Understanding Industrial Ecology Dynamics and Competitive Enterprise Strategies in the Large Commercial Aircraft Industry

HYBRID AGENT-BASED SYSTEMS DYNAMICS SIMULATION AS A TOOL FOR ARCHITECTING THE EXTENDED ENTERPRISE

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Research Presentation
LAI PLENARY CONFERENCE

San Antonio, TX
April, 20th 2006
Agenda

• The Aviation Industry Ecosystem
• Why model the aviation industry?
• Methods: existing models and frameworks
• The hybrid agent-based System Dynamics modeling approach
• Expected Value
A view of the Commercial Aviation Industry Enterprise Ecology

Business Passengers

Leisure Passengers

Airport Authorities

American
SouthWest
Lufthansa
Ryanair
JAL
...

Unions

Boeing
Airbus
?

Capital Markets

Leasing companies

Engine Manufacturers

Suppliers

WTO

EU Government

US Government

Congress

DOE

DOT

EPA

FAA
A taxonomy of the extended-enterprise

Different enterprises interact with their environment differently
Why Model the Aviation Industry?

Oscillatory behaviors. Response amplification.

What are the mechanics behind the observed behavior?
What are the dominant causality drivers?
How can the response be damped?
Is damping desirable by all stakeholders?
Why Model the Aviation Industry?

Several layers of Complexity

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Commercial Aviation Modeling Overview

- Lynn 1997
- Aris 2002
- Gillet 1994

- Narrative-based
- Framework-based
- Agent-Based
- Econometrics
- Game Theory
- System Dynamics / Differential Eq.

- Piepenbrock 2004
- Hansen 1990
- Bhadra 2003
- Benkard 2004
- Krugman 1987
- Esty and Ghemawat 2002

Some examples of applications

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Agents provide the flexibility to model individual behaviors (schemata) that may reflect:

- strategies,
- utility functions,
- path-dependencies (e.g. effects of chance events, learning, and evolutionary behaviors / emergency).
Model Dashboard View (SD Version)

Parameter Settings
- Average Aircraft Size: 100, 300
- Aircraft Delivery Time: 1000, 2000
- Aircraft Fuel Burn (gallons/mile): 15
- Aircraft Mile Capacity: 0.1
- Airline Profit Margin: 0.3
- New Aircraft Price: 10M, 200M
- Airline Forecast Period: 0.5
- Aircraft Life: 2
- Use of Aircraft: 1000
- Aircraft Backlog Visibility: 1
- Aircraft Backlog: 0

Stochasticity
- Deterministic
- Random

Aircraft Integrators and Airline Industry Interactions
Proof of Concept Model based on US Domestic Characteristics

Engineering Systems Concepts
Lean Aerospace Initiative

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Some EEA questions for the model to assist in …

• What are the long-term effects of aircraft OEM pricing decisions on the aviation industry as a whole?
  – Should the extended enterprise include the airlines?
  – Will seat overcapacity make point-to-point / low-cost airlines more prevalent?

• What are the critical parameters that determine the aviation industry’s reaction to shocks (factors / demand, disruptive technologies, competition) and how can they change in the future?
Value

• Applied:

A Tool for long-term Enterprise Architecting

Supporting the consideration of impacts in strategic decision-making by

Experimenting with the performance of different strategies in various scenarios (forecasting)

Testing hypotheses of agent behavior drivers (customers or competitors) against their revealed actions (strategic understanding)

• Methodological:

– contributions in the applied modeling of enterprises by developing the ABM/SD hybridization concept
Questions?

Photo credits: Robert and Shana Parkeharrison; www.parkeharrison.com
Selected References


Selected References


Summary:

• My intention is to understand and forecast under different scenarios the long-term behavior of the aviation industry.
• I propose to create a fairly detailed model of the aviation industry as an extended enterprise with a focus on [long-term] decision making from the primary agents (passengers, airlines, leasing companies, and aircraft manufacturers and their suppliers) taking into account government policies.
• The methodology that I am proposing is an AB/SD modeling hybrid that would illustrate the differences of modular vs. integral enterprises. Inputs from other disciplines are by necessity abundant.
• As a by-product of this research, I am expecting that my methodology can be generalizable to model other industries.
Back-up
## Methodology Use in this Effort

<table>
<thead>
<tr>
<th>Methodology Type</th>
<th>Qualitative</th>
<th>Quantitative</th>
<th>Project Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrative-based</td>
<td>√</td>
<td></td>
<td>Forming model structure. Forming agent rules.</td>
</tr>
<tr>
<td>Framework-based</td>
<td>√</td>
<td></td>
<td>Testing hypotheses generated by the Piepenbrock framework.</td>
</tr>
<tr>
<td>Econometrics</td>
<td></td>
<td>√</td>
<td>Using as inputs for certain functions (e.g. pricing estimates)</td>
</tr>
<tr>
<td>Game Theory</td>
<td>√</td>
<td>√</td>
<td>Forming agent rules.</td>
</tr>
<tr>
<td>System Dynamics</td>
<td>√</td>
<td>√</td>
<td>Form the agents’ world view. Create structures not replicated by agents.</td>
</tr>
<tr>
<td>Agent-based</td>
<td></td>
<td>√</td>
<td>Primary system modeling methodology.</td>
</tr>
</tbody>
</table>
Pricing Decisions for Aircraft

List prices seem to be an almost perfectly linear function of capacity.

Regression can be used to provide the basic pricing model: e.g.:

\[ PR = -18.4 + 0.45\text{CAP} + 5.05\text{RN} \]

But the critical number is the discount offered...
Intersecting Architectures

- Aircraft Capacity and Range (787 vs A380)
- Network Type (HS vs PtP)
- R&D Financing
- WTO Rulings
- Push vs. Pull Manufacturing and Marketing

Preliminary

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Enterprise Bounded rationality

Are enterprises rational agents?

We know that for persons and everyday decisions the assumption of rationality does not hold true in most cases. People tend to use heuristics to narrow their choice set and even then when utility cannot be defined exactly they may make random choices.

This should not be the case for enterprises, since the timeframe is longer and the capacity to calculate probabilities of outcomes for uncertain events is larger. Yet (i) the decision makers in the latter case are still human and (ii) imperfect information and discounting of risk may prevail.
Modeling Approaches

Waiting for internal structure to develop (emergence)
Passengers

Pax choice set (given OD) =
{travel, connections, airline, price-range}
Pax utility =
\[ f \{\text{price, connections, frequency, class}\} \]
Airlines

Airline choice set () =

{aircraft, OD-pair, price-setting, network type}

{capacity, range, engine, specific consumption, manufacturer, lifecycle cost, lifecycle flexibility?}

Airline utility (from aircraft) =

f {revenue, operational cost, capital cost, reliability}
Aircraft Manufacturers

Aircraft OEM choice set () =

{introduce new model, extend existing model, product family, aircraft price, OD-pair, price-setting, network type}

{capacity, range, engine, specific consumption, manufacturer, lifecycle cost, lifecycle flexibility?}

Aircraft OEM utility () =

\( f \{R&D \text{ cost, financial backing, sales revenue, production cost}\} \)