MODELING AND SIMULATION OF RAPID EXIT TAXIWAYS

Researchers have used AirTOP software to improve runway capacity and minimize congestion at Italy's Costa Smeralda Airport

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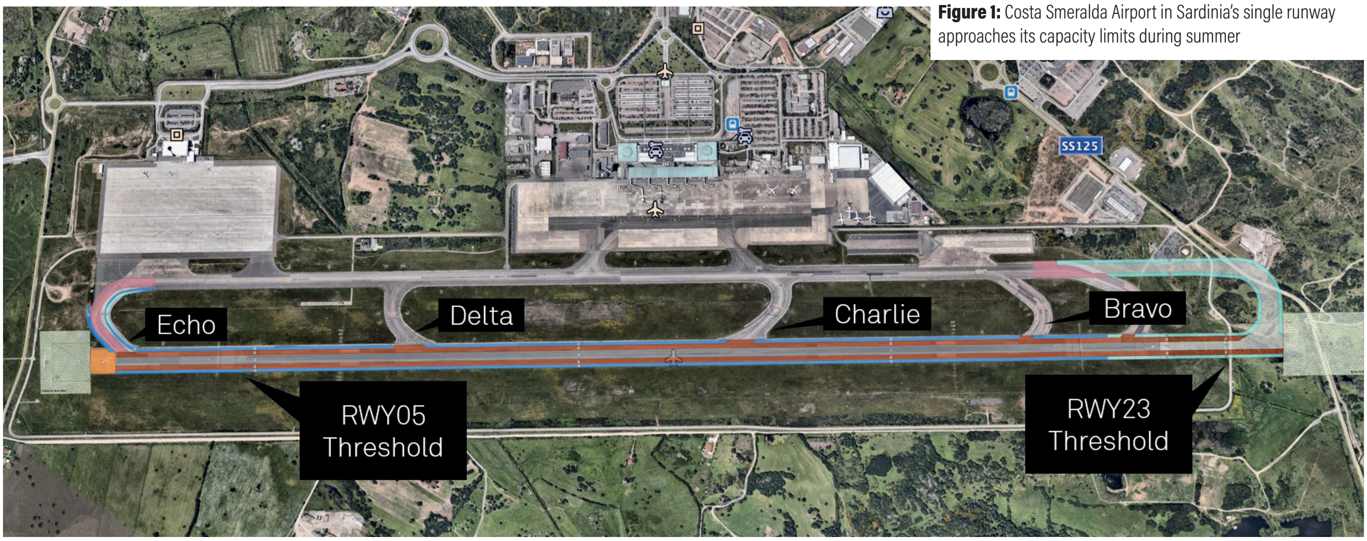

Figure 1: Costa Smeralda Airport in Sardinia's single runway approaches its capacity limits during summer

With airports being the nodes of the air transportation network, their infrastructure plays a crucial role in the air transportation system. Their presence contributes significantly to the development and attraction of an area at domestic and international levels.

To address the ever-adapting demand for passenger and freight traffic, it is imperative to foresee and plan enhancements to improve airport infrastructure and optimize its efficiency, whilst minimizing the impact on the environment. To this end, researchers at the University of Cagliari (UNICA) studied possible designs of Rapid Exit Taxiways (RET) on the Costa Smeralda Airport of Olbia, Italy with a particular focus on identifying the optimal position along the runway.

The study posed the question of whether the implementation of RETs could provide sufficient runway throughput capacity to accommodate the traffic during peak traffic hours. One important reason to provide sufficient capacity is to avoid congestion, which can arise if the demand exceeds the capacity for a sustained period. In this case, the expected delay might exceed the required level of service. This article walks the reader through the methodology adopted to tackle this type of analysis.

Initial assessment and preliminary design

Costa Smeralda Airport (Figure 1) is located entirely within the municipality of Olbia in northern Sardinia and is an important transport hub for flights into and out of the region. Its traffic pattern is highly seasonal and volume has grown constantly. The airport infrastructure comprises a single runway which, in combination with growing demand, poses the risk of approaching its capacity limits during the high season, especially when considering the large share of general aviation traffic.

For this reason, researchers decided to assess possible options for improving the capacity of the single runway system, including considering structural interventions such as the introduction of one or more RETs (Figure 2). A RET connects to a runway at a sharp angle and is designed to allow landing aircraft to maintain a higher rolling velocity after the touchdown by making it possible to exit the runway at speeds higher than those achievable when using runway exits with sharper turns. The increase in taxiing speed minimizes runway occupancy time, which in turn increases runway capacity.

The design of the RETs was initially carried out following the guidelines made available by the International Civil Aviation Organization (ICAO) through the Doc 9157 Aerodrome Design Manual. As a first step researchers assessed the potential of RET implementation. The hourly movements of both general and commercial aviation were considered as the metric for evaluation. This indicator had to exceed a predefined threshold for a sustained period to justify the choice for the RET option.

The number and location of RETs were based on four basic planning criteria: firstly, for runways exclusively intended for landings, RET design should provide reduced runway occupancy times consistent

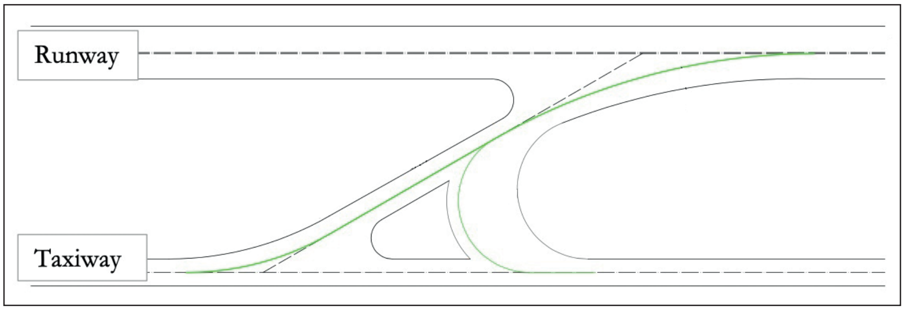

Figure 2: Rapid exit taxiways allow landing aircraft to move off the runway at a higher speeds than exits with sharper turns

with minimum inter-arrival spacings. Secondly, for mixed-use runways the required time separation between the landing aircraft and the following departure should be the main factor limiting runway capacity. Thirdly, with different types of aircraft ideally requiring different RET locations, the aircraft fleet mix had to be considered. Finally, braking characteristics and operational turn-off speed of aircraft will determine the location of the exits.

In the case of Olbia Airport with a single runway, the second criterion generally is more relevant than the first: allowing an arrival to vacate the runway faster means clearing the following departure earlier, therefore increasing the overall throughput. The third and fourth criteria, together with the recommendations by the Federal Aviation Administration (FAA) regulation (AC 150 / 5300-13 A) on the distance between runway and taxiway, guided the initial positioning of the RET benefitting the highest number of arrivals for a traffic sample representing the demand on a busy summer day.

The "Three Segment Method" (Figure 3) was employed to establish the location of the RETs. This method determines the typical segmental distance requirements from the landing threshold to the "optimal turning point" (OPT) based on the operational procedures of the individual aircraft and the effect of the specific parameters involved.

The methodology is based on analytical considerations complemented by empirical assumptions. For exit taxiway design, aircraft can be grouped based on their threshold speed. The number of exit taxiways will depend on the types of aircraft and the number of each type that operates during the peak period. In this analysis, given the traffic sample, one RET per runway direction was assessed.

The three distances were calculated analytically for different wind conditions representative of the area. Since the location of the touchdown point, the transition distance, and the braking distance are only known with a degree of uncertainty, a margin around the OTP was added, identifying the optimal turn-off segments (OTS). This led to the evaluation of the OTSmax, i.e., the OTS with the highest percentage of aircraft being served. Thus, a first set of values for the optimal distance of the RET from the runway threshold was identified, one for each runway direction.

Modeling, simulation, and validation

Following the preliminary design, the researchers set up and performed a series of simulations to establish the optimal point for positioning the RET and to validate the initial results. The first step was to conduct preliminary simulations using a FAA software solution, which quantifies the runway occupancy time and the assignment of aircraft to runway exists. For Olbia Airport, the distance from the threshold for the two runway directions obtained by the FAA software differed from the preliminary design results. The second step was then to improve simulation accuracy for the different locations of the RETs obtained through the initial assessment and preliminary simulation and to compare results against the current runway layout.

Transoft Solutions' AirTOP, an integrated software solution for the simulation of air traffic systems, was the tool of choice for this purpose. A model of Costa Smeralda Airport, created using AirTOP's Airside Aircraft and TMA/TRACON modules, enables the recreation of both the airfield and airspace system in great detail, providing a clear picture of the traffic situation during the peak hours. Furthermore, AirTOP is able to assess runway capacity considering the RETs while providing the complete picture, enabling the designer to identify potential, operational bottlenecks and to evaluate possible solutions.

To build the model, the airport's layout was first defined, which made it possible to reproduce the physical and technical characteristics of the airport. At Olbia Airport, the runway is used in two directions (05 and 23). Following the runway layout, a minimum set of operational rules was specified, which is not the set of rules for actual operation at the airport, but consistent with the initial assessment criteria: dependencies between departures and arrivals (departure clearances before and/or after an arrival), the minimum separation between consecutive departures (for instance the required time/distance separation for consecutive departures to the same airspace fix) and required arrivals gaps.

The ground operations on the remaining part of the airfield were simplified since the focus of the study was the analysis of the runway system. Aircraft performance characteristics played an important role, since the positioning of the RETs is strongly dependent on braking performances, landing speed, and touch-down location. All these parameters can be defined in the AirTOP model, also allowing for randomization of some input data for uncertainty propagation and analysis. Finally, a traffic sample for a busy summer day was imported.

The first set of results showed that the airport could handle the demand, with no significant benefit due to the RETs. To measure the effect of the RETs on achievable runway throughput, the demand needed to be increased further. Using the AirTOP Runway Capacity Analyzer module it is possible to simulate different traffic samples simultaneously and crucially to generate new traffic samples during runtime, gradually increasing pressure on the runway.

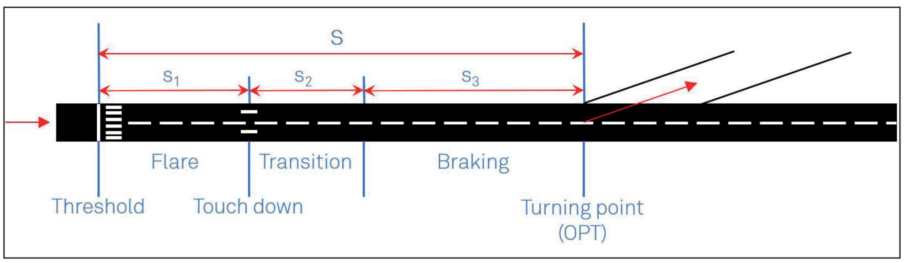

Figure 3: The Three Segment Method determines a rapid exit taxiway location according to specific parameters

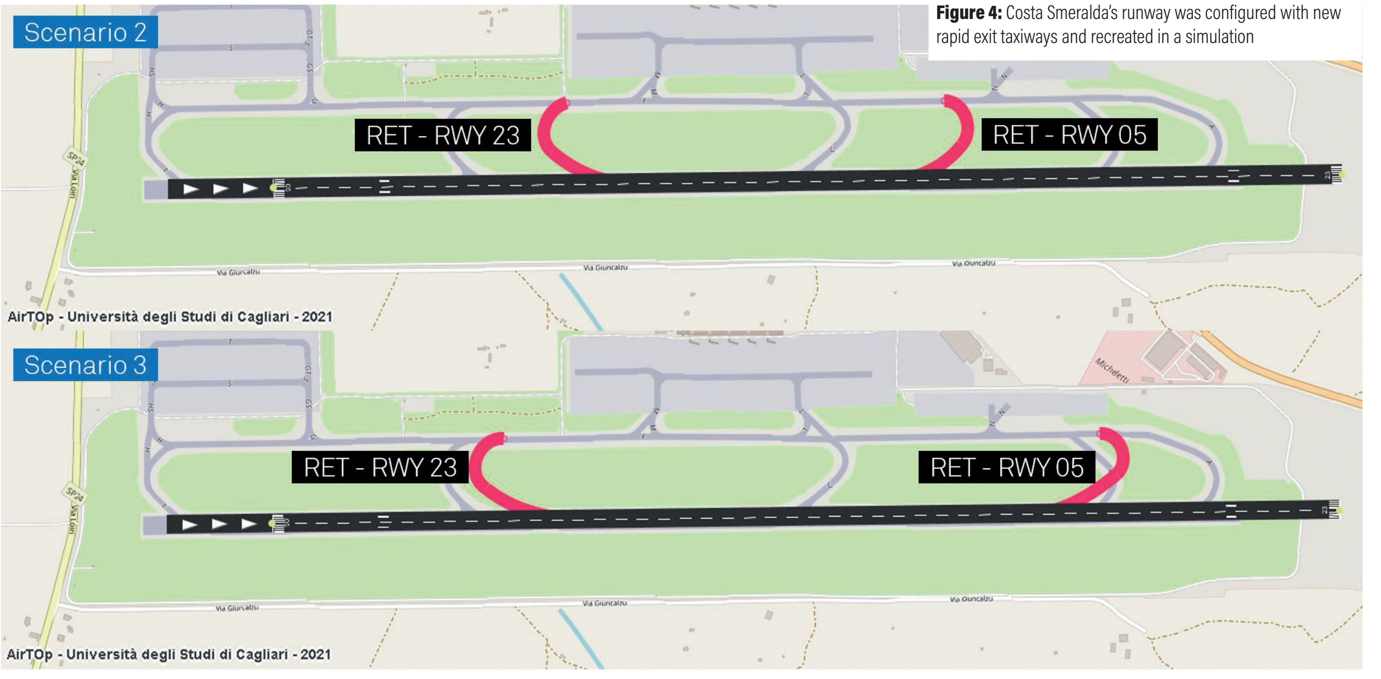

Figure 4: Costa Smeralda's runway was configured with new rapid exit taxiways and recreated in a simulation

Demand levels approaching the capacity of the current runway system highlight the benefit of the RETs. Six different configurations were defined, i.e., three scenarios for each runway direction: the current runway system (baseline), the first set of RET positions obtained from the initial assessment, and the second set obtained from the preliminary simulation. The first image (Figure 1) shows the baseline configuration of the Costa Smeralda Airport. Both, the entry taxiways, namely Echo for runway 05 and Alpha for runway 23, as well as the exit taxiways, namely Charlie and Bravo for runway 05 and Delta and Echo for runway 23, are indicated. In the second scenario (Figure 4) the Delta and Bravo exit taxiways are replaced by the RETs positioned at approximately 1 NM from the threshold of each runway direction. In the third scenario the Echo exit taxiway is replaced by the RET located around 0.9 NM from the runway 23 threshold, while the Charlie exit is replaced by a RET located at a shorter distance, about 0.8 NM, from the runway 05 threshold.

Capacity increases achieved

Simulations in AirTOP facilitated estimating the capacity of the runway system at Costa Smeralda Airport for the current runway configuration, with no RETs and two configurations with the RETs. The capacity of the runway was estimated by subjecting the system to the maximum traffic load possible to accommodate, by increasing demand without exceeding a certain delay threshold.

The results show that RETs are a valid way to increase runway capacity by reducing runway occupation time for arrival flights. In scenario number two, RETs placed at roughly 1NM from the runway threshold for both directions, the runway capacity can increase by approximately +22% in easterly/northerly operations (23 direction) and +4% for westerly/southerly operations (05 direction). The third scenario showed a capacity increase of +11% compared to the current state for easterly/northerly operations and up to +29% for westerly/southerly operations (Figure 5). Furthermore, the simulation results showed that a mixed set of RET locations, namely 1 NM from runway 05 threshold (scenario number two) and 0.9 NM from runway 23 threshold (scenario number three), can lead to a substantial improvement of the runway capacity. ❖

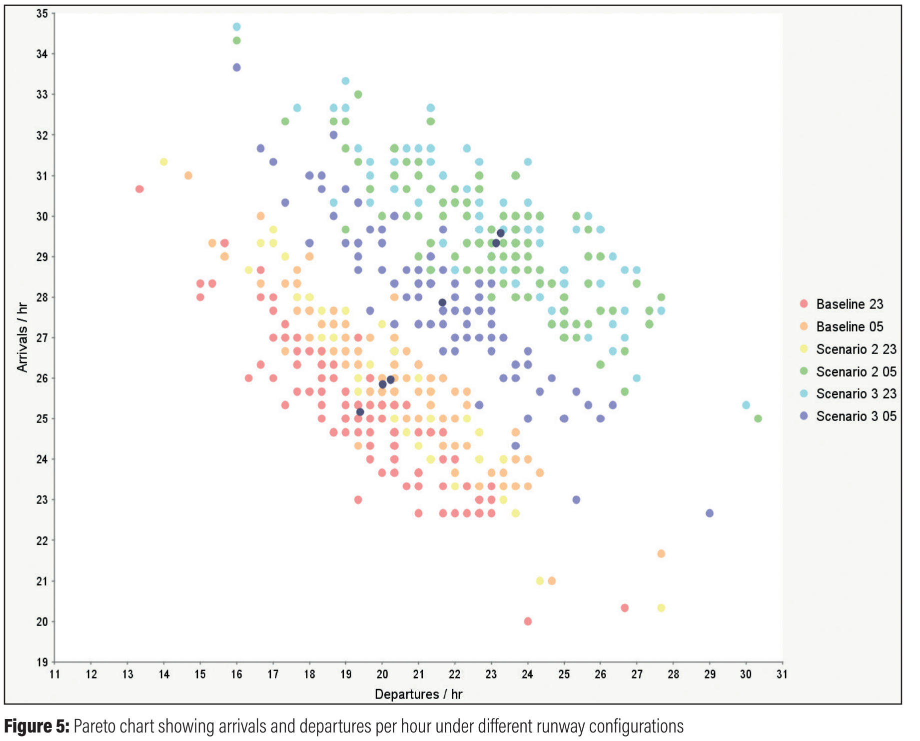

Figure 5: Pareto chart showing arrivals and departures per hour under different runway configurations