Analysis of New Arrival Operational Procedures in Terminal Airspace

João Gonçalo Patrício Duarte Anes Coelho
joaogoncalocoelho@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisboa, Portugal

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Abstract

In this dissertation a new arrival procedure to Lisbon airport was studied: Point Merge system. All the procedures of Lisbon terminal airspace, currently used, were analyzed, followed by the development of 8 scenarios with the implemented Point Merge system and, in addition, a reference scenario was created to work as a baseline. All the simulations were performed using the RAMS Plus, a Fast-Time Simulations software, which allowed the development and result analysis of these 9 scenarios. It was also analyzed the distance flown per arrival aircraft inside Lisbon TMA. In order to calculate the sectors capacity of each scenario the CAPAN method was used.

Keywords: Capacity, CAPAN, Lisbon Terminal Airspace, Point Merge System, RAMS Plus

1. Introduction

Nowadays we live in global world, where people travel every time more and more increasing the number of flights at airports and Lisbon airport is no exception. According to EUROCONTROL seven year forecast February 2016 the average annual traffic growth for Lisbon Flight Information Region is 2.7%. As a result Portugal airspace Air Navigation Service Provider NAV has been looking for solutions to increase the capacity of Lisbon terminal airspace. This study is mainly focused on the analysis of the Point Merge system, applied to Lisbon runway 03 arrival routes, with the aim of enhancing the capacity of Lisbon terminal airspace and also to decrease the distance flown by the arrivals within the Lisbon TMA, in order to save fuel and its consequent benefits on economic and environmental level. It is also included in this study the Montijo runway 01 as an auxiliary to the runway 03. The development of new approach routes to the runway should take into account several factors. The work was developed using EUROCONTROL guidelines in terminal airspace design[1][2]. 9 terminal airspace scenarios were created including the current baseline reference scenario. The other 8 new scenarios were a Point Merge system design type. The simulation of these scenarios was performed using the fast-time simulation tool: RAMS Plus.Sector capacity analysis was performed using EUROCONTROL CAPAN method[3] relating controllers workload with number of flights received in each sector.

2. Airspace Concept Development

Traffic increase in terminal airspace places a demand on the responsible bodies of ATM to take measures to promote the optimization of airspace, developing new procedures that allow more efficient traffic flow. The development of these new procedures should take into account the objectives of the project and it is divided into four phases: planning, design, validation and implementation. In planning, the project

objectives are defined, as well as the team that will be in charge of it. The controllers involved in the design try to choose the best location for the new route so that the traffic control can be done in an efficient way. During the validation phase several simulations of the new airspace are made using analytical models, fast-time simulations and real-time simulations. In the last phase, it is done the training of all users (controllers, pilots) that will work in this new airspace and it is made the publication of all the new procedures implemented. The process of developing a new airspace it is an iterative process[1][2].

3. Point Merge System

The Point Merge system was developed in 2006 by EUROCONTROL and it is already implemented in several European airports. The Point Merge is supported by P-RNAV systems and allows to sequence efficiently the traffic on runway final approach, making possible the continuous descent approach, even with a lot of traffic. The arrival routes which work with the Point Merge system have a convergent geometry that allows the path stretching or shortening, and comprise a merge point - where traffic is integrated into the runway final approach - and sequencing legs - which should be isodistant and equidistant from the merge point and shall be separated from each other on lateral and vertical level[4].

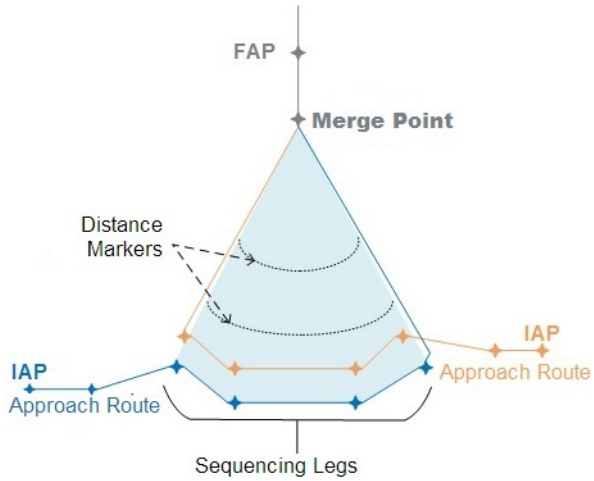

Figure 1: Point Merge System Route Structure

The inner leg should be located at an higher altitude than the outer leg to ensure that the flights using the latter do not cross the inner leg[4]. To simplify the separation between aircrafts and to sequencing them are employed RNAV STAR's that allow an effective transition from en-route phase to the runway approaching phase of the flight, sequencing the traffic into a single stream to the runway. The terminal airspace controllers must ensure the separation between arrivals/arivals and arrivals/departures, and integrate the flights on the runway landing sequence in a safe and efficient way[5]. In the Point Merge system, controllers need to give a "Direct To" clearance so that the flights turn out the leg to the merge point. In the approach to the merge point, the controllers must ensure that flights are properly separated and if necessary give speed control instructions to avoid the violation of these separations[4]. This new procedure is quite intuitive and the number of instructions given by the controllers is smaller than in the conventional procedures, causing the reduction of the workload and permitting a more efficient handling of the incoming traffic[6][7].

4. RAMS Plus

RAMS is an air traffic management fast-time simulation model developed at the EUROCONTROL Experimental Center (EEC)[8]. Currently, this software is distributed and developed by the company ISA Software under the name of RAMS Plus. The RAMS Plus provides gate-to-gate fast-time discrete-event simulation to quantify performance benefits for ATM management decision support and it is used to measure a wide variety of ATM parameters, such as workload, capacity and delays[9]. To analyze these parameters it is necessary to set an airspace scenario with the properly configurations. Firstly, it is necessary to define an airspace sector through the definition of a specific area and altitude, laying down on a tri-dimensional space. It is also possible to establish restrict areas, on a specific time schedule or day, and where only authorized aircraft can fly[9]. In each sector there are two con-

trollers: a planning controller (who checks the in and out traffic on the bordering sectors) and a tactical controller (who ensures the separation between the aircraft)[8]. Despite the differences, they both are responsible for the traffic that flows over their sector and have defined separations between the aircrafts to check conflict situations. The controllers tasks are used to indicate their workload and, consequently, the capacity of the airspace sectors. In what concerns to the routes, these are defined by a NAVAID sequence and linked to one runway. The routes can have holding points and restrictions based on the velocity and altitude. Runways should be linked to one airport. The user can also determine the occupation and scheduling time of the runway. Generally, it used a real traffic sample in the simulations with the properly aircraft performances[9]. The separations parameters set for the controllers are used to create a conflict zone around the flight and a conflict occurs when two flights are contained in the conflict zone of the other[8].

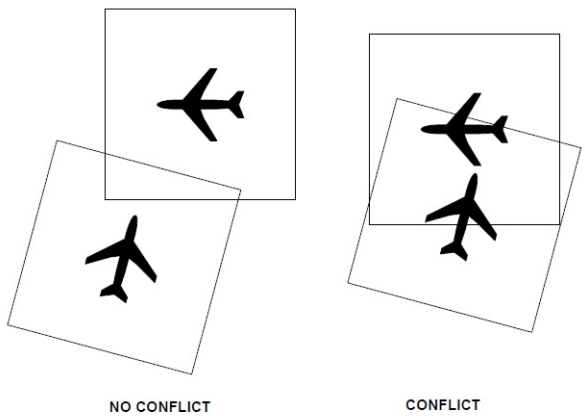

Figure 2: Conflict Detection for Flights[8]

When RAMS detects a potential conflict situation, an appropriate set of resolution rules are activated to solve the conflict[8].

CAPAN Method

The CAPAN method was developed by EUROCONTROL to evaluate sector capacities and new airspace designs. According to CAPAN, the capacity of an ATC sector is considered to be the maximum number of aircraft that can enter in it, in the period of an hour, without exceeding an acceptable level of workload for the controller (70% threshold)[3]. The RAMS is used to determine the controllers workload and the number of sector entries. After that these data is related and, using a regression analysis, the function $WL = F(N_{sector})$ is obtained, with WL corresponding to controllers workload and N_{sector} corresponding to the number of flights that enter into the sectors. The sector capacity is the value of the intersection of this function with the 70% threshold[3].

5. Lisbon Airspace

The Lisbon airport is the largest and the most important of Portugal. And in the last year, between January and September, it handled with 47.74% of all Portugal arrivals and departures[10][11]. The Lisbon airport declared capacity is 38 movements per hour[12].

Airspace

The Lisbon terminal control area comprises the airspace of Lisbon TMA, excluding the portion of Lisboa CTR within these limits. Lisbon TMA can be divided in up to 4 sectors: TMA Upper Sector, TMA Lower Sector, APP Sector 1 and APP Sector 2[13]. The vertical limits of these sectors are presented in Table 1.

	TMA *Upper Sector*	**TMA *Lower Sector***	**APP *Sector* 1**	**APP *Sector* 2**
Upper Limit	FL 245	FL 145	FL 85	2000 ft
Lower Limit	FL 145	FL 55	2000 ft	MSL[1]

Table 1: Lisbon TMA Vertical Limits

The most common configuration of Lisbon TMA works only with 2 sectors (Lisbon TMA and Lisbon APP), without being divided into sub-sectors. And this configuration is represented in Figure 3.

[1] Mean Sea Level

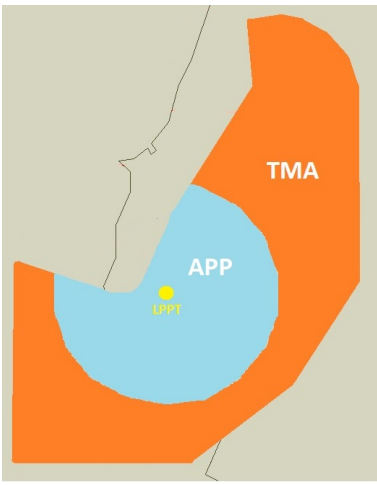

Figure 3: Lisbon TMA and APP Sectors

The Lisbon terminal airspace is surrounded by several restricted areas. These areas are used by the Portuguese military forces and conditioned the use of airspace, in particularly the areas of: Monte Real, Sintra and Montijo Air Bases and the Field Firing Range of Alcochete. It's only possible to use the Point Merge system in runway 03 approach routes because of this constraints.

Routes

The runway 03 of Lisbon airport has 9 RNAV departure routes (SID's) and 10 RNAV arrival routes (STAR's). These STAR's have 4 holding points: ADSAD, EKMAR, FTM and UMUPI. And the XAMAX4C STAR is only used when there is no military activity in Monte Real and Sintra Air Bases[13]. The majority of the income traffic to Lisbon airport comes from the North and East, the same occurs with the outcome traffic from Lisbon airport.

Runways

The Lisbon airport has a two crossing runways: 03/21 with 3800m and 17/35 with 2400m. It's no possible the use of both runways at the same time. The 17/35 runway is mostly used as a taxiway. In addition to the runways this airport has two civil and one military airport terminals[13]. The runway 03 is the most used runway of Lisbon airport for arrivals and departures. The Montijo Air Base has a two crossing runways like Lisbon airport: 01/19 with 2187m and 08/26 with 2448m. This Air Base is mostly used by military aircrafts but sometimes it is used by civil flights to train certain procedures. The plan to use Montijo Air Base as an auxiliary airfield of Lisbon airport establishes the use of 01/19 runway, since it is parallel to 03/21 runway of Lisbon airport. The use of 08/26 runway of Montijo would be impossible since there would be a conflict with flights arriving to Lisbon and to Montijo.

6. RAMS Plus Simulations

To achieve the goals proposed in the beginning of this study it was created 9 different scenarios. The first is a reference scenario and corresponds to the actual procedures of Lisbon terminal airspace. In the other 8 it was used the Point Merge system with small changes between them, that can be seen in the following table:

Scenarios	Description
LPPT03_PM_1	Lisbon's Approach Routes with Point Merge
LPPT03_PM_A_1	Same as LPPT03_PM_1 + Direct Routes
LPPT03_PM_AH_1	Same as LPPT03_PM_A_1 + Holding Points
LPPT03_PM_AHR_1	Same as LPPT03_PM_AH_1 + Restricted Areas Deactivated
LPPT03_PM_AH2_1	Same as LPPT03_PM_AH_1 + Sectorization of APP
LPPT03_PM_AH_2	Same as LPPT03_PM_AH_1 + Sequencing Legs at TMA
LPPT03-LPMT01_PM_AH_1	Lisbon and Montijo's Approach Routes with Point Merge
LPPT03-LPMT01_PM_AH_2	Same as LPPT03-LPMT01_PM_AH_1 + Sequencing Legs at TMA

Table 2: Differences Between the Point Merge System Scenarios

The same traffic sample was used in all 9 scenarios, with 231 departures and 222 arrivals. The airspace was divided into 4 sectors: Lisbon FIR, Lisbon TMA, Lisbon APP and Lisbon CTR. The introduction of Lisbon FIR and CTR was used to guarantee the correct separation between flights that approach Lisbon TMA (FIR) and the runway (CTR).

LPPT03_REF

The reference scenario represents the actual configuration of Lisbon terminal airspace and it works as a baseline for the other scenarios. The routes (Figure 4) and procedures were replicated as close as possible to the ones published in the portuguese AIP. The capacity of this scenario was calibrated in order to reach the actual declared capacity for Lisbon airspace: 38 movements per hour.

Figure 4: STAR's (blue) and SID's (red) - LPPT03_REF

LPPT03_PM_1

The Point Merge System was used in these and in the following scenarios, maintaining the same TMA point entries as the reference scenario. The sequencing legs are located in Lisbon APP, with the inner leg 14 NM distant from the merge point and the outer 16 NM far from the same point. The SID's used in the Point Merge scenarios are the same as the ones used in the reference scenario.

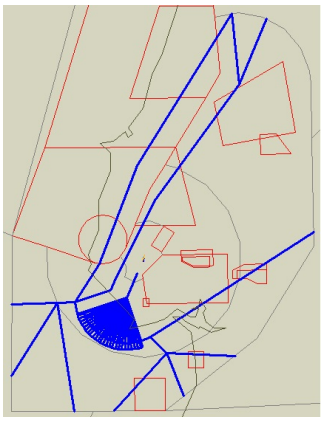

Figure 5: STAR's - LPPT03_PM_1

LPPT03_PM_A_1

It was used the same configuration of the LPPT03_PM_1 scenario with the introduction of direct approach routes. If the traffic demand is not too high, the flights can use these direct routes instead of using the sequencing legs of the Point Merge system, flying a shorter path.

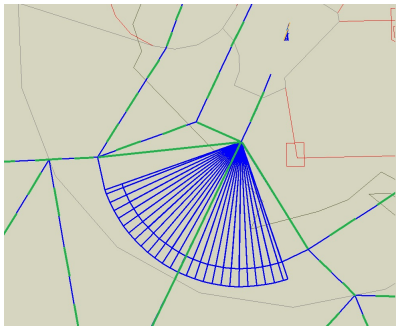

Figure 6: Direct Routes (Green) and Point Merge System Routes (Blue) - LPPT03_PM_A_1

LPPT03_PM_AH_1

Holding points were used in this scenario while keeping the same routes and configuration of the LPPT03_PM_A_1.

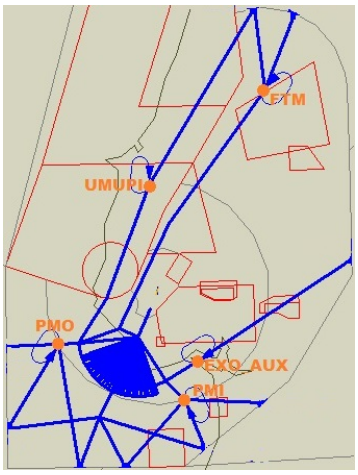

Figure 7: STAR's (Blue) with the Holding Points (Orange) - LPPT03_PM_AH_1

LPPT03_PM_AHR_1

The LPPT03_PM_AH_1 scenario configuration was used in this one with the restricted areas of Monte Real and Sintra deactivated. In this scenario the flights that come from the North can use the STAR XAMAX4C.

LPPT03_PM_AH2_1

The Lisbon airspace capacity is limited by the Lisbon APP sector. This sector was divided in two sub-sectors (APP Sector 1 and APP Sector 2) to study if it is possible to increase the capacity of Lisbon airspace with this configuration.

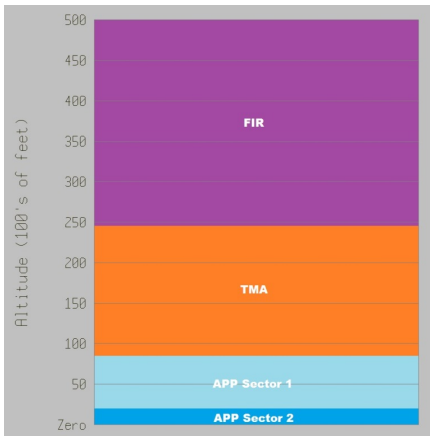

Figure 8: Sectors Vertical Profile - LPPT03_PM_AH2_1

LPPT03_PM_AH_2

The configuration of LPPT03_PM_AH_1 was used in this scenario with the relocation of Point Merge sequencing legs to the TMA (Figure 7). With this new location of the sequencing legs the Point Merge tasks ("Direct To") will be executed by the TMA controllers instead of APP controllers, trying to reduce the workload of the last ones.

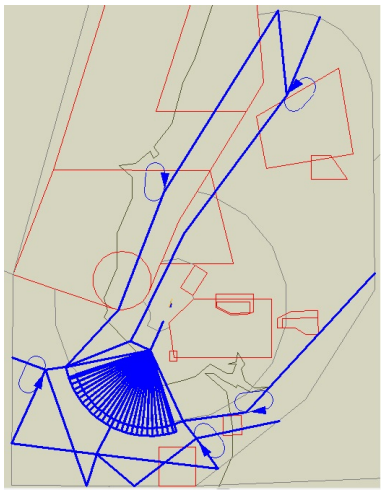

Figure 9: STAR's - LPPT03_PM_AH_2

LPPT03-LPMT01_PM_AH_1

In this scenario was used the Montijo 01 runway as an auxiliary runway to Lisbon 03 runway. The STAR's (Figura 8) of both runways have the same Point Merge system, with the sequencing legs within the APP sector. It was also created a new set of SID's (Figura 8) for both runways to avoid conflicts with the departures. The traffic sample used in this scenario was the same as the one used in the others scenarios with the difference that it was divided for both runways, with the traffic of Montijo corresponding to the flights of airlines that use Lisbon airport Terminal 2[14].

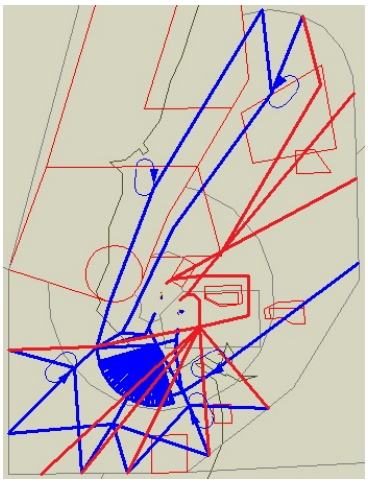

Figure 10: STAR's (blue) and SID's (red) - LPPT03-LPMT01_PM_AH_1

LPPT03-LPMT01_PM_AH_2

It was used the same configuration of the LPPT03-LPMT01_PM_AH_2 scenario with the relocation of the sequencing legs to the TMA sector, like it was done in the LPPT03_PM_AH_2 scenario and to study if this new locations of the Point Merge legs can reduce the APP controllers workload.

Figure 11: STAR's (blue) and SID's (red) - LPPT03-LPMT01_PM_AH_2

7. Results and Discussion

The results from the 9 simulations were analyzed and will be presented with a brief description for each scenario. The Lisbon airspace capacity for all of the 9 scenarios refers to the APP sector capacity, once it is this sector that limits the capacity of Lisbon airspace in all of the scenarios.

LPPT03_REF

The following figures presents the controllers workload, number of conflicts in the sector and number of flights in the sector obtained, with the estimation of the capacity using the CAPAN method.

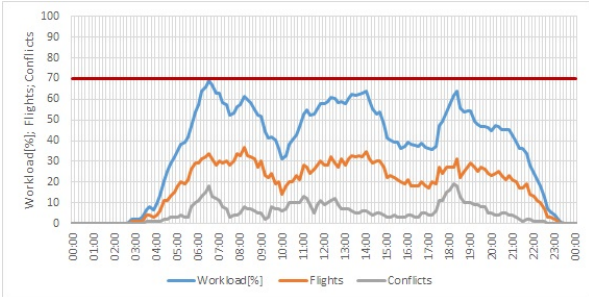

Figure 12: APP Sector Workload, Flights and Conflicts - LPPT03_REF

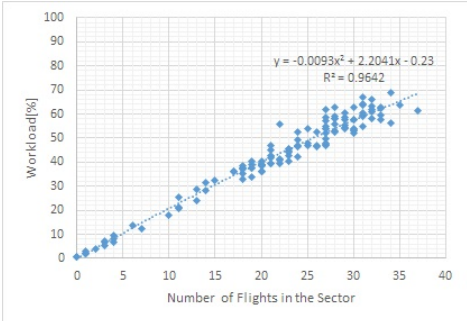

Figure 13: APP Sector Workload, Flights and Conflicts - LPPT03_REF

The capacity is estimated in 38 movements per hour, like it was already referred in the previous section. The average distance flown by the arrivals inside the Lisbon terminal airspace is 97.78 NM.

LPPT03_PM_1

The controllers workload reduces compared with the reference scenario and the capacity increases to 39 movements per hour. The average distance flown by the arrivals is now 111.87 NM, this is related to the increase of the approach routes lenght.

LPPT03_PM_A_1

The introduction of the direct approach routes decreases the average distance flown by the arrivals to 100.06 NM because this new routes are shorter than the Point Merge routes and the majority of the flights uses it (76.73%). The APP sector capacity increases to 41 movements per hour.

LPPT03_PM_AH_1

The integration of holding points in the approach routes reduces the controllers workload and the capacity increases to 42 movements per hour. There is no significant changes in the average distance flown by the aircrafts compared with the LPPT03_PM_A_1 scenario. The number of flights sent to the holding points and the average time they stayed there is similar to the obtained in the reference scenario.

LPPT03_PM_AHR_1

The values of the workload are similar to the ones obtained in the previous scenario but the capacity decreases to 41 movements per hour. The average distance flown by the arrivals is 103.56 NM, with an increase of the average distance flown by the arrivals that entry in the Lisbon TMA by XAMAX. This is because the STAR used in this scenario (XAMAX4C) is longer than the one used in the other scenarios (XAMAX4A).

LPPT03_PM_AH2_1

The results obtained for these scenario were close to the ones from LPPT03_PM_AH_1 scenario. The APP Sector 2 is practically unused and the APP Sector 1 receives the same traffic as the APP sector from the LPPT03_PM_AH_1 scenario, being the APP Sector 1 the limiting scenario and its capacity remains unchanged in the 42 movements per hour.

LPPT03_PM_AH_2

The results of the APP controllers workload increased comparatively to the ones from LPPT03_PM_AH_1 scenario. This occurred because the number of flights in the APP sector also increased. But its capacity remains in the 42 movements per hour. In this scenario the sequencing legs where relocated to the TMA sector and the workload of TMA controllers increase as expected. There is also an increase in the distance flown by the arrivals.

LPPT03-LPMT01_PM_AH_1

The introduction of Montijo 01 runway as an auxiliary runway of Lisbon 03 runway has a significant impact in the capacity of the APP sector, which increases to 44 movements per hour. And the average distance flown by the flights decreases to 98.89 NM, a result close to the one obtained from the reference scenario.

LPPT03-LPMT01_PM_AH_2

The APP and TMA controllers workload increases relatively to the one of LPPT03-LPMT01_PM_AH_1 scenario. And its capacity remains unchanged in the 44 movements per hour. There is also an increase in the average distance flown by the arriving aircrafts because the sequencing legs are now more far away from the merge point comparatively to LPPT03-LPMT01_PM_AH_1 scenario.

Design Adopted

The main objective of this study is to verify if the use of the Point Merge system in Lisbon terminal airspace could increase the capacity of the airspace. All of the 8 scenarios with the Point Merge system implemented achieved that goal.

Scenarios	Capacity	Average Distance[NM]
LPPT03_REF	38	97.78
LPPT03_PM_1	39	111.87
LPPT03_PM_A_1	41	100.06
LPPT03_PM_AH_1	42	101.66
LPPT03_PM_AHR_1	41	103.56
LPPT03_PM_AH2_1	42	101.80
LPPT03_PM_AH_2	42	109.05
LPPT03-LPMT01_PM_AH_1	44	98.89
LPPT03-LPMT01_PM_AH_2	44	110.16

Table 3: Capacity of Lisbon APP Sector and Average Distance Flown by the Arrivals in the Lisbon Terminal Airspace for the 9 Scenarios

The two scenarios with Montijo 01 runway presents the best results for the capacity of the Lisbon APP sector: 44 movements per hour. Of these two it was choose the LPPT03-LPMT01_PM_AH_1 design because the average distance flown by the arrivals is smaller than in the other one, and it is almost the same of the values obtained in the reference scenario.

8. Conclusions

In this study was verified that Lisbon terminal airspace is quite conditioned by the military areas and as a result the Point Merge system could only be implemented in the approach routes of the Lisbon 03 runway. It was also verified that the Lisbon APP is responsible for the maximum capacity of this airspace with 38 movements per hour.

The 8 scenarios with the Point Merge system show that system can be implemented in the Lisbon terminal airspace and all of them increase the capacity of Lisbon APP sector. This study also demonstrated that the best results for the capacity were obtained in the scenarios with Montijo 01 runway as an auxiliary of the Lisbon 03 runway.

Although it has improved the capacity of Lisbon APP sector, it has to take into account that this study focused on fast-time simulations and to validate this new proposal design must be conducted another studies in particular real-time simulations.

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