Adaptation of roads winter maintenance strategies to weather influences

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«Weather – Meteorology – Consumer» system structure
Losses which take place at complex weather conditions

\[ L_{CW} = E_{RO} + L_{V} + L_{A} + L_{E} \]

- **Ero** - the road organizations expenditures for the winter maintenance work
- Losses in transport complex and national economy from unsatisfactory road conditions:
  - **Lv** - Lower speed on a slippery road surface,
  - **La** - Cost of accident,
  - **Le** - Damage of polluted environment.
The matrix of losses

<table>
<thead>
<tr>
<th>Predicted conditions</th>
<th>The decisions, accepted by the road organization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protective measures are accepted adequately, according to weather conditions</td>
</tr>
<tr>
<td>$F$</td>
<td>$S_{11}$</td>
</tr>
<tr>
<td>$F_1$ (ice presence)</td>
<td></td>
</tr>
<tr>
<td>$F_2$ (ice absence)</td>
<td>$S_{21}$</td>
</tr>
</tbody>
</table>
# ROAD WINTER MAINTENANCE STRATEGIES

<table>
<thead>
<tr>
<th>Number of strategy</th>
<th>The name</th>
<th>Type of road slipperiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Post salting</td>
<td>Glaze, ice, black ice</td>
</tr>
<tr>
<td>II</td>
<td>Pre-salting</td>
<td>Glaze, ice, black ice</td>
</tr>
<tr>
<td>III</td>
<td>Mechanical clearing of snow, patrol snow removal</td>
<td>Fresh snow</td>
</tr>
<tr>
<td>IV</td>
<td>Pre-salting, mechanical clearing of snow</td>
<td>Compacted snow</td>
</tr>
</tbody>
</table>
The time diagrams

I

$$t_{inf} \quad t_i \quad t_{bw} \quad t_{fw} \quad t$$

II

$$t_{bw} \quad t_{bw} \quad t_{fw} \quad t$$

III - IV

$$h$$

$$h_{adv}$$

$$t_{bw} \quad t_{fw} \quad t$$

Patrol snow removing cycle

$$h_s \geq h_{adv}$$

$$h_s \leq h_{adv}$$

$$t_{s7}$$

$$t_{et}$$
The distribution diagram for possible losses at protective actions

\[
\begin{align*}
S_{11} & \quad S_{12} = E_{11} & \quad E_{12} & \quad L_{11} & \quad L_{12} \\
S_{21} & \quad S_{22} = E_{21} & \quad E_{22} & \quad L_{21} & \quad L_{22}
\end{align*}
\]

\[ L_{\text{max}} = (E_{12} - E_{11}) + L_{12} \]

- **Cost of protective actions**
- **Preventing losses**
- **Unpreventing losses**
ADAPTATIVE PARAMETERS

- $\varepsilon = \frac{L_{11}}{[(E_{12} - E_{11}) + L_{12}]}$
  - $\varepsilon = 0$ - protection means are cardinal;
  - $\varepsilon = 1$ - losses are maximal and cannot be prevented

- $B = \frac{E_{11}}{[(E_{12} - E_{11}) + L_{12} - L_{11}]}$

- $\beta = (1-B) + \frac{(1-2\varepsilon)}{(1-\varepsilon)}$
  - for $\beta < 1$ the forecast loses economic utility

- $F = 1 - 2\varepsilon - \frac{E_{11}}{[(L_{12} - L_{11}) + E_{12}]}$
  - the values of this parameter should be positive
THE RESULTS OF THE COMPUTING TESTS  (for roads of I class)

<table>
<thead>
<tr>
<th></th>
<th>Works are spent to cycle time</th>
<th>$\varepsilon = 1$</th>
<th>this strategy is not &quot;meteosensible&quot;</th>
</tr>
</thead>
</table>
| I | Works are spent in view of the minimal air temperature forecast | $\varepsilon = 0,31$  
$\beta = 1,06$  
$F = 0,04$ | this scheme gets in a zone of adaptation. Forecasts of the minimal air temperature allow to receive the certain economic benefit |
| II |                                        | $\varepsilon = 0,06$  
$\beta = 1,86$  
$F = 0,75$ | at pre-icing strategies losses practically are completely prevented and protection measures are cardinal. |
| III | the parameters of adaptation are near to threshold value. The matrixes of losses were calculated for average parameters of snow intensity and intensity of movement. It is possible to assume, that there are certain combinations of weather and road factors at which parameters of adaptation will exceed threshold values. Researches for this strategy will be continued. |