ESTIMATING THE COST OF DISRUPTION TO TRAVEL CAUSED BY SEVERE WINTER WEATHER

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ABSTRACT

Scotland has suffered severe winters in recent years with December 2010 being the coldest since records began, highlighting the need for a better understanding of the economic welfare impact of the resulting disruption.

Impacts include: the lost output from people late for, or not getting to, work; freight vehicle disruption; individuals' own time lost; vehicle collisions; personal injuries; costs to social service providers and others.

With key data gaps, judgement has been employed, thus the average daily welfare cost of disruption is presented as a range between £10-57m with a central figure of £30m. The historical average number of days of severe disruption per year caused by snow is 11.1. Consequently, the average annual welfare cost to Scotland is approximately £330m in the core scenario within a range of £115-633m.

Transport Scotland responded proactively to the recent disruption by increasing investment in the trunk road winter service from £10 million to £14 million approximately. Additional gritters, increased salt stocks, greater use of technology and getting information to people 'on the move' are just a few of the ways we have strengthened the winter treatments, decision making and communication with road users to minimise disruption and the subsequent economic cost.

1. INTRODUCTION

The experience of severe winter weather in December 2010 highlighted the need to understand the impact on the transport system and associated costs of severe winter weather disruption. This paper provides an overview of the impact of the 2010 severe winter weather on the trunk road network[1], investigates the economic and social impacts associated with the disruption caused by severe winter weather, explores the response of Transport Scotland to the severe 2010 winter and illustrates the potential benefits of increased expenditure on winter resilience. Because it has not been possible to determine the marginal benefits of this extra expenditure in terms of reduced delays, a traditional cost-benefit analysis has not been possible, however, case studies have been presented. To derive the estimates in this paper, Scottish data has been applied to the UK Department for Transport Winter Resilience Review cost model.[2]

[1] The trunk road network is the responsibility of Scottish Ministers, and comprises all motorways and some of the main A roads.
[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/4557/an-assessment-of-the-case-for-additional-investment.pdf

2. ECONOMIC AND SOCIAL COSTS OF WINTER DISRUPTION

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

The effects of winter weather on the transport cover a wide spectrum – from the direct economic costs of lost output if people cannot get to work and of freight vehicle delays, to the personal time lost from travel delays and journeys not made at all, additional road vehicle collisions, the personal impact of slips, trips and falls, as well as the costs to the health service, hardship endured by those dependent on access by carers and service providers, and other categories.

Estimating the impact of snow disruption requires numerous assumptions about the impact of disruption and how individuals respond. In many cases, hard evidence is unavailable so model parameters rely on judgement. Results are therefore extremely uncertain. To reflect this, the model provides a range of estimates to demonstrate the impact of alternative assumptions.

This paper focuses on the costs of disruption to the road network and therefore the costs of delays to other modes have not been considered. Applying Scottish data to the WRR model results in an estimate of the average daily welfare cost of disruption caused by severe weather of £30m in Scotland (in 2010 prices), though this could plausibly range between £10m and £57m. To put these figures in context, the WRR estimate the average daily cost of severe weather disruption in England to be £275m.

Using Met Office data for snow days in Scotland for 1968-2010 an estimate of the average number of days of severe disruption per year caused by snow can be calculated. This calculation also takes into account the possibility of some recovery over long spells of disruption. The data provides a figure of 11.1 days of severe disruption per year. Consequently, the average annual welfare cost to Scotland is approximately £330m in the core scenario within a range of £115-633m, depending on whether conservative, central or aggressive assumptions are used. Examples of varying assumptions include length of delay per trip (taken to be 2, 4 or 6 minutes respectively on the road) and the number of pedestrian slips per day (taken to be 25, 50 or 75).

It should be noted that much of the analysis presented in this paper depends on the accuracy of the predicted number of snow days per year in Scotland. A Met Office briefing on the likelihood of severe winter weather over the next 20-30 years highlights that the latest available regional climate projections for the UK indicate a reducing likelihood of severe winters in future, due to the long-term warming climate. Natural climate variability implies that severe events remain possible but with reduced likelihood. Therefore the average annual welfare cost to Scotland of severe weather may be expected to fall in the future. It could, thus, be argued that with a gradually warming climate, and figure of 11.1 days of severe disruption per year is too high going forward. The Table below illustrates the impact on the result if we were to calculate the number of snow days based on more recent data only.

Table 1 - Sensitivity Analysis, Snow Day Estimate

		Average Annual Welfare Cost to Scotland	
Years Snow Data	**Number of Snow Days**	**Range (£)**	**Central Estimate (£m)**
1968-2010	11.1	£115m - £633m	£330
1981-2010	6.6	£65m - £374m	£195m
1991-2010	3.8	£35m - £217m	£112m

A breakdown of the costs and main assumptions are in the Annex. The central scenario 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. The estimates presented therefore represent the long term cost of disruption.

2.2. The impact of winter-related transport disruption on Gross Domestic Product (GDP)

The resulted outlined in the section above reflect the welfare cost of travel disruption. A subset of this provides the direct impact of disruption on GDP. This is estimated to be £15m per day in Scotland, within a range of £4m to £31m. Therefore, the GDP cost of fourteen days disruption, i.e. the 2010 winter, in the central scenario is approximately £210m.

It should be noted that the cost to commuters is regarded as a GDP cost in this analysis, as it is assumed that the cost of unforeseen commuting delays are a cost to the employer time.

2.3. Other areas of potential costs

Although the WRR model does attempt to take into account a wide range of impacts, there are potential additional costs that have not been quantified within this analysis. These are provided below:

- Lost education;
- Damage to highway and damage to cars through increased number of potholes;
- International travel and trade;
- Carbon dioxide impact and operating costs of driving – fewer vehicles but longer slower journeys;
- Changes in fuel use at home, work, school etc.;
- Effects of mode shift, change of destination etc.;
- Costs of additional breakdowns, recovery, parking tickets; and
- Any costs associated with investment, e.g. environmental impact of salt spreading.

3. BENEFITS OF INCREASED EXPENDITURE ON WINTER RESILIENCE

The WRR's economic model also provides an approach to assessing whether it is worthwhile to increase expenditure on winter resilience. This section provides the results from that model when combined with the Scottish context and data.

There is assumed to currently be an annual spend of approximately £120m – a combination of circa £110m spent by Local Authorities and £10m spent by Transport Scotland. A nominal increase of 50% in the expenditure on winter resilience on the trunk and local road network – i.e. increasing the amount spent on winter maintenance by approximately £60m per annum to £180m per annum – has been assumed.

The results are heavily dependent on the assumptions made and are different depending on the assumed impact of the winter weather. Conservative, central and aggressive assumptions were made concerning a number of key inputs in this model, primarily on what proportion of winter weather related disruption could be avoided by investment (20%, 25% and 30% for the conservative, central and aggressive estimates respectively), but also in terms of factors such as the length of delays caused by winter disruption (2, 4 or 6 minutes averaged across all trips depending on the estimate). Therefore, a range for the estimated benefits from the increased expenditure has been provided. Winter has been assumed to consist of 11.1 days of severe disruption, as calculated using Met Office data in section 3.1.

Table 2 - Estimated benefits from £60 million increase in expenditure on winter resilience and maintenance

	Range	Central Estimate
Hard benefit	£8m - £95m	£38m
Welfare benefit	£6m - £70m	£31m
Total benefit	£15m - £165m	£70m

NB Totals may not sum due to rounding.

As can be seen from the results, the benefits could significantly outweigh the costs. However, the analysis also illustrates that depending on the impact of the increased expenditure, the benefits may not be high enough to cover the costs.

Wider evidence reinforces the notion that increased expenditure on winter resilience and maintenance could be worthwhile. A study by Dr John E. Thornes [4] into the cost-benefit of winter road maintenance in the UK in 1996 found that for every £1 currently spent on winter maintenance, £9 are saved, and that for every £1 spent on road weather forecasts, £100 are saved. Further to this, a study in Sweden [3] where there they typically have harsher winters than in the UK, concluded that there is a benefits to cost ratio of current winter resilience of approximately 20 – for every £1 spent £20 are saved.

Again, much of this analysis is based on the estimate of 11.1 snow days per year. The following Table shows the impact on the results if a more conservative approach was taken.

Table 3 - Sensitivity Analysis, Snow Days Estimate

		Total Benefits of £60m Investment	
Years Snow Data	**Number of Snow Days**	**Range (£)**	**Central Estimate (£m)**
1968-2010	11.1	£15m - £165m	£70m
1981-2010	6.6	£6m - £99m	£40m
1991-2010	3.8	£1m - £59m	£23m

4. EXPERIENCE OF THE 2010 WINTER

From late November to 26 December 2010 the UK experienced two spells of severe winter weather with very low temperatures and significant snowfalls, causing widespread interruption throughout Scotland. The emergency services, local authorities and utilities were all put under great pressure. Schools were also closed and hospital admissions increased markedly with accidents and falls. Many people were unable to get into work. The freezing temperatures also caused problems with water supplies.

Most of these were knock-on impacts from the disruption caused to the transport network, with the then Scottish Transport Minister, Stewart Stevenson, describing the period as “the worst snow and ice conditions in the early winter since the 1960s” and, indeed, the Minister subsequently resigned in the political aftermath of the disruption. Flights were suspended for a period at Edinburgh and Glasgow airports, while many bus and rail services were disrupted, but arguably the biggest impact was on the road network.

The impact of the first spell of snow and freezing conditions on the trunk road network in Scotland is shown in figure 1 below. The figure shows the daily average total vehicle flows for 2009 and 2010, with the 2010 traffic flows prior to the snow disruption broadly consistent with 2009 traffic levels. However, the average daily weekday flow in week 1 of the disruption was 41% down on the 2009 traffic flows while week 2 flows were 36% down.

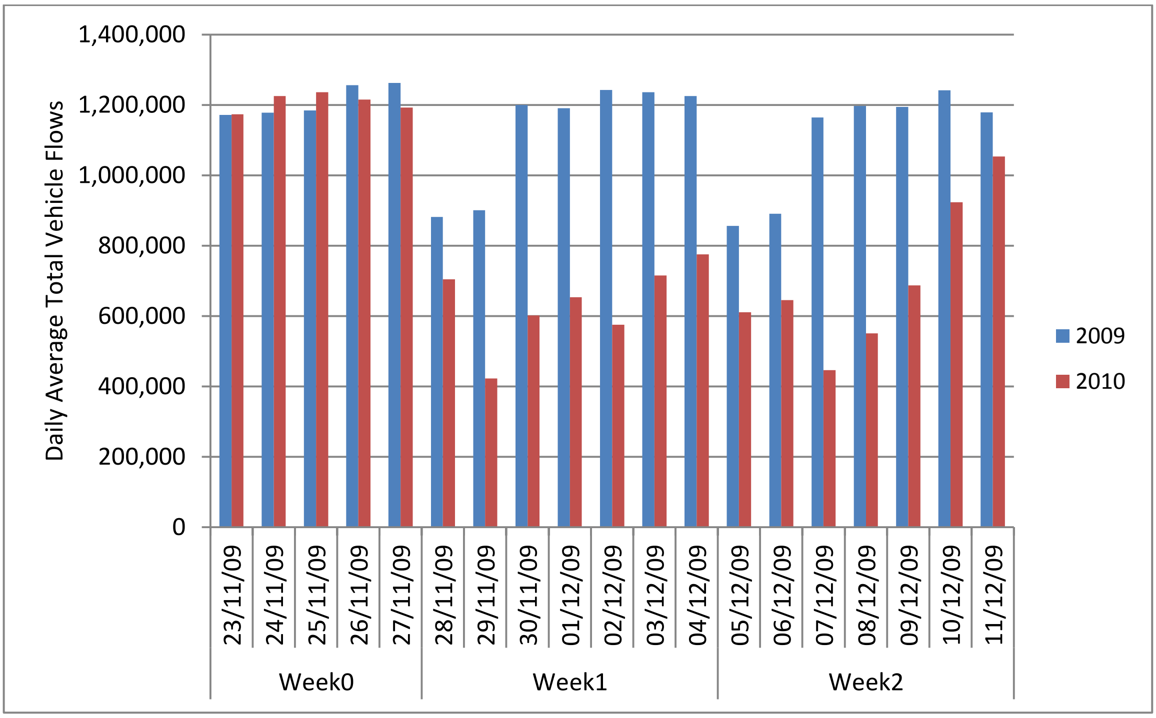

Figure 1 – Scottish Road Traffic Database (SRTDb) Daily Average Total Vehicle Flows

The worst weather during this period arrived on Monday 6th December leading to the closure of several of Scotland's motorways, including a 20 mile stretch of the M8, linking Glasgow and Edinburgh, which was closed westbound from 1400 GMT on the Monday to 1300 GMT on Wednesday 8th December. Figure 2 shows the monthly average daily traffic flow on the M8 between 2007 and 2013 and a significant drop in traffic can be seen in December 2010, with 19,158 vehicles travelling westbound per day as compared to 25,446 in December 2009 and 23,844 in December 2011. In addition to the significant drop in traffic the heavy snowfall saw hundreds of people sleep in their cars or abandon them on the highway on Monday 6th as the motorways and roads clogged up.

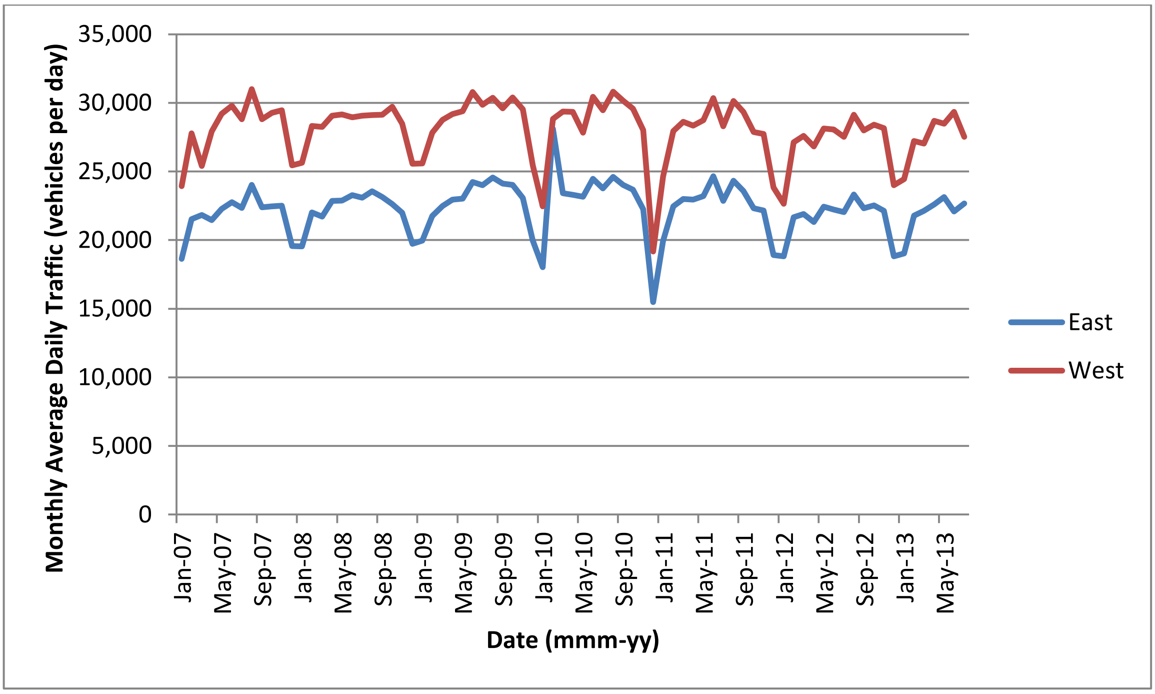

Figure 2 - Monthly Average Daily Traffic Flows on the M8, 2007-2013

A total of fourteen days of serious disruption in December 2010 as a result of winter weather implies a total welfare cost to Scotland of £420m in the core scenario.

5. TRANSPORT SCOTLAND'S RESPONSE

Following the challenging conditions experienced in December 2010 Transport Scotland set out a programme to make its winter service more resilient. Three key areas of influence supporting the winter resilience were identified as Winter Treatments, Decision Making and Communication with Road Users.

5.1. Winter Treatment

Although no road authority can guarantee to keep roads free from ice or snow, Transport Scotland have been proactive in planning and investing in our Winter Treatments, as shown by the following additional measures which have been employed:

- 23 additional patrol gritters – a 14% increase from the start of the 2010-11 winter
- All motorways are now covered by Winter Patrols giving a 30 minute (maximum) response to winter incidents. Previously, patrols had a 1 hour response time to mobilise and commence operations, and a 2 hour target for completion.
- Specialist plant, such as Raiko-Icebreakers (specialist equipment which can be fitted to vehicles allowing them to cut through problematic sheet ice and dense snow) and new footway snow blowers, are just two examples of innovative solutions which have been introduced. Inverted V-ploughs were also introduced to assist in the clearance of turning lanes and cross-overs on dual carriageways.
- For treatments in extreme cold, Transport Scotland developed guidance on the use of alternative de-icers that work at temperatures below which road salt (sodium chloride) becomes less effective.
- Vulnerable locations were identified where the road gradient can make it difficult for HGVs and other vehicles to make progress in wintry conditions. The Operating Companies have evaluated the most vulnerable locations within their unit and their

Winter Service Plans will specify the various measures they will employ when severe weather is forecast. The measures include additional salt applications during precautionary treatments, special attention during winter patrols, pre-positioning snow plough vehicles in advance of snow storms and enhanced arrangements for recovery vehicles.

5.2. Decision Making

To improve decision making and responses by those managing the winter treatments Transport Scotland has also invested in more technology, such as new weather stations, and are able to monitor in real-time the temperature and location of each patrol gritter. Collectively the enhancements have given the winter managers better information with which to make crucial decisions.

5.3. Communication with Road Users

One of the major lessons learned from winter 2010-11 was that information to the travelling public needs to be clearer and more specific about the risks of travelling in severe weather. Transport Scotland's Traffic Scotland Information Service has now strengthened the provision of information 'on the move''. The approach is to get information to the user on a device which they have with them.

5.4. Winter Service Patrols Case Study

The benefits of the Winter Patrols mentioned in Section 5.1 can be illustrated by considering the following case study. The Operating Company's contract states that there is a maximum 30 minute response time of Winter Service Patrols. Previously, reactive treatment of roads had 1 hour to mobilise and commence such snow and ice clearance, precautionary treatment and other de-icing operations with 2 hours to complete. The Winter Service Patrols are designed so as to be able to reach any part of the route within 30 minutes, and so it is reasonably assumed that the new Patrols lead to a typical response time improvement of 60 minutes.

The following analysis (in Table 4) illustrates the potential benefits of these improved services, in terms of the cost saving of avoiding an hour's delay in the morning peak across Scotland's Motorway and Trunk Road Network. From the total daily welfare cost of domestic transport disruption (Annex, Table 7), we can estimate that the benefit of avoiding 1 hour's delay across the network is £1.12m.

Table 4 - Impact of 1 Hour Delay Across entire Motorway and Trunk Road Network

Total Daily Welfare Cost of Domestic Transport Disruption (central estimate) (£m)	Proportion of Total Traffic on Motorways and Trunk A Roads (2011)	Total Morning Peak Hour Travel as a Proportion of Daily Traffic	Peak Hour Transport Disruption Caused by Severe Winter Weather (£m)
29.7	38%	10%	1.12

While it is not possible to assess the marginal impacts of the Winter Patrols and the improved response times, it is arguable that the investment in Winter Patrols can potentially achieve significant benefits.

Much of the work carried out by the Winter Patrols is pre-emptive, in that they treat the roads in advance of problematic weather conditions in order to mitigate any adverse impacts on the road network. This benefit is difficult to place an economic value on, however we can observe the specific reactive benefits of the Patrols on a scenario by scenario basis. 3 points were chosen on Scotland's Category A Roads (i.e. the roads which are serviced by the Winter Patrols – see Annex, Figure 3), and estimates made of the value of time benefits for reactive treatment preventing 1 hour worth of delay at that point on the road in the morning peak in order to illustrate the potential benefits of this service. In Table 5 below, Point 1 represents a point with high traffic flow, Point 2 a middling traffic flow, and Point 3 with a low traffic flow, relative to other points on the network of Scottish Category A roads.

Table 5 - Benefits

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

As we can see from the Table, a single incident of reactive treatment from the Winter Patrols in the morning peak, which is expected to prevent approximately 1 hour of delays, can have value of time benefits ranging between roughly £140,000 and £20,000. The estimates of hours saved by avoiding an hour's delay were made using our national transport model, Transport Model for Scotland (TMfS), which offers a generalised multi-modal representation of travel demands and infrastructure supply for a base (2007) and future forecast years. It should be noted that a limitation of this approach is that since the base year is 2007, any improvement in infrastructure since then (which may for example increase travel option in a way which cuts delays as a result of winter weather) will not be accounted for in the results.

The analysis in Table 5 is based on an entirely different methodology to that in Table 4. These results are based upon the assumption that alternative routes are open and completely unaffected by the adverse weather causing the delay – it is highly possible that this will not be the case. Additionally, the benefits of preventing a 1 hour delay in Table 5 are solely those of avoiding journey delays for travellers – the impact of the winter disruption on lost output, accidents etc. are not taken into account here, nor does this analysis include any benefits from pre-emptive work carried out by the Patrols to prevent winter disruption. As a result of this, these figures represent a highly conservative estimation of the benefits of the Winter Patrols.

To give a degree of context to these benefits, Table 6 below shows the approximate total spending on improved Winter Patrols, as well as the number of patrols, and the average cost per patrol in the South East unit of Scotland. It is crucial to note here that the benefits outlined previously in this section do not relate to these costs directly – a cost benefit analysis is not possible here as evidence about the marginal improvement in delays brought about by the additional investment is not available. The costs per incident and patrol in Table 6 are presented to give context, and should not be held relative to the cost of preventing an hour's delay given in Table 5.

Table 6 - Cost of Winter Patrols

Cost of Additional Winter Patrols, 2012-13, South East Unit	Number of Patrols	Cost per Patrol	Number of Winter Patrol Incidents, South East Unit, 2012-13	Cost Per Incident
£800,000	7	£115,000	234	£3,500

NEXT STEPS / CONCLUSIONS

Overall, it can be seen that the economic and social costs associated with winter disruption are high, with the average annual welfare cost to Scotland estimated at approximately £330 million. The analysis has also highlighted the potential positive net benefits from increased expenditure on specific well targeted and managed measures to reduce disruption. Additionally, analysis suggests that improved winter patrols as a result of increased winter resilience spending offer benefits in terms of value of time saved. However, caution must be taken with the results presented as they are highly dependent on the assumptions. This suggests further evidence and analysis would be required to support a generic case for increasing expenditure on winter resilience.

REFERENCES

1. Winter Resilience Review – Final Report, Economic Analysis spreadsheet

2. Met Office – Snow and Low Temperatures, December 2010 http://www.metoffice.gov.uk/climate/uk/interesting/dec2010

3. Murphy, A., (1995) "Research Report for Swedish National Roads Authority"

4. Thornes, Dr John E., (1996) "The Cost-Benefit of inter Road Maintenance in the United Kingdom"

ANNEX

Table 7 - Daily costs of domestic transport disruption, Scotland, 2010 prices

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	13.0 *(3.6 to 27.3)*	13.0 *(3.6 to 27.3)*
Lost output from working parents with dependent children not at school	0.4 *(0.1 to 1.0)*	0.4 *(0.1 to 1.0)*
Lost hospital appointments	0.1 *(0.0 to 0.2)*	0.1 *(0.0 to 0.2)*
Goods vehicle delays	1.1 *(0.5 to 1.6)*	1.1 *(0.5 to 1.6)*
Wastage on food and perishables	0.2 *(0.1 to 0.3)*	0.2 *(0.1 to 0.3)*
Road vehicle collisions	0.0 *(-0.2 to +0.1)*	0.0 *(-0.5 to +0.5)*
Pedestrian accidents	0.3 *(0.2 to 0.5)*	2.4 *(1.2 to 3.7)*
Lost journeys - personal travel		4.6 *(1.1 to 10.9)*
Journey time delays - personal travel		3.2 *(1.9 to 4.0)*
Pedestrian delays		4.7 *(2.2 to 7.3)*
Total	**15.1** *(4.4 to 31.1)*	**29.7** *(10.3 to 56.8)*

Table 8 - Main assumptions made

	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

Note: Assumptions based on analyst judgment

Figure 3 – Scottish Trunk Road Winter Patrols

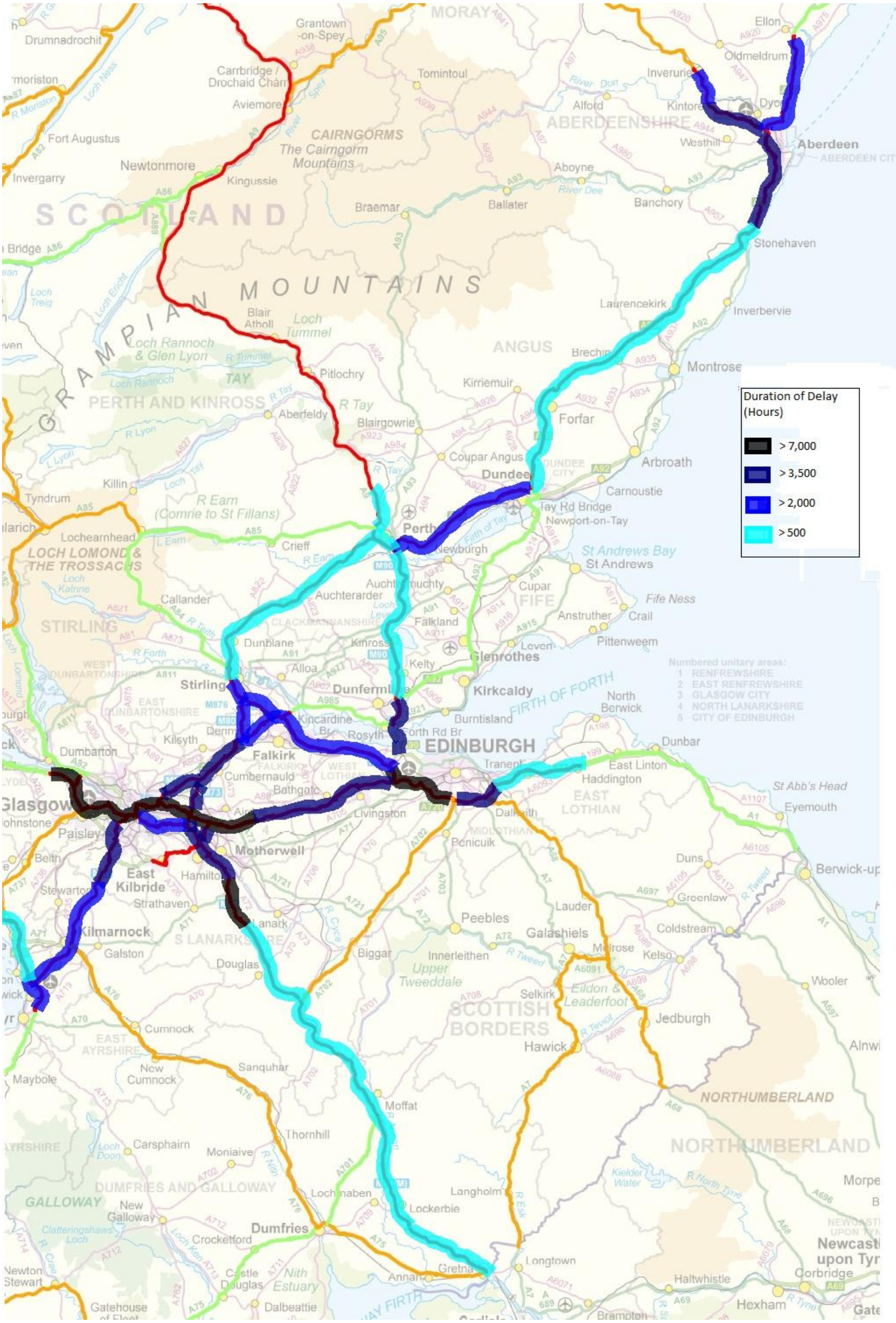

Figure 4 -Time impact on travellers of 1 hours delay in the morning peak