PROACTIVE RISK MANAGEMENT IN WINTER MAINTENANCE

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ABSTRACT

The Centre for Economic Development, Transport and the Environment for Uusimaa (Uusimaa ELY Centre) which is the road maintenance authority for public roads in the Uusimaa region, has analyzed natural and other risks in road maintenance. Applied risk management is based on the risk management procedure released by the Finnish Transport Agency.

Comprehensive risk management requires proactive actions which include contacts and cooperation with other authorities and participation or follow-up in different research programs. Gathered information forms a basis for risk analysis and enables authorities to plan adequate procedures to manage identified long-term risks. Short-term risks are managed satisfactorily on the operational level of maintenance because risk management, and especially risk identification, is based on the know-how and experience of authorities and contractors and utilization of risk management procedure. Short-term risks are usually quite maintenance-specific but not very extensive.

The Finnish Transport Agency has participated in several European research projects. One of them was IRWIN (Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios). IRWIN produced areal models for climate change in winter. These can be utilized in the risk identification phase. According to the areal models it is possible that the basis and content of maintenance contracts need to be renewed to some extent in the future due to the different areal changes in winter temperatures and precipitation.

Climate change may be a reason to modify the quality requirements and grounds for payment in maintenance contracts in order to guarantee quality and cost-efficiency in winter maintenance. Knowledge of areal weather conditions and their changes help to set area-specific requirements for separate maintenance contracts. Changes may effect the need for additional finance for road maintenance in the budget.

Management of long-term risks and development of suitable policy and procedure for that is a challenge. Long-term risk management of maintenance has a connection to areal investments in roads and road structures. Climate change should be taken into account in the planning phase of construction to create a favorable basis for winter maintenance and to avoid such investments that will not serve winter maintenance properly in the future. This relates for example to the design of drainage and culverts.

1 INTRODUCTION

The Centre for Economic Development, Transport and the Environment for Uusimaa (Uusimaa ELY Centre) is the road maintenance authority for public roads in Uusimaa, Kanta-Häme and Päijät-Häme provinces in southern Finland. There are a total of 78,200 km of state-owned public roads in Finland, of which 9,100 km are located around the capital city of Helsinki in the region of operation of Uusimaa ELY Centre. The whole country is divided into 82 maintenance areas, and Uusimaa ELY Centre is in charge of 12 of them. All maintenance areas have been put out to tender since the year 2004.

Figure 1 - Region of operation of Uusimaa ELY Centre

Maintenance service contracts include road surface and device cleaning, pavement patching, green works, upkeep of road devices, and small repair works. Winter maintenance consists of snow removal (45%), salting (35%), and sanding/gritting (20%). The total yearly funding is 200 million euros in the whole country in maintenance and 35 million euros in Uusimaa ELY Centre. The portion of winter works is about 60% of the total maintenance service contract costs.

Uusimaa ELY Centre applies the risk management procedure released by the Finnish Transport Agency. The risk management procedure for maintenance service contracts is described in this article as well as the present status of risk management and challenges in maintenance service contracts.

The Finnish Transport Agency has determined twelve strategic risks, of which six are key risks. One of the key risks is uncontrolled disturbances for road maintenance and traffic due to extreme weather events resulting from climate change. This risk is used as an example of proactive risk management in this article.

On Finland’s south coast, winter begins in November and ends in April. The total amount of snow falling during the winter is equivalent to around 155 mm of water. Converted to snow, this is equivalent to a depth of 1.55 metres. On average, there are 12 days on which a lot of snow falls. On such days, over a 24-hour period, there is an average of 10-20 cm is received. Smaller snow showers occur much more frequently. The winter temperature varies from a few degrees above 0º C to approximately -20 ºC. Controlling slippery conditions calls for continuous maintenance procedures. Every winter, it is necessary to send out road maintenance equipment an average of 100 times in order to combat slipperiness. This is mainly controlled using salt and grit.

2 RISK MANAGEMENT PROCEDURE IN MAINTENANCE SERVICE CONTRACT

2.1 General

At the Finnish Transport Agency and ELY Centres, risk management means a systematic process where the goal is to identify the risks and prepare necessary actions proactively rather than detecting risks passively. The aim is to find problems and make corrective measures sufficiently early.

The risk management process involves identification of critical hazards and risks, assessment of the importance of the risk, determination of risk management measures, and risk monitoring and measurement [1]. The risk management process is always project-specific. Each project has its own peculiarities that affect the risks of the project.

Hazard and risk factors are identified in risk assessment sessions that are arranged 2 to 4 times, depending on the size and complexity of the contract. Risk evaluations are initiated during the planning phase, from which the assessment continues firstly to the tendering phase and then to the implementation phase.

The recommended size of the working group is about 3 to 5 people in order to achieve a sufficiently wide-ranging discussion of hazard and risk factors. The composition is determined by the scale and complexity of a maintenance service contract. In case of large and demanding contracts, the number of participating experts is higher than in the smaller basic contracts.

The composition of the working group is as follows:

- maintenance service contract planner
- tendering specialist
- client's supervisor of the contract
- authority (when needed)
- contractor's representative (implementation phase)
- risk assessment expert.

2.2 Risk management in maintenance area contract

The main focus in maintenance service contracts is in the management of technical risks in planning and implementation phases of the contract and in occupational safety risks and the security of road users. In the future, the technical and administrative risks include the planning, tender documents, tendering, contract management, implementation, environment, quality, work methods, environmental requirements and other issues related to risk identification, and communication of these risks between the client and contractors as part of the tendering phase. Identifying these risks is supported by a risk map [1].

In addition, the client must inform the security-related danger and risk factors of the project in the security document. The assessment of the danger and risk of construction work is based on Government Regulation of construction safety.

The result from a risk management process is contractual material, where the significant hazards and risks have been mapped comprehensively from a planning, tendering, and implementation perspective. These hazards and risks have adverse effects on the timetable, costs, safety, technical solutions, and working methods of the contract.

Risk assessment in the planning phase is intended primarily for the task of the management of the organization, because the risks of the maintenance service contracts are in this phase mainly national and thus applicable in all contracts. The ELY Centres are responsible for updating contract-specific risk management plans.

In the tendering and implementation phases of an individual maintenance service contract, the risk assessment is specified as the contract-specific risks. In this phase, the occupational safety risks of the contract are identified. The aim is to include the identified risks in the implementation phase. Therefore, the risk assessment documents are connected with an invitation to tender. Each ELY Centre is responsible for risk assessment of maintenance service contracts in its own geographical area in the tendering phase.

The contractor supplements the client's contract-specific risk assessment during the implementation phase. The implementation phase includes, in addition to completion of a risk assessment, the planning and monitoring of actions and updating the risk management plans. Success in risk management in an individual maintenance service contract can be mainly verified in the implementation phase in terms of measured quality and customer feedback and satisfaction. The client assesses the success of risk management and the realization of required measures twice a year after each summer and winter period. Properly completed and updated risk management plan will serve as a risk diary of the contract [1].

2.3 Risk Assessment

The risk management process starts from a risk analysis carried out in collaboration with the expert group. Hazard and risk factors in the contract are identified by using risk maps. Identified risks are then described in the risk management plan.

The most important issues related to the maintenance service contracts are combined in the risk map into larger sets of topics, divided into the planning, tendering, and implementation phase.

Risk entities at different phases are presented as subheadings on the risk map. The subheadings include individual issues and risks which belong to risk entity of each subheading. Subheadings of different phases are as follows [1]:

Planning phase

- cost management
- policies
- quality requirements and quality assurance
- definition of the contract
- customer needs and their changes

Tendering phase

- preparation of tender documents
- sharing of risks and responsibilities
- baseline data of the contract
- specific provisions relating to the contract
- definition of quality
- tendering process and practices
- contractor's eligibility
- acceptability of offer

Implementation phase

- cooperation
- quality management during the contract
- responsibilities during the contract
- personnel risks
- customer satisfaction
- safety plans

- incident management
- environmental risks
- the finished product risks

Identified risks are transferred for further treatment and monitoring to the risk management plan form. A description and the consequence of each identified risk are recorded. In addition, the risks are shared between the client and contractor on the risk management plan form, where possible.

The degree of risk is determined in the risk matrix on the basis of likelihood and severity of consequence of an event (Figure 2). In case of likelihood, attention should be paid to the question of how often the realization of risk is possible and how often the risk normally occurs. In determining the severity of the consequences, it should be considered what would normally follow from the realization of the risk and what would be the consequence of the worst case scenario.

		Consequence of event				
		None	Minor	Severe	Very severe	Extreme
Likelihood of event	Very common	Low	Moderate	Major	Intolerable	Intolerable
	Common	Insignificant	Low	Moderate	Major	Intolerable
	Occasional	Insignificant	Low	Moderate	Moderate	Major
	Rare	Insignificant	Insignificant	Low	Low	Moderate
	Very rare	Insignificant	Insignificant	Insignificant	Low	Low

Figure 2 - Risk matrix [1]

The measures to prevent or reduce the degree of risk, persons in charge of implementing measures and follow-up, and the schedule for the measures are determined after the risks are prioritized.

Operative action is steered by a risk management plan to select the correct and adequate solutions to eliminate or reduce risks. In addition, it is ensured that all necessary measures to prevent the realization of risk are taken into account.

3 EXAMPLE OF PROACTIVE RISK MANAGEMENT

3.1 General

The Finnish Transport Agency has participated in several European research projects and one of them was IRWIN (Improved local winter index to assess maintenance needs and adaptation costs in climate change scenarios). The aim was to create a local winter index that would take into account the impact of global climate change on various weather parameters and further to required winter road maintenance actions [2].

The resolution of ordinary meteorological data was not adequate for the new winter road index, and therefore the global climate scenarios were combined with much more accurate spatial data from field stations of Road Weather Information Systems.

Results from the research project can be utilized in identifying long-term risks related to winter maintenance due to climate change and in the continual development of quality requirements and contract models. The quality requirements in winter maintenance have been developed gradually, and the aim is to guarantee reasonable fluency and security of road traffic in every weather condition.

Earlier results from different national projects show that some of the most probable and prominent changes in Finnish climate affecting winter road maintenance will be:

- an increase in the number of traffic disturbances due to heavy snowfall even though total snowfall will decrease
- a decrease in the total amount of freezing and melting cycles in southern parts of Finland
- an increase in tree falls because of a thinner layer of frost, though there are no indications that destructive storms will increase.

The new winter indices can be linked to maintenance costs and this enables cost/benefit analyses in the present situation as well as for the future. A new compensation model for balancing the costs between the client and contractor due to the climate change is presented in this chapter.

3.2 New local winter indices

The factors taken into account in the winter index are ice, precipitation, and wind. Temperature fall from positive to negative degrees indicates the risk of ice formation and the need for salting operations [2].

Precipitation includes direct snowfall, with air temperatures below 0 ºC, melting snow, or drifting snow when the snowfall occurs with strong winds. Rain, especially intense rain, may influence road safety by decreasing visibility and by causing aquaplaning. Super cooled rainwater or rains preceded by cold weather are hazardous as well because they may cause ice on the roads.

Strong winds may force vehicles off the roads or in unwanted directions. Fallen trees or flying materials such as tree branches or litter may be troublesome to drivers. Winds may also create road blocks from drifting snow.

Indices were calculated for three different regions in Finland and Sweden in the research project. The areas are shown in Figure 3. Only results from Finnish areas F1, F2, and F3 are presented in this article. Areas F1 and F2 cover the region of operation of Uusimaa ELY Centre.

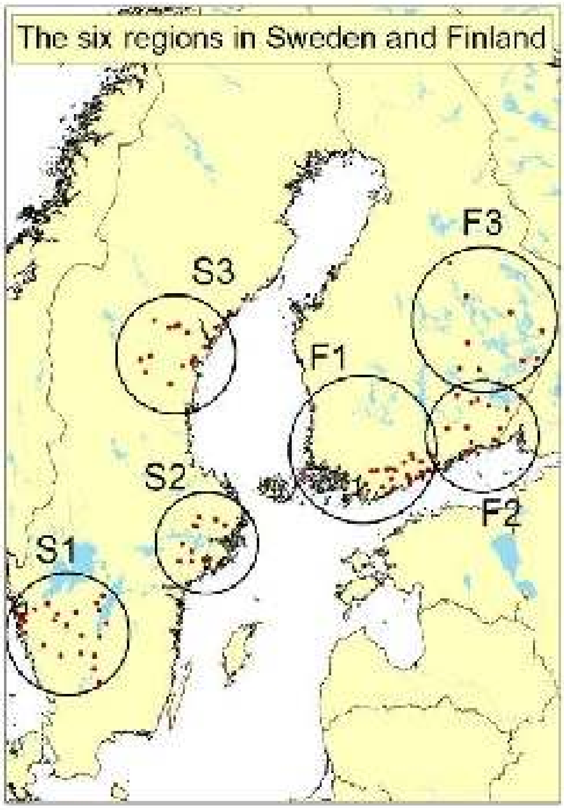

Figure 3 - Areas for which the new winter indices were calculated [2]

The indices are shown in Table 1. Indices 1 - 6 are ploughing indices, and 7 - 10 are salting indices. The indices were created to be able to study the potential change in need of maintenance activities such as ploughing and salting in the future. The applied climate models are described in the final research report of the project [2]. A period of 4 hours presents an event in the indices.

Table 1 - New local winter indices [2]

Index	Description
Index 1	- Number of events when the amount of snow is more than 1mm - Temperature -3 - +1°C - Wind velocity 0-7 m/s
Index 2	- Number of events when the amount of snow is more than 1mm - Temperature -3 to + 1°C - Wind velocity 7-14 m/s
Index 3	- Number of events when the amount of snow is more than 1mm - Temperature between -3 to + 1°C - Wind velocity more than 14 m/s
Index 4	- Number of events when the amount of snow is more than 1mm - Temperature less than -3°C - Wind velocity between 0-7 m/s
Index 5	- Number of events when the amount of snow is more than 1mm - Temperature less than -3°C - Wind velocity 7-14 m/s
Index 6	- Number of events when the amount of snow is more than 1mm - Temperature less than -3°C - Wind velocity more than 14 m/s
Index 7	- Number of events when it is raining and the surface temperature is less than 0.5°C (risk of freezing rain and black ice)
Index 8	- Number of events when the surface temperature is between -6°C and 0°C during 4 hours and the dew point is higher than the surface temperature (risk of hoar frost)
Index 9	- Number of events when the surface temperature shifts from +1°C to -1°C (risk of slipperiness)

The results for indices from the historical period (1980-2010) to the future period (2025-2055) are shown in Table 2.

Table 2 - Percent change in ploughing indices 1 - 6 and salting indices 7 - 9 from historical to future period [2]

	Seasonal mean events change (%)		
Index	Area F1	Area F2	Area F3
Index 1	-2.7	5.9	13.2
Index 2	-0.3	-16.7	-26.7
Index 3	-50.0	0	0
Index 4	-18.0	-15.6	-13.1
Index 5	31.9	-11.6	-9.1
Index 6	-50.0	0	0
Index 7	-5	12	13
Index 8	12	10	11
Index 9	13	11	18

Index 1 is negative in area F1 and therefore there will be fewer of these kinds of events in the future. The change in events is positive in areas F2 and F3, and there will be more of these kinds of events in the future. Index 2 is negative in all areas and there will be a decrease in the events described in this index. Index 3 remains the same. It should be noted that index 3 is not based on representative data in area F1.

There will be fewer events of index 4 and 5 in all areas in the future except in area F1, where the number of events of index 5 increases. Index 6 remains the same. Index 6 in area F1 is not based on representative data.

The number of events of all salting indices increases, despite the index 7 in area F1.

The precipitation values have been subdivided into three groups, depending on the amount of precipitation during a 4-hour period. This has been done to illustrate the change in ploughing times in the future. The groups are shown in Table 3.

Table 3 - Precipitation groups [2]

Group	Description
A	Number of events when the snow amount reaches 1-3mm
B	Number of events when the snow amount reaches 3-5mm
C	Number of events when the snow amount reaches over 5mm

One ploughing event can be enough for group A, but ploughing events will increase in groups B and C. The changes in events of 4-hour periods are presented in Table 4.

Table 4 - Percent change in snow events from historical to future period [2]

Group	Seasonal mean events change (%)		
	Area F1	Area F2	Area F3
A	-4.85	-4.35	-0.62
B	-2.76	-1.71	0.45
C	-0.60	2.48	1.90

The events of all groups decrease despite events for group C in area F2. This means that the number of ploughing times decreases in area F1 and for groups A and B in area F2.

3.3 Winter maintenance quality requirements

The general requirements for preventing slipperiness in all winter maintenance categories of roads in Finland are shown in Table 5. The time to reach the quality requirements starts when the slipperiness has been detected.

Table 5 - Quality requirements on public roads in Finland, 2011 [3]

	Classification of Roads (Winter Care Category)					**Pedestrian Roads**	
	Is	**I**	**Ib**	**II**	**III**	**K1**	**K2**
Lowest allowed friction value	**0.30**	**0.28**	**0.25**	**Roughened or sanded surface**			
Description of friction values:	**as wet asphalt**	**as cold and roughened ice cover**	**as cold and roughened ice cover**	**0.20 - 0.24 smooth cold ice cover without roughing 0.15 - 0.19 smooth warm ice cover without roughing under 0.15 wet ice cover**			
The friction to be reached from start of procedure	**2** h or **0** h*)	**2** h	**3** h/salt **4** h/grit	**6 h**	**8 h**	**2** h, 10:00 pm - 6:00 am	**3** h, 10:00 pm - 6:00 am
Max snow depth when snowing	**4** cm	**4** cm	**4** cm	**8** cm	**10** cm	**3** cm	**4** cm
Clear after snowfall has ended - if slush the time is shorter:	**2,5** h 2 h	**3** h 2,5 h	**3** h	**4** h	**6** h	**3** h	**4** h
Eveness requirement (depth of holes in ice)	**0** cm	**1** cm	**1,5** cm	**2** cm	**2** cm	**2** cm	**2** cm

*) Average Daily Traffic (ADT) > 15 000

Requirements for every road have also been set for snow removal and evenness. The allowed maximum amount of snow and the required maximum time to clean the road after snowfall is also qualified, as shown in Table 5. During the snowfall, ploughing units have to be on the road when half of the allowed maximum snow depth has been measured.

Under discussion is that enormous snowfalls could be noticed earlier than nowadays. Now there is a rule that if it snows more than 10 cm during a 4-hour period, the situation is considered abnormal, and the contractor has 12 hours time to solve the situation after the end snowfall. But if it snows, for instance, more than 30 cm, it is evident, that a contractor cannot solve the situation during 12 hours. This situation is extraordinary and there must be an action plan for such situations.

3.4 Winter difficulties compensation

3.4.1 Meteorological information

There has been an assumption that a time period from five to seven years is adequate to level the weather differences between winters so that this time period presents a long time average winter. It has been noticed that this assumption is not necessarily true. There can be seven warm winters followed by seven cold winters. The length of maintenance service contracts are usually from 5 to 7 years.

The Arctic Ocean north of Finland has a big influence on the Finnish climate. The sea water temperature has risen due to climate change and the ice-covered area on the sea is smaller than before (Figure 4 and 5), causing a wall effect against the winds from Siberia. This wall effect is described by the so-called North Atlantic Oscillation (NAO) index and it is based on the difference in normalized sea level pressure between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland since 1864 (Figure 6). A positive value in the index leads to warm winters and a negative value leads to cold winters. The index has been negative in the winter of 2010-2011, and there been long-lasting cold periods in North Europe that winter.

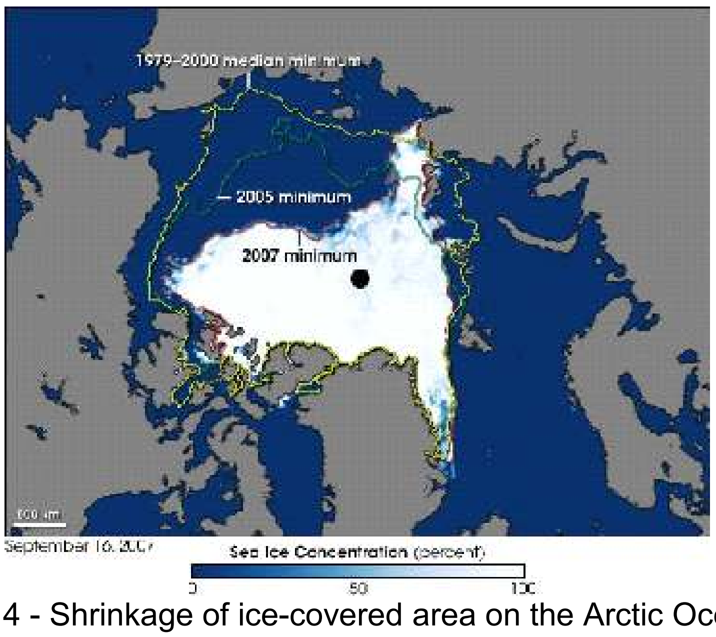

Figure 4 - Shrinkage of ice-covered area on the Arctic Ocean [4]

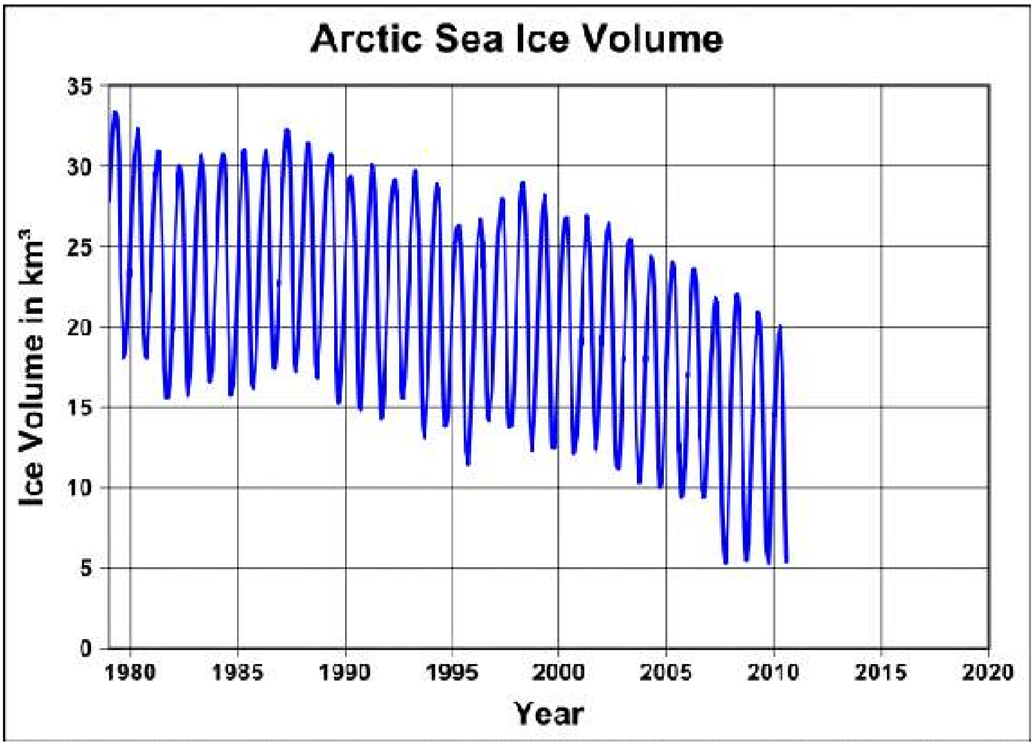

Figure 5 - Seasonal variation and long term decrease of Arctic Ocean ice volume [5]

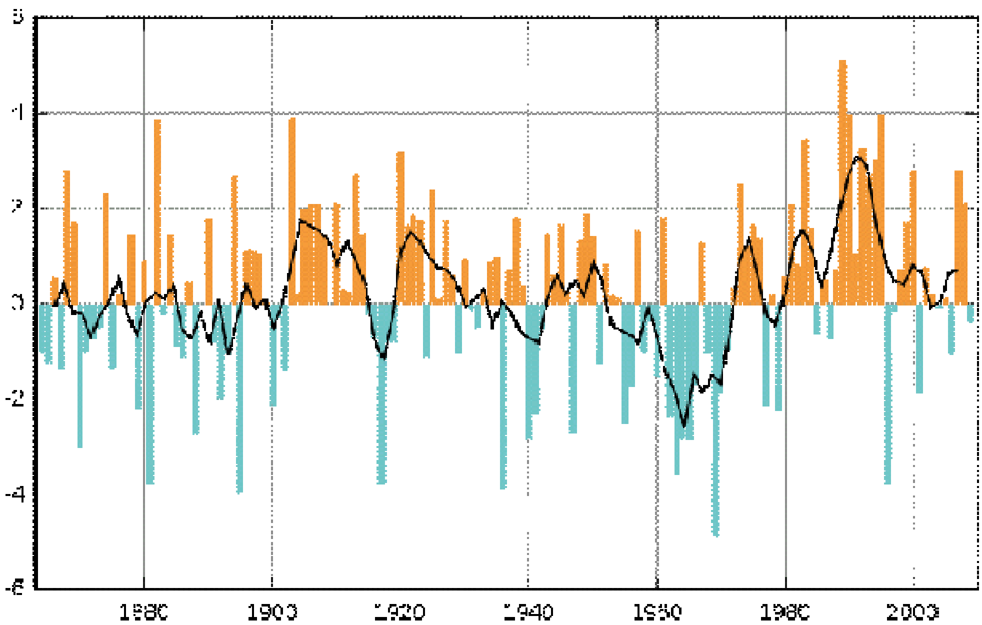

Figure 6 - Winter index of the North Atlantic Oscillation (NAO) with a five year moving average (black) [6]

3.4.2 Economic risk share

There has been a model in Finland to calculate the influence of winter conditions on costs since the year 2001. A contractor's economical loss has been compensated if the winter has been harder than the long-term average winter. Correspondingly, the client has been compensated for mild winters.

A few years ago, after several mild winters, the use of the compensation model was halted mainly upon request of contractors. The compensation model also had some deficiencies, and it caused additional work for the client and therefore the decision to stop using the models was an easy one to make. After two hard winters, contractors noticed that they took a big economical risk waiting for continual mild winters and requested a halt to the model.

The new maintenance service contracts that come under competition would probably be more highly prized than the earlier ones due to the lack of the compensation model. Therefore Uusimaa ELY Centre has decided to test a new compensation model in some of the new contracts. The use of the compensation model is also beneficial for minor contractors who only have a few maintenance areas or whose maintenance areas are in close vicinity to each other. Without a compensation model, the economic risk in these cases is higher than for large contractors with several maintenance areas located far apart from each other.

3.4.3 New compensation model

One maintenance service contract area where the new compensation model is tested is in the city of Raasepori. The area consists of an 850 km road network. The contract is for five years.

The statistics, for which the compensation model is based on, is shown in simplified form in Table 6. The statistics follow the same trend as the new winter index 9 in Table 2 and precipitation changes in Table 4.

Table 6 - Yearly snow depths, de-icing materials and statistics from October to April, (Maintenance Area Raasepori, South-West Finland) [7]

Winter	**Snow depth** (cm)	**Salt** (t)	**Grit** (t)	**Winter Months (7)** From + to - (pcs)	Average temperatur °C
2000 - 2001	99	-	-	47	1,5
2001 - 2002	192	-	-	80	0,6
2002 - 2003	90	-	-	62	-3,1
2003 - 2004	169	1 367	11 362	70	0,0
2004 - 2005	117	1 926	13 021	65	0,0
2005 - 2006	120	1 771	13 023	52	-0,9
2006 - 2007	102	1 581	9 671	51	1,8
2007 - 2008	108	1 855	8 226	58	2,3
2008 - 2009	89	1 654	8 416	59	1,0
2009 - 2010	128	1 241	7 218	45	-2,1
Averages					
2000 - 2010	**121**	**1 628**	**10 134**	**59**	**0,1**
1971 - 2000	**142**	**-**	**-**	**54**	**-0,7**

The yearly snow depth from 120 to 135 cm is considered as normal and does not result in any compensation. Winter costs are 1,200,000 €/a. The percentage of snow removal is 55%. So its costs are 660,000 €/a. If all snow removal equipment is owned by the contractor and the winter is normal, the percentage of a contractor's changing costs is 40% and capital costs are 60%. Compensation concentrates on the changing costs and its value is 660,000 x 0.4 = 264,000 €/a. The snow depth value for the last ten years has varied from 89 cm to 192 cm, with an average of 121 cm. The compensation value is

264,000/121 =2,164 €/cm/a. It is easier to use a rounded sum. So the value used is 2,200 €/cm/a for the client if the amount is below 110 cm (average -10%) and for the contractor if the amount is more than 133 cm (average +10%).

The other compensation calculation concentrates on de-icing; it includes both salting and gritting. We also have long-term statistics from phenomenon where the temperature goes from plus to minus degrees Celsius, which has a good correlation to the need for de-icing. In the same way as with snow, we have calculated the value of compensation. The percentage of de-icing is 45%. So its costs are 540,000 €/a. Contractor's changing costs are 40% and capital costs are 60%. Compensation concentrates on the changing costs and its value is 540,000 x 0.4 = 216,000 €/a. The freezing from + to - degree value during the last 10 years has varied from 45 to 80, with the average of 59. The compensation value is 216,000/59 =3,670 €/pc. It is easier to use a rounded sum. So the value used is 3,700 €/cm/a for the client if the amount is below 53 (average -10%) and for the contractor if the amount is more than 65 (average +10%).

The balancing of winter costs can be formulated in the model as below, which was made for the Raasepori maintenance area.

Balancing of winter costs =

$$\mathbf{k \times SRC / SAM_{avg} \times (SAM_{real} - SAM_{avg}) + k \times DIC / Ice_{avg} \times (Ice_{real} - Ice_{avg})}$$

where

k = 0.4 = the share of changing costs 40%/100

SRC = 660,000 €/a = annual snow removal costs, estimated by the client

DIC = 540,000 €/a = annual de-icing costs, estimated by the client

- **SRC /** $\mathbf{SAM_{avg}}$ and **DIC /** $\mathbf{Ice_{avg}}$ rounded to nearest 100 €

$\mathbf{SAM_{avg}}$ = 121.3 cm = the average snow amount in area during the winters from 2000 to 2010

$\mathbf{SAM_{real}}$ = the real snow amount of the winter under comparison;

- $(SAM_{real} - SAM_{avg}) = 0$,

  if $SAM_{real} = 0.9 \times SAM_{avg} \leq SAM_{real} \leq 1.1 \times SAM_{avg}$ = truth

$\mathbf{Ice_{avg}}$ = 59 pcs = the average amount of freezing (climate temperature from plus to minus) during the winters from 2000 to 2010

$\mathbf{Ice_{real}}$ = the real amount of freezing

- $(Ice_{real} - Ice_{avg}) = 0$,

  if $Ice_{real} = 0.9 \times Ice_{avg} \leq Ice_{real} \leq 1.1 \times Ice_{avg}$ = truth

The differences from the averages are calculated yearly, but the final account and payment is done after the end of the contract.

CONCLUSIONS

Short-term risks are managed satisfactorily at Uusimaa ELY Centre on the operational level of maintenance. Risk management, and especially identification of these risks, is based on the know-how and experience of client and contractors and the utilization of a detailed risk management procedure in maintenance service contracts.

The challenge in risk management is the provision for long-term risks. The provision often requires contacts and cooperation with other authorities and experts and follow-up in different research programs due to multidisciplinary nature of several potential long-term risks. A traditional risk matrix is not necessarily suitable for valuation and prioritizing of different risks due to the strategic nature of long-term risks and the uncertainty of their underlying phenomena.

The possible effects of climate change on quality requirements and costs of winter maintenance often provide a new risk identification and assessment process. This forms a basis for decision-making and even making a policy on how to react to different threats and possibilities. Sharing of economic risks between the client and contractor is an essential part of risk management.

Climate change and possible extreme weather events related to winter maintenance are examples of long-term risks that require decisions on how to adapt the winter maintenance requirements and processes to the possible changes. The extreme alternatives are reactive and proactive action. Reactive action could mean neglecting the predicted changes and developing the processes on the basis of realized changes to prevent the realization of the same kinds of risks in the future. Proactive action could involve minimizing the inconvenient effects of predicted climate change on road traffic before the actual changes by modifying the design criteria for roads and road structures and by adapting to the risks before the changes happen.

A reactive action strategy may at worst lead to serious disturbances and accidents in road traffic and huge costs to society and industry and commerce. However, this alternative can be the most cost-effective economically if the climate does not change as strongly as predicted in climate change scenarios. A reactive action strategy may be the least cost-effective if the climate change scenarios come true and especially if the scenarios underestimate the change [8].

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