Weather service chain analysis
WSCA

An approach for appraisal of the social-economic benefits of improvements in weather services

Adriaan Perrels (FMI)
Väinö Nurmi, Pertti Nurmi (FMI)
SIRWEC 2012 Conference
Helsinki 23/25-5-2012
Structure

• Effects of weather vs. those of weather information
  • Transport tends to have a large coping range
  • Response time and rigidities
• Traditional cost-loss model
• WSCA approach
• WSCA application example
• conclusions
Don’t blur weather and weather information effects

• Damage in transport due to extreme weather can be substantial, e.g. via
  • Infrastructure, vehicles, fatalities, cargo, delays, loss of confidence and subsequent demand loss/mode switch
• Yet, the question is what difference weather information can make as compared to an uninformed system / users
  • Traffic volume reduction largest factor in accident reduction when adverse weather is expected (Cools et al 2010) – including a selectivity bias towards less skilled drivers
  • In Finland – the hotter the summer seems to boost road casualty numbers more than the colder the winter
Capacity rigidity affects weather service benefit
Traditional approach – cost/loss model

<table>
<thead>
<tr>
<th>Action</th>
<th>Adverse weather</th>
<th>Not adverse weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>No protection</td>
<td>L</td>
<td>0</td>
</tr>
</tbody>
</table>

\[ q = \frac{p_1 - p}{1 - p} \]

where \( q \) denotes the forecast quality \((0 < q < p_1)\), 
\( p_1 \) is the conditional probability of adverse weather 
(given that adverse weather was forecast),

\[ q^* \geq \frac{C}{L} - \frac{p}{1 - p} \]

\( q^* \) is the critical value where weather service starts 
to produce benefits.
Cost/Loss model – limiting assumptions

- Weather information acquisition cost are zero
- All users of weather information are – otherwise – all perfectly informed
- Prevention cost are zero
- Uncertainty range around the forecast is constant over time and not extremely large
- Information level of other market parties does not affect decision

These assumptions imply that the Cost/Loss model (incl. uncertainty extensions) is only straightaway applicable in aviation and maritime navigation.
Weather service chain analysis 1

• Information decay and ability to exploit information varies, therefore we have to consider the weather service information chain (WSCA) in detail.

• From forecast generation to eventual societal benefit 6 (or even 7) steps can be distinguished.

• Approach can be formalized by means of survival analysis:
  • product sum of consecutive fractions
  • fractions can change over time
### Weather service chain analysis 2

<table>
<thead>
<tr>
<th>Information filtering steps</th>
<th>Present qualities and room for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>weather forecast accuracy</td>
</tr>
<tr>
<td>2</td>
<td>information/message customer orientation</td>
</tr>
<tr>
<td>3</td>
<td>access to weather information</td>
</tr>
<tr>
<td>4</td>
<td>comprehension of the information</td>
</tr>
<tr>
<td>5</td>
<td>ability to respond timely and effectively</td>
</tr>
<tr>
<td>6</td>
<td>actual effectiveness of responses</td>
</tr>
<tr>
<td>7</td>
<td>incidence of the costs and benefits of the response</td>
</tr>
</tbody>
</table>
Weather service chain analysis 3

\[ Q_{mt} = \prod_{s=1}^{7} \{P_{ms_t}\} \]
where \( 0 \leq P_{ms} = f_{ms}(x_{s_i}, \ldots, x_{s_{i+n}}) \leq 1 \), and therefore also \( 0 \leq Q_{mt} \leq 1 \)

\[ B_{mt} = Q_{mt} \cdot \gamma^{\alpha(1-Q_{mt})} \cdot B_{m,t}^{max} \]

\[ P_{ms} = \frac{\sum_{j=1}^{M} \sum_{i=1}^{N} p_{j,i}}{M \cdot N} \]

\[ p_{j,i} = \frac{e^z}{1 + e^z} \]

\[ z = \beta_0 + \sum_{i=1}^{n} \beta_i x_i \]
Weather service chain analysis 4

• now only 14% of theoretical potential realized
• this score equals to approx. 36 million €
• raising forecast accuracy only would generate 3 mln. € at most
• raising (also) access and ability boosts leverage of investment in forecast accuracy

NB! 7th step (redistribution effects) not considered

NB2! Interaction with weather service for road clearance planning to be reviewed
Conclusions

• Appraisal of net social-economic benefit of weather services requires identification of the end-user’s response to the (incremental) information.

• Only for highly professional users (aviation, marine navigation, electric power generation) the actual and theoretical benefit potential are quite near to each other, i.e. forecast accuracy the most decisive factor.

• For most other user groups – e.g. road users – the information’s benefit decay is substantial → this means that other features than forecast accuracy – e.g. information access, information tailoring, cognitive capabilities, etc. deserve equal or more attention.

• The annual economic benefits of road weather information in Finland are preliminary estimated at € 36 mln. For the whole of Europe the corresponding figure amounts to € 3.4 bln. By addressing the entire WSC could be probably doubled.
Thank you

- ERIK PALMÉNIN AUKIO 1
  00560 HELSINKI
  Puh. (09) 192 91
  Faksi (09) 179 581

www.ilmatieteenlaitos.fi