Model of each flight, a copy of which is supplied with Simmod (the INM is an FAA model that determines aircraft noise impact at and around airports). The aircraft model descriptions in the INM database include takeoff weights for trips of various lengths. The maximum INM aircraft weights generally indicate the size category of the individual aircraft models. Thus, aircraft are assigned to size groups according to their weight category, as in the following table:

Table 1 - Aircraft size groups

INM max.weight [lb]	Aircraft Group	Group number
< 10.000 lb	Single engine / GA	1
da 10.000 a 100.000	Twin engine / Small	2
da 100.000 a 300.000	Commercial jet / Large	3
> 300.000	Wide body and jumbo jet / Heavy	4

The model simulation maintains the separation between aircraft along links and passing through nodes. In trail separation requirements for each aircraft of given group followed by another group (the wake vortex separation requirements) is defined uniquely, as shown in the following example.

Table 2 – Separation Requirements in Simmod

Aircraft Size	Followed by:			
	Heavy [NM]	Large [NM]	Small [NM]	GA [NM]
Heavy	4	5	6	6
Large	3	3	4	3
Small	3	3	3	3
GA	3	3	3	3

For the ground movements, is been defined, in the model, ten aircrafts categories with similar characteristics of which one dedicated to the helicopters and General Aviation. Using the parameters of this last classification has been possible to model the aircrafts different performances to simulate the necessary lengths to the take-offs and the landings, the movement speeds to ground and the necessary spaces to the turns on the taxiways.

2.5.   The inputs of the simulation process

The input of the system is built with a considerable number of files that constitute the Simmod database. The indications contained are reassumed in the model principal files afterwards, they contain information detailed on the simulated system, among which:
- the airport data and the possible restrictions (for example stands restrictions for airlines, for aircraft model, for the movements on the taxiways; of the queues management logic restrictions);
- the aircrafts data and the possible restrictions as: the separations caused by the wake turbulences;
- the airspace data and the possible restrictions (the speeds on the net subdivisions, separated for aircraft type);
- the data of interface between the airspace and the airport (for example, the procedures of arrival and those of departure; the runways use logic);
- the geographical confinements of the sectors ATC and their possible restrictions (for example, the maximum capacity of the sectors ATC);
- the simulation events scheduling (for example flights data and schedules);
- the meteorological conditions as: the winds direction and the intensity and the visibility.

2.6.   The outputs of the simulation process

The Simmod simulation system furnishes, at the end of the simulation process, a series of results related to the principal simulated greatness.
These output data are brought in a tabular shape or converted in graphics and histograms; they can include various subject specified following. The Simmod results usually are divided for operation type (arrival/departure), for time intervals or for airlines groups selected. Among them the most important are:
- operations on the airport runways for aircraft type;
- operations on the runways;
- times and delays on the runways;
- times and delays separated for iteration;
- airport operations for stands;

- airport operations for airlines;
- times of taxiing and delays for stand;
- times of taxiing and delays for airlines;
- flights number with delays that reverts in specific time interval;
- behaviour in the time of the departure queue;
- aircrafts total number that has crossed a sector in a specific time interval;
- aircrafts maximum number, in every area of sector responsibility, for a specific time interval;
- middle times of flight for sector;
- aircrafts number of a levelled flight, in slope or in descent for every sector, in a specific time interval;
- traffic flow intensity in a whatever point of the model in the time;
- aircraft number levelled, in slope or in descent on any model point for time intervals;
- number of potential conflicts that will require an intervention ATC;
- distance middle times for every route;
- aircraft number for every route, for time intervals.

Additionally to the simulation output data, the Simmod produces some graphic animations of the air-side and of the air-land that:
- they facilitate the input data debugging;
- they simplify the model calibration and validation;
- they allow to analyze the simulation visually;
- they put in evidence the areas or the time intervals with possible problems;
- they show the correctness of the simulation;
- they allow an accurate representation of the developed job.

3.   THE MODEL APPLICATION TO THE CASE OF STUDY

3.1.   The input data

The simulation process has required the insertion in the Simmod of all data to try so that the real phenomenon can be interpreted by the simulator correctly. Their acquisition is characterized by a sequence of specific operations that knot all these elements in five files, that can be examined to appraise, with immediateness, the developed job. These files are some printouts with which it's possible to interact with the program to verify both the correctness of the inserted information, both some parameters lack that can be essential for the event correct simulation. Their subdivision is made for data typology that has allowed a better orientation among the hundred files to elaborate. The input data are represented in:
- SIMU01 (aircraft): files in which are gathered the data related to the aircrafts and to their characteristics;
- SIMU03 (airspace): files in which are gathered the data related to the characteristics of the airspace;
- SIMU07 (airfield): files in which are gathered the data related to the airport characteristics physics;
- SIMU09 (events): files in which are gathered the data related to the events that it's intended to simulate;
- RUNDATA: files in which are gathered the data related to the simulation start procedures, included the probability functions associated to a determined event that it's wanted to simulate;

The logic adopted with the Simmod to acquire the necessary data to try an event has been that to produce some files that insert one in the others in such way that the simulator always has the knowledge of all the connected variables to the unwind some real phenomenon. Being many procedures common on different airports, the Simmod has a default data series that can be modified or substituted for transforming a particular phenomenon.

The data have been picked up through the characters and numbers insertion in special forms of interface; the advantage of these procedures is that they are intuitive and they allow to have always the knowledge of all the fields to fill. They have been modified only those data concerning to the phenomenon that it's intended to simulate; the others, not pertinent with the objective that it's intended to reach, is characterized by parameters of default.

The modified models are:
- AC_MODEL; AC_MODEL_FAA; AIRLINE; AIRPORT; AIRSPACE_NODE; AIR_AC_GROUP;
- AIR_AC_GROUP; AIR_LINK_TYPE; AIR_AC_GROUP_SEPARATION; AIR_LINK; AIR_LINK_TYPE;
- DEGENERATE_AIRPORT; DEPARTURE_Q; END_SIM; FLIGHTS; GATE; GATE_AIRLINE;
- GATE_LINK_BLOCKED; GND_AC_GROUP; GND_LINK; GND_NODE; INTERFACE_NODE; PLAN;
- PRIMARY_ROUTEE; PROBCAPACITY; PROBCAPACITY_DISTRIBUTION; PROCEDURES;
- PROC_AIRSPACE_AC_GROUP; RELATED_GROUP; ROUTEE; RUNWAY; RUNWAY_AFFECTED;

- ▪ RUNWAY_LINK; RUNWAY_OPPOSITE_DIRECTIONS; SETPLAN; TAMPS_AC_GROUP;
- ▪ TAMPS_AC_GROUP_GND_AC_GROUP.

Such documents, that once compiled constitute the database from which the Simmod draws all the information to simulate the event required, are introduced with a structure nested in which there are some forms basis, that must be compiles before so that can be of reference for the others. Departing from the list above suitable, with the purpose to appraise, for Naples-Capodichino, the hourly practical capacity and the mean delays accumulated during the fly operations, part of these forms we have been compiled with all the data related to the characteristics physics of the airport and to the procedures applied.

3.2.   The process

The real phenomenon simulation with the Simmod begins with the data analysis that we have inserted in function of airport some characteristics. The runway, stands, approach and leave modeling, prepared in the preceding phase, is acquired by the Simmod as files and they complete all the forms whose gives they characterize the Capodichino airport. Departing from the input data related to the airport, we have been inserted in the model all the knots and the necessary links to simulate the phenomenon imposing, to every of these knots, the distances and the rules of wait and the temporal distance along the links. This model has examined the procedures of approach and leaving from the runway 24 and 06 imposing the departure queue in function of the distance middle storms and of the speeds assigned to the aircrafts.
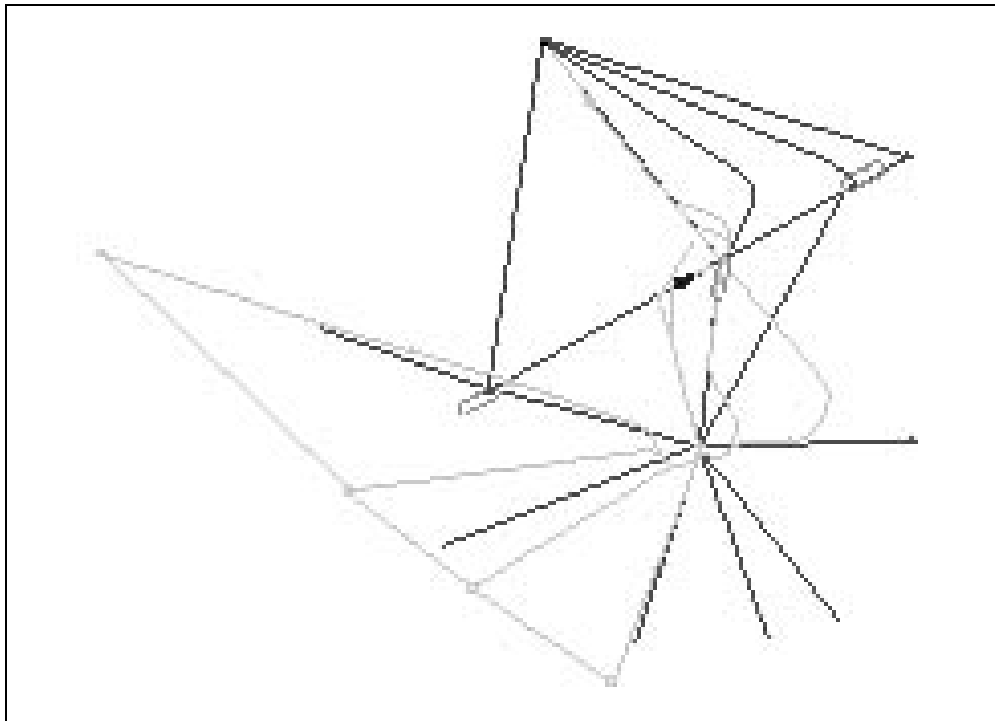

Figure 5 – Capodichino schematized in Simmod model

All the groups selected for the model simulation are examined in a window, from which it's possible to select or to cancel some of them, without to access again the basic model. In figure it is shown the window that allows to effect such operation. All the models used are brought, divided for groups, and those already selected during the preparatory phase to the simulation.

When the insertion and the data control it has been finished, the airport simulation operation it's started. Being a stochastic trial, in which many aleatory variables are contained, to produce some results that represents, day for day, the air traffic variations, they have been performed more cycles iterative of the trial. Since Simmod produces some results that aren't the real phenomenon, but approach them how much more possible, it's necessary to perform more cycles of simulation with the same type of data to establish a simulation significant tendency to the real phenomenon. The simulation produces random real number among 0 and 1, and this

number will be used for determining, through the curve of accumulated probability, the real values reproduced by the simulator.
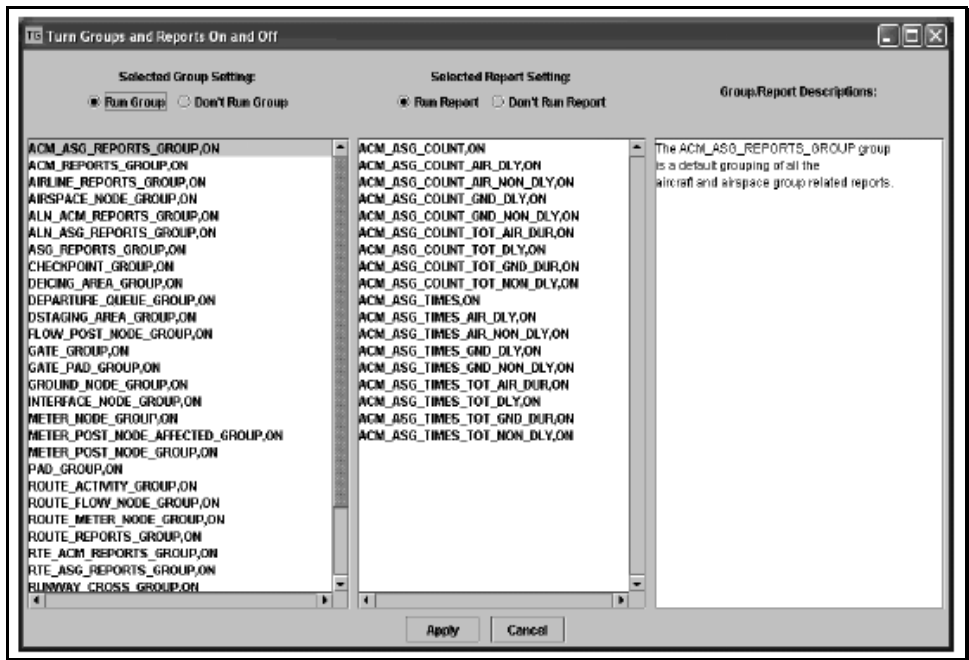

Figure 6 – Turn Groups and Reports On and Off

3.3. The output data

The output data deriving from the simulator, through a series of tools, have been analyzed to extract, from an enormous quantity of available information, how much necessary to answer to the questions set in the present research. The data tracing system results a fundamental assistance, because it has allowed to memorize, in some files, the operations developed during the simulation, while the events flowed. These files, of great dimensions (over 9000 pages every) bring detail information on the events that happen during the simulation, in function of their temporal succession. It's brought following an example extracted by these files, relative to an interval of simulated time very reduced (less than a second):

```
1 00:06:00 AZA 1278 _DNAP will be activated in the simulation at 00:10:23
1 00:06:00 ISS    974  is tentatively assigned to the specified gate E5_GATE_NAP
1 00:06:00 ISS    974  _DNAP created at NAP airport, gate E5_GATE_NAP; 567 sec late; tail 1.09
1 00:06:00 ISS    974  _DNAP will be activated in the simulation at 00:15:27
1 00:06:00 LIT    274  is tentatively assigned to the specified gate E1_GATE_NAP
1 00:06:00 LIT    274  _DNAP created at NAP airport, gate E1_GATE_NAP; 538 sec late; tail 1.08
1 00:06:00 LIT    274  _DNAP will be activated in the simulation at 00:14:58
1 00:06:00 MTC 824  is tentatively assigned to the specified gate A7R_GATE_NAP
1 00:06:00 MTC 824  is tentatively blocking gate A7_GATE_NAP
1 00:06:00 MTC 824  _DNAP created at NAP airport, gate A7R_GATE_NAP; 42 sec late; tail 1.07
1 00:06:00 MTC 824  _DNAP will be activated in the simulation at 00:06:42
1 00:06:00 AZA 1294 is tentatively assigned to the specified gate A2_GATE_NAP
1 00:06:00 AZA 1294 _DNAP created at NAP airport, gate A2_GATE_NAP; 28 sec late; tail 1.05
1 00:06:00 AZA 1294 _DNAP will be activated in the simulation at 00:06:28
1 00:06:00 BAW 2605 is tentatively assigned to the specified gate A4_GATE_NAP
1 00:06:00 BAW 2605 _DNAP created at NAP airport, gate A4_GATE_NAP; 598 sec late; tail 1.00
1 00:06:00 BAW 2605 _DNAP will be activated in the simulation at 00:15:58
1 00:06:00 AZA 990   is tentatively assigned to the specified gate A5_GATE_NAP
1 00:06:00 AZA 990   _DNAP created at NAP airport, gate A5_GATE_NAP; 323 sec late; tail 1.01
1 00:06:00 AZA 990   _DNAP will be activated in the simulation at 00:11:23
1 00:06:00 ELG  181  is tentatively assigned to the specified gate E2_GATE_NAP
```

Figure 7 – File example obtained as output from simulation system

It has been possible to analyze everything trial, deriving information on:

- the flows in arrival and departure, divided for category ATC;
- the entity of the delays accumulated by every operation, divided for the various parts of the model;
- the number of operations that the simulation has developed up to the capacity limit;

but also is possible to verify the single knots with the operation that it's developed during the simulation.

Recalling the knot name in code is underlined an edged what it furnishes, for an interval of pre-arranged time, all the activities that are developed, the airplanes that have transited it, the speed with which they have crossed the knot, the operations period eventually developed on it as, for example, a wait in queue. In figure is brought an example related to the data derived from the events that concern a generic knot:

Figure 8 – Node activity

A complete analysis of all the movements and all the operations that have characterized the simulation is brought in the file SIMU26, it furnishes two analysis possibilities, the first one: Standard Reports, that furnishes information on all the flights produced by the Simmod, the other: Node-to-Node Reports, that furnishes information on the aircrafts that have crossed a specific link.

The Standard Reports has allowed to verify if the operations, happened on the Simmod, have simulated the real phenomenon and it represent the tool with which to verify the output results. The final result has been the aircrafts movement in the airspace modeled for all period anticipated.

4. THE SETTING OF THE SIMMOD WITH THE GIVEN EXPERIMENTAL DATA

4.1. The methodological approach

The forms compilation in Simmod, related to the Naples-Capodichino airport characteristics, has allowed to build a model that allowed to derive the delays entity accumulated by every operation, the hourly practical capacity and the limit capacity.

The delays distribution function, individualized through the data analysis furnished by the computer, has been compared with that of the experimental data furnished by the ENAC' consistent in the 2003 year flights schedule. From the analysis conducted for every month, it's pointed out that the greatest number of fly operations in Naples-Capodichino, is in September. Departing from this data population has been determined a representative champion that has allowed the simulator to appraise the correct working of the airport. First of all we have individualized the middle day of the month of great traffic, that correspondent at the 15 September, on this champion they are been sought the theoretical probability functions that individualize the delays distribution for flight operation.

The delay is the synthesis of a series of events that they have happened in a link of time that goes from the phase of airplane take-off up to the landing of the same.

Generally it's possible to affirm that such event is correlated tightly both to the airplane typology, both to the middle speed and, for this motives, it's an aleatory nature phenomenon that can be treated with the methodologies of the statistic inference.

Statistically the meaningful champion research has been conducted departing from the individualization of the stationary periods that they represent that temporal intervals in which the distance among two following operations are constant or they oscillate around to a constant value in the time. Defined the stationary periods we have been individualized those that, to parity of duration, have the lowest averages; these intervals are defined the critical periods. As for the stationary periods, also for their individualization, the aircrafts are divided in two classes (M=Medium, L=Light), considering that the airplanes of class H don't have particular importance in the middle delays distribution on the Capodichino airport for the unsuitable conditions of runway that don't allow such typologies take-offs under conditions of full load. The delay analysis has been developed dividing also the flight operations in the take-off and landing phases. Leaving from the critical periods analysis inferior to two hours, as showed in the following table

Table 3 – Critical periods minor to two hours

Mean time separation among aircraft operations (hour:minutes:seconds)	Length of critical period (hour:minutes:seconds)	Number of operation	Day
0.03.25	0.41.00	12	01/09/2003
0.03.57	1.35.00	24	02/09/2003
0.02.06	0.21.00	10	03/09/2003
0.04.00	1.20.00	20	04/09/2003
0.01.54	0.16.00	10	05/09/2003
0.01.49	0.20.00	11	06/09/2003
0.04.12	0.42.00	10	07/09/2003
0.02.00	0.22.00	12	08/09/2003
0.03.17	0.45.00	14	09/09/2003
0.03.57	1.15.00	19	10/09/2003
0.03.36	0.50.00	15	11/09/2003
0.04.07	1.13.00	18	12/09/2003
0.02.24	0.23.00	10	13/09/2003
0.02.49	0.29.00	11	14/09/2003
0.02.30	0.25.00	10	15/09/2003
0.02.30	0.35.00	14	16/09/2003
0.03.45	0.58.00	16	17/09/2003
0.03.12	0.39.00	12	18/09/2003
0.02.34	0.33.00	14	19/09/2003
0.01.18	0.11.00	10	20/09/2003
0.06.34	1.44.00	16	21/09/2003
0.02.35	0.30.00	12	22/09/2003
0.05.00	0.57.00	12	23/09/2003
0.03.14	0.37.00	13	24/09/2003

0.02.50	0.32.00	12	25/09/2003
0.02.38	0.27.00	11	26/09/2003
0.02.18	0.46.00	20	27/09/2003
0.05.44	1.03.00	11	28/09/2003
0.02.24	0.24.00	10	29/09/2003

it's determined the delay, for flight single operation and for aircraft class type as difference among the real time of arrival (Actual Time) and that foreseen by the scheduling fly (Sched Time), as shown in the following table:

Table 4 –Delay on single flight operation in the critical period

nature	sched dates	sched time	given actual	actual time	model	class	type aviation	lasted period	n° operations	Delay
To	02/09/2003	14:00	02/09/2003	14:00	A72	M	C			+0.00.00
A	02/09/2003	14:10	02/09/2003	14:00	737	M	C			+0.10.00
A	02/09/2003	14:20	02/09/2003	14:07	ATR72	M	C			+0.13.00
A	02/09/2003	14:35	02/09/2003	14:15	CL6	L	C			+0.20.00
A	02/09/2003	14:30	02/09/2003	14:20	*M82*	M	C			+0.10.00
P	02/09/2003	14:15	02/09/2003	14:20	M80	M	C			-0.05.00
P	02/09/2003	14:15	02/09/2003	14:32	CL604	L	G			-0.17.00
A	02/09/2003	14:30	02/09/2003	14:35	D38	M	C			-0.05.00
A	02/09/2003	14:50	02/09/2003	14:40	B737	M	C			+0.10.00
P	02/09/2003	14:55	02/09/2003	14:40	737	M	C			+0.15.00
P	02/09/2003	14:55	02/09/2003	14:40	737	M	C			+0.15.00
A	02/09/2003	14:45	02/09/2003	14:46	C525	L	G			-0.01.00
P	02/09/2003	14:50	02/09/2003	14:50	A72	M	C			+0.00.00
P	02/09/2003	14:55	02/09/2003	14:55	D38	M	C			+0.00.00
A	02/09/2003	14:15	02/09/2003	15:00	321	M	C			-0.45.00
P	02/09/2003	15:05	02/09/2003	15:00	A320	M	C			+0.05.00
P	02/09/2003	15:00	02/09/2003	15:00	D38	M	C			+0.00.00
P	02/09/2003	15:10	02/09/2003	15:04	ATR72	M	C			+0.06.00
A	02/09/2003	15:00	02/09/2003	15:15	M82	M	C			-0.15.00
P	02/09/2003	15:05	02/09/2003	15:15	321	M	C			-0.10.00
P	02/09/2003	15:10	02/09/2003	15:27	M82	M	C			-0.17.00
P	02/09/2003	15:30	02/09/2003	15:30	CL6	L	C			+0.00.00
A	02/09/2003	15:35	02/09/2003	15:35	MD82	M	C			+0.00.00
P	02/09/2003	15:35	02/09/2003	15:35	B737	M	C	1.35.00	24	+0.00.00

In the last column we have calculated the delays for single operation and we have added the positive sign for pointing out a condition of advance in comparison to the time hypothesized in the sched time, besides we have been added the negative sign to show the delay condition in comparison to the horary foreseen in the sched time. Departing from the analysis of the delays effected on the critical periods, the champion data have been extrapolated dividing them for type of operation (Departure and Arrival) and for relative classes of aircrafts (M,L). It's brought a table that show some succession of the delays for single operation and for the single aircraft class, (from September 1 st 2003 to September 4 th 2003) related to the all critical periods.

Table 5 – Delay for aircraft class and flight operation

Type of operation	sched date	sched time	actual date	actual time	model	class	Aviation type	Length of period	n° of operation	Delay
P	01/09/2003	10:00	01/09/2003	13:56	A42	M	C			- 3.56.00
P	01/09/2003	12:15	01/09/2003	13:58	M82	M	C			- 1.43.00
P	01/09/2003	14:10	01/09/2003	14:10	M82	M	C			+ 0.00.00
P	01/09/2003	13:30	01/09/2003	14:25	737	M	C			- 0.55.00
P	01/09/2003	14:15	01/09/2003	14:25	M80	M	C			- 0.10.00
P	02/09/2003	14:15	02/09/2003	14:20	M80	M	C			- 0.05.00
P	02/09/2003	14:55	02/09/2003	14:40	737	M	C			+ 0.15.00
P	02/09/2003	14:55	02/09/2003	14:40	737	M	C			+ 0.15.00
P	02/09/2003	14:50	02/09/2003	14:50	A72	M	C			+ 0.00.00
P	02/09/2003	14:55	02/09/2003	14:55	D38	M	C			+ 0.00.00
P	02/09/2003	15:05	02/09/2003	15:00	A320	M	C			+ 0.05.00
P	02/09/2003	15:00	02/09/2003	15:00	D38	M	C			+ 0.00.00
P	02/09/2003	15:10	02/09/2003	15:04	ATR72	M	C			+ 0.06.00
P	02/09/2003	15:05	02/09/2003	15:15	321	M	C			- 0.10.00
P	02/09/2003	15:10	02/09/2003	15:27	M82	M	C			- 0.17.00
P	02/09/2003	15:35	02/09/2003	15:35	B737	M	C	1.35.00	24	+ 0.00.00
P	03/09/2003	17:35	03/09/2003	17:50	100	M	C			- 0.15.00
P	03/09/2003	17:35	03/09/2003	17:55	M82	M	C			- 0.20.00
P	03/09/2003	17:50	03/09/2003	18:00	M80	M	C			- 0.10.00
P	03/09/2003	17:50	03/09/2003	18:00	A320	M	C			- 0.10.00
P	03/09/2003	18:00	03/09/2003	18:00	734	M	C			+ 0.00.00
P	03/09/2003	18:10	03/09/2003	18:05	CR7	M	C			+ 0.05.00
P	04/09/2003	16:30	04/09/2003	16:30	CRJ	M	C			+ 0.00.00
P	04/09/2003	16:35	04/09/2003	16:35	733	M	C			+ 0.00.00
P	04/09/2003	17:30	04/09/2003	16:50	ATR72	M	C			+ 0.40.00
P	04/09/2003	17:15	04/09/2003	17:15	M82	M	C			+ 0.00.00

The statistic distribution of the delays relieved experimentally has been used for calibrating the simulation model implemented. Beginning from the scheduling fly, gotten by the Simmod, it have been effected the statistic test among the characteristics of the middle distance among fly operations and among the delays for operations, real and simulated.

The test realized is x_2 with which is verified if the distribution of the distance, the successions of the operations and the distribution of the real delays are reproducible in simulation.

4.2. Results

After having completed the implementation of the model, inserting the curves of the temporal distance in arrival and in departure and for classes of operation, it has been verified if the Simmod has provided to a correct logical representation of the problem. Therefore it has been verified that all the parts of the model were acting, both in independent way both together, and that has been used the correct data with the correct time (debugging).

Limitedly to the data to disposition (middle delays), it has been checked that the behavior of the model are represented validly the real system from which has been extracted. The simulations conducted on the system model have been developed with cycles of 30 runs. Such number results, in all the cases, enough to reach intervals of confidence for the purposes of the study. The results of output, produced by the simulator, are synthesized in 12 files, every container information and elaborations of the reproduced trial:

- SIMU02–it has furnished the interpretation of the input data from the simulator. Possible errors or incongruities are also underlined;
- SIMU04–it has furnished an extract of the actions practiced by the aircrafts during the simulation;
- SIMU06–it has furnished information on the state of the process of simulations and on the met errors;
- SIMU10–it has brought the final result of the execution of the process of simulation;

- SIMU16–it has furnished information on the knots and the ground links and on the debugging;
- SIMU20–it has furnished information on the movement of every tried airplane;
- SIMU26–For every simulated period it has brought the movement and the delay of every single airplane;
- SIMU40–it Represents the synthesis of the input data in a format consultable from the employer with great rapidity;
- SIMU44–it has furnished the statistic data of the simulation.

It's brought in the table following a settlement related to the operations that had developed since 7.00 at 13.00 o'clock, schedule that will be compared, with that of the simulation produced by the Simmod for the middle day of the month of great traffic (15/9/2003).

Table 6 – Abstract of scheduling flight in 15/9/2003

P	15/09/2003	07:00	15/09/2003	07:00	M80	C
P	15/09/2003	06:50	15/09/2003	07:00	M83	C
P	15/09/2003	07:05	15/09/2003	07:05	100	C
P	15/09/2003	06:55	15/09/2003	07:05	D38	C
P	15/09/2003	07:15	15/09/2003	07:15	CRJ	C
P	15/09/2003	07:05	15/09/2003	07:30	73C	C
A	15/09/2003	08:00	15/09/2003	08:05	320	C
P	15/09/2003	07:45	15/09/2003	08:05	M82	C
A	15/09/2003	08:00	15/09/2003	08:10	M80	C
A	15/09/2003	08:15	15/09/2003	08:15	D38	C
A	15/09/2003	08:20	15/09/2003	08:15	320	C
A	15/09/2003	08:25	15/09/2003	08:20	M82	C
A	15/09/2003	08:05	15/09/2003	08:20	100	C
P	15/09/2003	08:20	15/09/2003	08:20	C50	C
A	15/09/2003	08:10	15/09/2003	08:25	737	C
A	15/09/2003	08:20	15/09/2003	08:30	100	C
A	15/09/2003	08:10	15/09/2003	08:35	738	C
A	15/09/2003	08:25	15/09/2003	08:35	M82	C

Begun the simulation on Naples-Capodichino, with reference to such schedulato, for the period that has gone since 07:00:00 to 13:00:00 o'clock, the Simmod has furnished, through a trial iterative used for optimizing the sequence of the aircrafts, a new scheduling fly that points out the maximum increase of traffic compatible with an assigned level of service. In the file SIMU44 are pointed out all the phases of the trial, in the SIMU38 the new scheduling fly is brought, from which can be effected statistic analysis (it brings the relative sequence of a brief period really to September 15)

```
DEP    1   737        ^737_01154_NAPD^01154_DSA   .29558   1058   DEPAR_4
DEP    4   M82        MD101_DNAP^5.000000^        .29558   1058   DEPAR_7
DEP    2   737        ^737_01430_NAPD^01430_DSA   .15007    540   DEPAR_5
DEP    1   737        ^737_00098_NAPD^00098_DSA   .29558   1058   DEPAR_4
ARR    7   738        ^738_05048_NAPA^05048_734   .32825   1182   ARRIV_3
ARR    7   M82        ^M82_02954_NAPA^02954_734   .22710    818   ARRIV_3
DEP    2   320        ^320_01500_NAPD^01500_DSA   .15007    540   DEPAR_5
ARR    7   737        ^737_01055_NAPA^01055_734   .22710    818   ARRIV_3
DEP    1   738        ^738_00285_NAPD^00285_DSA   .29558   1058   DEPAR_4
DEP    1   M82        ^M82_00058_NAPD^00058_DSA   .29558   1058   DEPAR_4
DEP    3   100        ^100_05233_NAPD^05233_DSA   .17245    621   DEPAR_6
ARR    7   737        ^737_05502_NAPA^05502_734   .32825   1182   ARRIV_3
ARR    7   737        ^737_04702_NAPA^04702_734   .22710    818   ARRIV_3
DEP    5   737        MD104_DNAP^5.000010^        .20290    730   DEPAR_8
ARR    7   M83        ^A42_03350_NAPA^03350_734   .32825   1182   ARRIV_3
ARR    6   C50        ^C50_00117_NAPA^00117_734   .25178    905   ARRIV_2
ARR    7   737        ^737_05732_NAPA^05732_734   .32825   1182   ARRIV_3
ARR    6   738        ^738_00705_NAPA^00705_734   .25178    905   ARRIV_2
ARR    7   M82        ^M82_02815_NAPA^02815_734   .22710    818   ARRIV_3
DEP    3   A42        ^738_05079_NAPD^05079_DSA   .17245    621   DEPAR_6
DEP    8   737        MD108_DNAP^5.000020^        .17245    621   DEPAR_9
ARR    6   73C        ^73C_00851_NAPA^00851_734   .25178    905   ARRIV_2
ARR    7   M82        ^M82_01414_NAPA^01414_734   .22710    818   ARRIV_3
```

Figure 9 – Scheduling fly of Napoli-Capodichino in SIMU22

```
NAP AIRPORT -- RUNWAY     A R R I V A L     FLOW SUMMARY, BY ATC GROUP
BASED ON 1 ITERATION INCLUDED  IN THE FOLLOWING SIMMOD RUN:
Page #1
#1-#1  15/07/2003 AT 07:00:00      NAP           13:00:00 PST
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.


   TIME          24_NA 24_NA 24_NA 24_NA 24_NA
 INTERVAL        GA    SML   LRG   HVY   TOT


07:00-08:00        0     1     0     0     1
1
08:00-09:00        3     4     0     0     7
7
09:00-10:00        6     9     0     0    15
15
10:00-11:00        0     1     0     0     1
1
11:00-12:00        0     2     0     0     2
2
12:00-13:00        0     4     0     0     4
4

NAP ARR TOTALS:    9    21     0     0    30
30


This SIMMOD REPORT MODULE run was begun 15/09/2003 at approximately 13:00:00
Page #1
This page of the CMN.440.RWY.SECTION report was finished at 13:00:00
.PA   EJECT GOES HERE FOR PAGE 1     FIND.COUNT=206     TOP.FLIGHT=103
```

Figure 10 – Table Arrival class M/L in Simmod (SIMU44)

```
NAP AIRPORT -- RUNWAY   D E P A R T U R E   FLOW SUMMARY, BY ATC GROUP
BASED ON 1 ITERATION INCLUDED  IN THE FOLLOWING SIMMOD RUN:
Page #2
#1-#1  15/07/2003 AT 07:00:00      NAP           13:00:00 PST
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.



   TIME          24_NA 24_NA 24_NA 24_NA 24_NA
 INTERVAL        GA    SML   LRG   HVY   TOT


07:00-08:00        3    11     0     0    14
14
08:00-09:00        7    14     0     0    21
21
09:00-10:00        2     6     0     0     8
8
10:00-11:00        1     4     0     0     5
5
11:00-12:00        5     5     0     0    10
10
12:00-13:00        9     7     0     0    16
16

NAP DEP TOTALS:   27    46     0     0    73


This SIMMOD REPORT MODULE run was begun 15/09/2003 at approximately 13:00:00
Page #2
This page of the CMN.440.RWY.SECTION report was finished at 13:00:00
.PA   EJECT GOES HERE FOR PAGE 2     FIND.COUNT=206     TOP.FLIGHT=103
```

Figure 11 - Table Departure class M/L on Simmod (SIMU44)

In the figures 10 and 11 are brought the news related to the process of simulation and to the operations developed on the RWY24; a further elaboration has been effected for RWY06. For every temporal interval the number of developed operations is brought, that in the arc of the five hours, is passed by 96 actual operations at 103 after the resequencing effected with an increase of over 10% on the total fly operation. Departing from these new schedule, in consequence of the simulation, it's possible to analyze the delay accumulated for every class of aircrafts in every temporal interval, visualized in further printouts still furnished by SIMU22, of which a schematic representation is brought:

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NAP AIRPORT -- AVERAGE      A R R I V A L      AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 1 ITERATION INCLUDED IN THE FOLLOWING SIMMOD RUN:
Page #15
#1-#1  15/07/2003 AT 07:00:00      NAP           13:00:00 PST
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.


     TIME        ARRIVAL      TRAVEL TIMES (MIN)        DELAY TIMES (MIN)         #
OF FLIGHTS WITH DELAY (MIN)
   INTERVAL       FLOW      TOT    SDV    AVE        TOT    SDV    AVE
< 5    5-10   10-15   > 15


07:00-08:00        1        33.5   .50   16.77        0      0      0
0      0      0      0
08:00-09:00        7       154.6  2.97  19.32         0      0      0
0      0      0      0
09:00-10:00       15       324.3  3.18  19.07        47.5  2.59   2.80
10      4      0      0
10:00-11:00        1        17.6    1   17.60         0      0      0
0      0      0      0
11:00-12:00        2        28.7  1.04  14.35         0      0      0
0      0      0      0
12:00-13:00        4        28.00 1.67  16.77         0      0      0
0      0      0      0


07:00-13:00       30       582.3  3.43  19.41        47.5  2.39   1.58
9     21      0      0


This SIMMOD REPORT MODULE run was begun 15/09/2003 at approximately 13:00:00
Page #15
This page of the ARR.CMN.180.DELAY.INTERVAL.REPORT report was finished at
13:00:00
.PA  EJECT GOES HERE FOR PAGE 15     FIND.COUNT=206     TOP.FLIGHT=103
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Figure 12 – Delay on Arrival in Capodichino-Naples with the Simmod

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NAP AIRPORT -- AVERAGE      D E P A R T U R E      AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 1 ITERATION INCLUDED IN THE FOLLOWING SIMMOD RUN:
Page #16
#1-#1  15/07/2003 AT 07:00:00      NAP           13:00:00 PST
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.


     TIME        DEPARTURE    TRAVEL TIMES (MIN)        DELAY TIMES (MIN)         #
OF FLIGHTS WITH DELAY (MIN)
   INTERVAL       FLOW      TOT    SDV    AVE        TOT    SDV    AVE
< 5    5-10   10-15   > 15


07:00-08:00       14       288.4  4.10  19.22        13.6  1.02   .90
13     0      0      0
08:00-09:00       21       581.1  4.30  18.74       260.7  5.36   8.41
11     4      0      0
09:00-10:00        8       308.0  5.00  19.00        78.7  2.17   3.94
8      2      0      0
10:00-11:00        5       102.8  3.30  17.14        16.5  1.14   2.75
4      1      0      0
11:00-12:00       10        0      0     0            0      0      0
0      0      0      0
12:00-13:00       16        0      0     0            0      0      0
0      0      0      0


This SIMMOD REPORT MODULE run was begun 15/09/2003 at approximately 13:00:00
Page #16
This page of the DEP.CMN.180.DELAY.INTERVAL.REPORT report was finished at
13:00:00
.PA  EJECT GOES HERE FOR PAGE 16     FIND.COUNT=206     TOP.FLIGHT=103
```

Figure 13 – Delays in the departures with the simulation on Naples-Capodichino

In the figure it's brought the total delay accumulated in every timeframe and diversified for classes of five minutes. The coefficient SDV is a weight assigned to the total delay, accumulated to it in the relative timeframe, in operation of the keepings queue that every airplane has had assigned for maintaining the distance in the various links of the model. It's possible to analyze these delays, assigned in every knot and for every airplane, in a lines specified in SIMU26. Beginning from the analysis of these printouts, the theoretical distributions of probability of the middle delays have been determined for operation, express in minutes. These distributions, divided them also for classes L and M and for operations of Departure and Arrival, are already furnished by the Simmod in SIMU44 as tables where are brought the data related to the new middle delays accumulated for timeframes of a hour and divided both for typology of airplanes both for fly operation.

The course of these delays distributions is turned back divided for fly operation and reported to the class of airplanes "M." The operations of class L are not been compared, given the scarce number of operations in comparison to those of the class M, nevertheless following same methodology is possible to effect analysis, previously individualized, with the data of the process of Simmod simulation. Comparing every distribution of the delays can be observed a homogeneous course of the frequency distributions for temporal classes.
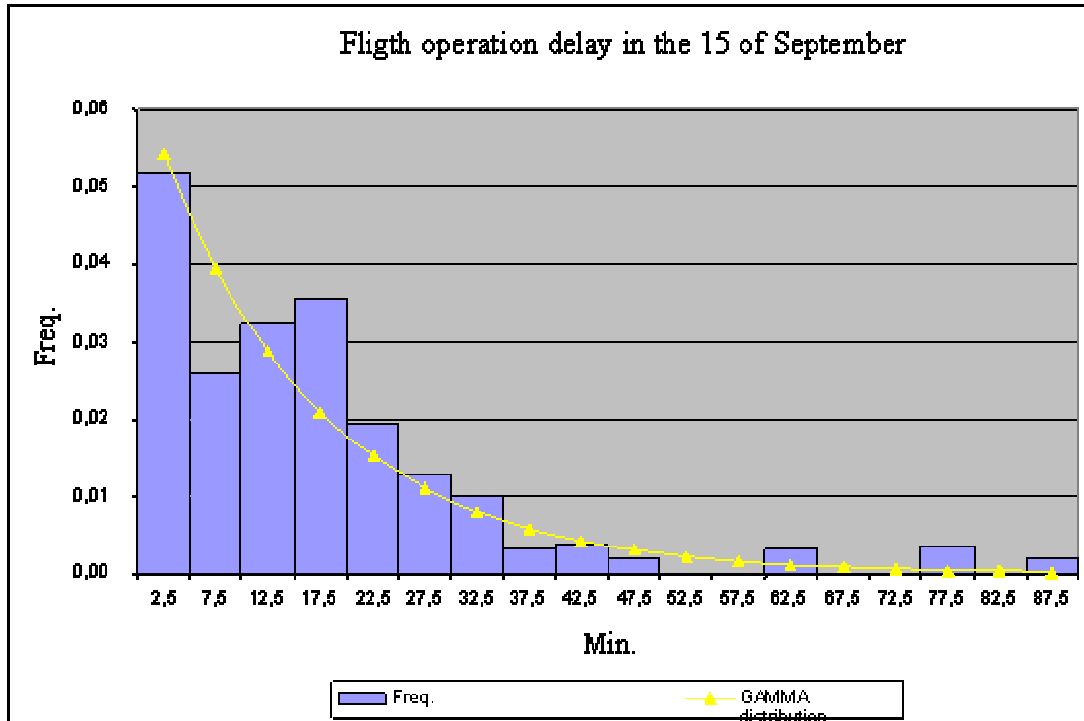
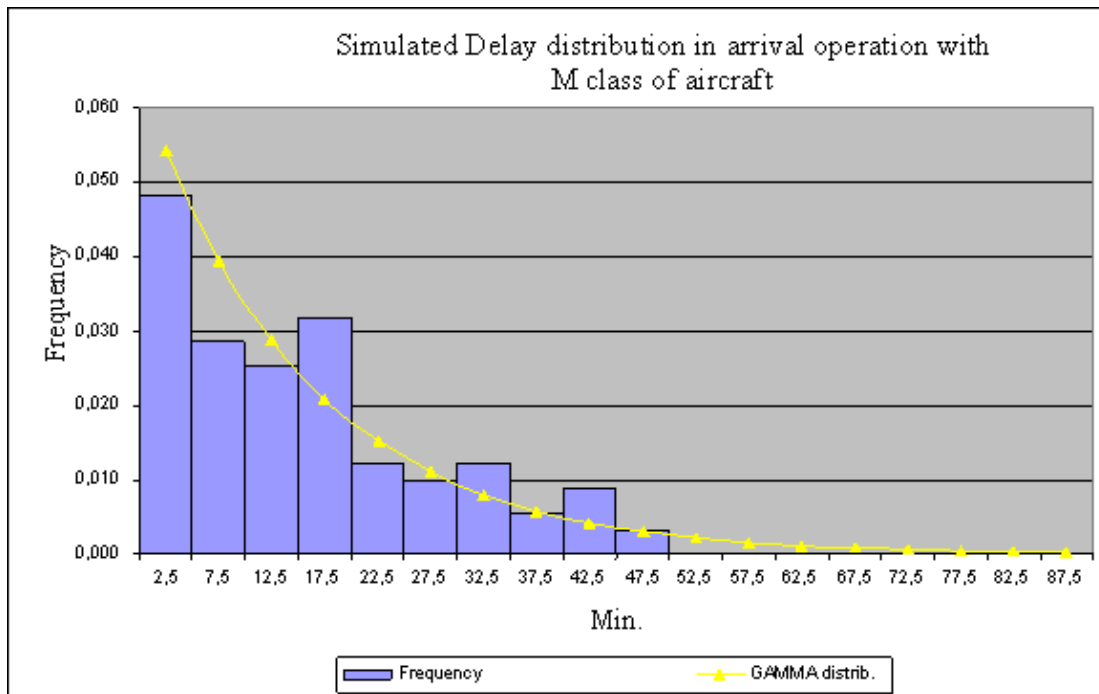**Figure 14 - Delay to 15/09/03 per operation Arr/M in Capodichino**

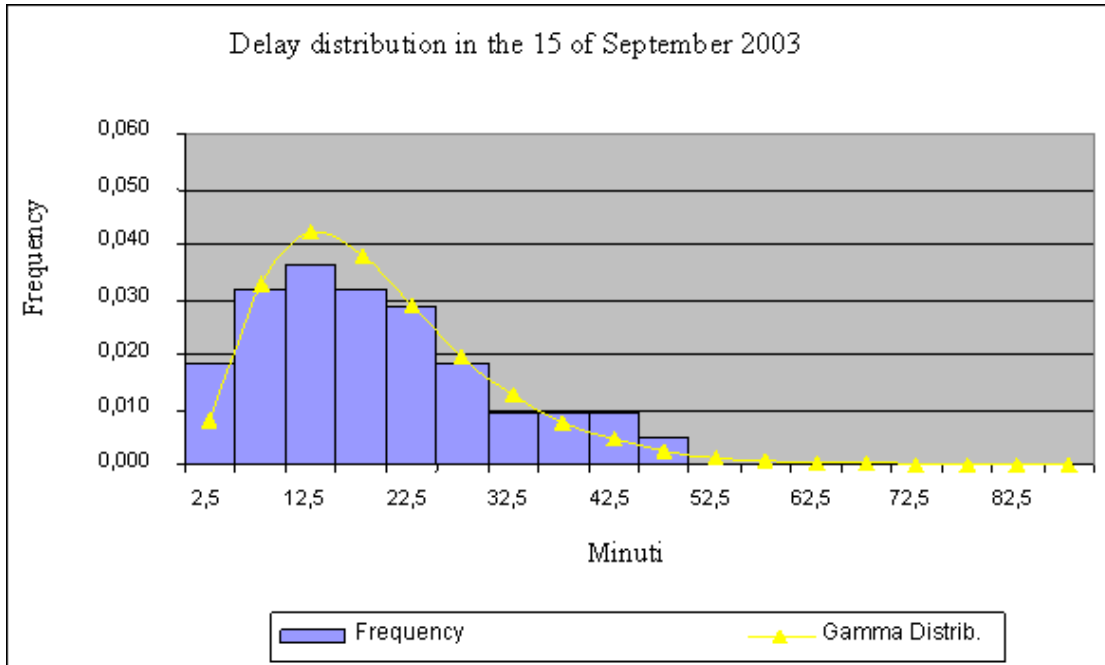**Figure 15 – Delay for flight operation Arrival/M in Simmod**

Figure 16 – Departure for flight-operation Departure/M at 15 September

Comparing the delays experimental distributions, for take-off and landing operations of airplanes of class M, drawn by the Simmod with the simulation in September 15, with the experimental distribution, drawn by the official schedule flight, we can be noticed that the probability function, that approach this distribution, is an exponential negative, both for the arrivals, both for the departures. We have compared the new distribution with the actual and we have appraised the removals among the two curves through the statistic test χ^2 with a good result.
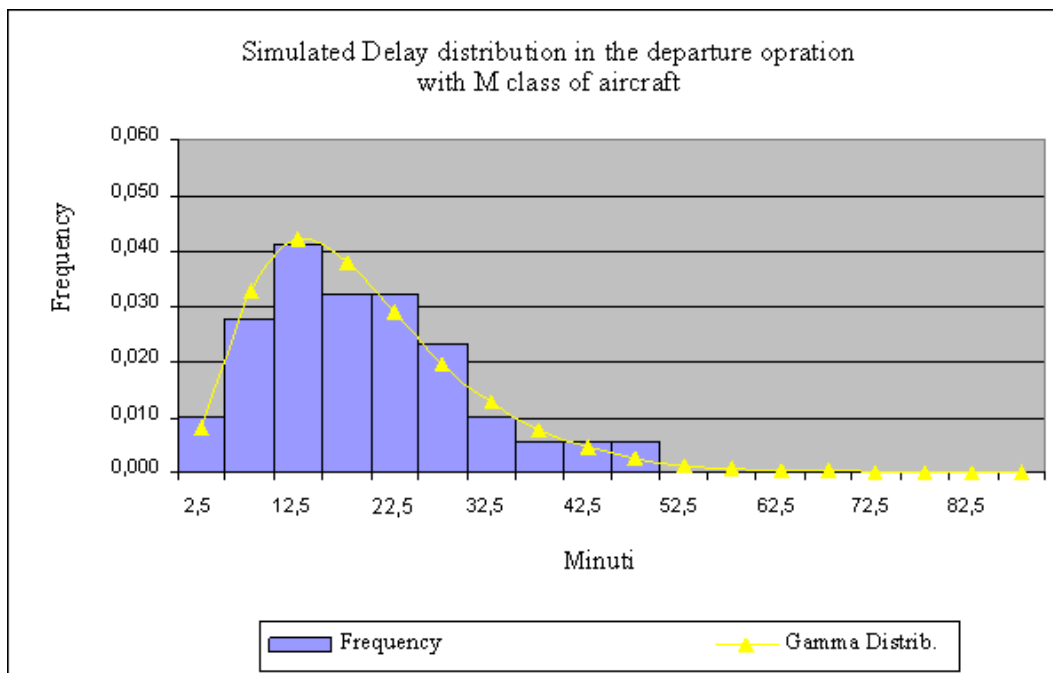

Figure 17 – Departures for class/M operation in Simmod

5. Conclusions

The possibility to produce some resequencing (new flight time schedule) on the fly operations with the Simmod has allowed a diminution of the middle delays and an increase of the fly operations number, that has had, in the recompose phase of the schedule, an over 10% increase. Comparing among them the graphics that return the middle delays behaviour for the arrivals and the departures, we have noticed that the delays curves in departure decrease in a less sensitive way in comparison to those curves in arrival. This means that the usual rules of precedence for the arrivals would been delay, over way, the departures. This consideration is usual for the airports with one runway, as Naples-Capodichino, in which the airplanes in arrival on the runway 24, independently from the type of used approach procedure have to go towards an unique corridor. From the printouts SIMU44 it's underlined that the middle delay for simulated operation is 2' 15''; if it's hypothesized a traffic increase of 10%, the delay is 3' 57'' that represents however a datum more acceptable second the standards of the literature. However the operations increase in the simulation has denounced a lack of necessary stands for the parking of other airplanes, this makes to hypothesize that, in a traffic increase hypothesis on Capodichino, the stands can become the neck of bottle of the infrastructure. It's been able to observe that the treated case has been simulated with over four departures queue that use the runway 24 or the runway 06 for the take-offs; the queue are selected by the system with a casual way in function of the route assigned to the aircraft and of the aircraft typology. To determine the utility of new openings of departure queue, the system has been programmed for a first casual assignment up to the attainment of a critical number of airplanes in queue. When this value is exceeded, the simulator assigns the flights to another departure queue if this queue doesn't saturate. Finally it's observed that the scenery hypothesized without traffic increase, realized in the present study, report middle values of the aircrafts in queue among 0 and 1.11 with the maximum values of 5 aircrafts; the values drawn for traffic increases of 10% take the maximum point in wait up to 7 airplanes. This clean difference can be imputed mainly to two factors: the first one, dependent from the increasing traffic quantity and the other dependent from the traffic management formality in which the departures are penalized for the arrivals. From simulations developed it's possible to draw some indications for further studies to develop, as for example:

- to verify the efficacy of interventions to demolish the time of runway occupation with the realization of one or two exit-rapid taxiways for the runway 24;
- to verify the efficacy of possible separations reduced in arrival, at least among categories of similar aircrafts and at least for the runway 24;
- to verify the efficacy of possible separations reduced in departure, at least among categories of different aircrafts;
- to verify the efficacy of the increase of the stands in comparison to the increase of capacity attended and to the diminution of the delays;
- to verify the efficacy of the position of new stands in comparison to the ground circulation.

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