Supporting Arrival Management by Visualizing Uncertainty

The Third SESAR Innovation Days

Ir. M. Tielrooij
AMAN: Extending the Horizon

Flow Management

ATC

boarding & departure

Airline

en-route

arrival

24 hours

3 hours

1 hour

20 minutes

0 min

AMAN

Tactical ATC
AMAN Process

- Schedule Deviation
- Weather forecast error
- Performance model error
- Surveillance error

Input Data

Trajectory prediction modeling error

Trajectory Predictor

Human-Machine Interface
Uncertainty

19 busiest connections from Amsterdam

Stockholm

Milan
Addressing Uncertainty

- Improve prediction
- Close the loop
- Account for remainder
Abstraction Hierarchy

- **Functional Purpose**
  - Safety
  - Capacity
  - Cost Effectiveness
  - Environmental Sustainability
  - Efficiency

- **Abstract Function**
  - Separation Requirements
  - Legislation on Airport Operation
  - Workload Principles
  - Locomotion, Flight Dynamics and Propulsion
  - Economics of on-time performance

- **Generalised Function**
  - Runway Planning
  - Runway Assignment
  - Scheduling

- **Physical Function**
  - Weather
  - Inbound Schedule
  - Outbound Schedule
  - Runway
  - Taxiway infrastructure
  - Airspace Structure

- **Physical Form**
  - Weather Attributes
  - ETA
  - Aircraft Properties
  - Direction, Length, Availability
  - Routes, Availability
  - Routes, Capacity

- **Legend**
  - Addressed nowadays
  - Not addressed nowadays
  - Low uncertainty
  - Medium uncertainty
  - High uncertainty
Visualisation: Relating ETA and Separation
Visualisation: Relating Separation, Demand, and Capacity
Visualisation: Demand and Capacity, and Delay
Visualisation: Showing Uncertainty
Visualisation: Relating Uncertainty to Demand
Visualisation: Relating Uncertainty to Demand
Visualisation: Relating Uncertainty to Demand

The diagram shows a visualisation of capacity over time, illustrating how uncertainty relates to demand. The x-axis represents time, and the y-axis represents capacity. The graph includes markers for AC1, AC2, AC3, AC4, and AC5, indicating specific points or events along the timeline.
Initial Concept
Experiment

- 7 Aerospace Engineering students
- PC simulation without operational context
- 4 Demanding but feasible scenarios
- 8 + 16 runs
Results: Relating Demand to Delay
Results: Workload

- Subjects used knowledge on uncertainty
- Display difficult to understand
- Training insufficient
Conclusions and next steps

- Visualising uncertainty is difficult to make easy
- Relating demand to delay improves decision making
- Improve experiment, sufficient training
- Create uncertainty model
- Test in operational setting
Next Prototype
Supporting Runway Assignment
Challenge the future
Visualizing Uncertainty
AMAN

Demand
 Arrival Schedule
 Aircraft Types
 Weather

Capacity
 Runways
 Taxiways
 Airspace
 Weather

VS
AMAN

**Graph:**
- Speed vs. time
- Lines indicate:
  - **Green line:** Fuel optimal
  - **Black dashed line:** Early action
  - **Orange dashed line:** Late action
Uncertainty

Typical departure time error (Mueller et. al. 2002)

Uncertainty in plan view (Nicholls et. al. 2003)
Visualizing Uncertainty
The multidisciplinary approach is based upon the proven CSE and EID frameworks

The five steps of CSE:

- Work Domain Analysis: what is the purpose of the system?
- Control Task Analysis: what must be done?
- Strategies Analysis: how can it be done?
- Cooperation Analysis: how can work be shared?
- Worker Competencies: how can operators best be supported?
Example displays using the ecological approach