THE USE OF PERFORMANCE INDICES AND THE ADVANCEMENT IN THEIR DEVELOPMENT FOR IMPROVED ACCOUNTABILITY

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ABSTRACT

Following the successful introduction of the Idaho Storm Performance Index [1], direct measurement of performance in relationship to winter maintenance activities is now possible. This paper examines the portability of that index to other climates and countries. It suggests that there may now be a way to not only measure individual performance but also to examine techniques and methodologies at their highest level for their effectiveness. Results show clear evidence that a proactive treatment regime does indeed deliver far better overall performance for road users in terms of the incidence of ice or snow on the roadway. This means a greater accountability for investment decisions made by government and local authorities.

1. INTRODUCTION

Globally each responsible authority for winter highway maintenance operates to an organizational standard. In countries with climates that could be described as marginal (temperatures often around the 0C point) many of these aim for a 'back to black' policy where the aim is to either remove ice and snow quickly after it appears on the road surface or indeed pre-treat the road in advance of the hazard formation. The former can be categorized as a 'reactive' stance where the operator will await the onset of the event and then react accordingly. The latter actually means second guessing the weather and treating before the event takes place with the intention of having very little or no occurrence of ice or snow on the road surface. It is also a common policy to have a dead time for treatment where crews are on stand down overnight. Justification for this is often addressed by the limited traffic flow overnight on the roads where this policy is implemented.

The return on investment on these differing policies has until now been very difficult to gauge. In 1996 a paper [2] tried to identify the cost to benefit ratio and calculated a headline value of 1 to 9 cost to benefit. However almost every aspect of the systems then studied have changed and with investments being made gradually over the years the individual component benefits are somewhat lost in the overall effectiveness of the service.

However a number of recent studies have started to assess the overall economic losses following a severe weather event such as widespread snowfall. In the UK one study by the Department for Transport [3] stated the cost of a widespread snow event where roads became relatively impassable was in the order of £280M per day. Whist another paper [4] estimated the average daily welfare cost to Scotland to be in the order of £30M per day of total disruption with the annual cost in the order of £330M. It is this second paper presented at PIARC in Andorra in 2014 that will be used later in this paper for the detailed analysis of possible cost allocations.

What is clear is that there is an inherent understanding that keeping the roads in a state which does not significantly impair the road user not only reduces the accident risk, but also enables economic activity to continue. Losing the road or pavement surface to ice and snow increases that accident risk and can have huge implications to the overall economy of that area or country.

2. MEASURING THE WEATHER

Many sensors exist in today's winter maintenance environment that will measure the various parameters that make up our climate. However as explained above it is the presence of ice and snow on the road surface that is particularly important in terms of understanding the impact on the road users ability to move from point A to point B.

This study focusses on the sensing technology developed and manufactured by Vaisala called the DSC111 [5]. This sensor uses three separate lasers at slightly differing frequencies to independently assess the layer thickness of Ice, Snow/Frost and Water in its water equivalent where relevant. This is then translated into an index called Grip. This Grip value is intended to give an estimation of the friction reduction associated with those layer thicknesses appearing on the road surface. It is not a friction measurement per se as it does not take into account the inherent level of friction of a dry road. However as that road starts to have layers of weather form on its surface that initial dry friction becomes less important and in fact very quickly the Grip value correlates well with more traditional friction testing methods. When the road is dry the Grip value is stated as a maximum of 0.82 (It should be noted that a maximum Grip value of 1.0 would be unrealistic as if correlated directly to Friction Coefficient (μ) this would indicate perfect grip). A Grip value of 0.1 indicates extremely slippery conditions caused by hard packed ice.

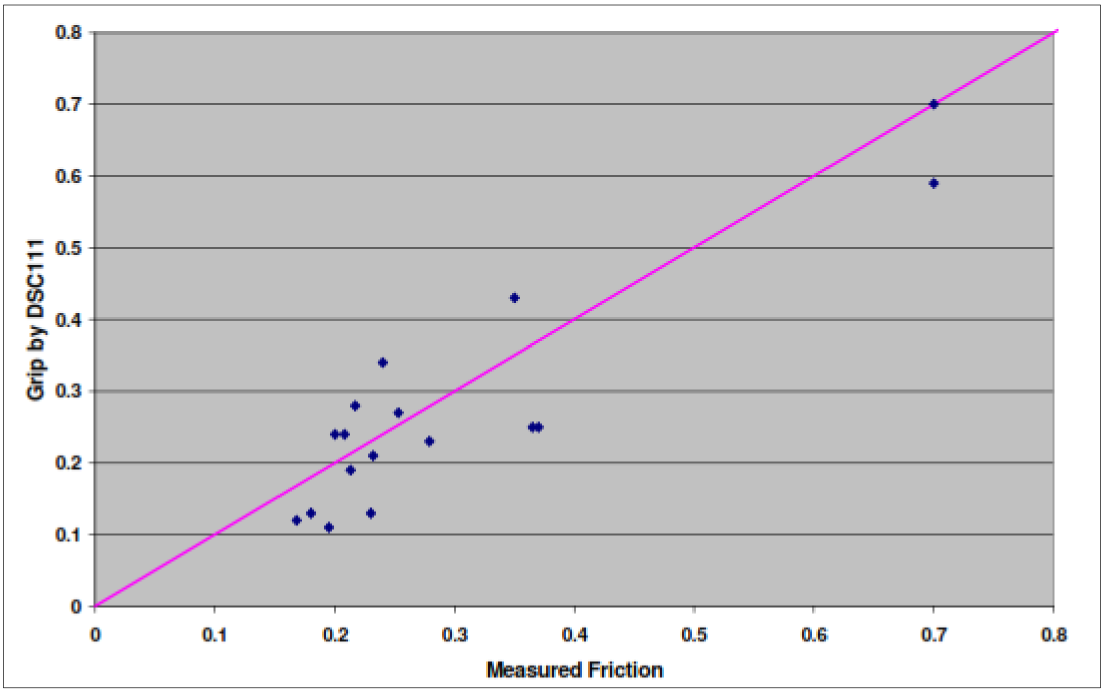

Figure 1 – Correlation between DSC111 Grip value and measured friction

General guidance on how to interpret this Grip value in terms of the effect on the driver comes from the paper written by Idaho Transportation Department (ITD) on the performance index they developed primarily using this sensor [1].

Table 1 – Interpretation of Grip readings from Idaho Transportation Department

Grip Value	Interpretation
> 0.6	Usually dry (or wet) surface
0.5 to 0.6	Slush or ice forming
0.4 to 0.5	Snow pack or icy
0.3 to 0.4	Icy - vehicles may start sliding off
<0.3	Icy - multiple vehicle slide offs possible; mobility greatly affected

The ITD Index goes through several stages to assess the performance of winter maintenance activities giving a score for each event as seen in figure 2.

Storm Performance Index Legend	
0	Successfully treated
0.00 - 0.30	Significantly accelerated grip recovery
0.31 - 0.49	Some success at grip recovery
0.50 - 0.69	Very little success at deicing
0.70 -	Limited maintenance or no deicer success

Figure 2 – Performance levels as described by the Idaho Storm Performance Index

To achieve this scorecard there are four components that are based upon the readings taken from the DSC111, both from the Grip value and the reported layer thickness and also the readings from its sister sensor the DST111 which provides the road surface temperatures for the calculations.

Identification of an event – Roads surface temperatures below zero Celsius with some form of layer thickness present. If left untreated this would mean ice, snow or frost on the road surface would be present.

Ice-Up Time is when the grip is below 0.6 for at least a 30 minute period. This shows that for an event the road was lost to the conditions for a time.

Storm Severity Index = (Maximum wind speed in mph) + (Maximum Water equivalent layer from DSC111 in mm) + 300/(Minimum Road Surface Temperature °F)

Winter Performance Index = Ice-Up Time (hours) / Storm Severity Index

3. ASSESSING DIFFERENT WINTER MAINTENANCE METHODOLOGIES

Studying the data produced automatically within the Vaisala RoadDSS software we can calculate the occurrence of events over a period of a winter by the hour in which it occurs. We then use the Ice-Up Time data to ascertain how well these events were treated. We have then chosen two different locations that have differing winter maintenance practices to assess how these differences manifest themselves in the occurrence of ice/snow on the road surface.

Initially we focus on an area of Eastern France in the Département Conseil Général des Vosges (CG88). Here we have chosen a site in the hilly area to the east of the Département. Operations here cease overnight so give us a good example of what can be expected in terms of ice occurrence under a non- 24 hour regime.

The results below in Figure 3 show data from the site Le Collet on the road RD417 in terms of number of hours throughout the winter period with data points occurring from October to April. These observations are taken from the road side weather station at this location.

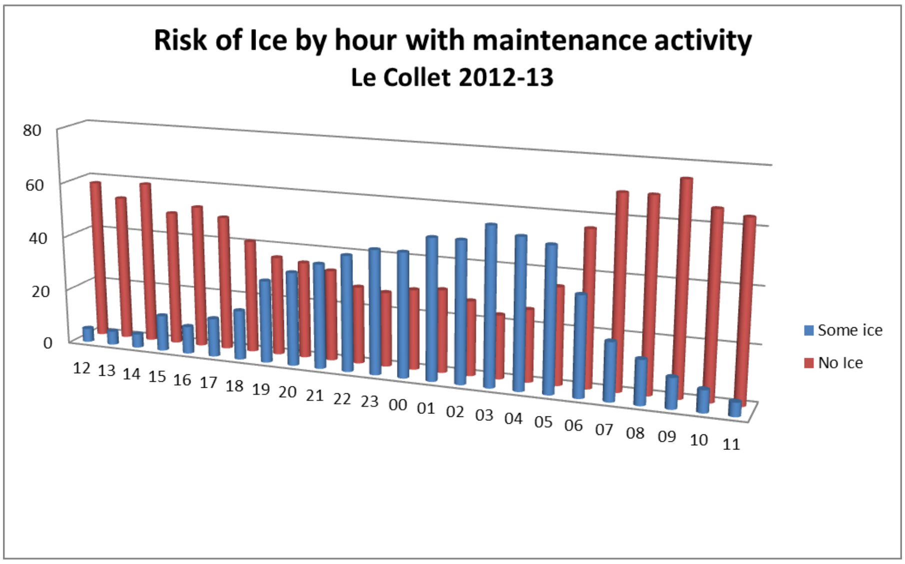

Figure 3 – hours of ice reported versus hours when ice would have been present if not for successful winter maintenance activities

What is striking immediately is that it appears that ice on the road is more than twice as likely in the early hours of the morning than a treated road. What this demonstrates is that evening treatments become ineffective towards 0300-0400 and ice is allowed to form or snow to settle. This paper does not investigate the reasons for this but many possibilities exist including lack of salt activation by low levels of traffic in this region.

Table 2 – Observation results from Le Collet in CG88 for winter 2012-13

Le Collet winter 2012-13	Hours	Percentage of total
Total Event Hours	1832	
Total with Grip < 0.6	807	44%
Total saved hours	1025	56%

A simple summary of the data in Table 2 shows that under this treatment regimen with no overnight treatments taking place the performance still has merit in that over 1000 hours (nearly 43 days) of potential reduced mobility are saved from a total of 1832 hours possible disruption which is just over 76 days. However a significant proportion of the events are in effect missed by this regime. As also shown in Table 2, 807 hours (nearly 34 days) see the road fall into a state where road users will start to see a reduction in their mobility.

Now we look at a site in Scotland. Here we have chosen a main highway where roads are watched 24 hours a day and a proactive treatment regime is in place which makes use of all aspects of winter maintenance from observation stations to forecasting and Decision Support Software. Data for the same year is shown below in Table 3.

Table 3 - Observation results from A702 Boghall in Scotland for winter 2012-13

A702 Boghall winter 2012-13	Hours	Percentage of total
Total Event Hours	301.7	
Total with Grip < 0.6	25.2	8%
Total saved hours	276.5	92%

Looking at this data it is immediately apparent that the percentage of roads lost to ice and snow under this regime is far less than CG88 with only 8% of the total hours seeing a Grip value less than 0.6 as opposed to that for CG88's road of 44%.

4. APPLYING A COST BENEFIT

As stated earlier an earlier PIARC paper [4] attempted to analyse the cost per hour to the economy of Scotland when bad weather strikes across the country. This looked at the effect of transport disruption on Gross Domestic Product (GDP) so was a view on economic cost only. Although the figures demonstrated above only provide a single point view it is worth taking a look at these values in terms of the hourly costs associated to try to understand better the overall cost benefit of the differing types of treatment methodology. This assumes that similar results are likely at other locations which remains untested at this time and suggests further research effort. As a result these values are probably at best showing the order of magnitude.

Table 4 – Estimated GDP values for avoiding disruption

	Point 1 (high)	Point 2 (middling)	Point 3 (low)
Hours Saved by Avoiding 1 Hour Delay	18,000	6,000	3,000
Value of Time Benefit (£) (2010 Market Prices)	140,000	50,000	20,000

From Table 4 above the suggestion is that each hour delay on a main highway cost approximately £140,000 at 2010 values. These values differ from the country wide costs stated at the beginning of this paper as they assume other local roads are open. Hence this can be seen as a loss per route of a highly trafficked road.

Hence if we take the Scottish A702 Boghall figures from 2012-13 winter and apply the differing treatment ratios we get the following cost to the economy values for a single route – Table 5. The assumption is that one hour of Grip below 0.6 gives one hour delay to the drivers. This is by no means clear but given that some events are likely to give longer delays and other less it is a good starting point.

Table 5 – Calculations of estimated savings from differing treatment methodologies

Total hours of weather likely to lead to reduced mobility (winter 2012-13)	302		
Economic cost of 1 hour delay (£)	140,000		
Cost of winter service operations to Scotland (£)	14,000,000		
Assumption 1 hour Grip below 0.6 = 1 hour delay	Estimated economic loss	Estimated saving over do nothing	Cost to benefit ratio
No treatment	42,238,000		
Assuming national daytime only treatement (44%)	18,584,720	23,653,280	
24 hour treatment (8%)	3,379,040	38,858,960	**2.8**

This gives us a ball park figure of a return on investment to the economy of something in the region of 1-3 per strategic, well trafficked route. This figure however does not include the cost of accident and subsequent human cost which makes this a potentially very conservative estimate. Should several routes be affected simultaneously in a widespread event then these numbers will multiply accordingly, but with the same total cost of £14M of winter maintenance activities the cost to benefit ratio will expand significantly. Indeed a widespread event is likely to attract longer delays. Table 6 shows an estimation of total country wide cost benefit given an 8 strategic route allocation but not taking into account any knock-on effect of widespread disruption and can be considered 8 independent events under the terms of the cost allocation. It should be noted that the estimate provided by Johnston et al [4] for the average annual welfare cost to Scotland is approximately £330m per winter.

Table 6 – Application of cost benefit assuming 8 strategic routes with similar characteristics to Boghall data.

Assume 302 hours for 8 strategic routes per annum	2416		
Economic cost of 1 hour delay (£)	140,000		
Cost of winter service operations to Scotland (£)	14,000,000		
Assumption 1 hour Grip below 0.6 = 1 hour delay	Estimated economic loss	Estimated saving over do nothing	Cost to benefit ratio
No treatment	338,240,000		
Assuming national daytime only treatement (44%)	148,825,600	189,414,400	**13.5**
24 hour treatment (8%)	27,059,200	311,180,800	**22.2**

5. CONCLUSION

The value obtained above for the cost to benefit ratio may be considered to be a conservative estimate due to the cost of accident and recovery not being covered, but as can be seen from the clear evidence of ice on the road when operations cease a case for full 24 hour operations, with the latest most accurate sensing, forecasting and visualization support system gives clear value for money in terms of ongoing investment. Quality of systems in all aspects is vital to achieve the best results and obtain the maximum cost to benefit ratio.

Further research and data gathering is needed to refine these numbers to a point where confidence can be attributed to them but now we have a way of measuring performance we have the tools necessary to complete this task in the very near future.

It should also be noted that this data could prove to be very useful in assessing performance of operations in terms of chemical use. Past measurement indices have shown how salt usage can be measured by using weather station data [6]. The link between this and Grip data from the DSC111 seems to lend itself to further investigation in these terms as well.

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