COMPARING RUNWAY CAPACITY BETWEEN TWO ITALIAN AIRPORTS BY AN INNOVATIVE ANALYSIS PROCEDURE

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ABSTRACT

In this paper runway capacity of the airport Fontanarossa in Catania, located in Sicily, southern Italy, has been evaluated. This was scientifically estimated through an analysis procedure set up in 2001 and already applied to another airport in Italy.

The need of a definite methodology to get runway capacity based on survey data arises from the fact that, till now, only american airports have been subjects of deep and extensive researches.

The main difference betweeen USA and Italian airports lies in the aircraft sequencing rules: in fact, space distances between aircraft in USA are different depending on the aircraft itself weight class; in general, they are shorter than those adopted in Italy. This means that results obtained in US airports cannot be applied to european ones.

In this paper a methodology previously developed has been applied to the runway capacity estimate of Catania airport. Its infrastructural facilites are similar to those of Naples airport, whose capacity has been evaluated in a previous paper.

The characterization of capacity periods takes place in three phases: in the first one, stationary periods have been extracted from the database. Stationary periods have similar time distance values between one flight and the subsequent. In the second phase only stationary periods with the lowest average values have been considered. These periods have been named "critical periods". In the third phase, critical periods have been cleared of all data over 7 minutes, so becoming capacity periods. Results obtained on the Catania runway have been finally compared to Naples runway ones.

Even though both airports have similar total yearly traffic movement, the infrastructural differences at the time of survey show very different capacity values. The work is still to be developed considering other runway airports and matching data in order to get a quick method to estimate runway capacity.

Keywords: airpor,t capacity, runway.

1. PROBLEM STATEMENT

Airports are infrastructures composed mainly of three parts: Runway(s), Taxiways and Apron. The runway is suitable for aircraft landing and take off; taxiways allow aircraft to leave the runway for the stands close to the terminal and vice versa; on the apron stand all ground handling operations take place, i. e. embarking/desembarking of passengers and bags, cleaning, refuelling etc.

Each of the components have a capacity value, which can be expressed in flight operations per hour. As all components can be considered in sequence, the capacity value of the whole infrastructure is the smallest of the three single components.

The aim of this paper is the capacity evaluation of the runway component. Runway capacity depends directly on the space distance between aircraft: the less is the distance, the higher the capacity is. If, for instance, space distances were all the same and “d” was their value, we should have that

$$C = 60/d$$

“d” being expressed in minutes and C in flight operations per hour.

It is interesting to note that international space distances rules are different from USA ones. In fact, international rules have been established by the International Civil Aviation Association (ICAO) Council. ICAO generally fixes space distances at 10 Nautic Miles (NM). Nevertheless, it is possible for a single State to modify this value as long as it is notified to the other States. In Italy this value changes from airport to airport: the average value is 5NM. In the USA, space distances vary depending on the weight class of the trailing and leading aircraft. Values are assumed between 2,5 and 6 NM.

Why in the USA are space distance rules less restrictive than international? Radar facilities are about the same in the USA and Italy, so does in the saturation period exist the possibility to reduce safety distance values in order to improve capacity?

This paper is a small step towards the definition of a “Manual for determining runway capacity”, similar to the FAA one but calibrated for Italian infrastructures. The manual could be probably used by european countries too with a small extra calibration effort.

2. BACKGROUND

Scientific literature available is based on studies developed on US airports operating with flight rules substantially different from the Italian and European ones. Safety space distances are always less than Italian ones so that capacity values are higher.

Robert Harris was the first author to investigate airport capacity in an organized study [2]. Specifically, he studied runway and gate capacity, the gate being the door towards the approach path to the runway. He built a space/time model which allowed the definition of a “distance matrix” by which it was possible to determine runway capacity.

The Federal Aviation Administration (FAA) commissioned a large study concerning US airports traffic characteristics. The result was a milestone (updated in 1994) for the matter and still today it works well supplying capacity values for all operational situations (landing only, take off only, mix take off /landing, one runway, two runways, three runways, etc.). This study is still today the most complete available and its results are usually applied by professionals [1].

In 1992 Vandevenne developed a parametric model describing the interval probability distribution between two subsequent operations. The work was developed on Los Angeles (LAX) airport. The aim of the model was to characterize, and avoid, capacity falls caused by wake vortex.

In 1993 Venkatakrishnan et al. [5] developed a work showing a methodology to manage and elaborate experimental data (landing only). The average value of time distances is used in an optimization procedure to maximize runway capacity once a batch of aircraft is assigned.

In 2000 Vandevenne e Lippert [7] developed a study using maximum likelihood estimate in order to determine the statistical model parameters for time intervals between two consecutive operations.

In 2005 Rakas and Yin [8] analysed landing time distances on LAX airport. They compared dominant airline times with those of other airlines. Modeling time intervals with a mathematical model showed that time interval distributions can be different depending on the airline.

As for the Italian references we cite the work of Crispino et al. who showed an approach path model derived from railway engineering while de Riso et al. [10, 11] studied Ialian airport runway capacity based on the average and 25th percentile of time interval statistical distribution.

3. DATA COLLECTING

The Catania Fontanarossa airport is located a few kilometers from the center of the city. The vicinity influences the approach and departure procedures. The airport (fig. 1) is a single runway, heading 08-26, 2550 m lenght, 45 m wide. The runway is open in the nightime too (H24) thanks to radio, lighting equipment and facilities available: at the time of survey, Instrumental Landing System (ILS) CAT I and Distance Measuring Equipment (DME) on runway 08-26, VHF Omnidirectional Range (VOR), DME and Non Directional Beacon (DME) on runway 26-08 were present.

The Catania airport can be considered as a regional hub. Traffic data collected for the survey were available from June 14th 2000 to June 30th 2000 and from Aaugust 7th 2001 to August 22nd 2001. Total days surveyed were 33 in which 6400 flight operations were performed. The average value was 194 op/day. The lower value was 136 and 259 the higher. Unfortunately, there were few H class aircraft, meaning that a very low number of wide-body aircraft attended the infrastructure in the period under examination. This led to the decision to leave apart all operations including these aircraft. This will be better explained later.

Data collected were given in form of a 5-column table (tab. 1). The meaning of acronyms is the following:

Flight : ID of flight;

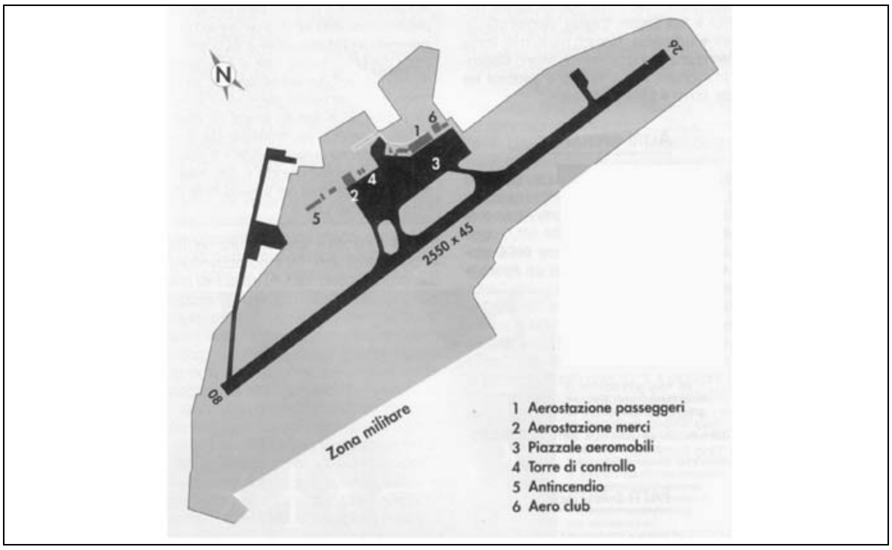

Fig. 1: Catania airport layout at the time of survey

Type : type of aircraft;
C: aircraft class: L stands for Light; M for Medium; H for Heavy;
ATD: Actual Time of Departure;
ATA: Actual Time of Arrival;
Op. : A for Arrival, D for Departure.
Dist: time distance between two consecutive operations.

Tab. 1: example of collected data (Departures in grey)

Date: 14/06/00

Flight	Type	C	ATD	Op.	Dist
BCS 7422	B727/2	M	1.21	D	
AZA 967	MD80	M	1.24	A	0.03.00
AMC 640	B737/3	M	3.02	A	1.38.00
MNL 809	F27	M	4.09	A	1.07.00
AZA 1712	A321	M	4.19	D	0.10.00
AMC 641	B737/3	M	4.25	D	0.06.00
DLH 3941	B737/3	M	4.40	D	0.15.00
AZA 1734	MD80	M	4.54	D	0.14.00
ISS 1171	B737/3	M	5.00	D	0.06.00
AZA 1714	MD80	M	5.04	D	0.04.00
MSA 617	BA46	M	5.07	A	0.03.00
ISS 695	MD80	M	5.14	D	0.07.00
AZA 1703	MD80	M	5.18	D	0.04.00

Subsequently, all survey data have been shared in pairs. Each pair represents a sequence of aircraft belonging to specific weight classes.

LL LM LH ML MM MH HL HM HH

For instance, the ML sequence means that the M weight class aircraft leads and the L trails. Then, each sequence (LL, MM, LM etc.) can be considered in one of the following operational conditions:

DD DA AD AA

Where:
D: Departure, Take off;
A: Arrival, Landing.
In this way it has been possible to define 36 different classes. Nevertheless, it was not possible to make survey for some classes, due to the low operation rate (all of those including H class aircraft).

4. DATA ANALYSES

Runway capacity depends on time distances between aircraft. Therefore, it has been necessary to define the distance variation rule for different weight class. The rule has been determined on the basis of statistic survey criteria. The main problem consists in determining when and in which conditions an airport runway is at capacity level.

First, we have defined the stationary demand conditions. This has been done with the aim to discard data concerning transitory periods before or after the regime phase. Stationary periods have been characterized with a linear correlation between a growing sequence of natural numbers and time distance values evaluated in a daily sequence. This has been done on all of the 33 days under study.

In fig. 2 we have reported the lenght of stationary period along abscissa and the average value of time distance between aircraft along the ordinate. In fig. 3 we have the same draft with the period lenght limited to 3 hours.

The trend of the diagram is typical of 1-runway airports [5, 8, 11]: if the period lenght is short the possible time distance variation is low. Of course, if the period lenght increases, we will have a substancial variation.

The trend of average time distance values grows up if the period lenght increases. It is possible to note this in the draft of fig. 3. This can be explained with the fact that if demand arises (long stationary periods), the flight controller will probably start to increase time distances between aircraft.

5. PEAK PERIODS

It is now necessary to extract capacity periods from the stationary ones, i. e. the periods in which runway works at capacity level. In order to characterize capacity periods, those with the lowest average time distance values have been considered (fig. 3). These periods have been designated as “critical periods”.

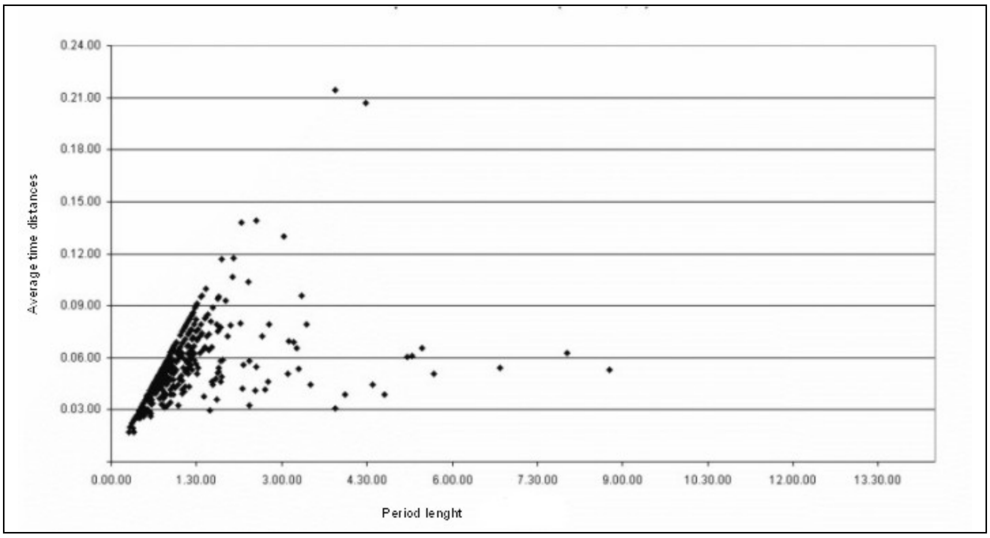

Fig. 2: diagram period lenght/average time distances

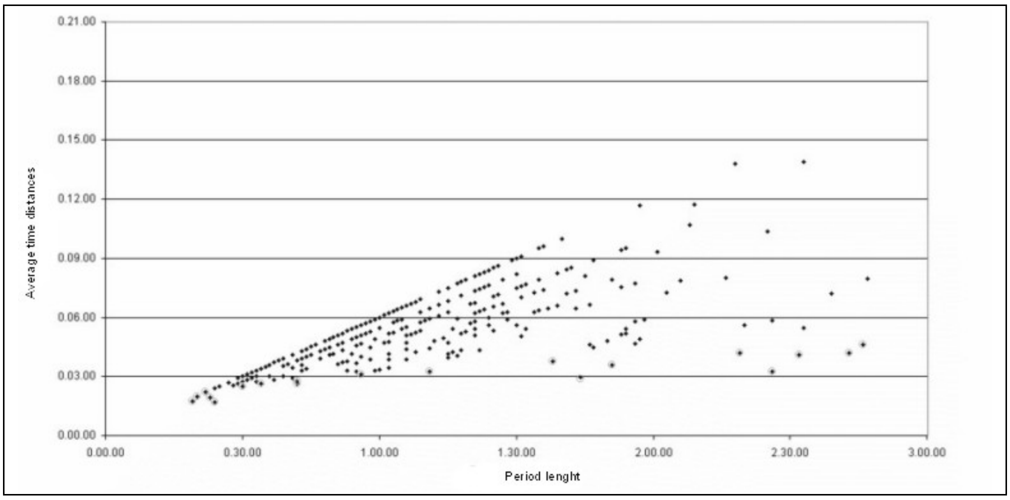

Fig. 3: diagram period lenght/average time distances (until 3 hours)

The 20 points which define the lower limit in fig. 3 have been taken into account. These have been highlighted in fig. 3. In tab. 2 we have reported each of the 20 critical periods examined with starting and end time.

A substancial part of the examined periods is included in the time window [07.00-10.00 AM]. Some others have been recorded in the [13.00-16.00] noon time window. This suits with the general demand trend in the average traffic airports: in these infrastructures usually 3 peak points take place: early morning, noon and the evening peak.

Tab. 2: critical periods

Period	Date	Start time	End time	Lenght
1	14/06/00	8.22.00	10.48.00	2.26.00
2	19/06/00	9.16.00	9.38.00	0.22.00
3	21/06/00	9.05.00	10.56.00	1.51.00
4	27/06/00	6.43.00	9.29.00	2.46.00
5	30/06/00	7.29.00	9.07.00	1.38.00
6	08/08/01	8.44.00	9.18.00	0.34.00
7	09/08/01	8.15.00	9.59.00	1.44.00
8	09/08/01	17.23.00	18.01.00	0.38.00
9	10/08/01	8.44.00	9.08.00	0.24.00
10	10/08/01	14.57.00	15.39.00	0.42.00
11	10/08/01	16.51.00	18.02.00	1.11.00
12	13/08/01	7.21.00	10.04.00	2.43.00
13	13/08/01	12.00.00	12.19.00	0.19.00
14	14/08/01	8.39.00	9.01.00	0.22.00
15	17/08/01	13.59.00	16.18.00	2.19.00
16	21/08/01	8.28.00	9.10.00	0.42.00
17	21/08/01	9.17.00	9.40.00	0.23.00
18	21/08/01	13.22.00	15.54.00	2.32.00
19	21/08/01	15.54.00	16.14.00	0.20.00
20	22/08/01	6.18.00	7.14.00	0.56.00

Tab. 2 periods have been carefully investigated. In fig. 4 an extract of fig. 3 draft has been reported. It is interesting to note that with a correlation coefficient of 0,878, the trend of the curve increases, according to the consideration that if the peak period duration increases, time distances between aircraft would increase too.

In practice, the statistical sample created with critical period time distances has been shared in each of the 16 weight classes previously defined. For each of the 16 classes, relative frequencies and weighted average values have been determined. The weighted values so determined define the critical demand time distances.

The survey showed that often the minimum distance spacings have been violated. We have registered subsequent landing at time distances less than 1 minute which implies space distances lower than mandatory rules. Nevertheless, average values are higher than these values. Few cases are exceptions. In tab. 3, average weighted values in critical demand conditions for each kind of operations have been reported.

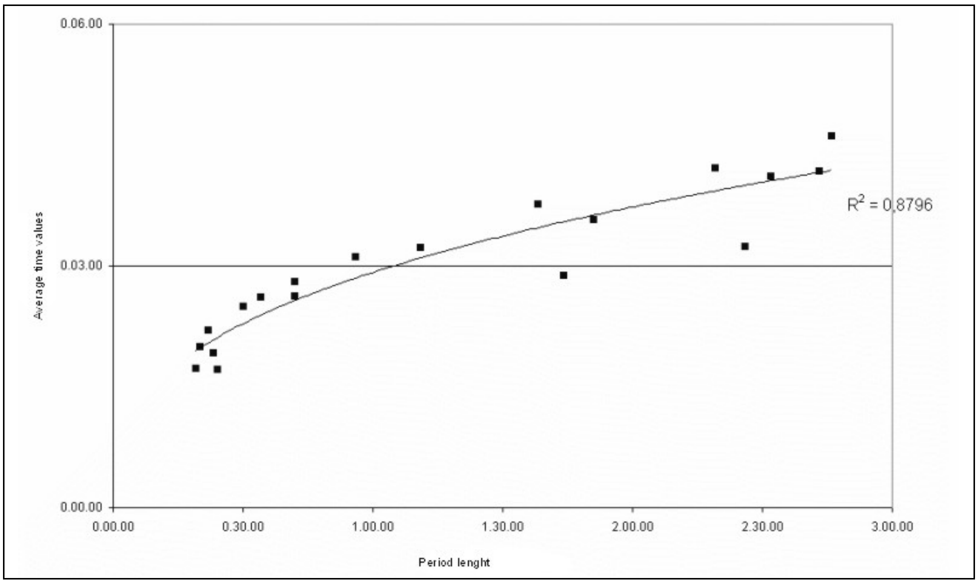

Fig. 4: diagram critical period lenght/average time distances

Tab. 3: average weighted values for each of the 16 classes under study

	LL	LM	ML	MM
DD	2,08	4,06	2,43	4,27
AA	1,95	1,92	2,04	3,61
AD	3,59	5,37	2,89	3,73
DA	1,91	4,04	2,75	5,28

6. CAPACITY CONDITIONS

We have defined in the previous paragraph critical demand conditions. Critical demand cannot be considered as capacity conditions as we have surveyed time distance values of 20 minutes too. This happens mainly for periods with a duration lenght of 1 hour or more. For periods with duration lower than 1 hour in general we have not registered demand fall, i. e. time distances higher than 7/8 minutes. That's why we cannot talk of capacity conditions in the critical demand study. It is so necessary to pass from critical demand conditions to capacity conditions.

To do so, the statistical sample created with critical period time distances has been processed again removing all time distances higher than 7 minutes. In this way, we have considered that on the final approach path there is at least one aircraft waiting to be served. This condition has already been applied in the past in Harris model [2]. So we had new "capacity periods". Results in terms of average values are plotted in tab. 4.

We observe that average values are consistently lower than those registered in the critical demand conditions (see tab. 3 for a comparison). These values define capacity conditions. It is possible now to evaluate the time necessary to get through a batch of aircraft in capacity conditions.

Tab. 4: Average time distance values in capacity conditions

	LL	LM	ML	MM
DD	1,52	2,95	2,04	3,62
AA	2,80	3,76	2,42	3,56
AD	1,95	1,92	1,77	3,20
DA	1,75	3,22	2,43	3,67

7. EQUIVALENT OPERATION

The background presented in chapter 3 of this paper shows how capacity can depend on several parameters. More specifically, the FAA work [1] characterizes several parameters like Mix Index, Arrival Percentage, VFR and IFR conditions and so on. As for the Mix Index, we have taken into account this parameter by sharing time distance values in classes depending on the weight of the aircraft. The same consideration can be done for the parameter arrival percentage.

It is now necessary to define a new parameter by which the capacity evaluation can be immediate and comparable between different airports. This parameter could be useful to planning phase, especially in the slot assignation phase by Eurocontrol.

We have defined this parameter as the “standard operation” or “equivalent operation”. This is an “average” operation which can represent all others with the help of equivalence coefficients. The equivalent operation has been choosen between the 16 available.

First we have evaluated the global average operation time. This has been obtained weighting the presence of all operations in the statistical survey. Then, we have choosen the standard operation as the one which better approaches the global average operation time. In this case, the operation was the sequence MM in the AD operational conditions. The standard operation will be used in the next chapter to compare Catania airport capacity and Napoli ones.

Once determined the standard operation it is possible to relate to it all kinds of operations with the help of equivalence coefficients. In other words, it is possible to assign an equivalence coefficient reporting the i operation to the equivalent one.

In tab. 5 equivalence coefficients are showed. Of course, the standard operation coefficient will be 1 (MM sequence in AD operational conditions).

The value obtained for the Catania Fontanarossa airport is 19 op./hours. We define this value as 19 equivalent operations per hour.

8. COMPARING CATANIA AND NAPOLI CAPACITIES

It is now possible to compare Napoli and Catania capacity values. Both capacities have been determined with the same mothodology.

Tab. 5: equivalence coefficients

	LL	LM	ML	MM
DD	0,48	0,92	0,64	1,13
AA	0,88	1,18	0,76	1,11
AD	0,61	0,60	0,55	1,00
DA	0,55	1,01	0,76	1,15

The first tab (see tab. 6) shows the statistical sample for both airports, in each of the operational conditions. In tab. 7 capacity time distances are showed. We have highlighted the standard operation for both airports. These are different for the reasons explained in the previous paragraph. In tab. 8 we compare all equivalence coefficients assuming as standard operation the Catania one. In tab. 9 we have insted reported all equivalence coefficients assuming Napoli's one as standard operation.

Tab. 6: Statistical sample

CATANIA

	LL	LM	ML	MM
DD	21	21	25	21
AA	15	21	26	39
AD	19	25	22	46
DA	24	27	28	30
Sum	79	94	101	136

NAPOLI

	LL	LM	ML	MM
DD	10	13	15	55
AA	4	6	8	44
AD	6	11	15	45
DA	3	16	15	37
Sum	23	46	53	181

Tab. 7: Time distances

CATANIA

	LL	LM	ML	MM
DD	1,52	2,95	2,04	3,62
AA	2,80	3,76	2,42	3,56
AD	1,95	1,92	1,77	3,20
DA	1,75	3,22	2,43	3,67

NAPOLI

	LL	LM	ML	MM
DD	2,20	2,54	2,33	2,98
AA	1,80	4,50	2,13	3,61
AD	2,50	2,91	1,67	2,31
DA	3,67	4,25	2,93	3,35

Tab. 8: Equivalence coefficients assuming Catania's standard op.

CATANIA

	LL	LM	ML	MM
DD	0,48	0,92	0,64	1,13
AA	0,88	1,18	0,76	1,11
AD	0,61	0,60	0,55	1,00
DA	0,55	1,01	0,76	1,15

NAPOLI

	LL	LM	ML	MM
DD	0,69	0,79	0,73	0,93
AA	0,56	1,41	0,67	1,13
AD	0,78	0,91	0,52	0,72
DA	1,15	1,33	0,92	1,05

Tab. 9: Equivalence coefficient assuming Napoli's standard op.

CATANIA

	LL	LM	ML	MM
DD	0,51	0,99	0,68	1,21
AA	0,94	1,26	0,81	1,20
AD	0,65	0,64	0,59	1,07
DA	0,59	1,08	0,81	1,23

NAPOLI

	LL	LM	ML	MM
DD	0,74	0,85	0,78	1,00
AA	0,60	1,51	0,71	1,21
AD	0,84	0,98	0,56	0,78
DA	1,23	1,43	0,98	1,12

The study of the previous reported tabs allows some interesting considerations. First of all we have to remind that at the time of the survey in 2001 Catania had the old layout (pictured in fig. 1) without a parallel taxiway. On the other side, Napoli had a parallel taxiway all along the runway. So, the 2 airports were infrastructurally different.

As to tab. 6 we note that L class aircraft were much popular on Catania airport than Napoli. The layout of exit taxiways was also in favour of L aircraft, allowing them to leave early the runway. The relatively high presence of L class aircraft let Catania airport capacity approach Napoli one, as it is possible to read in tab. 7: operations involving L class aircraft have nearly always time distances lower than Napoli. On the other side, operations involving M class aircraft get lower capacity values on Catania. This has been probably due to the lack of a parallel taxiway to the runway and to the missing of adequate exit taxiways from the runway. In other words, the typical M aircraft operation implies that a good part of the runway must be covered before the operation itself could take place. This, of course, increased runway time service and decreased capacity. The final result is 19 standard op/hour for Catania and 26 for Napoli considering the MM-DA as standard operation (Catania) for both.

9. CONCLUSIONS

In this paper a new methodology for evaluating single runway airport capacity has been applied. Results have been compared to others coming from the first application which was carried out at Napoli airport [6, 10, 11]. The airport and its runway studied in this case is Catania/Fontanarossa. The survey was made before the main works involving Fontanarossa were made. So, all results refer to a single runway airport, without a parallel taxiway, which was recently added. It will now be interesting to compare capacity values before and after this. The database was made of 6.400 flight operations, surveyed from 2000 to 2001. The operation times considered were the real ones and not the scheduled ones.

The backgroud, showed in chapter 3, is composed by studies and surveys developed in other coutries than Italy, mainly in the States. Nevertheless, there are many differences between aircraft space distance rules which do not allow the use of US survey results to Italian airports and airspace. This is the reason why this methodogy came up. In this paper it was applied to Catania airport.

The methodology showed that Napoli and Catania airports have a runway capacity of, respectively, 19 and 26 standard operations per hour. The official Air Traffic Flow Management (ATFM) capacity values were 12 and 20 respectively, at the time of survey. The difference has been probably due to their infrastructural difference at the time of the survey and the traffic difference, consisting in more General Aviation operations for Catania.

This paper is a small step towards the definition of a "Manual for determining runway capacity", similar to the FAA one but calibrated for Italian infrastructures. The manual could be probably used by European countries too with a small extra calibration effort.

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