PERFORMANCE AUDIT METHOD FOR WINTER MAINTENANCE

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1. INTRODUCTION

The primary purpose of highway winter maintenance is to improve the safety of road users. Although Road Traffic Accidents (RTAs) will always occur, regardless of weather conditions or the level of maintenance afforded a network, the incidence of RTAs on roads adversely affected by ice, frost or snow should be reduced by the undertaking of preventative and reactionary winter maintenance. All English Trunk Roads are part of a network that is subject to precautionary salting operations in advance of adverse conditions arising by way of ice, frost or snow. Such operations are reliant upon the severity of winter conditions and the accuracy of weather forecasts. However, the number of RTAs that occur during these conditions should be inversely proportional to the success of the system by which winter maintenance is effected by the highway authority's Maintaining Agents. A road network subject to a well-planned and well-implemented winter maintenance system should exhibit fewer winter weather related RTAs than one on which the system is less effective.

There is a need for a simple performance audit method that measures the consequences and value of correct and incorrect decisions to salt roads. A type 1 error is defined as when roads should have been salted but were not. A type 2 error is when roads were salted when they need not have been. Up to now these checks have been applied to the forecast providers only. This paper suggests that verification statistics can also be used to measure the performance of highway agencies and private consultants or who ever decides when roads should be salted.

2. BENEFIT/COST STUDIES

Very little research has been carried out concerning the efficiency and value of winter maintenance activities. Thornes (2000) has shown that for every £1 spent on winter maintenance in the UK approximately £8 are saved in the reduction of winter related traffic accidents and delays. Table 1 shows a comparison of benefit/cost studies across the world. Values range from 2:1 to 18:1 but it is likely that a ratio of 8:1 is typical for UK

TABLE 1	EPA (1976)	TISA (1976)	TRB (1991)	Hanbali (1994)	Sakshaug et al (1995)	Fraser et al (1998)	Thornes (2000)
	United States	United States	United States	New York, Illionois, Wiscon.	Norway	N. Ireland	United Kingdom
BENEFITS							
1. Reduce Traffic Accidents	No	Yes	No	Yes	Yes	Yes	£630m
2. Reduce Traffic Delays	No	Yes	No	Yes	Yes	Yes	£1,500m
3. Emergency Response	No	Yes	No	No	No	No	£235m
4. Fuel Economy	No	Yes	No	Yes	No	No	£16m
Total		$18,400m					£2,381m
COSTS							
1. Vehicle Corrosion	$2,000m	$643m	$3,500m	No	No	No	£150m
2. Bridge/Road Corrosion	$500m	$160m	$225m	No	No	No	£5m
3. Street Furniture Corrosion	$10m	$2m	$100m	No	No	No	£2m
4. Water Contamination	$150m	$10m	$10m	No	No	No	£1m
5. Vegetation & Soil Damage	$50m	Zero	n.a.	No	No	No	£2m
6. Cost of Salt Spreading	$200m	$200m	£1,500m	Yes	No	£5m	£140m
Total	$2,910	$1,015m	$5,335m				£300m
Benefit/Cost Ratio		18 to 1		6.5 to 1 - 2 to 1			8 to 1

Table 1 A comparison of International winter maintenance Benefit/Cost studies

conditions. It would probably be counterproductive to have a higher ratio as it would encourage oversalting of the roads. A more recent study in the United States by the Salt Institute showed a benefit/cost ratio of more than 60:1 for cities paralysed by snow. Certainly if a motorway or major trunk road was closed due to winter weather then the impact would be extremely serious. Snow is not normally a significant problem in England but every 5 or 6 winters it can cause serious problems for a few days. For the purpose of this Performance Audit Method (PAM) it is best to consider road surface temperature which is widely measured by Road Weather Information Systems (RWIS) networks and ignore snow which is not usually measured by RWISs. Where snow is a problem then the same methods can be used.

3. WINTER INDICES

Any PAM should take into account winter severity and it must be recognised that there is more skill involved in deciding when to salt roads in areas that have few frosts compared to areas where there is a frost every night in mid winter. Several winter indices have been suggested over the years including the Hulme winter index (HWI Cornford & Thornes 1996); the Met. Office Open Road Index (MOORI: Johns 1996), the COST 309 index and the GAB Index (Gustavsson 1996). These indices were developed when RWIS systems were new and road weather data was not archived. Hence they are based on standard weather data collected at sites well away from roads. If we look at an estimated number of road frosts (based on an average of ground and air frosts) for the period 1961-90 for England the values vary from approximately 25 in parts of West Cornwall to about 75 in the Pennines and Cumbria. Figure

1 shows the average number of road frosts between November 1st and March 31st and it can be seen that the coasts are less affected than inland except in Northern England where even coastal areas can receive a significant number of road frosts.

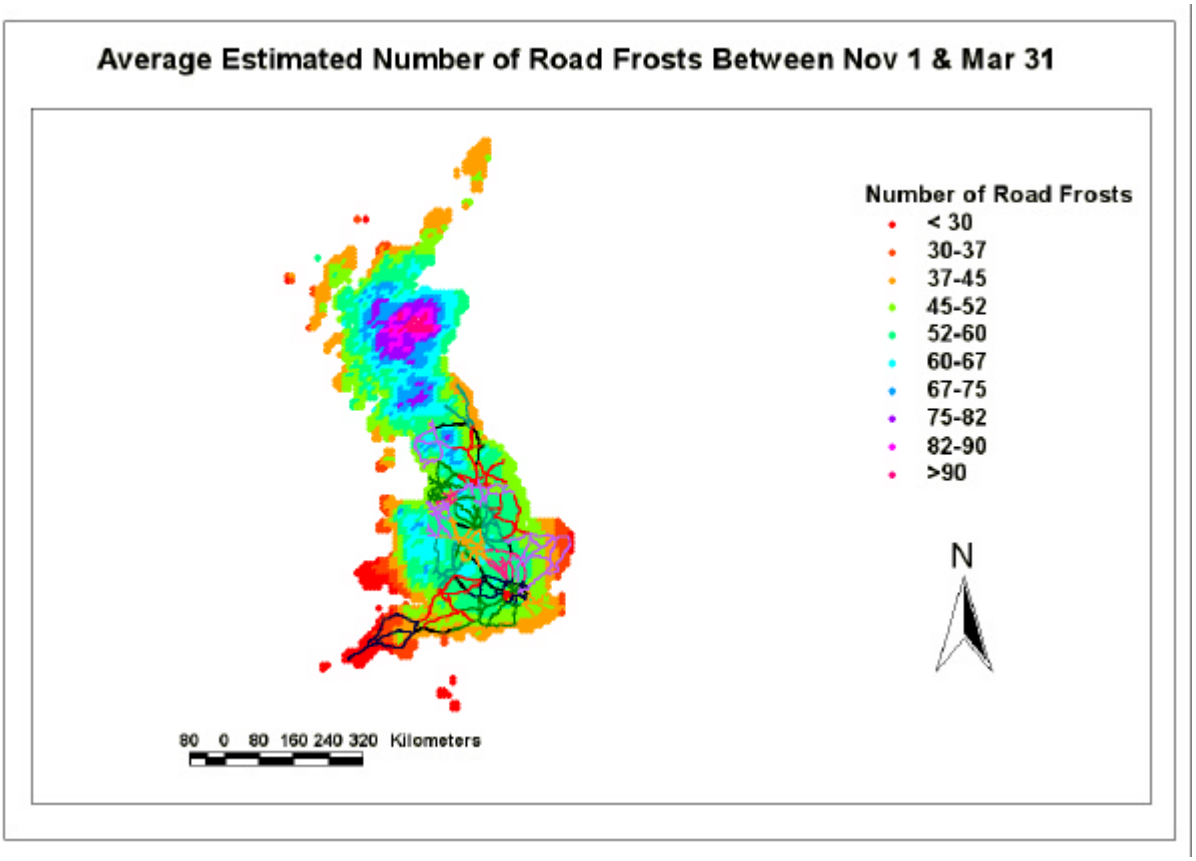

Figure 1 Average Estimated Number of Road Frosts and Area Networks

4. **PROPOSED PERFORMANCE AUDIT METHOD (PAM)**

For PAM it would be ideal to use actual RWIS data for the forecast sites on a network. The number of nights when the road surface temperature was below 4 deg.C (n) and the winter index (W) could then be calculated for each Area and maps similar to Figures 1 calculated using the GIS. As with the road weather forecasts a value of (n – W) = 50 would be required as a minimum for analysis. Although these figures should be calculated centrally it is proposed that each Area consultant will calculate their own Winter Index and compare it to their performance as follows.

Each Consultant will keep a daily record sheet:

Date	WM Action	Routes Salted	Spread Rate	Time of Decision	Time Salt Started
01/11	Presalt	All	10	23.00	0300

Also the daily record sheet will contain the forecast and actual road surface conditions:

Date	Sensor A		Sensor B		Sensor C		…….
	Forc Min	Actual Min	Forc Min	Actual Min	Forc Min	Actual Min	
	-0.8	1.0 (dry)	1.0	1.5 (moist)	0.5	-0.5 (salt)	

The time of minimum forecast and actual road temperature could also be stored automatically. The daily sheet would be completed each morning and could easily be automated.

A contingency table would then be constructed, either on a daily basis or monthly or at the end of the season. At the end of the season, by the end of May at the latest, a final contingency table would be analysed for each Area Consultant for the nights when the minimum RST was 4 deg.C or below:

		Necessary to Salt		
		YES	NO	
Salt	YES	35(a)	5(b)	
Spread	NO	3(c)	47(d)	n = 90

The normal range of statistics would then be calculated:

Percent Correct PC	= ((a + d) / n)*100	(90.1%)	
Winter Index W	= (a + c)	(38)	
Minimum 50	= (n – W)	(52)	
Bias	= (a + b) / W	(1.05)	
Miss Rate M	= (c / W)	(0.08)	
False Alarm Rate F	= (b / (b + d)) = (b / (n - W))		(0.1)
Value Index	= ((c + d) – c/p) / (n - W)		(0.5)
(where p = C/L = 0.125)			

In order to compare the quality and value of forecast providers we need an index that takes into account the number of Type 1 and Type 2 errors as well as the size of the Cost/Loss ratio. The relative value ‘V’ of a forecast system compares the mean expense ‘ME’ of a forecast with that of a forecast based on climatology (Richardson 2000) such that:

$$V = (ME(climate) – ME(forecast)) / (ME(climate) – ME(perfect))$$

V will have a value of 1 if the forecast system is perfect and will have a value of zero if the forecast is no better than climatology. A forecast based on climatology would, for example, predict a frost on a certain night if on average over the last 30 years there had been a frost on that night. Unfortunately the users of weather forecasts rarely have access to climate data and often their forecast sites are nowhere near a climate station.

The Value Index (V) is therefore defined as:

$$V = (ME(without\ forecast) – ME(forecast)) / (ME(without\ forecast) – ME(perfect))$$

Where ME(without forecast) can relate to climatology, persistence or chance, or whatever is used to compare with the forecast. For example one could compare the expense of salting all

marginal nights or salting all nights or not salting at all, whichever is the cheapest method that does not use a forecast. In the example used above it is cheaper to salt all marginal nights (E(S) = £1.54m) than not to salt at all (E(N) = £5.28m). Therefore we can state that:

$$V = (E(S) - E(A)) \ / \ (E(S) - E(P))$$

It can be shown that the V can be simply calculated as follows

$$V = ((c + d) - (c/p)) / (n - W)$$

The question arises as to whether or not this can be self regulated. The annual returns from the Consultants should be audited and perhaps each year, 2 or 3 Areas should be audited in more detail. Certainly the Winter Index W can be checked independently.

Target performance levels should be set in the Agent contracts. The suggested targets are:

1. Percent Correct salting decision PC >= 90%
2. (n – W) minimum of 50 nights
3. Bias <= 1.2
4. Miss Rate <= 0.1
5. False Alarm Rate <= 0.1
6. Value Index >= 0.7

If an Agent does not meet these targets then the Highway Authority should ask for an explanation in writing by the end of June of the same year. In the above example the Agent has passed all the targets apart from the Value Index. The reason for the failure would have to be explained.

PAM should be calculated for each salting route or for each depot or for the Agent as a whole. The forecast sites and thermal maps to be used to verify the decision to salt would have to be agreed in advance.

5. Conclusion

Targets for the suggested Performance Audit Method will be different for differing climates, but the same basic verification analysis can be carried out. It is important to monitor the performance of highway agencies as well as weather forecast providers.

REFERENCES

Cornford, D. & Thornes, J.E. (1996) 'A comparison between spatial winter indices and expenditure on winter road maintenance in Scotland', *Int. J. of Climatology***,** 16, 339-357

Fraser, G. & Drew, J. (1998) Route selection and salt management in Northern Ireland, *Xth PIARC Winter Road Congress Proceedings,* Vol 1, 41-52

Gustavsson, T. (1996). Use of Indices for Classification of Winter Climate, *Proceedings of the 8th International Road Weather Conference,* Birmingham, 11-21

Hanbali, R.M (1994) The economic impact of winter road maintenance on road users, *Transportation Research Record,* 1442, 429-439

Johns, D. (1996). The MOORI. A new winter index for Winter Maintenance, *Proceedings of the 8th International Road Weather Conference,* Birmingham, 22-26

Richardson, D. (2000). Skill and economic value of the ECMWF ensemble prediction system. Quart. J. Royal Met. Soc., 126, 649-668

Sakshaug, K. & Vaa, T. (1995) Road salting and traffic safety, SINTEF Transport Engineering Report No. STF63 A95005, Norway, 59p

Thornes, J.E (2000) Road Salting – an international benefit/cost review, in *Proceedings of the 8th World Salt Symposium*, 787 –792, Elsevier, Amsterdam

TRB (1991) *Highway De-icing – comparing salt and CMA,* TRB Special Report No. 235, NRC, Washington D.C.