Estimation of Airport Capacity through the Determination of the Tower Controller Time Load

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Abstract

MICA[1] studies airport capacity from an organisational and human resource management point of view. Using this point of view permits to establish a relationship between controller time load -percentage of time that the controller spends performing an activity - and capacity. The application of the MICA methodology to the Palma de Mallorca airport has shown that the methodology is viable and that it produces acceptable results.

Introduction

Airport capacity is usually defined as the number of landings and takeoffs performed per hour. This value is usually determined through the application of analytical formulas or simulations that take into account the airport infrastructure, the traffic density and its distribution.

This point of view tends to oversimplify the determination of capacity, since it presents capacity as a function of airport layout, but in fact experience shows that capacity is a complex combination of factors such as the workload of the tower controllers, weather, airspace capacity, network effects, and, of course, airport layout.

To take into account this fact, Aena has launched a research programme that analyses capacity from the points of view of both airport configuration and human resource organisation. This research is performed through two programmes PICAP (Programa de Investigación de Capacidad de Pista[2]) and MICA.

These two programmes describe airport capacity as a combination of both airport infrastructure and configuration, as well as controller workload. Specifically, MICA studies airport capacity from an organisational and human resource management point of view. Within MICA, capacity is defined as **the number of landings and takeoffs managed by a group of controllers with a specific organisation, time load and airport configuration.**

From the MICA standpoint capacity is viewed as a function of:

- Controller organisation
- Operations, events, activities and actions performed by the controllers
- Types of positions and roles of the controllers
- Roles or activity organisation
- Technical means available -including communication and surveillance -.

Thus the MICA project is focused on the estimation of airport Air Traffic Control (ATC) capacity[3].

Estimation of Air Traffic Control capacity in an airport Control Tower

The assessment of actual controller workload in the Control Tower environment is difficult since it is not possible to measure it through traditional ways -such as pupil enlargement or heart rate -. Workload measurements usually require the use of instrument packages that might interfere with the controller's operations. To avoid this problem MICA has investigated the relationship between time load[4] and Control Tower capacity.

Key to the time load concept is also the concept of saturation. Within MICA time load saturation occurs when a controller has to perform more activities that he / she may handle. Beyond a certain time load[5] the controller is no longer

[1] *Modelo Integrado de Capacidad ATM* – Integrated ATM Capacity Model

[2] Research Programme for the Increase of Runway Capacity

[3] In this instance ATC is assumed to include also apron and taxiway operations.

[4] Time load –as defined by MICA – is defined as the percentage of time during which a controller performs any physical activity.

[5] MICA assumes a conservative saturation point of 60% ([1], [2] to ensure that any additional

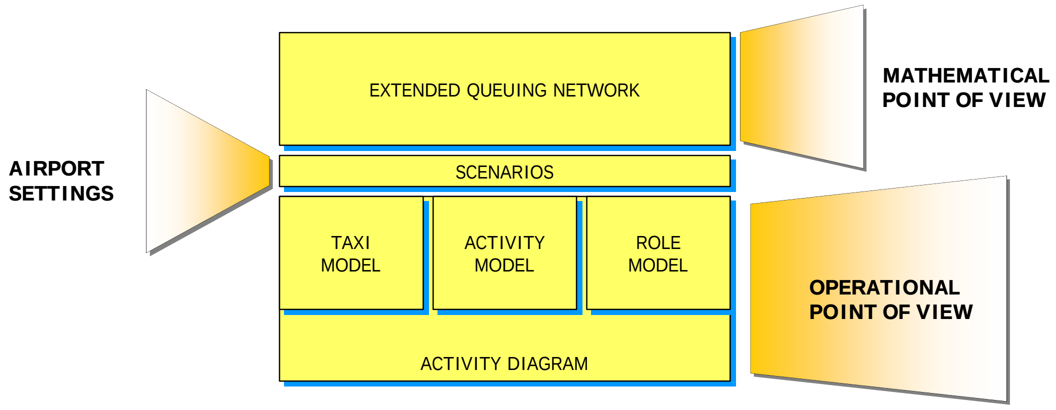

Figure 1. MICA Three Layer Capacity Model

able to satisfy the demand for new activities. Even more, the addition of new activities results in a decrease of his / her productivity due to the additional communication and management overheads.

The methodology proposed by MICA to estimate the capacity is based on elaboration of a three-layer model –as shown in Figure 1 -. The MICA model is developed in four phases:

- Identification of controller activities
- Field measurement of the time spent by the controller performing an activity
- Elaboration and Validation of an Extended Queuing Network Model (EQN Model)
- Estimation and analysis of airport capacity

MICA Model Development Methodology

As it has been indicated previously the MICA model is developed in four different phases. The purpose of this strategy is to ensure that the model reflects as accurately as possible the actual operations and to facilitate the collaboration of the different persons involved in the Control Tower operations.

The first phase "*Identification of Controller activities*" focuses on the elaboration of an activity diagram based on a Three-Layer model and a set of scenarios for the Control Tower.

The "*Field Measurements*" phase concentrates on the compilation of the timing associated to each activity identified in the first phase.

During the third phase "*Elaboration of EQN Model*", MICA elaborates and validates an EQN Model based on the activity diagram and on the scenarios identified in phase 2. The EQN Model is calibrated using the measurement obtained in phase 2. Once the model has been calibrated and validated it is possible to solve it using new traffic patterns and densities.

The last phase "*Estimation and analysis of airport capacity*" of the methodology is dedicated to the estimation and analysis of the airport capacity. This is done using the results from the previous phases.

The results of the MICA process are a set of curves relating each controller time load – specific to a role or set roles associated to the controller – and to the maximum number of movements achievable on the airport. These curves allow analysing the effects of the different Control Tower organisations on airport capacity,

MICA Three-Layer Capacity Model

The use of the three-layer model provides three different views of ATC capacity: Operational, Airport Setting and Mathematical.

These facilitates the use of the model by different groups of people and increases its potential reuse through the generation of "generic" diagrams that can be customised for each Control Tower. For example, activity diagrams can be used to explain and analyse operational issues with Tower Controllers; scenarios can be used to understand how different Control Tower organisations affect capacity from a management point of view; extended queuing networks can be used to assess and analyse the capacity.

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activities not reflected in the model –such as vehicle crossings – are adequately dealt with.

The **activity diagram** is the cornerstone of the MICA methodology since it provides the basis of the measurements, and of the analysis and estimation of the capacity. Figure 2 shows a section an activity diagram corresponding to the departure sequence of the Palma de Mallorca Control Tower.

The activity diagram contains three sub-models that describe different aspects of the Control Tower activities. The *activity model* describes what the Control Tower personnel does, how and when it does it, and the rules that must be followed. The *role model* groups the activities into sets that are normally assigned to specific positions within the Control Tower. The *Taxi model* identifies the physical points within the airport layout that, due to the need to provide traffic instructions, require the attention of the Control Tower.

The activity diagram is used to measure the time spent by a controller on each activity.

Scenarios are used to describe the airport settings, e.g. the traffic density, different organisations of the Control Tower personnel, specific taxiway layouts, etc. The use of scenarios permits to identify the expected traffic patterns and to assign different roles to specific persons, thus enabling the identification of the associated workloads. This permits the study of "new" control positions based on actual configurations. Each scenario associates specific traffic patterns and densities to a Control Tower organisation based on the Activity Diagram.

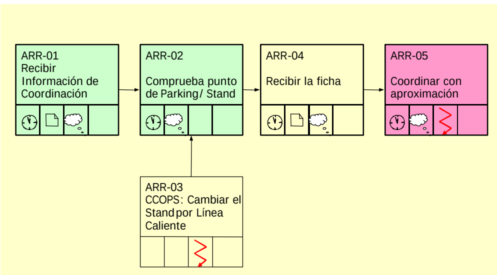


Figure 2. Partial Activity Diagram for the Departure Sequence Activities

The **EQN Model** presents a mathematical representation of the activity diagram based on a specific scenario. The EQN Model facilitates the analysis of the activity diagram enabling the identification of the activities that contribute to the airport capacity.

The Control Tower activity model has been solved through the use of simulation techniques in order to produce a set of capacity estimates related to specific control tower human resource configurations.

MICA Three-Layer Model: Calibration

Once the MICA model has been elaborated it is validated to ensure that the results obtained from it are at least similar to the actual airport operations. This action ensures that airport operations are reflected in an accurate manner.

MICA models are validated using two complementary ways: expert validation and through the execution of the EQN Model using measurements obtained from the Control Tower[6].

A team of active, experienced controllers reviews all the activities described in the Activity Diagram to ensure ensures that the model describes accurately the operational procedures performed within the Control Tower.

Further validation of the MICA three-layer model is performed through the execution and analysis of the results of the EQN Model. This model is run using both the measurements obtained in phase 2 and a special calibration data set designed to exhaustively trace all the activities.

MICA Application to the Palma de Mallorca Control Tower

To test the methodology Aena has performed an initial application of the methodology to the Palma de Mallorca airport. During the exercise, a group of operational experts from the control towers of Palma de Mallorca, Madrid Barajas and Barcelona El Prat, as well as the project team elaborated a detailed model of the airport activities. After implementing it as an EQN Model, it was validated through the use of a number of measurements taken in the period

[6] Measurements are performed within the Control Tower of the airport, for different traffic configurations, densities and distributions. Each data point corresponds to a specific activity. All data points are recorded in a database for their later use.

In order to reflect human behaviour, the data points are analysed to identify the mean, maximum and minimum operation times, together with a measurement of the data set dispersion.

ranging from June 2000 to October 2000. As a result of this exercise the methodology was validated and a model of the airport ATC capacity was constructed.

The MICA model was used to perform an analysis of the existing airport ATC capacity and an estimation of the capacity as a function of the number of controllers and their organisation. Figure 3 and Figure 4 show sample results from the application of the MICA methodology.

Figure 3 presents a set of curves which present the relationship between the time load for each one of four different control positions and the number of airport movements per hour. This example shows that the "Local" controller in charge of landing and take-off authorisations is saturated at 60 movements per hour. Since the maximum airport declared capacity is 60 movements per hour, this is not a great problem. Nevertheless if the airport infrastructure was improved to handle up to 70 movements per hour, figure 3 shows that the Control Tower would not be able to give service to this demand since the "Local" controller would not be able to handle more than 60 operations.

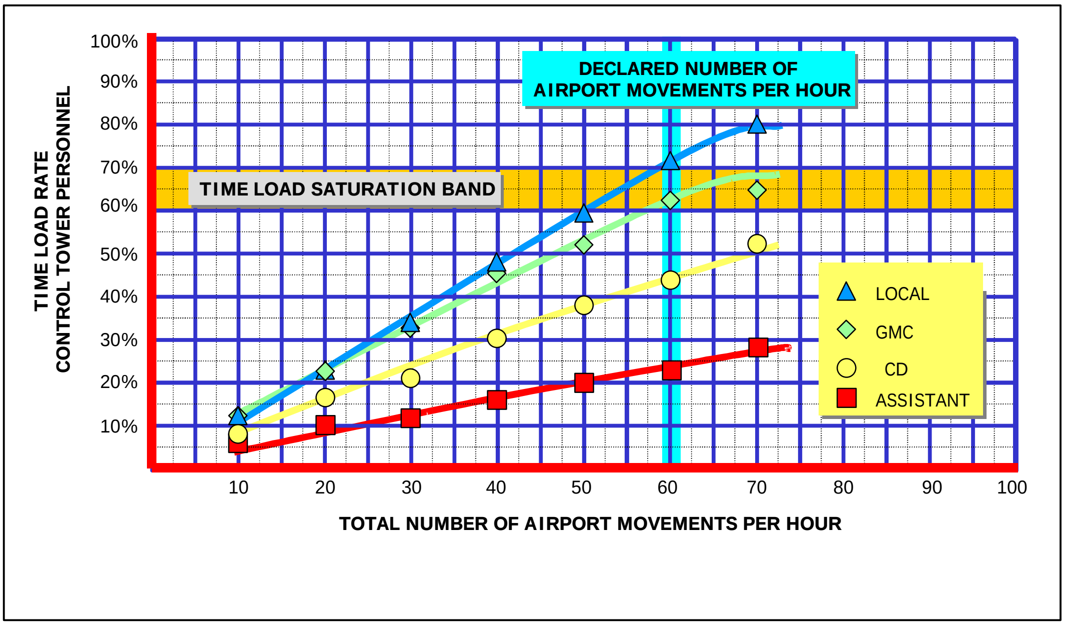
Figure 4 presents the different organisations of the Palma de Mallorca Control Tower, and their related capacities. This figure permits to plan ahead of time the human resources needed to meet a specific demand.

Conclusions

Even though the MICA methodology has been applied initially to the Palma de Mallorca airport, the resulting model and methodology can be applied to different airports. The flexibility of the model facilitates the definition of new configurations and scenarios, thus enabling the use of the model as a planning or a "what-if" tool.

The purpose of the MICA project is to associate the Control Tower ATC capacity with the organisation of the available resources -both human and technical. This has been achieved through the elaboration of a methodology and an airport model that enables the estimation of ATC airport capacity as a function of human resource organisation, control activities and available technical means.

The results of MICA obtained so far have shown also the advantage of using a common generic MICA activity diagram, since it provides a baseline of "best practices" which all Control Towers may use to compare their operation against other Towers.



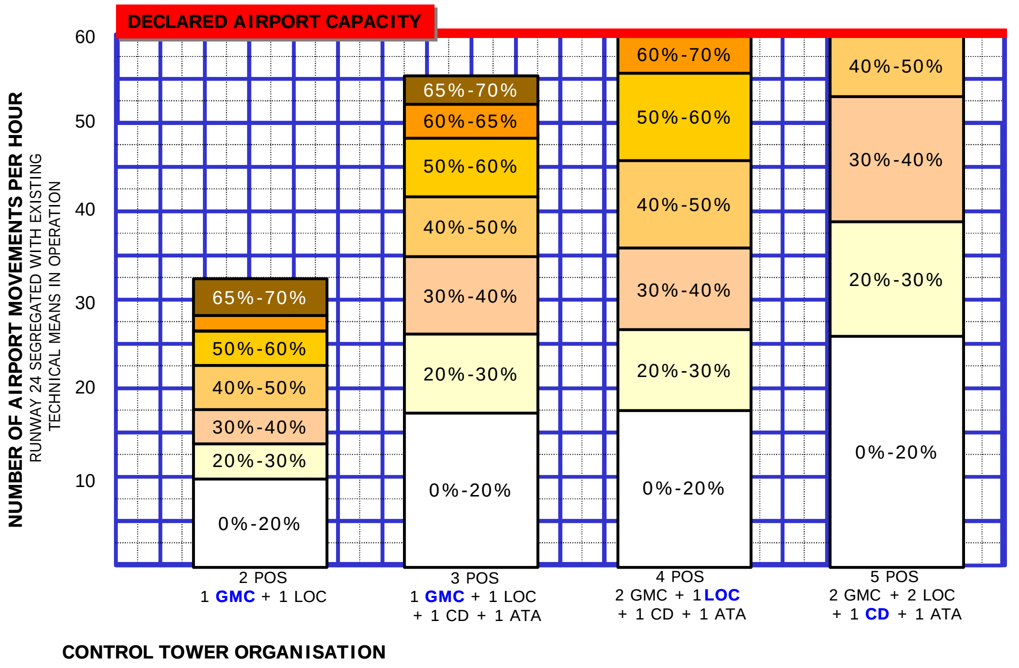


Figure 4 Relationship between capacity and control tower specification

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ACRONYMS	
ATC	Air Traffic Control
ATM	Air Traffic Management
EQN	Extended Queuing Network
MICA	Modelo Integrado de Capacidad ATM – ATM Integrated Capacity Model

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Obtained a B.S. in 1987 from the University of Kansas. His areas of specialisation are related to the analysis, design and operation of ATM Air Traffic Management systems. He currently works in Isdefe and has participated and managed several research programmes including the development and application of MICA (*Modelo Integrado de Capacidad*) to the Palma de Mallorca, and the Madrid Control Towers. He is also a consultant for Aena and the Spanish DGAC –Dirección General de Aviación Civil- in the area of air traffic management and navigation.