Road Salting – an international benefit/cost review

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In many countries around the world public expenditure on the winter maintenance of roads is under scrutiny as budgets are trimmed and services are privatised. A number of 'value-for-money' studies have been undertaken and the benefits and costs of winter maintenance have been assessed. This paper attempts to review these international benefit/studies and examine their relevance for the United Kingdom. A number of new concepts are interpreted such as the development of an objective way, at the micro level, to determine which roads and what proportion of roads, should be salted in a region. Currently the percentage of roads salted varies considerably across the UK from more than 60% in some local authorities to less than 20% in others. At the macro level a new benefit/cost model is presented which shows a benefit/cost ratio of 8 to 1 for the winter maintenance of roads in the UK.

1. INTRODUCTION

The winter climate of the United Kingdom is different to that of most other countries and therefore the winter maintenance of roads in the UK is unique. Each country has it's own climatic idiosyncrasies that shape the level of service and commitment to winter maintenance. The unique climatic factors in the UK include:

1. Icy roads are most slippery at zero degrees Celsius and this is a common road
   Surface temperature in winter in the UK.
2. Snow is a small problem in most years in much of the UK. Up to 80% of the winter maintenance budget is spent on the pre-salting of roads to prevent the formation of 'black ice'.
3. UK drivers are not used to wintry road conditions and are not allowed to use snow chains, studded tyres or winter tyres as they do in many other countries. Hence there are likely to be more accidents and delays on icy roads in the UK than in other countries.
4. Icy roads in the UK are intermittent and road surface temperatures may fall to zero or below for just a short time. Hence drivers are not always expecting slippery road surface conditions as they are in colder climates. In our marginal climate it is common for some road surface temperatures to be above zero and some to be below zero along the same stretch of road.

These and other factors mean that the winter maintenance of roads is vital in the UK as black ice can catch out drivers without warning. Snow and ice on roads represent a serious threat to human life as well as causing delays to both individuals and industry. The amount of snow or ice encountered in a winter will depend upon the regional climate and will also vary considerably from year to year. Nevertheless snow can cause problems in any part of the UK and highway authorities have to be prepared to deal with it. In other countries snow is the major hazard (eg Canada) and in others there is a more even balance between the snow and ice hazard (eg Sweden).

Table 1 shows the benefits and costs of the use of salt as estimated in a number of studies around the world. Different studies have included different elements of benefits and costs in their calculation and one has to be careful therefore when comparing the results of one study with another.

The Darmstadt Technical University (OECD 1989 p107) carried out a detailed study of the accident rate before and after the salting of roads in Germany. The number of accidents analysed was more than 4,700 on 650km of rural roads with just under 1900 casualties over 4 winters. It was found that the average accident rate on these roads on ice-free days was approximately 1.6 per million vehicle kilometres (MVK). In the four hours prior to salting the accident rate rose to 9.5 per MVK - six times the rate

for ice-free days, falling to 2.6 per MVK in the four hours after salting. In terms of benefits it was shown that the costs of salting the roads were met after 140 vehicles were driven over the de-iced road, or expressed in another way a salt spreader paid for it's costs after half an hour of operation.

The accident rate in the UK for all accidents is about 1.7 per MVK (in 1992 there were 233,025 accidents and 400,000 km driven = 1.72) but there has not been any research on the accident rate in wintry conditions

Edwards (1996) shows that road deaths in the UK account for about 40% of all accidental deaths in the UK. In 1992 there were 4668 road deaths (196 other transport deaths), 4521 accidental deaths in the home and 2307 elsewhere. This total of 11,692 equates to 32 accidental deaths every day. The emergency services (Ambulances, Fire Service, Police and Lifeboats etc.) must save at least as many lives ie more than 30 every day. They rely on getting accident victims to hospital as quickly as possible. Speakman (1994) shows that much of Birmingham is accessible by ambulance within 5 minutes of a call out and that during the severe snow event of December 1990 in Birmingham ambulance response time went up to nearly 60 minutes in places. Not only do ambulances need to get quickly to accident victims but also to victims of heart attacks and strokes and other possible fatal illnesses. In severe weather conditions Ambulance Services are put under severe strain as often there are more call-outs due to more accidents and yet it takes them longer to complete each mission. The Birmingham Ambulance Service normally receives about 600-700 calls per 24 hour period. On the night of December 8/9 1990 they received 900 calls and yet the severe weather led to three ambulance failures and one ambulance was lost from service for the full 24 hours.
Very little research has been conducted in this important area - but it is clear that the salting of roads is vital to maintain access for the emergency services. An attempt to put a value on this benefit is given below.

2. RECENT TRENDS IN WINTER MAINTENANCE IN THE UK AND LEGAL ISSUES

The organisation of winter maintenance in the UK has recently undergone considerable change due to the restructuring of local government, the increasing use of compulsory competitive tendering (CCT) and the use of private contractors. This means that virtually all winter maintenance is contracted out to either private contractors or the local DLO (District Labour Organisation). In theory this should lead to greater efficiencies and savings as CCT ensures that a competitive rate is needed to win the contract. Also it should be possible to compile much more accurate winter maintenance statistics as every turn-out has to be monitored in detail. The comparative cost per km for winter maintenance should be readily available for each road segment. This cost per kilometre will vary from winter to winter according to winter severity but typical values in the UK range from £200/km to £800/km (Cornford and Thornes 1996). Future benefit/cost analyses may well be conducted at road segment level in order to justify the salting of individual roads - as in Northern Ireland.

It is clear that increasingly highway authorities are going to have to decide upon a minimum number of vehicles per day (VPD) for each road in order to justify salting. This will require a set of procedures in order to facilitate the assessment e.g.

1. Divide all roads in region into segments (eg every few km or every junction)
2. Assess number of VPD for each segment from the following traffic bands:
   e.g. >0 >500 >1000 >1500 >2000 >5000
3. Construct new salting routes taking into account emergency services, bus routes, minimum VPD threshold, local climate (eg frost/snow frequencies) and local required levels of service.

Further research is required to determine the optimum level of service for each region but it should be possible to make objective decisions as to which roads should be salted. These decisions can be updated as traffic levels change. The statistic of

Vehicles Per Day is becoming accepted as the simplest indicator of maintenance needs.
There has been a recent increase in the number of court cases involving winter maintenance as the driving public have become more aware of their statutory rights and also because insurance companies want to reduce their payouts. If a driver skids and crashes on an icy road that should have been salted it is now common place to sue the local authority. The law in the UK requiring local authorities to salt roads is vague and indeed varies in the different legal structures of England/Wales, Scotland and Northern Ireland. Generally the local authority has to be shown to have been negligent if the driver is to successfully sue. All local authorities and private contractors have to have liability insurance but this is becoming increasingly expensive and it could be argued that it is increasing the cost of winter maintenance unnecessarily

Pressures on local authority budgets have led to the reduction of salting routes in some areas in an attempt so save money. The decisions to reduce salting routes are rarely made objectively and it appears that levels of service vary considerably across the UK. A recent survey by the County Surveyors Society revealed that the average percentage of routes salted varies considerably from region to region:

Scotland	46%
Northern England	39%
Central England	35%
South East England	29%
Northern Ireland	27%
Wales	26%
South West England	22%

This large variation is surprising and requires further research to investigate the reasons behind the figures. Variations within regions are just as great and motorists are surely unaware that winter driving in some parts of the UK is likely to be more hazardous than in others.

3. THE ECONOMIC AND SAFETY BENEFITS OF ROAD SALTING IN THE UK

It is impossible to present a complete benefit/cost analysis of winter maintenance in the UK as accurate figures are just not available. It is possible to make realistic assumptions that should give a clear indication as to whether or not the benefits outweigh the costs. Thornes (1996) presented a preliminary average benefit/cost ratio of 9 to 1. In the light of further research the figures used have been reworked and the results are presented in Table 1 as Thornes (1999) together with a summary of selected previous research. The Thornes (1996) report was based on 1994 prices and therefore for consistency and ease of comparison the Thornes (1999) figures are also based on 1994 prices.

Table 1 also shows most studies have only considered the benefits of reduced accidents and delays and have ignored the benefits of maintaining emergency services and reducing fuel usage. On the cost side most studies have ignored the environmental costs of salt usage. Each term in the Thornes (1999) benefit/cost ratio will now be briefly considered and justified in turn. For the calculations it has been assumed that in an average winter there are 50 turnouts in the UK, of which 90% are correct (ie 45 out of the 50). Of the 5 incorrect decisions to salt it is assumed that 2: Type 1 errors (didn't salt but should have done) occurred and 3: Type 2 errors (salted unnecessarily) occurred. The costs and benefits are based on comparing the present winter maintenance situation with what would happen if no roads were salted at all.

4. BENEFITS:

4.1. Reduce Traffic Accidents:

The benefit of £675m used in the 1996 study has been adapted due to two factors. Firstly the number of damage only accidents is higher than that assumed before so that the total benefit should be £900m. Secondly this has been reduced by 30% to £630m following the Northern Ireland data (Fraser & Drew1998) that showed that 70% of the accidents reported on icy roads were on roads that would normally have been salted. The original study had to assume that all the accidents occurred on salted roads because of a complete lack of data to assume anything else. The Northern Ireland data is assumed to be a typical sample of the whole of the UK.

4.2 Reduced Traffic Delays
The original figure of £1,500m is retained and is considered to be a conservative estimate. It includes wage losses for lateness to work and absenteeism and production and delivery losses.

4.3 Maintain Emergency Response
This estimate of £235m is based on 5 or 6 lives being saved for 47 nights per winter season on average when the roads needed to be salted. If roads were not salted at all then ambulances, fire engines, police and other emergency services would have difficulty getting through and there would be a reduced response time for heart attacks, strokes, burns, home accidents and work accidents. More research is required to confirm these numbers but they are likely to be conservative estimates.

4.4Fuel Economy
It is estimated that 1 litre of fuel is saved by 25 million vehicles at 65p/l = £16m. The fuel savings are achieved by being able to drive in higher gears on a salted road than on an unsalted road.

5. COSTS:

5.1. Vehicle Corrosion:
The estimate of vehicle corrosion has been increased to £150m which is the equivalent of £6 per annum of corrosion for each of the 25 million vehicles due to salt. It must be remembered that environmental corrosion would rot vehicles without salt. If an exhaust pipe has to be replaced every 5 years this would cost about £10 per annum on average of which a proportion would be due to salt damage..

5.2 Other Environmental Damage
This has been estimated to be small amounting to £10m in total. The salt is spread in a diluted fashion and is stored effectively to avoid spillage. Note that the total environmental costs including vehicle corrosion are estimated to be £160m - more than the cost of winter maintenance. Some have argued in the past that the environmental costs of the salt are several times the costs of spreading it (Table 1) but there is no recent evidence to confirm this. Dobson (1991) gives a comprehensive review of the environmental effects of salt on trees and shrubs but does not attempt to put a cost on the damage.

5.3. Cost of salt spreading
This is assumed to be £140m as before to include all authorities in the UK.

The calculated Benefit/Cost ratio is 8 to 1 as opposed to 9 to 1 in 1996. Further research is required to fine tune these figures further, but it is clear that winter maintenance in the UK is providing excellent value for money. Of the £8 saved for every £1 spent, approximately £2 are saved by reducing accidents, £5 are saved by reducing delay costs and £1 is saved to keep emergency services functional.

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TABLE 1	EPA (1976)	TISA (1976)	TRB (1991)	Hanbali (1994)	Sakshaug et al (1995)	Thornes (1996)	Fraser et al (1998)	Thornes (1999)
	United States	United States	United States	New York, Illionois, Wiscon.	Norway	United Kingdom	N. Ireland	United Kingdom
BENEFITS								
1. Reduce Traffic Accidents	No	Yes	No	Yes	Yes	£675m	Yes	£630m
2. Reduce Traffic Delays	No	Yes	No	Yes	Yes	£1,500m	Yes	£1,500m
3. Emergency Response	No	Yes	No	No	No	No	No	£235m
4. Fuel Economy	No	Yes	No	Yes	No	No	No	£16m
Total		$18,400m				£2,175m		£2,381m
COSTS								
1. Vehicle Corrosion	$2,000m	$643m	$3,500m	No	No	£100m	No	£150m
2. Bridge/Road Corrosion	$500m	$160m	$225m	No	No	No	No	£5m
3. Street Furniture Corrosion	$10m	$2m	$100m	No	No	No	No	£2m
4. Water Contamination	$150m	$10m	$10m	No	No	No	No	£1m
5. Vegetation & Soil Damage	$50m	Zero	n.a.	No	No	No	No	£2m
6. Cost of Salt Spreading	$200m	$200m	£1,500m	Yes	No	£140m	£5m	£140m
Total	$2,910	$1,015m	$5,335m			£240m		£300m
Benefit/Cost Ratio		18 to 1		6.5 to 1 - 2 to 1		9 to 1		8 to 1

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