Decision Support for an Optimal Choice of Subsidised Routes in Air Transportation

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Introduction

• Deregulation led to lack of air service along routes with insufficient demand

• Countries adopted subsidy schemes to guarantee accessibility for small communities

• Subsidy schemes are implemented based on defined criteria:
  – Accessibility to a major city, advanced health care, an international airport, etc.
  – Related to a time target e.g., 4 hours
Aim of the study

• Develop a decision support tool that can assist decision makers select an optimal network of subsidised routes

• How?

  1. Assumptions
  2. Estimate the cost of subsidising a route
  3. Use a budget constrained optimisation model
  4. Assess both the current and optimal network of subsidised routes
Related work

• Flynn and Ratick (1988)
  – Maximised coverage and minimise the system-wide cost
  – Used Euclidean distance
  – Applied to the US

• Pita et al. (2014)
  – A socially oriented flight scheduling and fleet-assignment optimisation model
  – Minimise social cost
  – Applied to Norway
Model assumptions

- Three phases of a journey
- The transportation mode offering the shortest travel time is chosen
- Given target time
- Evaluate the suggested networks by the associated increase in the number of people served
Estimate the cost of subsidising a route

- Subsidisation cost \( (c_f) \) depends on the total route-ticket revenue \( (f(Demand)) \) and the route operating cost \( (f(Available \ Seat \ Miles, \ number \ of \ legs)) \)

\[
c_f = A + B \times legs + D \times Demand + C \times ASM
\]

New routes Demand:
- Catchment size
- Ground-flight time
- Number of flights
Binary IP for MaxCoverage

\[
\text{Max } Z = \sum_{p \in P} D_p y_p
\]

Subject to:

\[
y_p \leq \sum_{f \in F} A_{pf} x_f \quad \forall p \in P
\]

\[
\sum_{f \in F} c_f x_f \leq B
\]

\[
\sum_{f \in \Omega_{fk}} x_f \leq 1 \quad \forall k \in K
\]

\[
y_p \in \{0,1\} \quad \forall p \in P
\]

\[
x_f \in \{0,1\} \quad \forall f \in F
\]

- \( p \) – population centres
- route \( f \) with cost \( c_f \)
- \( B \) – Budget
- \( x_f = 1 \) if route \( f \) is selected
- \( y_p = 1 \) if \( p \) is covered

Each airport \( k \) has at most one route
## Case study: Swedish PSO network (1/2)

<table>
<thead>
<tr>
<th>Accessibility Criterion</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Stockholm</td>
<td>1. Less than 4 hours</td>
</tr>
<tr>
<td></td>
<td>2. Less than 5 hours</td>
</tr>
<tr>
<td></td>
<td>3. Prioritise 5 hours over 4 hours</td>
</tr>
<tr>
<td>To an international airport</td>
<td>4. Less than 4 hours</td>
</tr>
<tr>
<td>To Stockholm and an international airport</td>
<td>5. Less than 4 hours to Stockholm and Less than 4 hours to an international airport</td>
</tr>
</tbody>
</table>
Case study: Swedish PSO network

- \( c_f = A + B \times \text{legs} + D \times \text{Demand} \)
  \[ + C \times \text{ASM} \]

- \( B = -1,228,000, C = -102, D = 3 \)

- More reasonable results with no constant \( A \)

- Re-estimated cost of current 11 PSO routes is SEK 120.4 million

- 11 PSO routes to Stockholm-Arlanda (2 direct routes)
- 799 possible PSO routes
- 2778 binary variables
- 3200 constraints
Results

1. How many people would need PSO routes
   • Accessibility without PSO routes

2. How many people with improved accessibility
   • Accessibility with current PSO routes
   • Accessibility with optimal PSO routes
Accessibility without PSO routes

• To Stockholm within 4 and 5 hours
  – 97.04% and 99% can reach Stockholm within 4 and 5 hours respectively
  – The remaining 295,371 and 99,788 people, respectively need improved accessibility

• To an international airport within 4 hours
  – 88.71% do not need PSO routes
  – The remaining 1,126,603 people need improved accessibility

• The small communities and are a target for PSO routes
Accessibility to Stockholm within 4 and 5 hours (1/2)

Considered individually
Accessibility to Stockholm within 4 and 5 hours  (2/2)

Prioritise 5 hours over 4 hours
Optimal routes

- Direct route
- One-stop route

One stop routes appear with longer target times

Less than 4 hours

Less than 5 hours
Accessibility to an international airport within 4 hours

![Accessibility graph showing the increase in accessibility for different budget levels. The graph includes a label indicating the current accessibility within 4 hours and a target for accessibility within 4 hours.](image-url)
Comparison of optimal routes
SEK 120 million

To Stockholm within Less than 4 hours

To an international airport within 4 hours
Conclusion

- Accessibility without PSO route is quite good for most population centres
- Good job by Trafikverket but the results indicate room for improvement
- An optimisation-based decision support tool can be used to evaluate subsidised route networks
- Possible application to other regions/countries
Further research

• Consider
  – Additional criteria
  – Setup cost on new routes

• A detailed flight scheduling

• Explore possibilities of other air traffic networks
Questions

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