Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Hartmut Helmke, Ronny Hann, Maria Uebbing-Rumke:
German Aerospace Center (DLR)
Institute of Flight Guidance
Braunschweig, Germany

Daniel Müller, Dennis Wittkowski:
Deutsche Flugsicherung GmbH (DFS),
Langen, Germany
Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Contents

1. Time-Based Arrival Management
   a) Application 1: Integration of CDA into a conventional approach sequence
   b) Application 2: Arrival-Departure-Coordination for Dual Threshold Operation (DTO)

2. Lessons learned from both applications
3. Conclusions
Paradigm Shift to Time-Based Arrival Management

Time-based arrival management can be simultaneously used for different applications, in particular:
- Cross or head wind conditions,
- Mixed mode operations (arrival + departure coordination),
- Continuous Descent Approaches (CDA),
- Dual Threshold Operation ...

The crucial question is how the human operators can be supported in performing their tasks in the best way to cope with the new demands.

New automation in terms of advanced arrival managers (AMAN) is necessary to help the controller with appropriate time-based planning functions for all aircraft, matching with their equipage standards.
Continuous Descent Approach Concept

Figure from: Tom G. Reynolds et al. “Advanced Noise Abatement Approach Activities at Nottingham East Midlands Airport, UK” 7th ATM R&D Seminar, Barcelona, Spain, July 2007
Benefits of a CDA

- Noise reduction up to 5dB
- Reduction of fuel burn and emissions
- User preferred trajectories (idle descent)

Why are CDAs not common practice at busy hub airports during the whole day?
Problems of CDAs: Inhomogeneous Profiles

Different approach speeds of different aircraft types and flight operational uncertainties require an increased separation between aircraft when two consecutive aircraft start the descent at cruising altitude on the same arrival route.

However, this implies that constraints for the speed profile are necessary and no ideal idle descent is allowed.

Some of the lost capacity can be regained if a Modified Three Degree Deceleration Approach (MTDDA) is used.

Upper and lower bounds of IAS of a Three-Degree-Descent-Approach of a B737-300 and a B747-400.

L. Ren, J.-P. Clarke, N. Tan Ho:
Achieving low Approach Noise without Sacrificing Capacity
IEEE 2003
Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Contents

1. Time-Based Arrival Management
   a) Application 1: Integration of CDA into a conventional approach sequence (DLR’s FAGI project)
   b) Application 2: Arrival-Departure-Coordination for Dual Threshold Operation (DTO)
2. Lessons learned from both applications
3. Conclusions
Our Approach With a Late Merging Point and Distinct Routes (DLR project FAGI)

- Modified route structure:
  Sequent aircraft use different lateral routes to a late merging point (LMP).
- Aircraft co-use only a short common flight segment starting near the LMP and ending at the runway threshold.
- Homogenous speed profile or speed constraints are only necessary on the last flight segment from LMP to touchdown.

FAGI = Future Air Ground Integration
Before the **aircraft** are starting their CDA at the TOD, they should be on **separated routes**.

Therefore, different routes are assigned to the aircraft when entering ETMA.

The lateral separation between the routes allows each aircraft to choose an **individual optimal** (i.e. user preferred) **approach profile**.

The aircraft normally have to maintain a time constraint only at the LMP.
FAGI Route Structure

4 approach directions with 3 routes each

Everything fine?
All problems solved?

Yes in 2040, when only fully 4D equipped aircraft are flying which can maintain time constraints.
Integration of unequipped aircraft

- Shortening the trombone length enables an earlier time of arrival.
- An extension of the trombone enables a later time of arrival.
- This flexibility enables the possibility to compensate short-term events.
FAGI Route Structure for Unequipped Aircraft

- Unequipped aircraft (not 4D capable) use the trombone path stretching area.
- Deviating equipped aircraft can be reintegrated into the traffic flow via the trombone.
- This concept offers an incentive to modernize the aircraft fleet as a side effect, because the equipped aircraft will fly shorter routes on average.

Everything fine now?

No.
Currently controllers are not able / are not used to implement an exact target time. They are very good in relative spacing. Further support (tools) are necessary.
Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Contents

1. Time-Based Arrival Management
   a) Application 1: Integration of CDA into a conventional approach sequence
   b) Application 2: Arrival-Departure-Coordination for Dual Threshold Operation (DTO) (FP6 project OPTIMAL)

2. Lessons learned from both applications

3. Conclusions
Dual Threshold Approach on a Dependent Parallel Runway System
**ICAO-Separation Matrix (for a Single RWY)**

### Distance Based Separation Matrix (NM)

<table>
<thead>
<tr>
<th></th>
<th>Succ.</th>
<th>Heavy</th>
<th>Medium</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td>4</td>
<td>5</td>
<td>2.5</td>
<td>6</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>Light</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
<td>3</td>
</tr>
</tbody>
</table>

### Time-Based Separation Matrix (sec)

<table>
<thead>
<tr>
<th></th>
<th>Succ.</th>
<th>Heavy</th>
<th>Medium</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td>100</td>
<td>125</td>
<td>63</td>
<td>150</td>
</tr>
<tr>
<td>Medium</td>
<td>75</td>
<td>75</td>
<td>63</td>
<td>125</td>
</tr>
<tr>
<td>Light</td>
<td>75</td>
<td>75</td>
<td>63</td>
<td>75</td>
</tr>
</tbody>
</table>

Resulting separation matrix if succeeding (following) aircraft uses the displaced threshold.
Separation Matrix for a Parallel Runway System

Many combinations exist. When DEP are allowed, even more combinations are possible (384 combinations).
Previous Results

Results of dual threshold simulations performed by FRAPORT AG and DFS concluded that:

- An increase of 3-5 inbounds per hour was possible depending on heavy-medium mix.
- Controller workload increased.
- Outbound capacity significantly dropped down.

→ How can we overcome this?
Concept: DTO with Time-Based Arrival Management

Coordinator ADCO

AMAN 4D-CARMA

DMAN CADEO

Assigning arrival gaps for DEP

- Time-Based
- Trajectory-Based Advisories
Baseline: Radar Screen with Paper Strips

Without AMAN

- Radar Screen
- Paper Strips
- Coordination via Intercom / Phone
Time Line Support by AMAN – DLR’s 4D-CARMA (Four Dimensional Cooperative Arrival Manager)

- Normal Threshold (solid line)
- Arrival Free Intervals (AFIs) (pink)
- Displaced Threshold (dotted line)
- Departures (blue)
### Advanced AMAN Support

<table>
<thead>
<tr>
<th>+4</th>
<th>CTN410</th>
<th>Turn Left</th>
<th>25L</th>
</tr>
</thead>
<tbody>
<tr>
<td>+16</td>
<td>DLH4H</td>
<td>Reduce</td>
<td>KT220</td>
</tr>
<tr>
<td>+23</td>
<td>CTN410</td>
<td>Descent</td>
<td>Alt 4000</td>
</tr>
</tbody>
</table>

**Counter value of 0:** Pilot starts the advisory.

- **Callsign**
- **Target value**
- **Remaining time**
- **Advisory type**
## Simulation Trials Performed with 3 Controller Teams

<table>
<thead>
<tr>
<th>No</th>
<th>AMAN</th>
<th>Thresholds</th>
<th>Arr/Dep</th>
<th>Dep</th>
<th>Heavy-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>passive shadow</td>
<td>25R/25L</td>
<td>Master/Slave</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>2</td>
<td>passive shadow</td>
<td>25R/25L</td>
<td>Master/Slave</td>
<td>15</td>
<td>40%</td>
</tr>
<tr>
<td>3</td>
<td>passive shadow</td>
<td>25L/25R/26L</td>
<td>Master/Slave</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>4</td>
<td>passive shadow</td>
<td>25L/25R/26L</td>
<td>By Voice</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>5</td>
<td>time line</td>
<td>25L/25R/26L</td>
<td>Master/Slave</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>6</td>
<td>time line</td>
<td>25L/25R/26L</td>
<td>Master/Slave</td>
<td>15</td>
<td>40%</td>
</tr>
<tr>
<td>6-Ex</td>
<td>time line</td>
<td>25L/25R/26L</td>
<td>ADCO</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>7</td>
<td>advisory</td>
<td>25L/25R/26L</td>
<td>Master/Slave</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>8</td>
<td>advisory</td>
<td>25L/25R/26L</td>
<td>ADCO</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td>9</td>
<td>advisory</td>
<td>25L/25R/26L</td>
<td>ADCO</td>
<td>15</td>
<td>20%</td>
</tr>
<tr>
<td>10</td>
<td>advisory</td>
<td>25L/25R/26L</td>
<td>Master/Slave</td>
<td>15</td>
<td>40%</td>
</tr>
<tr>
<td>11</td>
<td>advisory</td>
<td>25L/25R/26L</td>
<td>ADCO</td>
<td>15</td>
<td>40%</td>
</tr>
</tbody>
</table>
Expectations & Results: Arrival Capacity in Aircraft per Hour

Exp: DTO shall allow an increase of the arrival flow

Res: DTO increases arrival flow by 3.4 arrivals per hour (average)

Exp: A higher percentage of heavy arrivals shall allow an even higher increase of the arrival flow

Res: DTO increases arrival flow by 5.2

Increase seems to be achievable with any level of decision support

passive mode: Trial 3

time line mode: Trial 5, 6

advisory mode: Trial 7, 10

<table>
<thead>
<tr>
<th>Trial</th>
<th>THR</th>
<th>Percentage Heavy</th>
<th>ARR / hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>20%</td>
<td>42</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>40%</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>20%</td>
<td>45,2</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>20%</td>
<td>45,6</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>20%</td>
<td>46</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>40%</td>
<td>44,8</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>20%</td>
<td>45,2</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>20%</td>
<td>44,8</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>20%</td>
<td>44,8</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>40%</td>
<td>45,6</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>40%</td>
<td>43,2</td>
</tr>
</tbody>
</table>
### Expectations & Results: Benefits of Tools

<table>
<thead>
<tr>
<th>Trial</th>
<th>Thresholds</th>
<th>Perc. Heavy</th>
<th>AR/ hour</th>
<th>Flow / Demand</th>
<th>Coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>20%</td>
<td>42</td>
<td>15/15</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>40%</td>
<td>40</td>
<td>15/15</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>40%</td>
<td>20%</td>
<td>45,2</td>
<td>6/15</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>40%</td>
<td>20%</td>
<td>45,6</td>
<td>13/15</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>20%</td>
<td>46</td>
<td>46</td>
<td>8/15</td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>40%</td>
<td>44,8</td>
<td>12/15</td>
<td>none</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>20%</td>
<td>45,2</td>
<td>9/15</td>
<td>none</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>20%</td>
<td>44,8</td>
<td>8/8</td>
<td>ADCO</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>20%</td>
<td>45,2</td>
<td>9/15</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>40%</td>
<td>45,6</td>
<td>12/15</td>
<td>none</td>
</tr>
</tbody>
</table>

ARR flow does not significantly depend on decision support level, but **DEP flow increases** with level of decision support, i.e. when using an ARR/DEP coordinator tool.

Note: It solves the drawback found by FRAPORT/DFS, i.e. no outbound capacity drop-down.

DEP queuing time can be reduced with automatic coordinator from 431s to 186s.
Controller Workload

If the controller is supported by sequence and runway information during dual threshold operation, the number of instructions can be reduced by 9.5% (pickup) and 0.8% (feeder).
Controller Workload (2)

Frequency utilization is reduced by 18.4% for the pickup with sequencing. If advisories are offered, the frequency utilization is even more reduced (21.1% pickup, 18.1% feeder) compared to no AMAN support.
Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Contents

1. Time-Based Arrival Management
   a) Application 1: Integration of CDA into a conventional approach sequence
   b) Application 2: Arrival-Departure-Coordination for Dual Threshold Operation (DTO)

2. Lessons learned from both applications

3. Conclusions
Controller Feedback

Controller worry about loosing situation awareness:

- If all instructions (speed, level and turns) are given to the controller by the system, the controller does not control the traffic anymore and will be “downgraded” into the position of an observer who tries to control the decisions done by the system.

- Especially in situations where he has to get in control of the traffic again (e.g. emergency or system failure) he will not be able or it will be harder to take over control in an efficient and - much more important - in a safe way.
Controller Feedback (2)

- Controller must be able to change the sequence if traffic causes or if it would be more efficient out of the controllers view.
- Controller must be able to freeze the sequence in order to prevent the AMAN from rescheduling the traffic.
- Multiple advisories (e.g. speed and altitude change) for the same aircraft should be grouped into one single combined advisory to reduce frequency blocking.
- The controller needs the ability to individually switch off special advisories types or all of them,
- All deviating advisories executed by the controller have to be identified and considered by the AMAN.
Lessons Learned:
Relative versus Absolute Separation

- Dual threshold operation is not the use case strictly requiring time-based arrival management.
- The integration of unequipped aircraft into a stream of fully equipped 4D aircraft following a user preferred trajectory (normally a continuous descent approach (CDA)), however strictly requires time-based separation.
Integration of Equipped and Unequipped Aircraft
Lessons Learned: Integration of equipped and unequipped by familiar distance based means (ghosting)
Time-Based Arrival Management for Dual Threshold Operation and Continuous Descent Approaches

Contents

1. Time-Based Arrival Management
   a) Application 1: Integration of CDA into a conventional approach sequence
   b) Application 2: Arrival-Departure-Coordination for Dual Threshold Operation (DTO)

2. Lessons learned from both applications

3. Conclusions
AMAN – DLR’s 4D-CARMA (Four Dimensional Cooperative Arrival Manager)

- The DLR 4D-CARMA is a trajectory-based AMAN.
- 4D-CARMA supports time-based arrival management.
- 4D-CARMA suggests advisories reducing controller workload.
- 4D-CARMA coordinates inbounds and outbounds.
- 4D-CARMA interacts with on-board FMS (air ground cooperation).
Conclusions

- Late merging guarantees lateral separation.
- Time-based separation is an enabler for integration of mixed mode traffic (arrival-departure-coordination and equipped unequipped integration).
- On the ground side time-based arrival management requires an AMAN with the key functions for
  - trajectory-based aircraft scheduling,
  - advisory generation,
  - monitoring and conflict detection support to ensure situational awareness.
- The tool support reduces controller workload and increases the predictability (important for CDM and TAM applications).
- The controller should not be forced to stick to the suggestions.
Thank you for your attention

Prof. Dr. Hartmut Helmke
Hartmut.Helmke@dlr.de