Department for Transport

Winter Resilience in Transport: an assessment of the case for additional investment

A report by DfT, DECC and Defra
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Foreword

In recent years Britain has experienced some of its most severe winter weather for decades. Plummeting temperatures and heavy snow have caused extensive disruption to transport networks, and brought travel misery to millions. The total cost of delayed journeys to both businesses and individuals was estimated to be around £280m a day in England alone.

Although both rail services and aviation were disrupted in the winter of 2009-10, the biggest problem was inadequate supplies of salt for gritting roads. So my predecessor Philip Hammond created a strategic salt stockpile, and a system to monitor supplies held by local highway authorities. As a result, we were better prepared in November and December last year for the coldest weather since records began a century ago.

But there is no room for complacency and we can do more to prepare. Predicting the impact of freezing weather on our transport infrastructure is still an inexact science, and developing an effective, flexible and affordable response is an ongoing challenge. So earlier this year we commissioned a review by the Chief Economists and Chief Scientists of DfT, DECC and DEFRA to establish if there was a case for greater investment in measures to improve winter resilience.

This report is the culmination of that review - and it shows that while we have the balance of investment broadly right to minimise delays to travellers during cold snaps, there are a number of areas where there is scope to do more.

In particular, we need to increase the resilience of the railway to heavy snow. Disruption late last year was greatest on the network to the south of London where trains draw power from a third rail at ground level. To tackle this challenge, I have authorised funding to introduce third rail heating at over 400 sites where trains require most traction. We are also fitting de-icing equipment to 20 passenger trains – with the potential for further applications in future.

This report also highlights a range of promising new measures to keep roads open and safe during severe winter weather, and to ensure that road authorities are able to meet their objectives in the most efficient and practical way. I have asked the UK Roads Board to explore a range of ideas to make better use of salt, equipment and infrastructure – including recalibrating gritters; training gritter operators; and the sharing of covered storage facilities for salt. We are also proceeding with a trial this winter of the temporary use of snow ploughs attached to certain types of heavy duty vehicles to help clear the network.

These are just a few of the ideas and technologies we are considering to boost the resilience of the transport system. But as this document also makes clear, new technologies can help warn us earlier and more accurately about weather patterns as they develop. In the longer term, the Met Office believes that investment in supercomputing capacity will provide improved information on the likelihood and impact of severe weather – from snow and heatwaves to gales and flooding – and help us plan our response more effectively. I have asked DfT scientists to work with colleagues across government to assess the business case for such investment, and to examine funding options.

There is a growing consensus that our climate is changing, and that we need to prepare ourselves for more extreme weather conditions in this country. Only by having a serious debate today about making our transport system more resilient - and our weather forecasting more accurate - will we be able to minimise the cost and impact of colder winters in future.

This report makes a highly valuable contribution to that debate.

The Rt Hon Justine Greening MP
Secretary of State for Transport

Executive summary

DfT estimates that the welfare cost of domestic transport disruption from severe winter weather is around £280m per day in England. The direct economic costs alone amount to £130m per day. Extreme winter weather can also generate disruption to the environment, rural economy and energy sectors, although in most cases such problems can be traced back to transport difficulties, for example when road closures hinder the delivery of food and fuel to isolated areas.

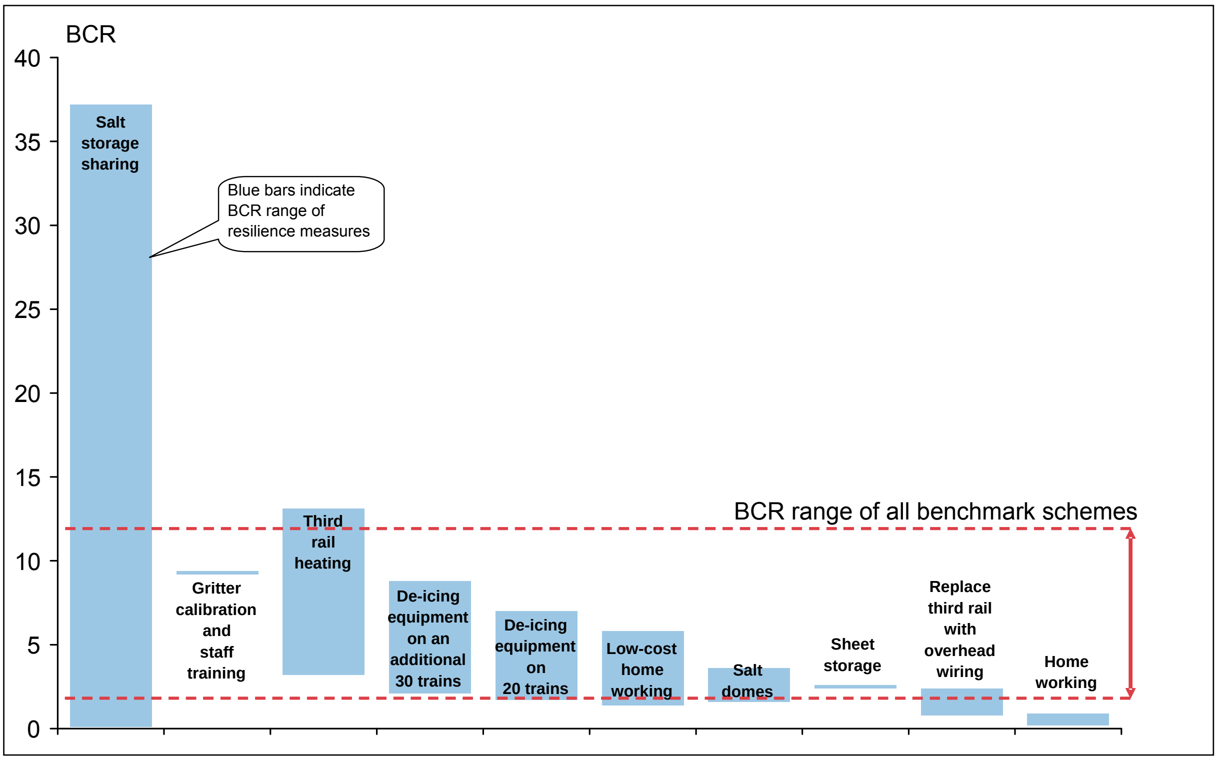
This paper assesses whether there is a case for greater investment in resilience measures to reduce the costs of transport disruption from severe winter weather. The benefits of such investment depend on the frequency and severity of future weather patterns, yet current forecasting techniques are unable to predict these accurately. This paper identifies three weather scenarios, based on data for the last 50 years, as the basis for a new methodology to appraise the costs and benefits of potential resilience measures. The methodology is applied to a range of potential resilience measures identified by DfT policy areas. Some of these proposals have been developed in response to previous work, most notably the 2010 Quarmby Review.

In many areas of the country there may be potential to increase resilience through increased cooperation and coordination, and the smarter use of existing assets. Such options could be explored before investing in new physical infrastructure. In particular, there may be a strong case for local authorities to invest in gritter calibration and operator training to realise the cost savings identified in the new Winter Service Guidance. There may also be a case for improving salt storage facilities to reduce wastage from uncovered salt, though sharing existing storage facilities potentially offers better value for money than constructing new stores or plastic sheeting. The analysis has been carried out at the national level; the case for investment will be stronger where severe weather occurs more frequently. There is a case for more research into alternative road treatments to reduce salting costs and ensure roads remain safe at extremely low temperatures. Responsibility for management of and investment in local road networks lies with local authorities. The Government hopes that the evidence on costs and benefits of alternative resilience interventions will aid local authorities in their decision-making.

The report finds strong support for third rail heating. The case for fitting de-icing equipment to trains on the third rail network is slightly weaker, although fitting the equipment to further trains would offer similar value for money as major rail schemes, as would the longer-term proposal to replace the third rail network with overhead wiring. Winter disruption can represent a good reason for employers to roll out remote working capabilities, particularly where they can be targeted at the most productive workers, and in parts of the country most prone to disruption. Airport operators have already responded to recent disruption with additional investment, and the new regulatory framework should further improve accountability and ensure better treatment for passengers during disruption.

The Met Office has requested funding to increase its supercomputing capability. This could increase its ability to model the future probabilities of extreme weather, enabling more informed decisions on resilience investments. Chief Scientific Advisors in interested departments should work together to formally assess the business case for this investment and identify funding options.

Comparing the Benefit-Cost-Ratio (BCR) ranges of resilience investments with the BCR range for benchmark schemes suggests there may be a strong case for investment in certain measures



The benchmarks in this analysis consist of local authority major schemes approved in the 2010 Spending Review, and major rail schemes.

1. This report draws on expertise from across Government to review whether current levels of investment in the resilience of transport to winter weather are optimised

1.1.1. Snow and ice caused widespread and prolonged transport disruption in many parts of the UK during November and December 2010. This followed similar events in February 2009 and January 2010.

1.1.2. In response, the previous Secretary of State for Transport agreed with the Secretary of State for Energy and Climate Change and the Secretary of State for Environment, Food and Rural Affairs that the Chief Economists and Scientists of their respective departments should review the evidence on winter weather patterns, and test whether current levels of investment in winter resilience are optimised.

1.1.3. The Cabinet Office subsequently agreed to chair a new inter-departmental 'Infrastructure Resilience and Economic Appraisal Committee' (IREAC) comprising senior economists, scientists and resilience experts from the Cabinet Office, DfT, DECC, DEFRA and the Government Office for Science.

1.1.4. The significant uncertainty around future weather trends means that assessing the case for additional investment in winter resilience is challenging. Nonetheless, DfT has developed a new methodology to address this challenge, having consulted with IREAC members at the inaugural meeting on 17 May 2011, and in separate bilateral discussions.

1.1.5. The purpose of this paper is to set out the methodology, before applying it to provide an indicative assessment of potential winter resilience measures. It is structured as follows:

- Section 2 summarises the costs of disruption from extreme winter weather across the transport, rural economy and energy supply sectors.
- Section 3 presents an overview of the evidence on future winter weather, drawing on work commissioned by the previous Secretary of State for Transport from the Government Chief Scientist.
- Section 4 describes the methodology developed by DfT, with input from the IREAC, to appraise the value for money of potential resilience investments.
- Sections 5 to 8 apply the technique to assess the value for money of potential resilience investments proposed by DfT policy areas, many of which respond to previous work in this area, notably the Quarmby Winter Resilience Review[1] and the 2011 House of Commons Transport Committee inquiry[2].

[1] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/

[2] Keeping the UK moving: The impact on transport of the winter weather in December 2010, report published May 2011, available at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/794/79402.htm

- Section 9 draws together the findings to make recommendations of where there may be a strong case for further resilience measures.

1.1.6. This paper focuses on transport disruption caused by snow and/or very low temperatures. It is envisaged that the appraisal model proposed could be applied to other sectors and risks.

2. Disruption from severe winter weather can impose significant costs on individuals and the country as a whole

2.1. The Office for National Statistics estimates that disruption from cold weather in late 2010 reduced quarterly GDP by 0.5 per cent

2.1.1. The Office for National Statistics (ONS) estimates that GDP decreased by 0.5 per cent in the fourth quarter of 2010, and that most of this decline was due to weather disruption[3].

2.1.2. During a period of severe weather, some activity may be delayed until future periods. This means that some of the initial loss from disruption may subsequently be made up.

2.1.3. Within the overall picture there will be winners and losers. The greatest losses may be felt by firms reliant on turnover, such as restaurants, where activity is discretionary and lost revenue may not be made up. Firms providing goods and services related to cold weather might gain, for example energy providers.

2.2. DfT estimates the welfare cost of transport disruption from severe winter weather to be around £280m per day in England

2.2.1. Building on a model used in the Winter Resilience Review[4] (WRR), DfT estimates the average daily cost of transport disruption caused by severe weather is £280m in England (in 2010 prices). In addition to 'hard' costs to the economy (e.g. lost output), this includes 'welfare' costs to individuals which do not directly impact GDP (e.g. delays to personal travel).

2.2.2. Estimating the impact of snow disruption requires myriad assumptions about the impact of disruption and how individuals respond. In many cases, hard evidence is unavailable so model parameters rely on analysts' judgement. To reflect the uncertainty, the model provides a range of estimates to demonstrate the impact of alternative assumptions. The central £280m daily welfare cost estimate could plausibly range between £100m and £520m. To put these figures in context, the welfare cost of road congestion on a 'normal' day is around £60m[5].

2.3. The direct economic costs alone amount to £130m per day

2.3.1. A subset of the welfare costs above indicates the direct impact of disruption on GDP. DfT estimates this to be £130m per day in England, within a range of £40m to £260m.

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[3] ONS Quarterly national accounts, 4th quarter 2010, published 29 March 2011, available at: http://www.ons.gov.uk/ons/rel/naa2/quarterly-national-accounts/q4-2010/quarterly-national-accounts.pdf

[4] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/

[5] Estimate produced using the DfT National Transport Model

2.3.2. The GDP cost of eight days' serious disruption[6] in the central scenario is £1.0bn, or 0.3 per cent of quarterly GDP. This is slightly less than the ONS estimate that weather caused a 0.5 per cent contraction in fourth quarter GDP. There are two main differences between these estimates:

- the DfT figure estimates the impact of transport disruption only, and assumes a proportion of the workforce is unable to reach its workplace or work effectively from home. The overall impact on GDP may be greater if those workers able to reach work are unable to carry out their duties to the usual extent, for example due to safety concerns or frozen equipment; and

- the DfT estimate assumes 50% of the output lost is made up in later periods, and so would be included in GDP data for subsequent quarters.

2.3.3. International travel and trade are not included in the model and estimates above. International impacts are even more difficult to quantify than domestic impacts. Short periods of disruption to international travel and trade are not likely to have a significant impact on national GDP, although can have large effects on individual operators and travellers.

2.3.4. Further details of DfT's assessment of the costs of transport disruption during severe winter weather are set out at Annex A.

2.4. Extreme winter weather also causes disruption to the rural economy, agriculture and environment sectors, although most problems can be traced back to transport difficulties

2.4.1. The greatest risk to the rural economy from severe winter weather is that of roads remaining impassable for long periods of time, preventing isolated residents from obtaining food and fuel, and farmers from reaching livestock. This has not been a significant problem during recent winters, but should be taken into account when considering transport resilience.

2.4.2. DEFRA reports that the past few instances of extreme winter weather had very little impact on agriculture. Some livestock and crops were lost, but this could be covered by insurance. In any case, such impacts are very difficult to mitigate.

2.4.3. Greater costs could arise if thawing snow led to flooding. The snow in winter 2010-11 caused a few localised floods, but harms were small and were not formally estimated. Burst water pipes led to larger problems in Northern Ireland, but this was largely a result of outdated infrastructure and plans are already in train to renew pipes to avoid a repeat.

2.5. The energy sector coped well with the cold spell in late 2010, although blocked roads created challenges for those undertaking repairs or delivering heating oil

[6] For the disruption cost analysis, DfT defined "serious disruption" as a day when at least ten per cent of trains were cancelled.

2.5.1. There was a healthy amount of spare electricity generating capacity during winter 2010-11[7]. National Grid came close to issuing a 'Notice of Insufficient Margin' immediately after the New Year break, but this was not weather-related.

2.5.2. There were no reports of a significant increase in faults on the electricity network during the severe weather in December 2010. However, problems on the local transport network made it more challenging to respond to incidents, particularly in remote areas.

2.5.3. There were significant challenges to meet the high demand for heating oil in late 2010. This was mainly the result of snow and ice on roads in rural areas. DECC estimates that up to 2,000 households may have run short of fuel in the lead up to Christmas, but there were few reports of homes being without heating over the Christmas period[8]. Many homes that use heating oil are able to switch to alternative forms of heating, either electric or solid fuel.

2.5.4. The extension to drivers' hours helped the industry respond to the difficulties by enabling distributors to meet the increased demand that resulted from the cold weather[9]. The extension also enabled distributors to clear the backlog that had accumulated when snow had made roads impassable in some areas.

2.5.5. There were some reports of localised and temporary shortages of road fuel, notably in areas of Scotland where heavy snow made roads impassable. However, this situation is normally offset by a fall in demand for fuel as motorists choose not to drive.

2.5.6. While it is difficult to calculate the costs to those affected by disruption to energy supplies, they are not believed to be significant at the national level. The information in this section does, however, highlight the importance of ensuring local road networks remain open, including the approach roads to infrastructure installations such as oil terminals and refineries.

[7] On the day of peak demand there was approximately 3GW of surplus available capacity. Further details are provided in the National Grid Winter Consultation Report 2011/12, available at: http://www.nationalgrid.com/NR/rdonlyres/C3A81245-D988-48A4-80F2-5082F601E06D/48771/WinterConsultation2011PUBLISHV2.pdf

[8] In any year there are normally a few customers who place orders too late to receive deliveries for Christmas.

[9] This included winter service drivers who could work longer hours to deliver more salt treatments on the road.

3. Three weather scenarios have been identified to reflect that the frequency of severe winters occurring in future is highly uncertain

3.1. Current forecasting techniques are unable to provide accurate estimates of the probability of severe winters over the next few decades

3.1.1. In December 2010 the previous Secretary of State for Transport sought advice from the Government Chief Scientist on the probability of severe winter weather occurring during the next 20 to 30 years.

3.1.2. The Met Office was commissioned to analyse this issue. Their report concluded that it is not possible to quantify with any certainty the number of severe winters we might expect over the next few decades[10].

3.1.3. There is no evidence that events in recent winters are linked to longer term climate change patterns. The Met Office noted that prolonged snowfall and low temperatures, comparable with the conditions experienced in late 2010, were within the range of natural climate variability observed over the past 50 years.

3.1.4. Long-term predictions are for winters to be warmer on average, due to the warming climate. Severe winter weather remains possible, but with a reduced likelihood. However, natural year-to-year variability is expected to dominate the warming trend for at least the next decade or two. Against this backdrop, current forecasting techniques are unable to provide accurate estimates of the probability of severe winters over the next few decades.

3.2. The cost benefit analysis in this report will be based on three weather scenarios to reflect the uncertainty around the average number of days disruption that may occur in future years

3.2.1. The benefits of resilience measures to a large extent depend on the frequency and severity of extreme winter weather. A snow plough is only useful if it snows; salt is only useful if ice is forecast, and so on. However, as described above, there is considerable uncertainty about the outlook for extreme winter weather. To reflect this uncertainty, this report proposes to assess potential investments against alternative winter weather scenarios.

3.2.2. Sections 5 to 8 of the report identify investment options for implementation during the next few years. Seven of the ten measures identified for quantitative analysis have assumed lifetimes of 15 years or less. For these measures it is appropriate to base appraisal on weather scenarios derived from current weather patterns because, as noted above, natural year-to-year weather variability is expected to dominate longer term climate change trends for at least the next decade or two. Three of the measures identified for quantitative analysis have longer assumed lifetimes. Detailed analysis of such options would normally be based on weather scenarios which incorporate

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[10] Briefing on the likelihood of severe winter weather over the next 20-30 years, prepared by the Met Office Chief Scientist (December 2010), available at: http://www.dft.gov.uk/pgr/resilience/briefing/pdf/report.pdf

climate change assumptions. However, for the purposes of this paper it was decided to base all of the appraisal calculations on a single set of weather scenarios derived from current weather patterns. This decision was taken to ensure a proportionate approach to deriving the high-level conclusions sought by this work, and to provide a consistent basis for appraising the measures identified.

3.2.3. Three weather scenarios have been identified. Each scenario makes a different assumption about the average number of disrupted days each year, when snow and/or very low temperatures could impact negatively on infrastructure networks across the country.

3.2.4. In the base case scenario, each part of the country is assumed to suffer an average of five disrupted days each year, based on the average number of days with lying snow since 1961[11].

3.2.5. Whilst the average number of disrupted days represents a useful starting point, it is important to recognise that in any given year there may be significant variation around this average. For this reason, the average number of disrupted days across a different 50-year period may not be the same as the average for 1961 to 2010. To reflect this, mild and severe scenarios have been calculated using a 95 per cent confidence interval around the average figure. This yields a mild scenario in which each part of the country suffers an average of two disrupted days each year and a severe scenario in which each part of the country suffers an average of nine disrupted days per year. That is, over a 50-year period we are 95 per cent confident that the average number of snow days per year will lie within the range two to nine.

3.2.6. The average annual number of disrupted days in the severe scenario is broadly equivalent to the severe winter weather event used in contingency planning in the National Risk Assessment (NRA).

3.2.7. Calculations underpinning the weather scenarios are set out in Annex B.

[11] Using Met Office data for England between 1961 and 2010 and adjusted using the methodology set out in Annex B.

4. A new methodology has been developed to appraise the costs and benefits of potential resilience measures under alternative weather scenarios

4.1. Potential transport resilience measures have been identified through consultation with policy experts and a review of previous studies

4.1.1. The greatest disruption during recent periods of extreme winter weather has occurred on transport infrastructure. As described above, cold weather disruption to other infrastructure can often be traced back to transport problems. This paper therefore focuses on measures to increase the resilience of the transport network.

4.1.2. To assess the economic case for greater investment in winter resilience this report estimates benefit cost ratios (BCRs) to test whether the returns from each pound spent on additional resilience measures would be greater than those obtained from other planned investments. This comparative approach recognises that any additional investment would have to be funded through a reallocation from elsewhere.

4.1.3. Potential resilience measures have been identified through consultation with DfT policy experts, and by reviewing previous work, such as the Quarmby Winter Resilience Review[12] and the report from the 2011 House of Commons Transport Committee inquiry[13]. The measures identified fall into one of three categories:

- measures for which specific proposals are available and indicative cost benefit analysis is possible to assess the economic case for investment;
- process or other enhancements to improve the resilience of existing infrastructure. These do not require additional investment beyond the cost of staff time; and
- measures which appear promising but require further research and testing before it is possible to make a meaningful assessment of costs and benefits.

4.1.4. The remainder of this section describes the methodology developed to undertake the cost benefit analysis of resilience measures. This methodology has been developed by DfT economists, drawing on the expertise of the other members of the Infrastructure Resilience and Economic Appraisal Committee.

[12] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/

[13] Keeping the UK moving: The impact on transport of the winter weather in December 2010, House of Commons Transport Committee (May 2011), available at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/794/79402.htm

4.2. A new framework has been developed to assess the economic case for additional investment in resilience measures under alternative weather scenarios

4.2.1. Appraising the value for money of winter resilience measures is challenging because:

- the future frequency of severe winters (and therefore the benefits of resilience measures) is uncertain;
- some of the measures are novel or innovative. Even with perfect information about future winter weather there would be limited evidence of their benefits; and
- in some cases, there is uncertainty about the costs of implementing a measure.

4.2.2. For these reasons the analysis presents a range of plausible benefit cost ratios (BCRs) for each option to provide a broad indication of value for money, whilst reflecting the uncertainty. The BCR range incorporates the alternative weather scenarios described in section 3.2, and other uncertainties around costs and benefits.

4.2.3. Some of the measures identified have previously been appraised using standard transport appraisal techniques. Where this is the case, the analysis builds upon and adjusts the existing evidence to generate new BCR ranges to reflect the alternative weather scenarios.

4.2.4. For schemes with a lifespan of more than 20 years, DEFRA Climate Resilience guidance suggests an adjustment to reflect that long-term benefits may differ from short-term benefits due to climate change[14]. The Met Office has advised it is not currently possible to predict changes in the frequency of severe winters with sufficient accuracy to make any meaningful quantitative adjustment of this type.

4.2.5. Additional expenditure on resilience would have to be funded through a reallocation from other areas. It is therefore proposed that the BCR range for each resilience measure is compared against BCRs for other planned investments to assess whether there is a case for such a reallocation (Figure 4.1, below). The appropriate pool of benchmark investments will depend on the resilience measure being assessed, and where money would need to be reallocated from to fund it.

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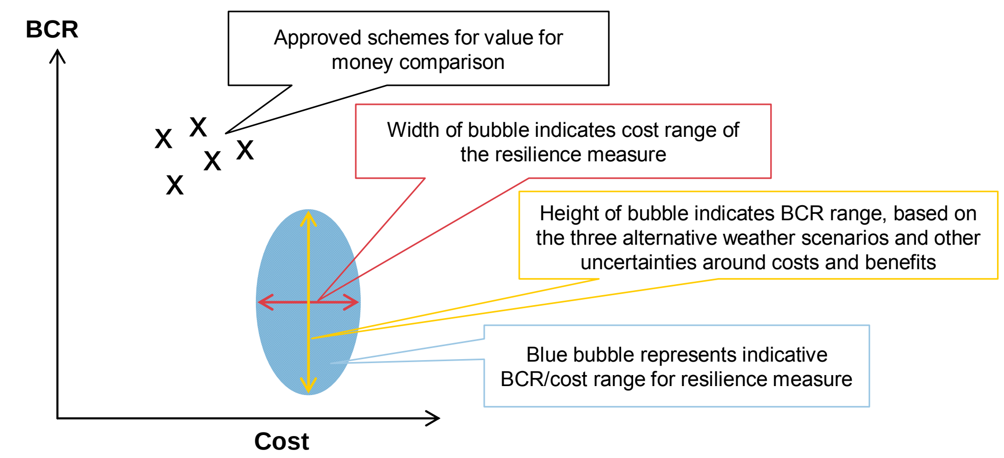
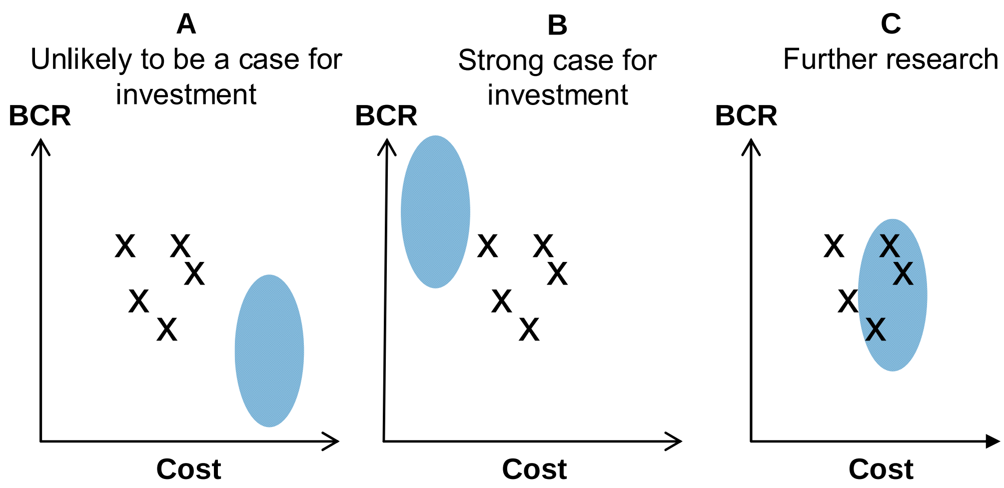
[14] DEFRA draft Green Book Supplementary Guidance on climate resilience

Figure 4.1: appraisal framework for potential resilience measures



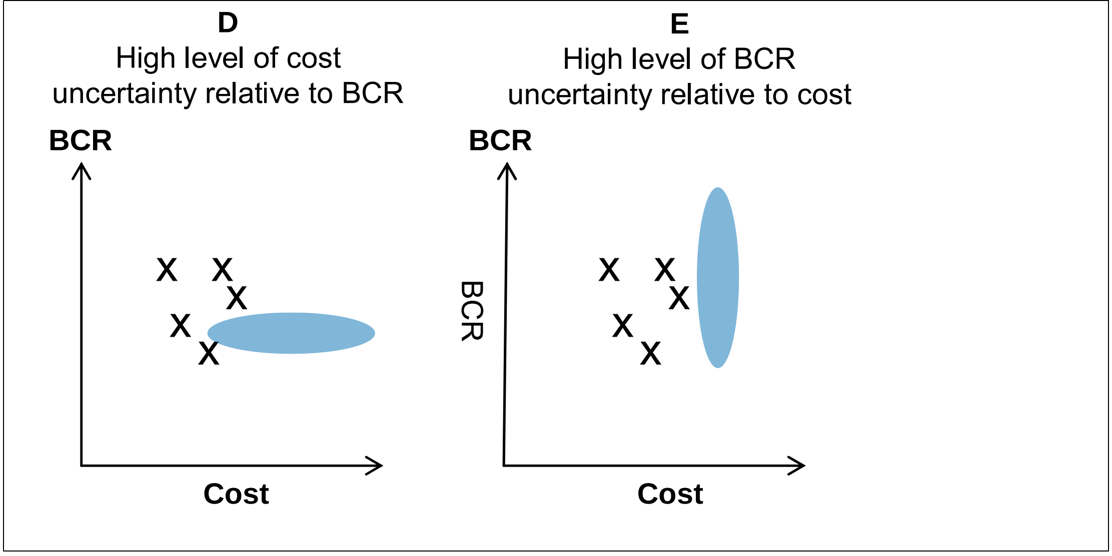
4.2.6. This high-level framework enables potential schemes to be allocated to one of three groups (see Figure 4.2, below). In example A, the resilience measure is unlikely to offer a case for investment because it offers worse value for money and is more costly than comparator schemes. In B, there is likely to be a strong business case for diverting expenditure to fund the resilience measure because it is cheaper and offers better value for money than comparator schemes. In C, it is not possible to draw a clear conclusion about value for money, so it may be desirable to undertake further work to refine evidence on costs and benefits.

Figure 4.2: interpreting the appraisal of potential resilience measures



4.2.7. The shape of the blue bubbles varies depending on the levels of uncertainty about the cost and/or BCR of each measure (see Figure 4.3, below). In example D, there is a relatively high level of uncertainty around cost, but value for money is reasonably certain. There may be a case for investment if costs can be kept low. In example E, the cost of the measure is relatively certain, but there is a large BCR range. There may be a case for investment if it is possible to ensure the measure delivers a BCR towards the top of the range.

Figure 4.3: representation of uncertainty in the appraisal framework



4.2.8. In the model above there would be a case for investment in resilience measures that perform well under all plausible weather scenarios. In some cases, it may be possible to design measures flexibly so they can be scaled to match different weather scenarios, improving cost effectiveness. For example, it may be possible to invest in a simple solution that is sufficient to cope in the mild weather scenario, but which could be upgraded at a later date if the severe scenario came to pass.

4.2.9. The case for investment may be strengthened if a proposed measure has wider benefits. For example, a measure that has winter resilience benefits might also increase resilience to flooding. The analysis in this paper focuses on winter resilience benefits, but the commentary notes where a measure is likely to increase resilience to other types of disturbance.

5. There are a number of options for local authorities to reduce salt usage and wastage

5.1. This section assesses the value for money of four measures that local authorities may wish to consider

5.1.1. The table below summarises BCRs for potential resilience measures that could be implemented by local authorities, including those in London. The ranges shown reflect uncertainties about the weather, costs and benefits.

5.1.2. The availability of evidence on costs and benefits varies considerably across the different options. The BCRs calculated indicate the likely order of magnitude of benefits relative to costs, but often within a wide range. It is envisaged that local authorities wishing to implement any of these measures would develop their own business case, including a detailed assessment of costs and benefits tailored to their individual area and circumstances.

Table 5.1: Summary of measures and BCRs for local authorities

Measure	BCR range
Building domes to cover all remaining uncovered salt storage capacity	1.6 to 3.6
Using sheet storage systems to cover all remaining uncovered salt storage	2.5 (no range available)
Gritter recalibration and staff training	9.3 (no range available)
Regional groups sharing salt storage facilities	0.1 to 37.2

5.2. There is a need to do more to reduce the amount of salt lost through inadequate storage

5.2.1. The Quarmby Winter Resilience Review highlighted that financial losses from uncovered salt could be reduced[15]. Wet weather washes away uncovered salt in storage and salt that is not washed away tends to be spread at greater rates (known as 'overspreading') because exposure to wet weather degrades its quality. As a result, between 24 per cent and 50 per cent of uncovered salt is lost each year[16]. Despite this, around 20 per cent of salt storage capacity in England remains uncovered[17]. If this uncovered storage capacity were fully utilised, 58,000 tonnes of rock salt would be wasted each year. Covered salt storage also reduces purchasing costs, since salt can be purchased during the summer when the price is lowest.

[15] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/
[16] Based on business case information provided by Dome UK
[17] Halcrow Highway De-icing Salt Restock Report (October 2010)

5.2.2. DfT, the Highways Agency and local authorities have worked in recent years to reduce the proportion of uncovered storage facilities, but further investment is needed to cover all remaining facilities, either by constructing salt domes or using protective sheeting. Both methods prevent leaching and the need for overspreading. Some local authorities use other methods for storing salt, such as renting agricultural barns, although arrangements are made on an ad-hoc basis and no evidence is available on the financial and non-financial costs of such approaches. Covering all remaining facilities could be met through existing local authority and Highways Agency budgets, but this would likely take a number of years. Highways authorities may therefore wish to consider whether there is a case for reallocating funding to accelerate this process.

5.2.3. **Building domes to cover all remaining uncovered salt storage capacity** would require 24 domes, each with a 10,000 tonne capacity. Each dome would last 40 years. Information on the cost of a dome is not widely available, but this analysis is based on a per-dome cost of £450,000 to £1,031,000, which reflects the range of cost estimates provided by a small number of dome providers and local highway authorities who have purchased a dome recently. Benefits from such an investment would include the ability to purchase salt outside of winter when prices are low and then store it without loss. This can generate substantial cost savings since winter prices can be up to three times those at other times of year. This option also provides protection against the uncertainties of future weather since salt can be stored for the lifetime of a dome without loss.
BCR range: 1.6 to 3.6 (central estimate of 2.1)
(Costs and benefits do not vary by weather scenario[18], but uncertainty about costs enables the calculation of a range.)

5.2.4. **Using sheet storage systems to cover all remaining uncovered salt storage** would generate the same benefits as domes. However, flexible sheeting needs more regular maintenance and attention, including removing the sheets when salt is needed. Sheet storage costs around £30,000 per 10,000 tonnes of coverage per year. However, the industry questions whether sheeting is a viable long-term solution. Drawbacks include health and safety concerns (operatives can suffer serious falls when managing the sheets); greater land area is required than for domes since the covers limit the height of piles; and significant failures have been suffered in the US.
BCR: 2.5
(Costs and benefits do not vary by weather scenario[19], and so no range calculated.)

[18] Construction is assumed to take place outside of the winter months, and so the costs of this option do not vary by weather scenario. Benefits are measured as the cost saving from not having to replace wasted salt. The amount of salt wasted is primarily driven by the amount of rain over the course of an entire year, not the number of days with snow disruption during winter. Benefits of the investment are therefore also assumed to be invariant to the three winter weather scenarios used in this analysis.
[19] For the same reasons as above.

5.3. Some local authorities could achieve further savings by making better use of existing equipment and infrastructure

5.3.1. In response to recommendation eight in the Quarmby Winter Resilience Review, the UK Roads Liaison Group has produced **new Winter Service Guidance for Local Authority Practitioners**[20] to recommend the use of lower salt spreading rates to reduce costs and demands on the salt supply chain. Whilst some local authorities have already implemented the new guidance[21], to do so across the whole country requires additional annual expenditure on gritter recalibration and staff training. A further option would be for the highways sector to more actively promote best practice at regional events. The cost of gritter recalibration and staff training is assumed to be around £230,000[22] and to last for 10 years. It is assumed that additional dissemination by the highways sector can be provided within existing budgets, by redrafting guidance and giving calibration issues greater prominence. The benefits of these activities accrue in the form of reduced salt usage for precautionary gritting, leaving more salt available for when the most severe weather occurs.

BCR: 9.3

(No range calculated as costs and benefits do not vary with weather scenario.)

5.3.2. Many local authorities do not possess sufficient salt storage facilities to meet their own needs, forcing them to purchase salt from the strategic reserve or import salt at times of high need. If **regional groups of local authorities put in place plans to share salt storage facilities**, cost savings in excess of £5m could be achieved over a ten-year period. These savings arise because salt could be purchased at lower cost in advance of winter[23]. The calculations take into account that the greater availability of salt would result in greater consumption. The main cost would be the staff time needed to agree coordinated plans and the costs of this are uncertain. It is envisaged that most of the necessary work could be delivered by existing staff and within existing local authority budgets. Nonetheless, to be conservative, an illustrative BCR range has been calculated on the basis that it would require an additional £1,000 to £5,000 for each of the 153 local highway authorities for which we have data.

BCR: 0.1 to 37.2 (central estimate 1.3)

5.3.3. The central estimate in this calculation is extremely conservative, assuming that the measure would require an additional £3,000 of costs for each local authority. If this could be reduced to £1,000, the central BCR estimate would rise to 4.0. The BCR estimates are also sensitive to the weather scenario. In the base case and mild scenarios the BCRs do not suggest a case for investment because most local authorities would hold sufficient salt stocks for

[20] This provides consolidated guidance from the UK Roads Liaison Group and the UK Roads Board on winter best practice as part of the Well Maintained Highways. Available at: http://www.ukroadsliaisongroup.org/en/guidance/index.cfm (November 2011)
[21] Halcrow Highway De-icing Salt Restock Report (June 2011) indicates 20 per cent of practitioners have fully implemented the guidance and a further 40 per cent have partially implemented it.
[22] Based on figures from the Transport Research Laboratory
[23] Based on the assumption that local authorities tend to focus on their own salt stocks and needs.

their own use and the need to share between local authorities would be limited. However, in the severe weather scenario there would be a significant need for salt sharing and potential cost savings increase significantly, leading to extremely high BCRs.

5.3.4. If the need for strategic stockpiles could be reduced or eliminated through this kind of coordination, there may be additional reductions in storage costs. Better coordination between local authorities could also generate unquantified benefits, such as reducing the duplication of road treatment where two local authorities' networks join and avoiding sections being left untreated at complex intersections.

5.4. There are a number of promising areas for further investigation

5.4.1. Though salt is effective in many circumstances, it does have drawbacks: dry salt can be blown off a road; in snow it needs to be driven over before becoming active (which can be problematic on quiet roads); and it becomes less effective at extremely low temperatures (below -8ºC). To address such drawbacks, a number of alternatives to salt are being examined by industry and highway authorities.

5.4.2. The Highways Agency and some local authorities have started using **pre-wet treatment**, which involves slightly wetting the rock salt with a concentrated brine at the point of application. The treatment is more effective than dry salting and because spreading is more accurate, the amount of salt used can be reduced by more than 20 per cent[24], cutting costs and benefiting the environment.

5.4.3. The main obstacle to greater use of pre-wet treatments by local authorities is the large up-front capital investment required[25] to purchase new spreading lorries and set up saturators (to produce brine). To address this, there may be a role for DfT to work with the UK Roads Board[26] to explore whether it would be feasible and cost effective for the highways sector to set up an advisory service to help local authorities identify whether they could realise savings through investment in the equipment needed for pre-wet treatments, and advise on funding options where such investments are viable.

5.4.4. The industry is also exploring **salt additives**, which involve coating rock salt in different chemicals to increase effectiveness in certain situations. This solution does not require the purchase of new spreaders or saturators. Coated rock salt is more expensive than standard salt, but this is generally offset by lower spread rates.

5.4.5. Laboratory tests undertaken previously by the National Winter Service Research Group (NWSRG) suggest there may be a good case for the greater

[24] The minimum spread rate for a modern pre-wet spreader is equivalent to 6.15g/m^2 of salt. This is 23 per cent lower than the minimum spread rate for dry salt.
[25] The Highways Agency made changes as part of a fleet renewal process, when the existing fleet had reached the end of its economic life. Analysis in the business case confirmed that cost savings from spreading less salt more than offset the additional investment.
[26] The UK Roads Board includes representatives from central and local government, the Transport Research Laboratory and the National Winter Service Research Group.

use of such coating substances, and there is anecdotal evidence of a correlation between local authorities who have performed well during recent cold spells and those using salt additives. Nonetheless, there is a need for a full evaluation in real-world circumstances to test whether manufacturers' claims can be substantiated[27]. Initial estimates suggest a cost in the region of £100,000, although this could be reduced by around one quarter if manufacturers could be persuaded to donate their coated salt products for use in the trials. We understand that a number of companies liaise closely with NWSRG and participate in research activities that are undertaken. We would suggest that it might be helpful if these companies could assist in any future research in this area to help reduce costs.

5.4.6. It is not yet clear where the trial would take place, but if it were successful, the £100,000 cost could be recovered in approximately half of one winter's precautionary gritting for London (this calculation is purely illustrative and London has been selected because it has provided high quality data on typical gritting rates). But given that such salt savings might be available from the use of coated salt, it could be worth exploring whether the cost of research and trials could be offset against future savings in salt costs.

5.4.7. Whilst pre-wet treatments and coated rock salt enable cost reductions, there is also a need to develop the evidence base on **road treatments that remain effective at extremely low temperatures** (below -8ºC), when standard rock salt becomes less effective. The NWSRG is working with Transport Scotland to prepare guidance on extreme cold treatments[28]. Based on initial findings, the use of alternative wetting agents for pre-wetting (such as magnesium chloride, calcium chloride, or treatments including additives) appears promising. Blending these substances with rock salt is likely to be an effective method for those without pre-wet spreaders.

5.4.8. The Highways Agency has proposed further testing of such treatments to assess their effectiveness in a UK context. A laboratory trial combined with limited field trial would cost in the region of £50,000 to £60,000, and could be funded within the existing Highways Agency budget. If the trial is successful, robust guidance on the use of alternative treatments could be confirmed for use by all highways authorities, and the cost of the trial could be recovered within six days of extremely cold weather. This is because in the most severe conditions, it is expected to be cheaper to use alternative materials (such as magnesium chloride), than the large amounts of rock salt that would otherwise be required.

5.4.9. A longer term solution is the **addition of materials into the construction of highways or footways** to minimise or remove the need for preventative treatments. The road building industry is keen to encourage this approach,

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[27] The Highways agency has already undertaken some initial research on effectiveness and environmental impact, available at:
http://www.highways.gov.uk/knowledge_compendium/87DEC9BCAEA04AA6B0CA449D793BB48A.aspx and
http://www.highways.gov.uk/knowledge_compendium/6DCA796F8CDA4553876C6B0711B3271C.aspx

[28] The research underway covers brine and direct liquid application; it does not cover all treatment options available to local authorities that do not have brine/pre-wet fleets. This work is expected to be completed by the end of 2011.

initially on footways and then on highways. There appears to be potential for considerable cost savings over time, but the technology is new and further testing is needed to fully understand its effectiveness and lifetime, and subsequently costs and benefits.

5.4.10. The terms of reference for the **Highways Maintenance Efficiency Programme (HMEP) Pot Hole Review** were agreed by Norman Baker MP in July. The review is assessing a broad range of factors relating to long-term road condition, including asset management, decision-making processes, lean management techniques, contract management, design standards, and shared planning processes. The intended outcome is a more rounded approach to increasing the resilience of roads to winter damage.

5.4.11. Some winter service decisions are taken by people who have no formal training or previous experience in winter service delivery. This does not necessarily mean that incorrect actions are taken, but it can lead to inconsistency between authorities and uninformed decisions. One way to ensure more consistency would be to develop a **formal training programme and qualification for winter service practitioners**. Such a measure could play an important role in disseminating best practice and ensuring that resources are used efficiently during times of disruption. This has been identified and discussed as part of the NWSRG and recognised by groups of practitioners[29]. It may be possible to expand the existing formal training programme for gritter drivers, which is a modular NVQ.

5.4.12. At DfT's annual Logistics 'Listening to Industry' event earlier this year, freight operators suggested that **weights and dimensions legislation might be relaxed to allow snow ploughs to be bolted onto heavy duty vehicles to help clear the network**. Local authorities already use snow ploughs attached to agricultural tractors on local roads, but permitting other large vehicles to fit a device could bring significant benefits at little cost to government. This suggestion would require consideration, for example to ensure that snow ploughs do not cause vehicles to exceed their maximum permitted weight, obscure lights or create a danger to other road users. DfT is investigating how a trial might best be taken forward over the coming winter.

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[29] The HA has already carried out some work in this area, available at: http://www.highways.gov.uk/knowledge_compendium/B8AA3647ECE64D96AE248E2917948894.aspx

6. Analysis of costs and benefits supports the use of third rail heating to increase the resilience of the third rail network

6.1. BCRs have been calculated for four rail resilience measures

6.1.1. The table below summarises the estimated BCRs for rail resilience measures. The calculations for third rail heating and de-icing equipment are based on analysis by Network Rail. The analysis of overhead electrification draws on the initial findings of the industry group tasked with studying this issue. Considerable further appraisal work is needed before a fully-informed decision on this scheme would be possible.

Table 6.1: Summary of rail measures and BCRs

Measure	BCR
Third rail heating	3.2 to 13.1
Fit de-icing equipment to 20 passenger trains	1.7 to 7.0
Fitting an additional 30 trains with de-icing equipment	2.1 to 8.8
Replace the third rail with a much higher voltage overhead electrification system	0.8 to 2.4

6.2. There is a need to increase the resilience of the third rail network to heavy snow

6.2.1. Rail disruption in late 2010 was greatest on the network to the south of London where trains draw power from a third rail at ground level. During heavy snow the conductor rail becomes covered in snow and trains are unable to draw power from it. In response, recent work on railway resilience has focused on measures to prevent the third rail from freezing.

6.2.2. One option is to introduce **third rail heating** at sites where trains require the most traction, such as when pulling out of stations or climbing hills. The BCR for this measure has been calculated using information provided by Network Rail. Costs are based on installation at a provisional set of sites at an initial set up cost of £16m to £20m, plus annual operating costs of £0.7m to £2.7m. Benefits are based on the reduced commercial costs of train delays and cancellations, which have been used as a proxy for the full costs of disruption, and are likely to represent a conservative estimate. For this reason, the BCR shown is likely to under-estimate the true BCR. The calculations assume the heating is operated by a simple on-off switch; developing a thermostatic control system could reduce running costs and increase the system's attractiveness even further.
BCR: 3.2 to 13.1 (central estimate 6.9)

6.2.3. When appraising major infrastructure investment projects it is prudent to take into account 'optimism bias', the systematic tendency for analysis to be over-optimistic about the costs and benefits of a scheme. For the third rail heating proposal, estimated scheme benefits have been reduced by 28 per cent to take this into account[30]. In addition, the benefits calculated are based on current service levels – they could turn out to be much greater if more train services run in future years. Network Rail has not made any explicit allowance for optimism bias in the set-up costs, but has reflected the inherent uncertainty by using a range of £16m to £20m.

6.2.4. Another solution to difficulties with the third rail during extremely cold weather is to **fit de-icing equipment to passenger trains**. By November 2011, 20 'Electrostar' trains had been modified in this way so that they can apply anti-ice treatment while operating in passenger service. Modifying the 20 trains involves an initial capital cost of £3.9m[31], and operational expenses of £0.5m per year. The benefits are estimated at £1.25m per year, although this is once again likely to be an underestimate because it is based only on the reduced commercial costs of delays and cancellations.
BCR: 1.7 to 7.0 (central estimate 3.7)

6.2.5. Network Rail suggests that fitting an additional 30 trains with de-icing equipment for use in Kent would enable a step change in managing ice formation on the conductor rail by allowing almost continuous application of de-icing fluid. Since the technology has already been developed, the costs of rolling out the equipment to 30 additional trains would be lower than for the initial batch of 20. So far, the equipment has only been designed for the 'Electrostar' fleet used on the Southern network. Rolling out de-icing equipment to the trains used on the Wessex routes would require additional technical development.
BCR: 2.1 to 8.8 (central estimate 4.6)

6.2.6. As with the third rail heating proposal, scheme benefits for de-icing equipment incorporate a 28 per cent allowance for optimism bias and are based on current service levels. Network Rail has provided an indicative point estimate of cost.

6.2.7. A longer term option to reduce the vulnerability of the third rail network would be to **replace the third rail with a much higher voltage overhead electrification system**[32]. In addition to the installation of overhead wiring, it would be necessary to modify signalling and train detection systems, and convert some of the existing trains themselves (which would cost around £500,000 per unit). Improved winter resilience would be just one small component of the overall benefits, which include energy and carbon savings, safety benefits and reduced track renewal and maintenance costs. Based on a provisional high level assessment, these savings would total around £320m per year, of which £29m (nine per cent) would relate to improved weather-related performance. As with the other Network Rail calculations, the value of reduced weather-related delays and cancellations is likely to be a conservative estimate. Costs are provisionally estimated to be in the region of

[30] Based on Network Rail's assumptions
[31] This is being funded by the rail industry without DfT input
[32] Plans for such a conversion would need to be put forward and proposed by industry as part of the Initial Industry Plan. Any decision on whether or not to fund would be part of the normal regulatory periodic review.

£2.5bn to £3.5bn.
BCR range: 0.8 to 2.4 (central estimate:1.2)

6.2.8. Because this proposal is at a very early stage of development, there is considerable uncertainty around both costs and benefits. Costs have been provisionally estimated to lie in the range £2.5bn to £3.5bn, which incorporates an allowance for optimism bias and broader uncertainty around cost assumptions. Further work would be needed to understand the full financial implications of an investment of this magnitude. Benefits are estimated to fall within a wide range of £79m to £320m per annum. As with the other rail investment proposals, calculations have been made under the assumption of current service levels. In reality, this investment could well reduce journey times and increase capacity, further increasing the attractiveness of overhead electrification.

6.3. Train companies are investigating smaller-scale measures to increase resilience

6.3.1. In addition to the measures above, which are under consideration by Network Rail, individual train companies are investigating a number of smaller scale solutions. Since this work is being undertaken by private companies, detailed evidence on costs and benefits is not held by DfT.

6.3.2. **Improved de-icing chemicals** are being investigated by some operators to keep train systems, such as doors, operational at slightly lower temperatures than current substances permit. The new de-icing chemicals also provide some temporary protection against snow build-up on the third rail. Nonetheless, the new chemicals do not provide protection at temperatures below -7°C and require regular application by staff whilst a train is away from maintenance depots, which is costly and creates practical challenges. The residue can also accelerate corrosion of sensitive systems in the longer term. Effectiveness relies on good weather forecasts so that scheduled maintenance tasks can be adjusted around four to six weeks ahead of poor weather, with further action 24 to 48 hours before the bad weather occurs.

6.3.3. Another initiative underway is to **review the design of the collector shoe and the way that trains collect power from the third rail**. It is relatively simple to fit and trial potential solutions, but there has previously been a marked lack of success. Some of the designs trialled have resulted in highly accelerated wear of the conductor rail and/or collector shoes. Further trials could be undertaken in winter 2011-12 if suppliers provide a new and credible proposal.

6.3.4. **Ice mode software changes** remove the need for a driver to put a train into ‘ice signalling interference mode’ at the start of every journey (reducing the risk of human error). This change can only be applied to newer trains and effectively reverts their performance to that of older models better able to cope with moderate snow and ice. This has already been rolled out to the Southern fleet.

6.3.5. **Improved collaboration between train companies and other local transport providers could also increase resilience of the transport network as a whole.** For example, Transport for London (TfL) has noted that the provision of better information from Network Rail and train operators could allow it to adapt tube, bus and tram services to help cope with disruption on the rail network. Improved information on rail services could also be forwarded to rail travellers on the TfL network to enable improved journey planning.

6.3.6. Some train operators are considering how to ensure staff can reach work during disruptive weather. For example, First Great Western has deployed a small number of 4x4 vehicles to fulfil roles including getting key staff to work during snowy conditions. Southern Railway asks staff to assist at a station near their home if they cannot reach their normal workplace. They have also trained a number of office-based staff so they can undertake station or conductor duties if required.

7. Business continuity measures such as remote working may provide a cost effective means to reducing the economic cost of severe weather

7.1. The costs and benefits of two remote working solutions have been assessed

7.1.1. An alternative to increasing the physical resilience of infrastructure is to enable employees to work effectively when they cannot reach their usual workplace. The analysis in this paper focuses on two remote working solutions which differ in the amount of equipment that the employer needs to provide.

7.1.2. Benefits have been assessed purely in terms of their value for business continuity; it is important to recognise that remote working can generate many other benefits (and some costs), particularly in terms of quality of life. There is also significant uncertainty around the cost of providing remote working facilities. It is envisaged that individual employers would take decisions based on a detailed assessment of the costs and benefits their organisation faces.

Table 7.1: Summary of remote working BCRs

Measure	BCR[33]
Home working with equipment provided by employer	0.2 to 0.9
Low-cost home working	1.4 to 5.8

7.2. Remote working can ensure that certain types of workers are able to remain productive when it is not possible to reach their workplace

7.2.1. A distinction may be drawn between 'business continuity' and 'resilience'. The latter implies physical investment to make infrastructure robust to disruptive events, whereas the former is concerned with ensuring that business and other activities can continue to operate when infrastructure is disrupted. Aiming for business continuity may offer cost advantages over enhancements to physical infrastructure.

7.2.2. **Remote working** is one way of ensuring some types of business can function during times of disruption. Remote working is not viable for some activities, such as manufacturing and construction, but many service based jobs could be done from home or other locations with internet access. In England, around 13 per cent of people work full-time from home, and a further 4 per cent work occasionally from home[34]. Around 13 per cent of employees who never work remotely say that they could do at least some of their work from home[35].

[33] BCRs only include the benefits of reduced winter disruption.
[34] UK Labour Force Survey 2009
[35] National Travel Survey 2008

7.2.3. Increased remote working would support business continuity when infrastructure is disrupted for any reason, not just severe winter weather. There can also be much broader benefits, such as reducing the need for office space and allowing workers greater flexibility to fit work around family and other commitments. Remote working can support more flexible working patterns, enabling commuters to spread journeys away from the morning and early evening peaks.

7.2.4. The costs of increased remote working would fall on employers. The benefits calculated below are restricted to reducing the amount of output lost due to extreme winter weather; there could be many other occasions when the option of remote working would be valuable to firms and individuals. Wider benefits of home working such as reduced office costs for employers and increased quality of life for workers are not included in these calculations.

7.2.5. Set up costs for remote working could be up to £2,000, if an employer provides a laptop and other office equipment, and has to purchase new servers to enable the office network for remote access. Using the same model that generated the estimates of disruption costs in section 2, it is possible to estimate the benefits of enabling 13 per cent of employees who never work from home (see paragraph 7.2.2) to do so, reducing the amount of output lost by workers being unable to reach work, or being delayed on a disrupted commute. A small allowance has also been made for a reduction in pedestrian accidents which might occur as commuters travel to work.
BCR range: 0.2 to 0.9 (central estimate 0.5)

7.2.6. It may be possible for employers to provide home working capability at much lower cost. One such system, provided by Becrypt, is already in use amongst some local authorities. It comprises a simple £100 USB device that enables secure remote working on an employee's own computer. Even allowing an additional £100 per user to upgrade an employer's IT infrastructure, and assuming that employers may still need to provide a basic laptop for one quarter of employees without a suitable machine at home, this solution could provide an attractive case for investment.
BCR range: 1.4 to 5.8 (central estimate 3.1)

7.2.7. In both remote working examples, the higher estimate in the range may provide the best indication of the value for money of increased remote working since it provides protection against any kind of disruption, not just extreme winter weather. In addition, the benefits of increased home working can extend far beyond resilience to transport disruption, suggesting the BCRs could be even higher than calculated.

7.2.8. While DfT can recommend that businesses ensure they have a suitable network to provide resilience in times of severe weather, it is for individual employers to implement continuity plans that meet their own needs. Nonetheless, as part of its alternatives to travel work, DfT is investigating what government can do to facilitate the take-up of remote working either on a regular or occasional basis. Work is ongoing, but early findings suggest this is likely to include providing guidance, education and leadership to highlight the benefits and encourage best practice. There may also be an opportunity for

Government to reduce its own costs through the adoption of emerging technologies that reduce set-up costs for employers.

8. A number of other initiatives are underway to increase the resilience of transport infrastructure

8.1. The Highways Agency is working to ensure drivers are better informed about severe weather conditions

8.1.1. The Strategic Road network performed reasonably well during recent incidents of extreme winter weather. In some areas the Highways Agency (HA) has actually had capacity to provide support beyond its network, for example in clearing port access roads.

8.1.2. In line with routine practice, the HA has reviewed its performance last winter. There does not appear to be a strong case for large scale changes or investment in new capital equipment or infrastructure, although a number of incremental changes have been identified for implementation ahead of winter 2011-12. This view is supported by the Transport Select Committee[36] who for the HA recommended measures to improve information and the targeting of resources.

8.1.3. The HA has identified a number of improvements that could be delivered at modest cost and within existing budgets. They include:

- working with the Freight Transport Association (FTA) and Road Haulage Association (RHA) to develop a process for warning heavy goods vehicle operatives of severe weather, similar to the existing and successful high wind alert system;
- developing the use of Variable Message Signs (VMS) to improve information to road users ahead of and during severe weather incidents;
- a review of sections of the strategic road network vulnerable to severe weather to develop mitigation plans to ensure resources are targeted effectively, both before and during severe weather. This will also identify major transport hubs, such as ports and airports, and any special measures or treatments to apply at these locations;
- assessment of depot resilience plans to reduce the risk of sudden heavy traffic flows on adjacent roads preventing winter service vehicles from accessing their routes;
- development of an improved regional/national incident management process to improve coordination and monitoring of severe weather service deployments;
- working with major stakeholders (including the RAC and the AA) to improve communications with road users so that they can plan journeys and adapt their driving behaviour during severe weather. This includes carrying appropriate emergency equipment in the vehicle; and

[36] Keeping the UK moving: The impact on transport of the winter weather in December 2010, House of Commons Transport Committee (May 2011), available at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmtran/794/79402.htm

- as described in Section 5, working with the National Winter Service Research Group to develop improved guidance for the treatment of roads when temperatures are extremely low.

8.2. Major airports are already taking steps to increase their resilience and this will be reinforced by new regulatory arrangements

8.2.1. In most cases it will be in an airport's best interest to make necessary investments. Heathrow experienced significant monetary and reputational costs in December 2010 and is taking steps to prevent a reoccurrence. The independent Heathrow Winter Resilience Enquiry, commissioned by BAA and published in March 2011, made 14 recommendations in the areas of preparation and planning, command and control, communications, and passenger welfare[37]. BAA announced it would take forward all 14 recommendations under a £50m investment plan and has already tested and developed new contingency planning and command processes, and strengthened its capacity management procedures.

8.2.2. Since December 2010, Heathrow has tripled its snow clearing fleet to 185 vehicles. The snow response team has also increased from 117 to 468 personnel per shift, including a new Reservist role which will see up to 950 non-operational staff deployed to terminals to help passengers during any disruption. In addition, BAA is also agreeing with airlines, NATS and Airport Coordination Limited (ACL) a new process for managing the necessary flight cancellations and slot allocation during weather disruption.

8.2.3. Similarly, since December 2010 **Gatwick airport** has invested £8m to double the size of its fleet of snow clearance and de-icing vehicles from 47 to 95.

8.2.4. Along with investment by airport operators, a proposed **new regulatory framework** will give more power to the Civil Aviation Authority (CAA) to ensure passengers' interests are protected. This would be achieved through the Airport Economic Regulation reforms due to be introduced as a Bill in early 2012[38]. Currently the CAA cannot react in real time to events such as snowfall. Through the introduction of individual licences for regulated airports, the CAA will acquire stronger and more flexible powers to respond to important passenger issues. These powers will allow the CAA to impose licence conditions to target specific issues, such as resilience to snow, should the CAA consider it appropriate. The conditions would be enforced through a stronger and more proportionate regime of financial penalties. These financial penalties should improve accountability and incentivise airport operators to be better prepared for disruption.

8.2.5. In addition, the **South East Airports Taskforce's sub-group on punctuality, delay and resilience** was asked to examine the provision of snow clearance equipment and de-icer, and the execution of reduced capacity plans at Heathrow, Gatwick and Stansted.

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[37] Report of the Heathrow Winter Resilience Enquiry (March 2011), available at: http://www.heathrowenquiry.com/HWRE%20Report%20220311.pdf

[38] The introduction of the new regime should not disturb the basis on which the current price caps at Heathrow and Gatwick are set.

8.2.6. The sub-group found that these issues had been covered adequately as part of the recommendations from the BAA Heathrow Winter Resilience Enquiry, the House of Commons Transport Select Committee inquiry and the CAA's ongoing work on the passenger experience during the disruption[39]. However, the Taskforce also acknowledged that the sub-group's wider work on performance charters, capacity utilisation guidelines and operational freedoms would be of benefit to airport users during periods of winter disruption. The CAA has been asked to chair an Airport Performance Facilitation Group to facilitate progress in these areas and it is anticipated that the Group will issue a first report in the first half of 2012 and a final report by the end of 2012.

8.3. Measures to increase the resilience of ports focus on improving local coordination between stakeholders

8.3.1. The main impact of extreme winter weather on ports occurs when roads and operational areas become impassable or dangerous, hindering operations and increasing costs. This can quickly have knock-on impacts for manufacturers who rely on the just-in-time delivery of components. For example, Honda and Rolls Royce have in the past shut factories as a result of closed ports (though not, so far, as a result of snowy conditions).

8.3.2. The overall maritime reaction to the severe winter weather in 2010-11 was much improved compared to 2009-10. Despite the difficulties encountered, the majority of UK ports remained open in winter 2010-11, with some operating at reduced capacity. Disruption at ports did not noticeably contribute to the dislocation of supply chains within the UK.

8.3.3. Certain ports receive salt shipments, and so play a crucial role in supporting the resilience of the wider transport network. Despite entering the winter with significantly greater salt supplies than in 2009-10, the prolonged severe weather in late 2010 rapidly depleted stocks which could not be replenished through the usual channels. DfT had to work with ports and salt suppliers to ensure operations were maintained.

8.3.4. Following an assessment of the problems experienced over the past two winters, a number of measures have been identified to further increase resilience:

- DfT issued an advisory note to ports in September alerting them to the need to begin winter preparations and making a number of recommendations for action based on past performance;
- the development of stronger links between ports, regional resilience forums, and local authorities. DfT hosted a Maritime Winter Resilience Workshop in October, which brought together stakeholders to consider winter resilience preparations and disseminate best practice advice. As a result, DfT are issuing ports with an advisory severe weather resilience planning template to act as a benchmark against which to test winter

[39] These findings were published alongside the Taskforce's main report in July 2011, see: http://www.dft.gov.uk/publications/south-east-airports-taskforce

resilience measures. This is designed to ensure a consistent approach across ports and aid development of a coherent and mutually supportive plan across the sector and government. DfT have also circulated guidance to the sector to advise ports on steps they may wish to take now to improve their resilience to sever winter weather.

- DfT have delivered a training programme to the Department for Communities and Local Government Resilience and Emergencies Division to provide detailed information on maritime operations and resilience issues.

8.4. The Met Office has requested additional funding to enhance its forecasting capabilities

8.4.1. At the inaugural meeting of the Infrastructure Resilience and Economic Appraisal Committee, it was agreed there is a clear gap in the UK's weather forecasting ability. Government has access to high quality short-term weather forecasts and a comprehensive set of climate UK change scenarios[40]. However, as discussed in Section 3, it is not possible to forecast the frequency of extreme weather events occurring during the next few decades with any degree of certainty. This was noted in the 'Brief on the likelihood of severe winter weather over the next 20-30 years' produced for Sir John Beddington[41] following the severe winter weather in late 2010.

8.4.2. Public and private organisations including BAA, Network Rail, the Salt Union and the Highways Agency have sought guidance from the Met Office on the likely frequency of severe weather events over the next 30 years, to enable extreme weather planning. Current decisions are based on historical weather statistics but these cannot provide information on the future frequency and intensity of hazardous weather events. The Met Office cannot provide these scenarios with an acceptable level of confidence with its current level of computing resource because current models do not capture the specific weather systems that give rise to extreme events[42].

8.4.3. To address this gap, the Met Office has requested additional funding to enhance its supercomputing resource by 20 per cent. This would cost around £10m over four years[43]. The Met Office believes that this would deliver a step-change in its ability to predict the frequency of extreme weather events occurring during the next 30 years[44].

8.4.4. If the investment is agreed in time for the 2012-13 financial year, the Met Office will be able to provide improved decadal weather advice from 2013 onwards, including improved information on the likelihood and impact of severe weather events such as snow, heat waves and flooding. This would, in

[40] http://ukclimateprojections.defra.gov.uk/
[41] http://www.dft.gov.uk/publications/resilience-briefing/
[42] The models do not have sufficient *resolution* to capture the relevant weather systems
[43] Approximately £2.5m funding in each year from 2012-13 to 2015-16
[44] The investment would increase the resolution grid in the atmosphere from 150km to 60km and in the ocean from 1° to 1/4°, enabling forecasts of more specific weather systems (such as El Nino/La Nina, blocking, North Atlantic Oscillation), and related extreme weather statistics, to be captured with more skill.

turn, enable better informed investment and planning decisions across the public and private sectors, including those relating to resilience investments.

8.4.5. In the 2010 'Review of climate science advice to Government and Met Office Hadley Centre role, governance and resourcing', Sir John Beddington recommended additional investment in the Met Office's supercomputing resource. The current Met Office business case is consistent with Sir John's recommendation, and partly addresses the recommended Option B+[45].

8.4.6. The Met Office is confident that the investment would deliver a significant improvement in its ability to predict the frequency of severe weather events during the next 30 years. DfT's Deputy Chief Scientific Advisor agrees that the investment has the potential to significantly increase the UK's ability to model the future probabilities of extreme weather events, and notes that the benefits of the investment would accrue across government.

8.4.7. It is therefore recommended that Chief Scientific Advisors in interested government departments work together to more formally assess the business case for the investment and, if appropriate, identify potential funding options. If that group decides that the investment would be desirable and affordable, it is recommended that scientific advisors from contributing departments continue to liaise with the Met Office as the investment is implemented to ensure it meets their operational needs.

[45] This suggested a 50 per cent increase in Met Office supercomputing power over the next ten years. The most immediate cross-government need identified was to be able to answer questions on regional climate variability to inform planning decisions across government. The requirement for 60km resolution climate simulations to address this need was stated. A number of other longer-term questions were identified, which could be met under the B+ option, requiring longer term investment and further supercomputing capability.

9. The analysis suggests there may be a case for additional investment to increase resilience in a small number of areas

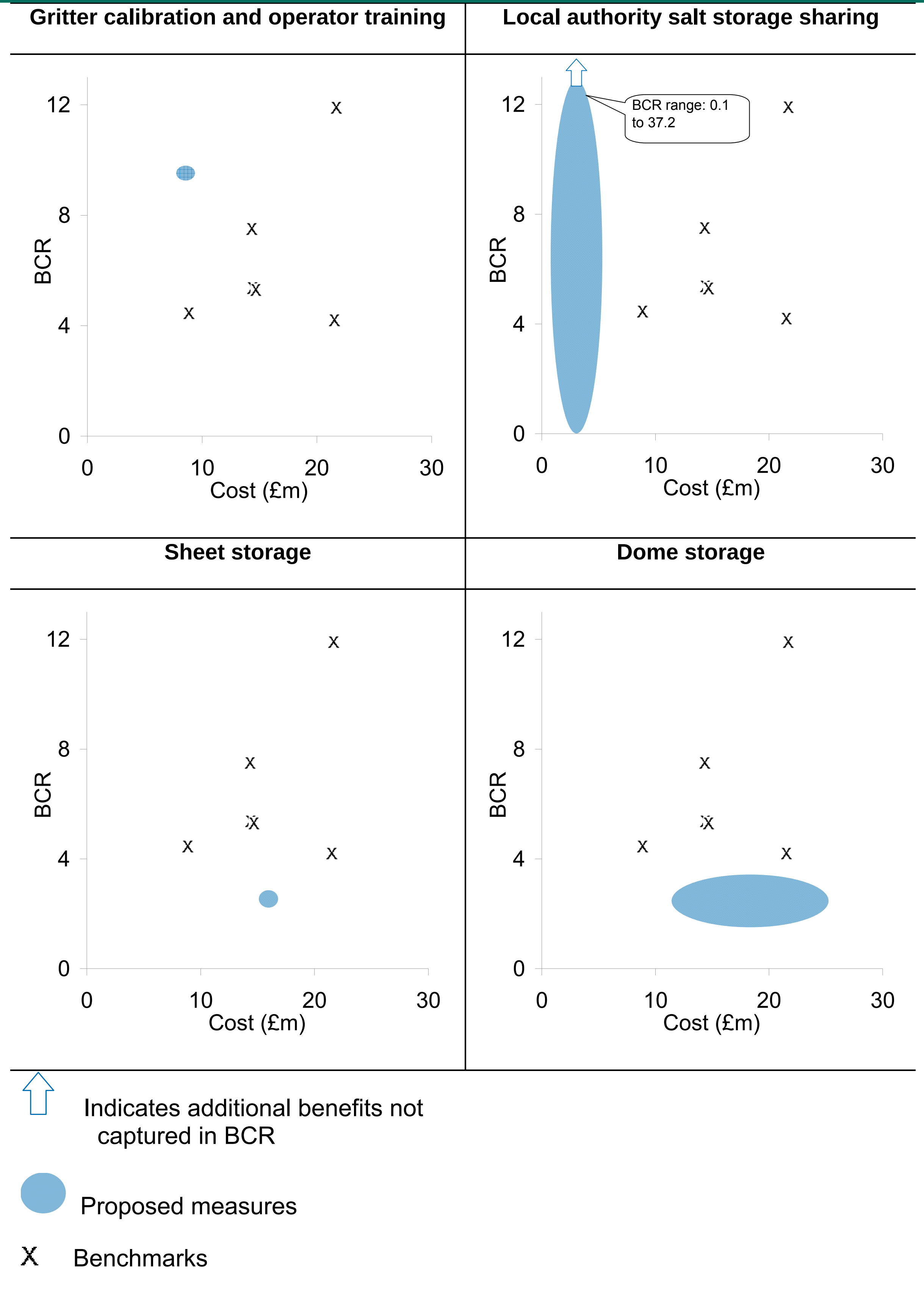
9.1.1. Sections 5 to 8 of this report set out a range of measures to increase the resilience of the transport network to severe winter weather. For some of these proposals it has been possible to calculate indicative BCRs to help understand where further investment may be desirable.

9.1.2. The first group of schemes identified included options to improve the storage and application of salt for local authority highways. The options are plotted as 'bubbles' in Figure 9.1 below. This follows the framework described in Section 4.2, with the width of each bubble indicating the estimated cost range of an option, and the height indicating the BCR range.

9.1.3. Since additional investment in resilience would need to be funded through a reallocation from elsewhere, the analysis requires a set of 'benchmark' investments to indicate the value for money of schemes that could lose out were such a reallocation to occur. As such, the black crosses in Figure 9.1 show where local authority major schemes approved in the 2010 Spending Review would fall.[46] This is not to suggest that local authority major scheme funding should be reallocated towards resilience measures; the major schemes data are used purely to indicate the typical value for money offered by non-resilience local transport investment.

[46] http://assets.dft.gov.uk/publications/investment-in-local-major-transport-schemes-update/transportschemesupdate.pdf

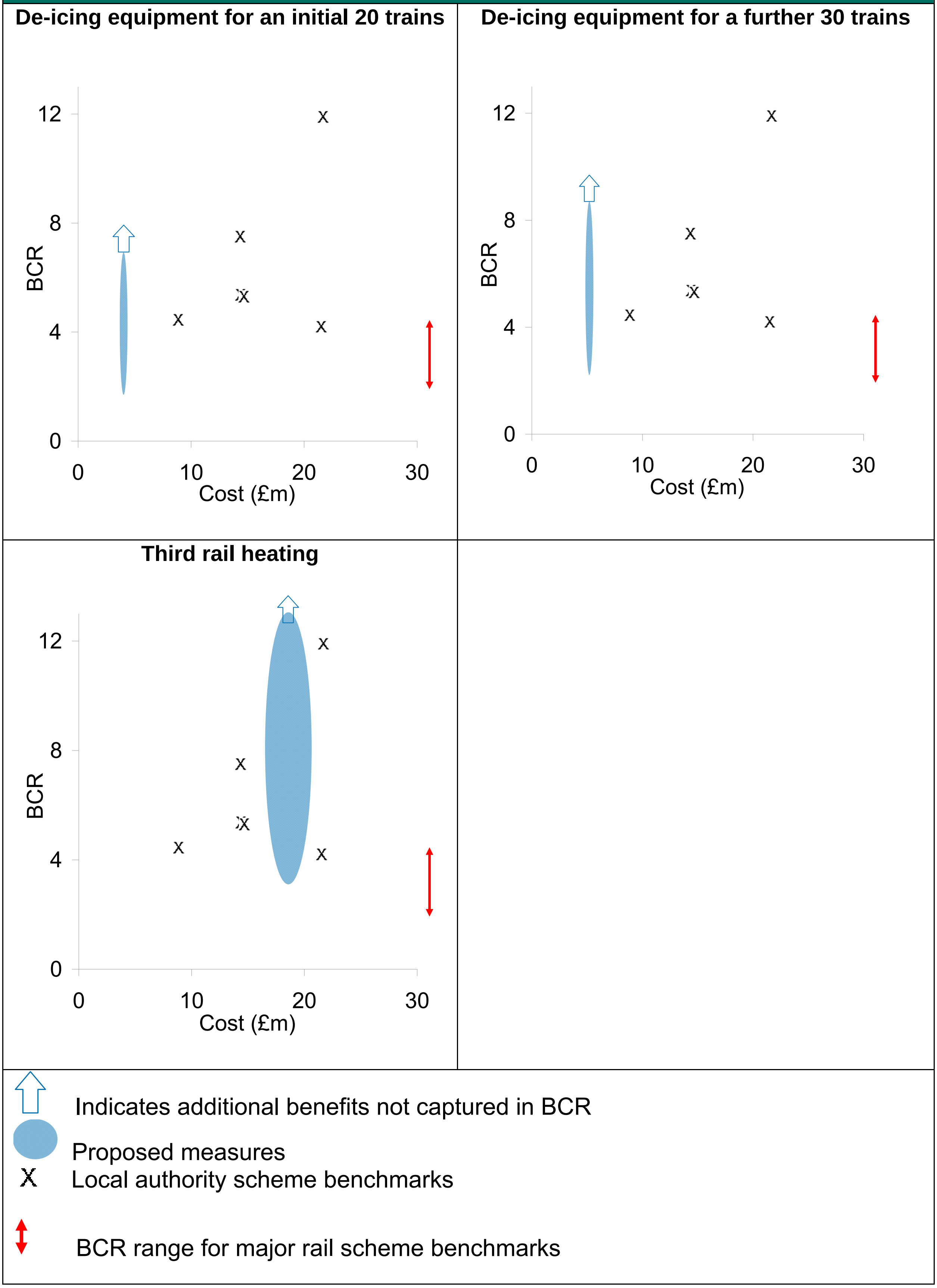
Figure 9.1: In the short term there is a very strong case for gritter calibration and operator training; sharing existing salt storage facilities could offer better value for money than constructing new stores or plastic sheeting



9.1.4. This comparison suggests there is a strong case for local authority expenditure on **gritter calibration and operator training** to ensure full implementation of the new Winter Service Guidance - the BCR of this scheme is greater than that of most of the benchmark schemes and the cost is comparable. The UK Roads Board would be well placed to consider how these measures could, in the first instance, be targeted towards those geographic areas where they are likely to generate the greatest net benefits. **Sheet and dome storage** fall at the lower end of the BCR range and so present a weaker case for investment. The wide cost range for dome storage suggests this investment could be risky. A better option may be for **local authorities to share salt storage facilities**. Although the BCR of this option is very uncertain, it may be possible to deliver it at minimal additional cost through the design of a standardised process that can be replicated across regions. Given that the benefits of sharing salt storage are very sensitive to the winter weather scenario which prevails, it may be prudent to pursue this option in those regions of the country where snow is most frequent. The approach could then be replicated elsewhere if successful. It is recommended that the UK Roads Board could explore this option in detail.

9.1.5. The second group of options analysed focuses on relatively small scale rail schemes (Figure 9.2). Benchmark information for other small-scale rail schemes is not available, so the local authority major schemes are again used as the benchmark. In addition, major rail schemes typically produce BCRs of between 2 and 4 and this is indicated by the red line on the right-hand side of the diagrams.

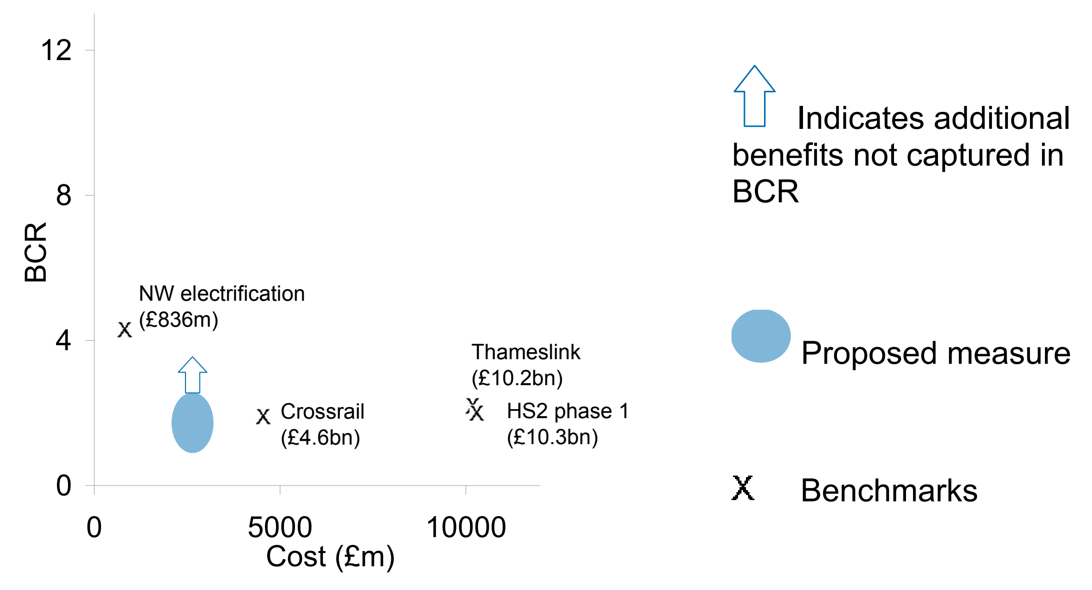
Figure 9.2: There is strong support for third rail heating; the case for fitting de-icing equipment to trains is weaker, although rolling out the equipment to additional trains would offer value for money in line with major rail schemes



9.1.6. **De-icing equipment** has already been fitted to 20 trains, and value for money is broadly in line with both the local authority and rail benchmarks. The fixed set-up costs incurred mean that there is potential to roll-out the same system to additional trains at lower cost. Fitting de-icing equipment to an additional 30 trains would in principle therefore offer slightly better value for money than the expenditure already incurred, particularly taking into account that the data shown do not reflect the reduction in lost working days that such an initiative might provide. The analysis is supportive of **third rail heating**: the BCR compares favourably with the benchmark schemes. Even in the mild weather scenario third rail heating is likely to deliver a BCR similar to that of major rail schemes.

9.1.7. Figure 9.3 shows provisional results for the proposal to **replace the third rail with overhead wiring**. The analysis suggests this option would deliver value for money broadly equivalent to Crossrail and Thameslink, although below that of the North West Electrification project.

Figure 9.3: Replacing the third rail with overhead wiring would offer value for money broadly equivalent to other major rail schemes



9.1.8. The proposal to **extend remote working to the 13 per cent of employees who do not currently work from home, but who believe some of their work could be done remotely**, would be funded by individual employers. It would be for them to assess the costs and benefits for their own organisation. It would not be necessary to divert expenditure away from other transport investments and so these do not represent an appropriate benchmark. Businesses typically look at internal rates of return (IRRs) to assess the attractiveness of an investment. The higher the IRR, the more attractive the investment.

9.1.9. Table 9.1 shows IRRs for investment in remote working, under the assumption that the only benefit to the business is the value of lost output avoided by employees being able to work effectively when they cannot reach the office.

Table 9.1: Investment by employers to increase the proportion of employees able to work remotely would improve resilience to all kinds of disruption but costs must be minimised to make the financial case attractive

	IRRs by weather scenario, per cent		
	Mild	**Average**	**Severe**
Working from home (employer provides equipment)	-39	-24	-8
Working from home (low cost option)	6	44	97

9.1.10. A business will typically seek to identify investments with an IRR greater than the cost of capital (around 5 per cent for a FTSE 100 company, or 7 to 10 per cent for SMEs). From the table it is clear that the case for increased investment in remote working may be attractive if it can be delivered at low cost, using employees' own IT equipment. This suggests DfT is right to be investigating what government can do to facilitate remote working.

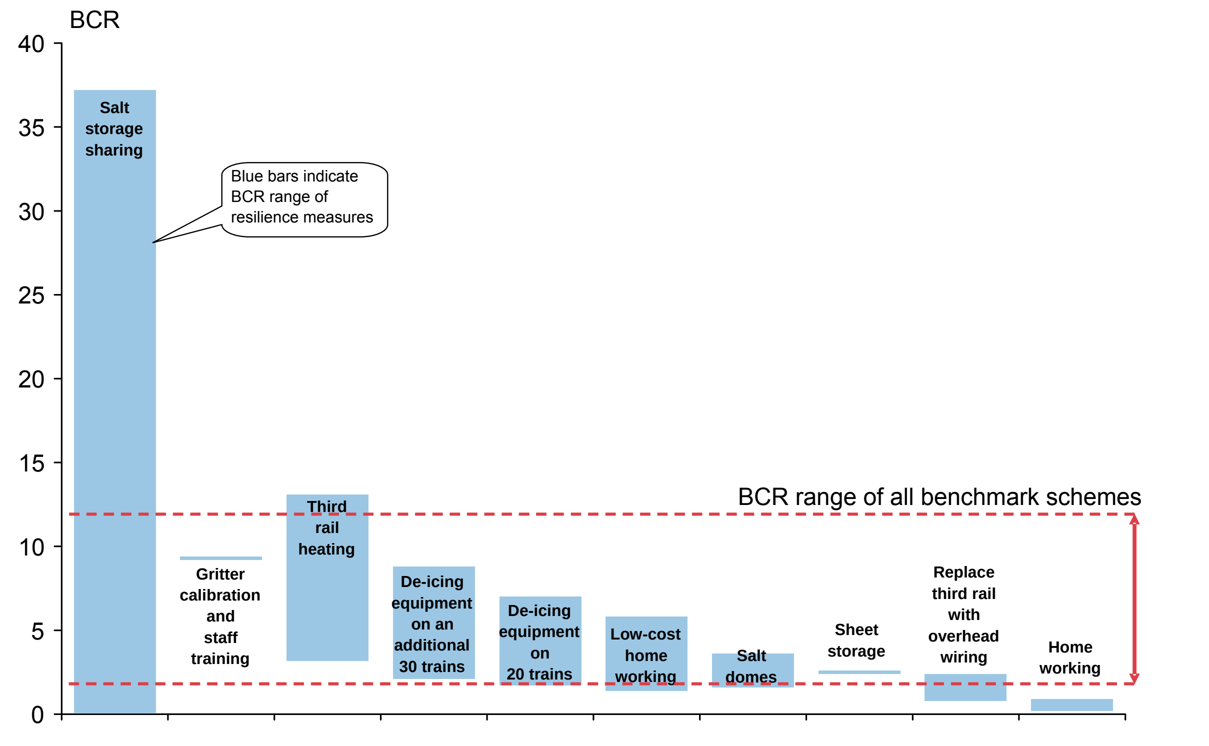
9.1.11. An important caveat is that this analysis is based on employees earning the average wage. The case for both types of remote working is stronger for those on higher wages, since the cost to a business of losing a day of their output is greater.

9.1.12. Since increased remote working potential would offer resilience to all kinds of disruption, it is reasonable to assume that the case for increased investment will be towards the top of the IRR range calculated. The value for money of remote working will be greatest in parts of the UK where transport is least reliable, whether due to snow or other reasons. In short, remote working is likely to provide an attractive solution where it can be targeted at the most productive workers in regions where disruption is most frequent.

9.1.13. Technological progress may reduce the costs of remote working in the future, further increasing the returns available from this option. For example, the development of cloud computing is likely to bring down the business hardware costs.

9.1.14. Figure 9.4 draws together all of the BCRs calculated in this analysis and compares them to the BCR range for all of the benchmarks used in the charts above to provide a cross-modal comparison. This analysis confirms the conclusions above, notably the strong case for sharing salt storage, calibrating gritters and training operatives, and third rail heating. Train de-icing equipment falls in the middle of the benchmark range, as does the low-cost remote working option if we consider the top of the range to be the most likely outcome, for the reasons described in the previous paragraph.

Figure 9.4: Comparing measures across modes confirms the conclusions from the analysis above



9.1.15. Uncertainty about the value for money of resilience investments could be reduced by improving our ability to predict the likelihood of extreme weather events occurring during the next few decades. The Met Office proposes additional investment in its supercomputing ability to do just this. This report recommends that Chief Scientific Advisors in interested departments work together to more formally assess the business case for this investment and, if appropriate, identify funding options.

9.1.16. This report identifies various other resilience options which appear promising, but for which no BCR analysis was possible. In particular:

- the UK Roads Board should further investigate examples of **effective collaboration between local service providers** and disseminate this to encourage best practice;
- **research into alternative road treatments** should continue to improve the highways sector's understanding of how roads can be kept safe when it is too cold for salt to be effective, and how the cost of salt spreading may be reduced. Initial work in this area suggests there may be substantial potential for savings in the cost of treating roads;
- there may be a role for the highways sector to explore the feasibility and cost effectiveness of setting up an advisory service to help local authorities identify whether they could realise savings through **investment in the**

equipment needed for pre-wet treatments, and advise on funding options where such investments are viable;

- there may be potential for the private sector to make a greater contribution to snow clearance work by **relaxing weights and dimensions legislation to allow snow ploughs to be bolted onto heavy duty vehicles**. DfT is investigating how a trial might best be taken forward over the coming winter;
- in the longer term there is a need to better understand the costs and benefits of **new road surfaces** which claim to significantly reduce the need for preventative measures; and
- there is a need for **better local coordination to ensure maritime ports remain operational**. DfT should continue to encourage best practice in this process, for example through the work underway to develop severe weather planning templates.

9.1.17. The fact that additional investments have already been made at Heathrow and Gatwick airports suggests that the financial and reputational damage imposed by recent disruption has acted as a powerful motivator to avoid future problems. This should be reinforced by the **new regulatory framework for aviation**, which should improve accountability and ensure better treatment for passengers during disruption.

ANNEX A: The costs of transport disruption from severe winter weather

A1. Impact of cold weather on the economy as a whole

The Office for National Statistics (ONS) estimates that GDP decreased by 0.5 per cent in the fourth quarter of 2010, and that most of this decline was due to weather disruption.

During a period of severe weather, some activity may be delayed until future periods. This means that some of the initial loss from disruption may subsequently be made up.

Within the overall picture there will be winners and losers. The greatest losses may be felt by firms reliant on turnover, such as restaurants, where activity is discretionary and lost revenue may not be made up. Firms providing goods and services related to cold weather might gain, for example energy providers.

A2. The impact of weather-related transport disruption on economic welfare

Building on a model used in the Winter Resilience Review[47] (WRR), DfT estimates the average daily cost of transport disruption caused by severe weather is £280m in England (in current prices). In addition to 'hard' costs to the economy (e.g. lost output, increased NHS costs), this includes 'welfare' costs to individuals which do not directly impact GDP (e.g. delays to personal travel).

Estimating the impact of snow disruption requires myriad assumptions about the impact of disruption and how individuals respond. In many cases, hard evidence is unavailable so model parameters rely on analysts' judgement. To reflect the uncertainty, the model provides a range of estimates to demonstrate the impact of alternative assumptions. The central £280m daily welfare cost estimate could plausibly range between £100m and £520m. To put these figures in context, the welfare cost of road congestion on a 'normal' day is around £60m[48].

A breakdown of costs and main assumptions is shown in the next section. The central estimate assumes that ten per cent of each day's work is lost due to workers being unable to reach their workplace or work effectively from home. This scenario also assumes that half of this lost output is subsequently made up[49]. The estimates presented therefore represent the long-term cost of disruption.

A3. The impact of weather-related transport disruption on GDP

It is possible to identify a subset of the welfare costs above to assess the direct impact of disruption on GDP. DfT estimates this to be £130m per day in England, within a range of £40m to £260m.

[47] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/
[48] Based on calculations using the DfT National Transport Model
[49] In reality, some of the lost output may be made up immediately through a short-term increase in the productivity of those workers who are able to reach the workplace.

The GDP cost of eight days' serious disruption[50] in the central scenario is £1.0bn, or 0.3 per cent of quarterly GDP. This is slightly less than the ONS estimate that weather caused a 0.5 per cent contraction in fourth quarter GDP. There are two main differences between these estimates:

- the DfT figure estimates the impact of transport disruption only, and assumes that a proportion of the workforce is unable to reach its workplace. The overall impact on GDP may be greater if those workers who are able to reach work are unable to carry out their duties to the usual extent, for example due to safety concerns or frozen equipment;
- the DfT estimate assumes some of the output lost is made up in later periods, and so would be included in GDP data for subsequent quarters.

Daily costs of domestic transport disruption, England

Costs	**GDP costs, £m** *(indicative range in brackets)*	**Welfare costs, £m** *(indicative range in brackets)*
Reduced economic output from lost commuting and business/commuting journey time delays[51]	108 *(32 to 225)*	108 *(32 to 225)*
Lost output from working parents with dependent children not at school	9 *(5 to 14)*	9 *(5 to 14)*
Lost hospital appointments	3 *(1 to 6)*	3 *(1 to 6)*
Goods vehicle delays	2 *(1 to 4)*	2 *(1 to 4)*
Wastage on food and perishables	2 *(1 to 3)*	2 *(1 to 3)*
Road vehicle collisions	0 *(-3 to +3)*	0 *(-9 to +9)*
Pedestrian accidents	3 *(2 to 5)*	24 *(12 to 37)*
Lost journeys - personal travel		49 *(12 to 110)*
Journey time delays - personal travel		34 *(20 to 40)*
Pedestrian delays		43 *(22 to 65)*
Lost education		6 *(4 to 7)*
Total	**128** *(39 to 258)*	**280** *(101 to 518)*

[50] For the disruption cost analysis, DfT defined "serious disruption" as a day when at least ten per cent of trains were cancelled.
[51] In standard DfT appraisal commuting costs are not considered to have a direct impact on GDP. For the purposes of this analysis, it is assumed that unexpected commuting delays translate into lost output as workers arrive late at work, and/or leave early to ensure they are able to get home. The model makes a separate allowance for the proportion of lost output that is subsequently made up.

Main assumptions[52]

	Low estimate, %	Central estimate, %	High estimate, %
Proportion of work lost due to workers being unable to reach their workplace or work effectively from home	5	10	15
Proportion of lost output subsequently made up	75	50	25

A4. Impacts on international travel and trade

International travel and trade are not included in the model and estimates above. Assuming that half of air passengers rescheduled their journeys or travelled by alternative modes, around 650,000 trips (incoming and outgoing) were 'lost' during December 2010, of which around 150,000 were business trips. UK firms may have lost revenue as a result, though there is currently no basis for quantifying this. Some firms may have mitigated impacts, for example through video conferencing.

The UK runs a tourism deficit. The lost revenue from overseas visitors being unable to come to the UK, all else being equal, would have been outweighed by the effects of UK nationals being unable to holiday abroad and stranded passengers spending in the UK whilst unable to return home.

BAA and BA estimate their financial losses at £24m and £50m respectively. However, whilst many firms lost money during the disruption, others may have seen an increase in activity (e.g. airport hotels). The Civil Aviation Agency is taking forward work to understand more fully the impact of disruption on passengers, to help inform a decision on whether regulatory change is needed.

Further evidence of the cost of disruption to aviation comes from work completed after the Eyjafjallajokull volcanic ash cloud in 2010. DfT estimates that the closure of all UK airspace cost the airline industry and tour operators around £50m[53] per day. That figure does not include losses to the wider aviation industry or additional, offsetting, spending that may have occurred elsewhere.

Based on experience during the volcanic ash closures, the impact on trade from snow disruption to airfreight would have been minimal.

Extreme weather in late 2010 also disrupted activity at several significant maritime ports. Some ports became inaccessible due to blocked access roads. Several ports ran low on salt and were quoted extremely high prices for re-supply. The overall impact was to slow operations in ports and associated supply chains in affected areas. This imposed additional costs on operators, particularly through de-icing, snow clearance and employment of hauliers for longer hours. These costs might ultimately be passed on to consumers in the UK and overseas, though this effect is not expected to be significant.

[52] Assumptions based on analyst judgment

[53] Includes the cost to UK airlines and tour operators of care and accommodation for both UK nationals stranded abroad and foreign nationals stranded in the UK; and lost revenue for tour operators due to refunds and lost demand.

In summary, international impacts are even more difficult to quantify than domestic impacts. Short periods of disruption to international travel and trade are not likely to have a significant impact on national GDP, although can have large effects on individual operators and travellers.

ANNEX B: Calculations underpinning weather scenarios

Introduction

The three weather scenarios set out in Section 3 are based on Met Office data for 1961-2010. As discussed in the Met Office *Brief on the likelihood of severe winter weather over the next 20-30 years*[54], there are significant limitations in our ability to predict the likelihood of severe winters in future. In response, DfT has adopted a methodology similar to that used in the Quarmby Winter Resilience Review[55] (WRR) to develop three alternative, but plausible, scenarios based on realistic assumptions.

The scenarios are based on the average number of days of disruptive winter weather each year, for England as a whole[56]. The estimates have been calculated using Met Office data on days with lying snow and are for years running from July to June.

Some types of cold weather disruption occur even when there is no snow. However, there is a strong correlation between the number of days when the average daily temperature is below 2ºC and the number of days with snow lying. It was therefore decided that a measure based on the number of days with lying snow provided a sufficient indication of days when transport is likely to be disrupted.

Approach

1. The average number of days of lying snow is calculated using data for winters 1961-62 to 2009-10 to give a central estimate of the number of snow days each year. In any given year the number of snow days could vary significantly from this central estimate. For this reason, the average number of disrupted days across a different 50-year period may not be the same as the average for 1961 to 2010. To reflect this, mild and severe winter scenarios have been generated using the upper and lower bounds of the 95 per cent confidence interval around the central estimate. That is, for a 50-year period, we can be 95 per cent confident that the average number of snow days per year will lie within the range given by the confidence interval. The results are in column A of the table below.

2. Whilst these figures indicate the presence of snow, no minimum depth of snow is needed for a day to count as having lying snow in the Met Office figures. Some days with lying snow will not be days when there is transport disruption. To reflect this, it is assumed that a certain proportion of days with lying snow will result in disruption in each type of winter (column B in the table below). In a mild winter, 25 per cent of snow days are assumed to result in disruption; in a medium winter 50 per cent; and in a severe winter 75 per cent[57].

[54] Available at: http://www.dft.gov.uk/pgr/resilience/briefing/pdf/report.pdf
[55] The Resilience of England's Transport Systems in Winter: An independent review (October 2010), available at: http://transportwinterresilience.independent.gov.uk/
[56] A more sophisticated approach could use region-specific weather scenarios to inform the economic appraisal. However, this would significantly increase the computational complexity of this exercise and it was decided that a national average approach would be sufficient to provide the high-level conclusions this work seeks.
[57] The Winter Resilience Review assumed 50, 50 and 75 per cent of snow days to be disruptive in mild, medium and severe winters respectively.

3. A second adjustment takes into account that the daily impact of snow disruption may be less in more severe winters because individuals and firms become adept at adjusting their behaviour when snow is more frequent. This argument is put forward in the National Risk Assessment. The degree of disruption during the medium and severe scenarios is therefore assumed to be only 80 per cent of that suffered in the mild scenario (column C in the table)[58].

4. Applying these calculations suggests that, in the base case scenario, each part of the country can expect an average of five days of disruptive winter weather each year. This is an average across both time and space: in any year, some parts of the country will suffer more than five days disruption, and some will suffer less. However, since it is not possible to predict when and where the most disrupted years will occur, an average provides a reasonable basis for appraising resilience investment options.

5. In the mild scenario, each part of the country can expect an average of two days of disruptive winter weather each year, whilst in the severe scenario nine days of disruption can be expected.

Weather scenario calculations

	95% Confidence intervals based on days of lying snow per annum, 1961-62 to 2009-10 (A)	% of days with snow lying when there is transport disruption (B)	Overall impact on disruption assuming some recovery over longer spells (C)	Days of equivalent disruption (D = A*B*C)
Mild (lower)	8.8	0.25	1	**2**
Base case (average)	12	0.50	0.8	**5**
Severe (upper)	15.1	0.75	0.8	**9**

[58] Based on analyst judgement

ANNEX C: Benefit Cost Ratio calculations

Build domes to cover all remaining uncovered salt storage capacity

Item	Costs (nominal current prices)			Benefits		
	Low	Med.	High	Low	Med.	High
Single 10,000 tonne capacity dome (upfront costs)	£450,000	£800,000	£1,031,000			
Single Sheeting (40 year lifetime)		£30,000 per year				
Salt no longer wasted (total - over 40 year lifetime)					Rises from £1.8m in year 1 to £1.9m from year 8 onwards	

Assumption	Value	Source
Pre season salt price	£27 per tonne	Dome UK
Import salt price	£52 per tonne	Dome UK
Strategic stockpile salt price	£75 per tonne[59]	Dome UK
Average salt price 70:20:10 Pre-season: import: strategic stockpile	£37 per tonne	Dome UK
Loss through leaching and overspreading	37% per year (based on range of 24% to 50%)	Dome UK
Proportion of uncovered salt in England	20.7%	Halcrow Highway De-icing Salt Restock Report (Oct 2010)
Proportion of gritters that cannot deliver lower spread rates	13% (capacity phased in over eight years)	Halcrow Highway De-icing Salt Restock Report (Oct 2010)
No leakage or loss of covered salt Salt stores filled to capacity before the winter season begins Stock levels are the same each April No building regulation restrictions on building domes Capital costs for Domes assumed to be upfront One snow day in Halcrow report = one day of disruptive weather in DfT analysis Sheeting analysis assumes salt under the sheets must be uncovered for use each season Annual benefits over lifetime (dome and sheet) discounted at a rate of 3.5%[60] for 40 year lifetime Benefits vary across eight years because they are influenced by the age of the current gritter fleet, after this period it is assumed that all gritters have variable spread rate capability		

[59] The price per tonne of the strategic salt, if made available to local highway authorities to purchase if necessary, in 2011-12 is £65 per tonne excluding VAT for 6mm Salt to BS3247. This cost excludes haulage, the cost of which varies depending on location of delivery. Typical haulage costs are estimated to be around £10.00 per tonne.

[60] Consistent with HMT Green Book methodology

	Low	Med.	High
BCR (Domes)	1.6	2.1	3.6
BCR (Sheeting)	n/a	2.5	n/a

Gritter calibration and operator training

Item	Costs (nominal current prices)			Benefits		
	Low	Med.	High	Low	Med.	High
Calibrate 600 gritters		£180,000 p.a.				
Training for two operativees per local authority		£47,490 p.a.				
Salt saved					£7.1m - £8.2m p.a.	

Assumption	Value	Source
Cost of calibrating 600 gritters	£180,000	Transport Research Laboratory: Provision of Calibration for Winter Maintenance Fleet (Jan 2011)
Number of gritters in England Dec 2010	2,795	DVLA
Cost of training	£47,490	TRL quote: Winter Service Guidance Training (Jan 2011)
Number of precautionary salting runs per winter season	55	Norfolk County Council, winter 2009-10
Cost of salt	£37 per tonne	Dome UK
Average precautionary spread rate	14.1 grams per m^2	Halcrow Highway De-icing Salt Restock Report (Oct 2010)
Tonnes saved per precautionary run	4,035	Halcrow Highway De-icing Salt Restock Report (Oct 2010)
Possible spread rate	8 grams per m^2	National Winter Service Guidance Document (Nov 2010)
Appraisal period: 10 years (annual costs and benefits discounted at a rate of 3.5%)		

	Low	Med.	High
BCR	n/a	9.3	n/a

Regional groups of local authorities share salt storage facilities

Item	**Costs** (nominal current prices)			**Benefits**		
	Low	Med.	High	Low	Med.	High
Total salt purchase cost-savings				£411,654	£5,332,606	£48,998,692
Total additional staff costs to coordinate (illustrative)	£1,316,976	£3,950,928	£6,584,880			

Assumption	**Value**	**Source**
Pre-season salt price	£27 per tonne	Dome UK
Imported salt price	£52 per tonne	Dome UK
Strategic stockpile salt price	£75 per tonne[61]	Dome UK
Source of salt during shortages	1/3 from strategic stockpile, 2/3 from imports	Dome UK
Tonnes of salt and number of treatments required by local authority		Halcrow Highway De-icing Salt Restock Report (October 2010)
Staff cost per authority (153 authorities in total)	£1,000 - £5,000	DfT estimate
April salt stocks constant every year All salt shortages are met by local authorities pooling reserves with other authorities in their region Costs and Benefits calculated over 10 years and discounted at a rate of 3.5%.		

	Low	Med.	High
BCR	0.1	1.3	37.2

[61] The price per tonne of the strategic salt, if made available to local highway authorities to purchase if necessary, in 2011-12 is £65 per tonne excluding VAT for 6mm Salt to BS3247. This cost excludes haulage, the cost of which varies depending on location of delivery. Typical haulage costs are estimated to be around £10.00 per tonne.

Third rail heating and fitting de-icing equipment to trains

Item	Costs (nominal current prices)			Benefits		
	Low	Med.	High	Low	Med.	High
Implement third rail heating	£16m set up cost (upfront) + £0.7m p.a.	£20m set up cost (upfront) + £1.4m p.a.	£20m set up cost (upfront) + £2.7m p.a.	£2.7m p.a. in delay costs to Network Rail £3.1m p.a. in cancellation costs to Network Rail	£5.8m p.a. in delay costs to Network Rail £6.8m p.a. in cancellation costs to Network Rail	£11.1m p.a. in delay costs to Network Rail £12.9m p.a. in cancellation costs to Network Rail
Fit de-icing equipment to 20 trains	£3.9m set up cost (upfront) + £0.2m p.a	£3.9m set up cost (upfront) + £0.5m p.a.	£3.9m set up cost (upfront) + £1.0m p.a	£0.6m p.a.	£1.3m p.a.	£2.4m p.a.
Fit de-icing equipment to a further 30 trains	£4.7m set up cost (upfront) + £0.4m p.a	£4.7m set up cost (upfront) + £0.8m p.a.	£4.7m set up cost (upfront) + £1.5m p.a	£0.9m p.a.	£1.9m p.a.	£3.6m p.a.

Assumption	Value	Source
Total excess delay	165,000 minutes	Network Rail analysis
Effectiveness	85%	Network Rail data on Tonbridge to Hastings line
Average saving per minute	£41.60	Network Rail data on Kent, Sussex and Wessex.
Train cancellations	9,600 trains (low scenario) 21,000 trains 39,800 trains (high scenario)	Network Rail data on SouthEastern, Southern and South West Trains
Factor weighting for train cancellation benefits to allow for optimism bias	28%	Network rail analysis
Network Rail annual discount rate of 4.75% applied to annual costs and benefits over a 15 year timescale Operational expenditure scaled to weather scenarios		

	Low	Med.	High
BCR (third rail heating)	3.2	6.9	13.1
BCR (de-icing equipment on 20 trains)	1.7	3.7	7.0
BCR (de-icing equipment on further 30 trains)	2.1	4.6	8.8

Overhead Electrification of the third rail network

Item	**Costs** (nominal current prices)			**Benefits**		
	Low	Med.	High	Low	Med.	High
AC electrification	£2.2bn	£2.86bn	£3.08bn			
Converting train detection	£22m	£44m	£66m			
Train conversion	£240m	£300m	£360m			
Total savings[62]				£79m p.a	£150m p.a	£320m p.a

Assumption	**Value**	**Source**
Length of DC track	4400 km	Network rail analysis
Replacement cost	£650,000 / km	
Number of converted trains	600	
Cost per unit for conversion	£500,000	
Energy savings	0.24 Twh p.a.	
CO2 emission reductions	500,000 tonnes p.a.	
Difference in fatalities	8 people p.a.	
Track maintenance uplift	£5,000 / km	
Performance difference	£2,680 pfpi / km	
Capital costs are upfront Benefits are calculated for a 60 year time period and discounted at a rate of 3.5%.		

	Low	Med.	High
BCR	0.8	1.2	2.4

[62] Figures include energy, carbon emissions, track renewal, maintenance, reduced fatalities & performance.

Remote working

Item	Costs (nominal current prices)			Benefits		
	Low	Med.	High	Low	Med.	High
13% of non remote workers set up to work from home (DfT cost)		£479m (upfront)		£109m (discounted total)	£238m (discounted total)	£452m (discounted total)
13% of non remote workers set up to work from home (Becrypt costs)		£78m (upfront)		£109m (discounted total)	£238m (discounted total)	£452m (discounted total)

Assumption	Value	Source
Percentage with access to 2Mbps broadband	89%	BIS
Percentage of employees who could work from home	13%	2008 National Travel Survey, DfT
Proportion of those who work from home full-time	13%	UK Labour Force Survey, 2009
Proportion of those who work from home part-time	4%	UK Labour Force Survey, 2009
Average wage per day	£74	WebTAG
Proportion of people unable to get to work on a disrupted day	10%	WRR Economic Cost model
Cost of setting up 1 employee to work from home (based on DfT estimate)	£2000	DfT IT Services
Cost of setting up 1 employee to work from home (based on Becrypt estimate)	£325	Becrypt estimate (this could be lower if ordered in bulk)
Appraisal period: five years with discount rate of 3.5%		

	Low	Med.	High
BCR (employer provides equipment)	0.2	0.5	0.9
BCR (low-cost option)	1.4	3.1	5.8