Dynamic Approaches from Complexity to Manage the air Transport Network

SESAR Innovation Days 2011
Marta Sanchez, R&D area
Isdefe, Spain

Toulouse November 30th 2011
Outline

1. NEWO Objectives of Research
2. The approach
3. Scenarios and 1st NEWO Workshop outcomes
4. Next Steps
NEWO Objectives of Research
NEWO Objectives of Research

Project funded under SESAR WPE.

NEWO stands for “emerging Network-Wide Effects of inventive Operational approaches in ATM”. Objectives:

- Evaluate changes in behaviour of European air transport network linked to diverse local operational approaches
- Further develop and explore the potential of innovative modelling and simulation techniques
NEWO Scope

- **Conceptual framework**: common concepts, current strategies, dynamic indicators, etc.

- Capture **out-of-the-box ideas** for managing complex networks: workshops, questionnaires, interviews, expert groups...

- Select scenarios and modelling.
NEWO Approach
The Approach: Problem Statement

Air Transportation System
a complex system

Irregular structure (neither purely regular nor purely random) dynamically evolving in time;

Small world and power law degree distribution;

Communities structures: vertices connecting different communities are usually hubs in their own community.

Nodes are dynamical systems whose dynamics are both influenced by and influencing other nodes dynamics;

Links between elements: there is more than edges;

Queueing generation, congestion and delay propagation.

X Community

Hub

Y Community
**The Approach: Modelling Complexity**

**Emergent Phenomena** are global behaviours which cannot be understood from the behaviour of individual elements:

- **Dynamic graphs**: structure is not fixed;
- More links between elements than topology: propagation of noise through the system capturing **interactions between elements**;
- **Simple behavioural rules** are able to generate complex behaviours;
- Inter-relationships between **structure and dynamics**;
- Incorporate “noise” in the behaviour of elements (non-determinism): modelling **uncertainty**.
The Approach: ATM-NEMMO

Mesoscopic model

- **Heterogeneous nodes** with capacity restrictions: airports and high density airspace areas;
- **Dynamic graph** generated from traffic demand;

Elements travelling between two nodes are aircraft.
The Approach: ATM-NEMMMO

- Nodes
- Structure
- Links
- Routing rules
- Uncertainty

Interactions between elements (propagation, reactionary delays):

- Late arrival of aircraft from previous flight
- Awaiting crew from another flight
- Awaiting load or passenger from another flight

<table>
<thead>
<tr>
<th>Cllsldgn</th>
<th>ET</th>
<th>ATOT</th>
<th>ATOT</th>
<th>ATOT</th>
<th>ETA</th>
<th>ETA</th>
<th>HTA</th>
<th>HTA</th>
<th>HTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balanced NOP</td>
<td>High Density Areas</td>
<td>Linked Flights</td>
<td>Initial NOP</td>
<td>Preceded/ Ensuing</td>
<td>ET</td>
<td>DT</td>
<td>QOT</td>
<td>ATOT</td>
<td>ETO</td>
</tr>
<tr>
<td>Callslgn</td>
<td>ETOT</td>
<td>Crossed Areas</td>
<td>Distance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— / XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xxx / XXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>xxx / —</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Approach: ATM-NEMMO

- Within time interval Tj, at each airport for outbound traffic:

1. Traffic Demand Tj
2. Check Links
3. OK
4. Check route, destination airport
5. OK
6. Outbound Capacity
7. Prioritisation
8. Reactionary
9. Regulation
10. Overload
The Approach: ATM-NEMMO

- **Nodes**
- **Structure**
- **Links**
- **Routing rules**
- **Uncertainty**

**Flight milestones and phases**

**Primary delays (internal disturbances):** variation in time required for each flight step

**Probability distributions based on primary delay data**
Scenarios and 1st NEWO Workshop outcomes
Scenarios...going through

Identify and evaluate flight prioritization rules in case of severe capacity shortfalls affecting departures at airports.

Workshop last 25th October

People with diverse backgrounds

Issue criteria for prioritisation and solve theoretically specific scenarios of demand - capacity imbalance

Selection of most promising ideas

Simulate and capture delay propagation and overload bunching with demand increase

Check if different strategies can palliate or not the problems
Scenarios: some ideas

Discussion about applicability and feasibility

Network approach
- Efficiency, capacity: connections, bigger aircraft, better equipped, short-haul...

Airline driven
- Business decisions

Random

❖ Flight priority in two parts: \( Pr = \alpha (\text{airlines criteria}) + (1 - \alpha)(\text{network criteria}) \)

Airline
- Airline specific, based on business models

Network
- ...first flights to hubs, to less congested airports, arrival slot at destination...

❖ Equity indicators;
❖ Does negative effect of a decision came back to the same people?
Next Steps
Next Steps

Main Activities

- Analysing workshop outcomes;
- Communication: gathering feedback;
- Select and define scenarios;
- Some model adaptation and development.

Support activities/tools

- Cross-fertilization in WP-E ‘Mastering Complex Systems Safely’ network;
- Links with academia;
- NEWO webpage and LinkedIn group.
Marta Sanchez Cidoncha
mscidoncha@isdefe.es
Tel: +34 91 271 19 24
Beatriz de Bobadilla 3
28040 Madrid, SPAIN