MODELLING, OPTIMIZATION OF RUNWAY OCCUPANCY TIME AND REVENUE MANAGEMENT IMPACT

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Abstract

Most of the Hub and Gateways are facing congestion problems due to the gap between capacity and airfreight demand which has substantially grown over the last 20 years, driving the need of a new strategy and approach to maximizing profit for airlines companies. Airport performance could be measured by different parameters, as flight delay, capacity, aircraft movement, and runway occupancy time, such parameters could be used to quantify and determine the level of the hub performance. Some statistics indicate that billions of Euros could be saved by the airlines companies if the airports capacity managed efficiently. Air freight growth in general has led to runway capacity constraints in the air transportation network. To increase capacity of HUB runways, airlines should reduce inter-arrival separations between flights. This research evaluates two major elements influencing runway capacity; runway occupancy and aircraft category which could be a constraint to the Hub and gateways capacity.

1. Introduction

Runway occupancy time is one of the most important factors affecting the capacity of any runway meaning the airport capacity in the meantime airlines companies could be penalized if there is any delay due to the capacity issue. Such parameter could be defined as the time that an aircraft or airplane occupies the runway until a new operation (arrival or departure) can be processed from to the same airport. Some of the most important parameters that could influence runway capacity are:
- In trail separations.
- Aircraft population mix.
- Exit locations and their type.

Many factors determine airside capacity, the runway capacity is one of the major elements influencing the aircraft movement, and after analysis we recognize that aircraft size is not the major parameter of the runway occupancy. The study also shows us clearly that high-speed runway exits can make a difference in runway occupancy.[1] In general, landing and departing time intervals are the main operational time intervals. The purpose of this scientific communication is summarized as:
- Measure runway occupancy times VS the optimal full capacity.
- Identify the runway occupancy constraints.
- Minimize the legs between aircrafts landing and take-off.
- Evaluate the revenue impact of reducing the Runway Occupancy Time.
- Maximizing Hub & Gateway capacity and minimizing delay costs

Keywords: Air Freight, Hub, Logistics, Transport, Supply chain.
2. Related Work

Modelling runway capacity

Measuring capacity to be runway exits only. The geometry of the taxiway/runway intersection of a rapid exit taxiway does not allow the crew to see the runway if it's clear of conflicting or other traffic in both directions. No entry signs should be used to avoid aircraft entering the runway via a rapid exit taxiway. Measuring the runway capacity is necessary to allow the air traffic controller to make any change related to the aircraft movement.

(Below the runway models)

Mathematical model

Many mathematical models have been developed during the last years to calculate or even to simulate the runway capacity. In our case a probabilistic model will be used as the basis for capacity estimation. In the beginning this model is developed by Blumstein (1959) to estimate the airport capacity “when the runway is used for arrivals only the geometry of the taxiway/runway intersection of a rapid exit taxiway does not allow the crew to see the runway is clear of conflicting or other traffic in both directions…” [4]

[Odoni] and [Neufville] extended this model to include departures and mixed movement (arrival and departure).
The arrival capacity model consist that arriving airplane share a common final approach path with a known final approach fix, as:

* r : is the length of the final approach.
* i : is the leading airplane’s weight group.
* j : is the following aircraft’s group.
* Sij : is the minimum required separation between the leading aircraft type and the following aircraft type.
* Tij : is the minimum time interval between successive arrivals for aircraft i and aircraft j.
* vi : is the final approach velocity for the aircraft i.
* vj : is the final approach velocity for the aircraft j.
The minimum time interval between 2 successive airplane arrivals is related either to the lead aircraft or trailing aircraft is flying the final approach faster.
When the leading aircraft is flying faster, the separation between the pair is at its minimum when the leading aircraft begins the final approach at the final approach fix as below:

![Diagram of aircraft separation](image)

Figure 2.2. Case used for the runway capacity model the minimum time separation between 2 aircrafts

Could be calculated from Equation 1

\[
TU = \max \left( \frac{r + s}{Vf} - \frac{5}{Vf} \cdot ROT \right) \quad \text{when} \; Vf > Vl
\]  

(1)

-Runway Capacity Estimation

Estimated (ROT): 54.35 (calculated based on real figures)

<table>
<thead>
<tr>
<th>Table 1: Runway occupancy time parameters</th>
</tr>
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<tbody>
<tr>
<td>Follower (NM)</td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>ROT(s)</td>
</tr>
<tr>
<td>Percent Mix</td>
</tr>
<tr>
<td>V approach (knots)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Calculation, Estimated runway occupancy time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Parameters (inputs)</td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Departure - Arrival Separation (nm)</td>
</tr>
<tr>
<td>Common Approach Length (nm)</td>
</tr>
<tr>
<td>Standard deviation of Position Delivery Error (s)</td>
</tr>
<tr>
<td>Probability of Violation</td>
</tr>
<tr>
<td>Cumulative Normal at Pv</td>
</tr>
</tbody>
</table>
3. Aircraft re-categorization

Wake vortex separation measurements show that aircraft pairs with small lead aircraft receive longer separation buffers than other aircraft pairs and airports with more runways implement longer separation buffers. The comparison of landing time intervals and runway occupancy illustrates that wake vortex separation requirements limit runway capacity when heavy or Boeing 747 is the Lead aircraft.

Benefits of re-categorization are:

- Reduced fuel burn.
- Reduced time in terminal airspace.
- Increased capacity.
- Mitigation of weather or sort delays.
- Better schedule reliability.
- Less opportunity for fatigue issues due to schedule disruptions

4. Wake-Turbulence and capacity management

The separation distances depend on the weight of both the leading and following aircraft. Adjustments in separation distances were made as more information on the wake-turbulence phenomenon was gained during the 1960s, 1980s and 1990s, but the basic concept of using aircraft weights remained constant.
The aircraft re-categorization is showing that with the same equipment the control tower could optimize the Wake vortex separation distance between 2 aircrafts. One of the main purposes of the aircraft re-categorization is to increase the airport capacity through the wake turbulence redefinition and the separations with the same or improved level of safety.

(Below the models)

Figure 4: Aircraft re-categorization

The runway occupancy time is a crucial parameter for the airfreight industry, one of the aims of this study is to show / increase the awareness of the importance of runway occupancy and highlight how improvements can be made.[3]

Table 3: Final approach separation minimum

<table>
<thead>
<tr>
<th>Follower (NM)</th>
<th>Super</th>
<th>Heavy</th>
<th>B757</th>
<th>Large</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super</td>
<td>2.5 / 3</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Heavy</td>
<td>2.5 / 3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>B757</td>
<td>2.5 / 3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Large</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>4</td>
</tr>
<tr>
<td>Small</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
<td>2.5 / 3</td>
</tr>
</tbody>
</table>

The table describes leader aircraft on the left column, and the follower aircraft on the top row. For example, a big/heavy airplane followed by a large aircraft requires a minimum of 5 NM as separation distance, and a large aircraft followed by a small aircraft requires a minimum of 4 NM. [6]
5. Revenue Management

Definition:

Revenue management is the collection of strategies and tactics firms use to scientifically manage demand for their products and services. The practice has grown from its origins in airlines to its status today as a mainstream business practice in a wide range of industry areas, including hospitality, energy, fashion retail, and manufacturing. This article provides an introduction to this increasingly important subfield of operations research, with an emphasis on use of simulation. Some of the contents are based on excerpts from the book: The theory and practice of revenue management (Talluri and van Ryzin 2004a), written by the first two authors of this article.

Revenue Management Benefit is about closing the gap potential current between current and potential Revenue.

![Figure 5.1: Gap (potential revenue vs current revenue)](image)

The main objective of the revenue management is to increase profitability by reducing the gap between potential and realized revenue.[9]

Revenue management is a supply-and-demand optimization tool. Key characteristics of a business that would benefit from the application of revenue management techniques include:

- Offers VS space,
- Serves different customers who are willing to pay different prices for the same product.

Airlines benefit from revenue management by selling space at a price that maximizes the revenue from various customers based on their willingness to pay.

**Dynamic Programming Model**

While facing the uncertainty of aircraft landed per day, the airport authority will charge the airlines companies based on the forecast.

The actual offer is materialized right before landing. These two quantities are denoted by C and by T for the rest of the paper. To capture the randomness of the runway use, T is modeled as a random variable with known distribution in this study. The number of denied boarding depends both on the space unsold before take-off and on the actual supply. Figure 6 illustrates the relation among these factors.
6. Conclusion

In this paper the runway occupancy times and the revenue management impact and model are presented.

In the airfreight industry the runway occupancy time is a major key in the air traffic management which has an important impact for the Management revenue for any airlines company.

The impact in the runway could cause considerable losses and impact on other actors in airfreight industry. To the best of our knowledge we tackled the capacity management problem. This has been modeled using mathematics, also showing the Management revenue impact if the airport stakeholders could optimize the runway occupancy as resources.

Figure 5.3: Occupancy time VS non-occupancy time of the runway
7. References:

[1] Tether, B and Metcalfe, J.S., “Horndal at Heathrow, Capacity creation through cooperation and system evolution”


