Environmental and socio-economic evaluation of four different sites for relocation of a domestic airport

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6th lecture
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The Airport in Vatnsmýri, Reykjavík
Reykjavík domestic airport

Short historical summary

- **First idea of an airport in Vatnsmýri in Reykjavík came about 1919**
  - Reykjavík City provided 9 ha of grassland (Briemstún, part of present university campus) for an airfield for Icelandic flying pioneers
  - Some interrupted activity until WWII (1940)
  - Difficult conditions due to wetness (“moorland”)

- **British occupation forces arrive in Iceland, May 10, 1940**
  - The British built a “paved” airfield in Vatnsmýri in the autumn of 1940. They requested that the Icelandic government pay a part of the cost, which the prime minister at that time, Ólafur Thors, declined. The old flight tower built then is still standing.
  - By a special agreement (the Icelandic, British and American governments), American land-based military force replaced the British occupation force in July 1941, to provide Iceland with military protection (prevent German invasion, and make Iceland able to claim neutrality!). The British, however, were in charge of the airport until end of the war.
  - After the war (1946), the British handed the airport over to the Icelandic government at no cost.
  - In the years after the war, Reykjavik Airfield became the main domestic airport, whereas the much larger Keflavik airport, built by the American forces during and expanded after the war, became the international airport.
Should the airport be relocated?

A highly controversial issue, nation split down the middle

- About 1970, discussions started about relocating the airport
  - The airport land is considered extremely valuable for urban development
  - The City of Reykjavík wants to relocate; people from the countryside and many Reykjavík residents want to keep the airport (convenient for running errands in the Capital)

- Year 2001, a public vote on the future of the airport:
  - 37% participation (Reykjavík residents only). Vote considered invalid!
  - 49% voted for relocation, 48% for maintaining present location. Impasse!!

- 2001–2014, bickering over whether to move the airport or not
  - April 2005, an official commission (Helgi Hallgrímsson, Ex-Director, The Road Department, Chair) was asked to investigate several relocation options as well as keeping the present site with possible changes
  - October 2013, the Government and Reykjavik City Council entered into an agreement to keep the airport (two runways) until 2022. Some land freed for building on it.
  - In July 2015, another official commission (Ragna Árnadóttir, Ex-Minister for Justice, Chair) published its findings, recommending Hvassahraun as a site for future domestic and possibly international airport. Old airport not considered (No 0-option) nor Keflavik

- Present City Government wants complete relocation (Social Democrats+Bright Future+Left Greens+Pirates)

- Strong opposition to moving the airport continues
Facebook page of friends of the airport
Facebook page of those who want relocation
Two proposals for urban renewal
Where to go?

- Until 2005, mostly four different possibilities studied
  - Present site (with variations/reductions)
  - Löngusker, landfill option in Skerjafjörður, close to present airfield
  - Hvassahraun, midways between Reykjavik and Keflavik
  - Move the domestic aviation to Keflavik International Airport

- The 2005 Helgi Hallgrímsson Commission was asked to study the above alternatives plus a new location at Hólmsheiði, up north from Reykjavík (elevation 110 metres)

- The 2013 Ragna Commission was asked to study following options only
  - Löngusker
  - Hvassahraun
  - Hólmsheiði. However, after building the main prison of the country there, location doubtful and elevation/weather conditions unfavourable? Recent studies indicate down time due to bad weather 7,2% (28 days a year), which is more than the 5% limit of ICAO.
  - And a new location at Bessastaðanes, close to Löngsker, requiring a road connection across the bay from Reykjavik/Kópavogur
A MSc study in environmental science

Ágúst Þorgeirsson MSc student, Júlíus Sólnes, Professor of civil and environmental engineering, supervisor and Páll Jenson, Professor of Industrial Engineering, co-supervisor, 2003–2004

Ágúst applied the Analytic Hierarchy Process and used Robust Planning, Delphi Consensus and Pareto optimization methodologies. Tried sending a questionnaire to all Reykjavík City Council members

The following presentation is based on his study
The four alternatives

- Present Reykjavík airport, possibly with some changes/reduction, RVA, (RVA50%)
- Reykjavík Löngusker Airport (landfill), RLA
- Hvassahraun Airport (rugged lava field), HHA
- Bessastaðanes, BSN, introduced by the Ragna Commission (very close to RLA)
- Keflavík International Airport, KIA
The four different sites + Hólmsheiði and Bessastaðanes
Main environmental factors considered (1st hierarchial level)

- Viability and economic impact (EI)
- Social impact (SI)
- Consequences for the natural environment (CNE)
- Safety concerns (SC)

Technical factors disregarded as it is assumed that the “best” technical solution will be found and applied in each case, both from technical and economic point of view
Evaluation of the four alternatives

Main difficulty is selecting appropriate environmental factors - Scoping

Main topics selected:

- “Safety”
- “Social impacts”
- “Environmental impacts”

Economics and viability of each alternative are considered separately
Safety

- Safety against ground damage due to air accidents
- Safety of airline passengers against traffic accidents (travelling to and from the airport)
Social impacts

- Impact of alternative on existing regional planning (urbanisation)
- Other feasible land utilisation (other than for an airport), e.g. urban renewal
- Level of service
  - Coefficient of utilisation, i.e. expected ratio of service \((\frac{d}{D}\text{ where } d \text{ is number of airport open days (acceptable weather), } D=365)\). The International Civil Aviation Organisation sets 95% as the lowest limit for a commercial airport.
  - Distance to airport from centre of gravity of the Capital Region
Environmental impacts

- Noise and pollution
- Impact of aviation on nature (not people)
- Impact of airport structures on nature (not people)
- Visual impacts
“Environmental” factors at different hierarchal levels

Reykjavik Domestic Airport
Aims - Policy

Level 1
- Safety
- Social Impacts
- Environmental impacts

Level 2
- Ground damage due to air accidents
- Road traffic accidents
- Regional planning changes
- Other noteworthy land use
- Level of service
- Noise/pollution
- Visual effects
- Impact of ground structures on the biosphere
- Impact of aviation on the biosphere

RVA
RLA
HHA
KIA
Three different “experts” asked to evaluate the “environmental” factors

- Planning architect from State Planning Institute
- Deputy director of Icelandic Civil Aviation Administration
- Professor of biology from the University of Iceland
- Experts asked to use standard scores and consider hierarchal subfactors
Differential evaluation scale for scores and weights (Canter, 1995)

Some controversy over the scale, one expert wanted more room for evaluation at the negative end of the scale. An obvious discontinuity exists as the range 3-4 is missing.

<table>
<thead>
<tr>
<th>Score</th>
<th>Interpretation of Importance of First Level Entries</th>
<th>Interpretation of the score of an Environmental Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Without any importance</td>
<td>Poor result, not acceptable</td>
</tr>
<tr>
<td>2-3</td>
<td>Of very little importance</td>
<td>Poor result</td>
</tr>
<tr>
<td>4-5</td>
<td>Of average importance</td>
<td>Mediocre result</td>
</tr>
<tr>
<td>5-7</td>
<td>Important</td>
<td>Acceptable result</td>
</tr>
<tr>
<td>7-8</td>
<td>Very important</td>
<td>Good result</td>
</tr>
<tr>
<td>8-9</td>
<td>Highest priority</td>
<td>Excellent result</td>
</tr>
</tbody>
</table>
The Delphi method is a systematic, interactive forecasting method, which relies on a panel of independent experts.

The carefully selected experts answer questionnaires in two or more rounds.

- After each round, a facilitator provides an anonymous summary of the experts’ forecasts from the previous round as well as the reasons they provided for their judgements.

- The experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process, the “range” of the answers will decrease, and the group will converge towards the “correct” answer.

- Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, stability of results), and the mean or median scores of the final rounds determine the results.
Query of Reykjavik City Councillors

A questionnaire sent to all 25 (they are now 15) city councillors and they asked to evaluate or rather prioritise the main “environmental factors,” i.e.
Viability and economic impacts (EI)
Social impacts (SI)
Consequences for the natural environment (CN)
Safety concerns (SC)

This exercise did not give satisfactory result. Only 6 out of 25 councillors bothered to turn in the questionnaire. One requested more information without answering. The councillors’ prioritisation seemed ill-defined and ill-advised. No one seemed concerned about safety, which received low marks
Evaluation results for the weights of the four first level categories

In the end it was decided to discard the councillors´query results because of too few answers and dubious prioritisation. The AHP methodology was applied instead. The two authors and an AHP expert carried out the AHP comparison study (evaluators 1-3)

<table>
<thead>
<tr>
<th>Weights, $w_i$</th>
<th>City council representatives</th>
<th>Evaluator 1</th>
<th>Evaluator 2</th>
<th>Evaluator 3</th>
<th>Average weight</th>
<th>Average adjusted weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>0.252</td>
<td>0.555</td>
<td>0.660</td>
<td>0.500</td>
<td>0.572</td>
<td>0.660</td>
</tr>
<tr>
<td>Economic impacts</td>
<td>0.250</td>
<td>0.092</td>
<td>0.060</td>
<td>0.250</td>
<td>0.134</td>
<td>0.000</td>
</tr>
<tr>
<td>Social impacts</td>
<td>0.271</td>
<td>0.164</td>
<td>0.140</td>
<td>0.125</td>
<td>0.143</td>
<td>0.165</td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>0.227</td>
<td>0.189</td>
<td>0.140</td>
<td>0.125</td>
<td>0.151</td>
<td>0.175</td>
</tr>
<tr>
<td>Sum</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The economic impact will be handled separately, hence the adjusted weighs
The scores for the “environmental” factors and subfactors

The evaluation carried out by the three outside “experts”, who complained over the little time given for the task

<table>
<thead>
<tr>
<th>Airport</th>
<th>Environmental Component</th>
<th>RVA</th>
<th>RLA</th>
<th>BSNA</th>
<th>HHA</th>
<th>KIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weights</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAFETY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Air accidents</td>
<td>0.4</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Road accidents</td>
<td>0.6</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Final Score</td>
<td></td>
<td>8.6</td>
<td>8.6</td>
<td>7.2</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>SOCIAL IMPACTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Regional planning</td>
<td>0.4</td>
<td>4.5</td>
<td>8</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Other utilization</td>
<td>0.2</td>
<td>2.5</td>
<td>4</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Level of service</td>
<td>0.4</td>
<td>8.6</td>
<td>8.4</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>Utilisation</td>
<td></td>
<td>0.4</td>
<td>9</td>
<td>7</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td></td>
<td>0.6</td>
<td>9</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Final Score</td>
<td></td>
<td>5.74</td>
<td>7.36</td>
<td>7.42</td>
<td>7.38</td>
<td></td>
</tr>
<tr>
<td>ENVIRONMENTAL IMPACTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise and pollution</td>
<td>0.3</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Aviation impact</td>
<td>0.3</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Impact of structures</td>
<td>0.3</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Visual impact</td>
<td>0.1</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Final Score</td>
<td></td>
<td>6.9</td>
<td>3.1</td>
<td>5.1</td>
<td>8.7</td>
<td></td>
</tr>
</tbody>
</table>

Note: The scores for “Impact of structures” are marked as a Red Flag.
The EQI for the four different development alternatives

\[ EQI = U(x) = \sum_{i=1}^{n} k_i U_i(x_i) \]

<table>
<thead>
<tr>
<th>Environmental factor</th>
<th>Safety</th>
<th>Social impact</th>
<th>Environmental impact</th>
<th>EQI = U(x) = \sum_{i=1}^{n} k_i U_i(x_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights ( w_i )</td>
<td>0,660</td>
<td>0,165</td>
<td>0,175</td>
<td></td>
</tr>
<tr>
<td>Reykjavik Airport RV</td>
<td>8,6</td>
<td>6,90</td>
<td></td>
<td>7,83</td>
</tr>
<tr>
<td>Reykjavik Löngusker Airport RLA</td>
<td>8,6</td>
<td>7,36</td>
<td>3,10</td>
<td>7,43</td>
</tr>
<tr>
<td>Bessastaðanes Airport BSNA</td>
<td>8,6</td>
<td>7,36</td>
<td>3,10</td>
<td>7,43</td>
</tr>
<tr>
<td>Hvassahraun Airport HHA</td>
<td>7,2</td>
<td>7,42</td>
<td>5,10</td>
<td>6,87</td>
</tr>
<tr>
<td>Keflavik International Airport KIA</td>
<td>5,0</td>
<td>8,70</td>
<td></td>
<td>6,04</td>
</tr>
</tbody>
</table>
**Economic viability and cost evaluation of the four alternatives**

Cost comprises investment, sacrificial cost (e.g. not available for urban development), 25-year operation cost at present value and travelling costs (2002 prices, Euros). This part was carried out in a separate study by students in an engineering economy course.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total cost (billion ISK)</td>
<td>total cost (million Euros)</td>
</tr>
<tr>
<td>Reykjavík Airport RVA</td>
<td>18.5 (39.6)**</td>
<td>217.4 (271.2)</td>
</tr>
<tr>
<td>Reykjavík Löngusker Airport RLA</td>
<td>19.9 (42.6) - 37.1***</td>
<td>234.5 (291.8)</td>
</tr>
<tr>
<td>Bessastaðanes Airport HHA</td>
<td>11.4 (24.4) - 22.3</td>
<td>134.6 (167.1)</td>
</tr>
<tr>
<td>Hvassahraun Airport HHA</td>
<td>11.4 (24.4) - 22.3</td>
<td>134.6 (167.1)</td>
</tr>
<tr>
<td>Keflavík International Airport KIA</td>
<td>8.6 (18.4)</td>
<td>100.6 (126.0)</td>
</tr>
</tbody>
</table>

*) ISK prices adjusted to 2015 niveau according to increase in Consumer Price Index 2002-2015, x2.139

**) Cost figures adjusted to 2015 prices (2002: 1 Euro = 85 ISK, 2015: 1 Euro = 146 ISK)

***) Investment cost according to the Ragna Commission 2015 (operation and travelling costs disregarded)
Robust planning

Robust planning is to seek the best multi-objective solution regarding strategic resources utilisation with deep uncertainties

- A plethora of decision-making methodologies is available for economic decisions
- Multi-attribute-decision-making MADM. An overview of such methods is given in a doctoral dissertation by Dr. Pan (his thesis found on course website (UGLA))
- Assess “environmental” impacts in parallel with the preliminary design and select “best” solution in a viability analysis
- Use a Pareto Optimal Solution, using trade-off curves or boundaries (after Vilfredo Pareto, an Italian economist)
Pareto optimality

A concept in economics

- **Pareto Optimum.** Given an initial allocation of goods among a set of individuals, a change to a different allocation that makes at least one individual better off without making any other individual worse off, is a *Pareto improvement*. An allocation is *Pareto Optimal* when no further Pareto improvements can be made.

- **Pareto Frontier.** Given a set of choices and a way of valuing them, the *Pareto frontier* is the set of choices that are *Pareto-efficient*. The Pareto frontier is particularly useful in engineering: by restricting attention to the set of choices that are Pareto-efficient, a designer can make trade-offs within this set, rather than considering the full range of every parameter.
A Pareto frontier. The boxed points represent feasible choices. Smaller values are preferred to larger ones. Point C is not on the Pareto Frontier because it is dominated by both point A and point B. Points A and B are not strictly dominated by any other, and hence do lie on the frontier.
A Pareto optimal solution for airport location?

Reykjavik Domestic Airport Viability and Environmental Quality Pareto Optimum

Reykjavik Domestic Airport Viability and Environmental Quality Pareto Optimum

Present value investment and 25 year operational costs (Million Euros in 2002 prices)
Sensitivity analysis

With increasing environmental concern, the value of keeping the old airport changes little. Moving to Keflavík is an improvement. Other options loose value.
Sensitivity analysis

Safety aspects. Old Reykjavík and Löngusker airport options become better with increased safety concern

Sensitivity Analysis
Safety Aspects

Environmental Quality Index

Importance weights; variation from the evaluated (0,66)
Sensitivity analysis

The social impact of the four options does not seem to be severely affected by variation of its importance. If anything the old airport loses value (freeing land for urban development)
Conclusions

A sensitivity analysis was carried out for each environmental factor to investigate if its exact score was of importance

- The Pareto solution is difficult to find (similar EQI’s).
- The trade-off boundary indicates three possible solutions, i.e. KIA, HHA and RVA (50%). Moving the airport to Keflavík seems the “best” solution (price of land (RVA) for urban renewal overvalued?)
- Increasing environmental concern: KIA offers best environmental quality, RVA and RVA (50%) both ok. RLA came up with a “red flag” during the environmental analysis, and loses greatly in environmental quality. The HHA option also loses appeal. Weather and aviation studies have indicated that this option (HHA) has less appeal than KIA and RVA. (Icelandair has just announced that they will start trial flights over Hvassahraun to investigate conditions there).
- Increasing safety concern: KIA loses appeal, whereas all other options improve their environmental quality
- Increasing social concern: RVA loses appeal. All other options improve their standing
Thank for your kind attention
Bear in mind that this study was carried out at no cost and had to be very limited in nature due to time constraints, lack of manpower and without any funding whatsoever. However, it is believed that its findings are quite significant.

A rapid transit train-Reykjavik-Keflavik-which has been proposed, may finally resolve this difficult issue.