Climate change and winter road maintenance: Will complacency be the new killer?

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Abstract

Winter weather can be a significant cause of road traffic accidents. This paper uses UKCIP climate change scenarios and a temporal analogue to investigate the relationship between temperature and severe road accidents in the West Midlands, UK. This approach also allows quantification of the changes in the severity of the winter season over the next century in the region. It is demonstrated that the predicted reduction in the number of frost days should in turn reduce the number of road accidents caused due to slipperiness by approximately 50%. However, the paper concludes by warning against complacency in winter maintenance regimes. A warmer climate may result in budget cuts for highway maintenance which in turn may well reverse long term declining accident trends.

1. Introduction

The British government has a continuing aim to reduce the number of casualties on UK roads by 40% in the year 2010 compared with the average for 1994-98 (Department for Transport, 2009: http://www.dft.gov.uk). There have been numerous studies into the influence of weather conditions as a cause of traffic accidents (e.g. Palutikof, 1991; Edwards, 1996). However, precipitation, and associated poor visibility, is the main cause of many weather related incidents (Koetse & Rietveld, 2009) and is a problem which becomes particularly acute in winter (Fridström et al., 1995). Indeed, there is often a pronounced peak in accidents in the month of December (Asano & Hirasawa, 2003), where the problems of winter weather are compounded with reduced daylight hours. In colder climates, the risk of an accident increases if the precipitation is falling as snow (Andreescu & Frost, 1998). Andrey & Olley (1990) found that 40% of the total number of winter accidents occurred on roads with ice/snow or rain. In particular, Norrman et al. (2000) identified that the largest amount of accidents occurred when snow was falling on a frozen road surface. However, these relationships are not universal. Some countries are well prepared for winter weather and the onset of snow can actually mean a decrease in the number of accidents (Fridström et al., 1995) or at the very least, the severity of incidents (Koetse & Rietveld, 2009). Drivers respond to the conditions by restricting travel to essential journeys (Smith, 1982) and by driving more slowly (Hassan & Barker, 1999). For example, Kilpeläinen & Summala (2007) showed that average traffic flow speed reduced by 6.7% in bad weather. Similarly, in wet and slushy conditions, speed reductions can be as high as 25% (Martin et al, 2000 cited in Koetse & Rietveld, 2009). However, there is always the danger that whilst motorists modify their driving to compensate for conditions today, the motorists of the future may grow complacent and lack the skills to cope with extreme events which will still occur, even in a milder climate (Andersson & Chapman, 2010).

Compared to other countries across Northern Europe, the UK does not have a particularly snowy climate, but the appearance of snow is often the cause of traffic chaos (e.g. Thornes, 2005; London Assembly, 2009). To some extent, this represents a further example of complacency in the winter maintenance regime. Although a duty of care exists to protect the motorist (as per section 42 of the UK Railways and Transport Safety Act, 2003), it is clearly not reasonable for every responsible party to maintain a stockpile of specialist equipment to deal with snowy conditions which may only occur once or twice per annum. Instead, the problem which is the focus of attention in the UK is the formation of ice on roads. On many winter nights, the forecast is straightforward and the roads are treated if necessary. However, marginal nights, where temperatures are close to freezing, are more problematic. This paper studies traffic accidents across the West Midlands during the winter months December to February with the aim of applying UKCIP (UK Climate Impacts Programme) climate change scenarios to determine how the number of days requiring winter road maintenance may change in the future and how this subsequently may affect road traffic accident statistics. The overall aim is to identify if a mild winters recently experienced could be used as a temporal analogue for future change. Furthermore, there may be some potential to use the UK as a spatial analogue for climate change for more northerly countries in Europe.

2. Methodology

2.1 Area of study and Accident Data

The focus of this study is the county of the West Midlands (Figure 1) which is the second largest conurbation in the UK. This study makes use of weather data obtained from the World Meteorological Organisation weather station located centrally in the region at Elmdon (Birmingham Airport).

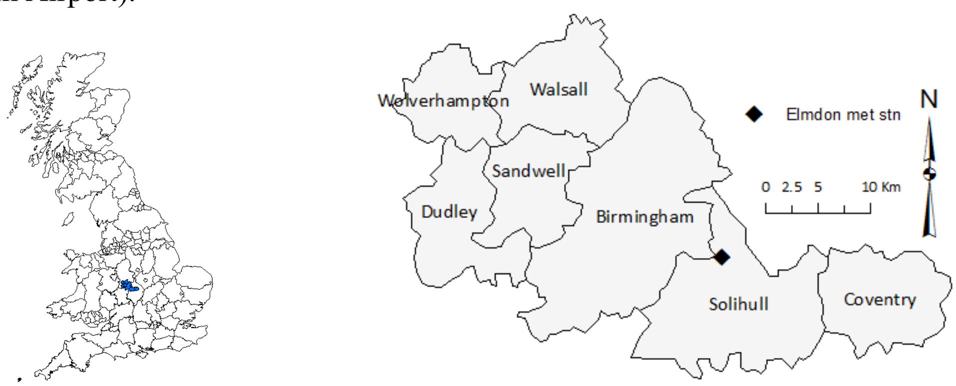

Figure 1. Area of interest, Showing the location of the West Midlands and Elmdon weather station.

In the UK, the recording of the weather as a factor in road accidents has been undertaken on police accident report forms (STATS-19) since 1969. All road accidents which involve a fatality or personal injury are recorded on the form, which is filled in at the site of the accident by an attending police officer. However, 'damage-only' or 'minor injury' accidents are not recorded. This means that true accident data are likely to be under-reported. Furthermore, although weather conditions are recorded in the database, it is important to appreciate that road accidents are caused by a combination of factors and that weather may not be the principal cause.

In this analysis, STATS-19 data was extracted for the region of study for two consecutive winters, DJF 2004-2005 and DJF 2005-2006. DJF 2004-2005 was chosen as this was an unusually warm winter with mean temperatures of 1.3°C above the 1961-1990 baseline. As a result, it may represent a temporal analogue of future weather conditions. For comparison, DJF 2005-2006 was selected for analysis as this was more an 'average' year being marginally warmer than the baseline conditions. Consecutive years were chosen so as to remove the impact of long-term trends on the accident data, for example, increasing traffic numbers or improvements in technology such as anti-lock brakes (Edwards, 1996).

In the West Midlands, there were 2204 traffic accidents in DJF 2004-2005 (although only 2102 had a full record suitable for analysis). In DJF 2005-2006 the amount of accidents was similar totalling 2081 (2070 with a full record). These accidents are cumulatively plotted in Figure 2 against the air temperature value measured at Elmdon when the accident occurred. Surprisingly, considering the difference in average temperature recorded in each of the two seasons, the total number of accidents in each of the years is very similar. A small difference can be identified with a greater percentage of accidents occurring below the 0°C threshold in DJF 2005-2006. In terms of winter maintenance, 0°C is a critical threshold as ice is most slippery when in a semi-frozen state (Moore, 1975). However, this is based on road temperature and not air temperature. Although the two are related, there is no rule of thumb to translate between the two. It is not unusual for RST to be several degrees below air temperature (Bogren & Gustavsson, 1991), but this is very much dependent on the local geography (Chapman et al, 2001). For example road surface temperatures during a clear and calm evening change more rapidly in valleys and depressions than at more exposed locations (Gustavsson et al., 1998). In Figure 2, the accident rate peaks at air temperatures around 4-6°C (therefore, road temperatures could theoretically be below freezing). For this reason, this study will use both 0°C and 5°C as thresholds.

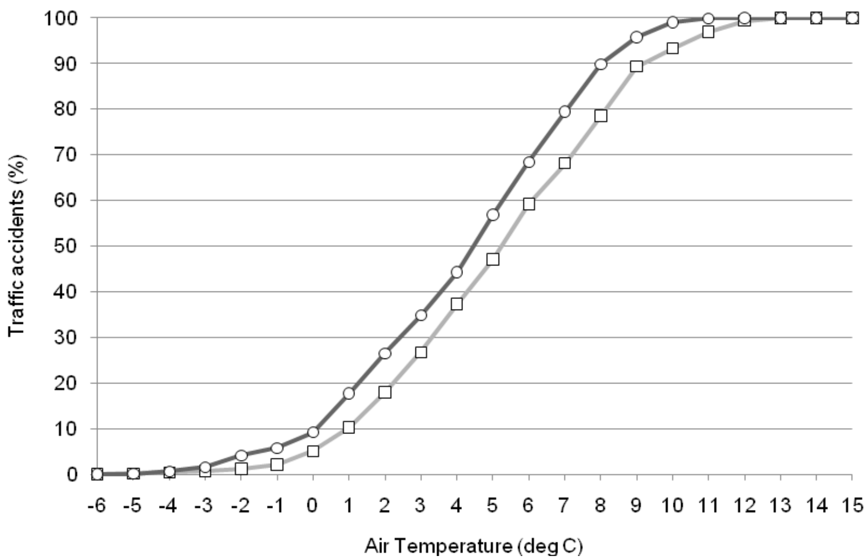

Figure 2. Cunmulative percentage plot of road accidents in the West Midlands. December to February 2004-2005 & 2005-2006, ℘ 2004-2005 Ta } 2005-2006 Ta.

2.2 Scenario Data

The climate change scenario data used in this study is taken from the UK Climate Impacts Programme (UKCIP). UKCIP co-ordinate the UK based climate change prediction models derived from the Intergovernmental Panel on Climate Change (IPCC). 2009 saw the launch of the UKCP09 probabilistic scenarios summarising the latest information on current and projected climate change. UKCP09 is based around three IPCC CO_2 emission scenarios, namely A1FI (High); A1B (Medium) and B1 (Low). It is also subdivided into several future scenario periods although the most commonly used are the 30-year periods centred on the decades 2020s (i.e. 2011-2040), 2050s (2041-2070) and 2080s (2071-2100) (Hulme et al., 2002). Figure 3 shows example output from UKCP09 detailing the change in temperature of the coldest night for a range of scenarios. All scenarios demonstrate a general warming trend indicating a reduced need for winter road maintenance in the future. Indeed, based on this evidence, it can be concluded that noticeable warming will occur over the next decade and that the winter DJF 2004-2005 may well represent a temporal analogue of the situation to be encountered in the 2020's.

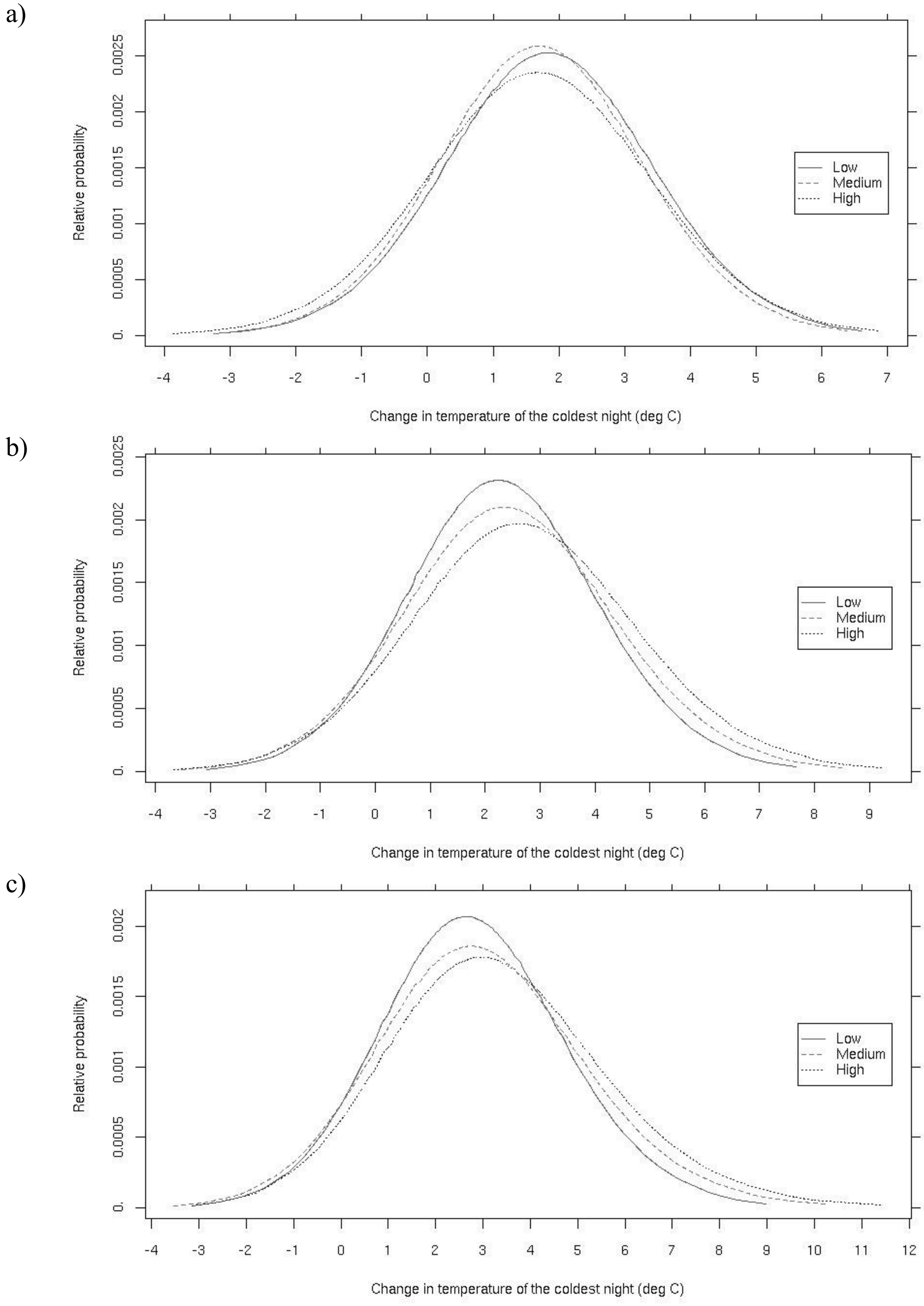

Figure 3. Change in temperature of the coldest night from UKCP09 climate change predictions for a) 2020's b) 2050's and c) 2080's.

2.3 Weather Generators

Weather generators have recently been adapted to account for climate change scenarios (e.g. Semenov & Barrow, 1997). Before the launch of the UKCP09 scenarios, weather generators were needed to produce probabilistic output. The increased information available from UKCP09 now means that the use of a weather generator is not necessary for many studies, but the functionality has been included to allow for studies at a daily time-scale. However, at the time of writing, the UKCP09 and associated threshold detector was still in development and hence for the purpose of the study, EARWIG (Environment Agency Rainfall and Weather Impacts Generator), which is based on the earlier UKCIP02 scenarios is used. EARWIG uses observed baseline (1961-2000) weather data from the UK Meteorological Office to produce daily weather records which can then be used to generate probability distributions. EARWIG uses two stochastic models, first a simulation of rainfall that is used in the second model that is generating the other variables that is depending on rainfall. Although EARWIG was originally developed for use in the climate impact assessments of agricultural and water system management (see Kilsby et al., 2007 for a full description of the model and application), it has since been used in other climate change impact assessments. For example, Dobney et al (2009) used the technique to study the impact of climate change on railway buckling in the southeast UK. In this study, EARWIG was used to calculate temperature distributions for the baseline scenario and also for the three future time slices, 2020, 2050 and 2080. In the interests of conciseness, only the most probable UKCIP02 medium-high emission scenario derived from the IPCC SRES A2 storyline is used (Hulme et al., 2002).

3. Results

3.1 Future climate scenarios

Using EARWIG, the percentage of days per month with air temperatures equal or below the two thresholds of 0°C and 5°C were calculated. As expected, in line with the UKCP09 scenarios, there is a general trend of increasing temperatures over time. This in turn translates into a decrease in the number of frost days and length of the winter season. At the moment, 40 frost days can be expected in the region, but this is predicted to shorten to 21 by 2080. A similar trend can also be seen using the upper threshold of 5°C. The frequency of each minimum temperature over the course of a year is summarised in Figure 4.

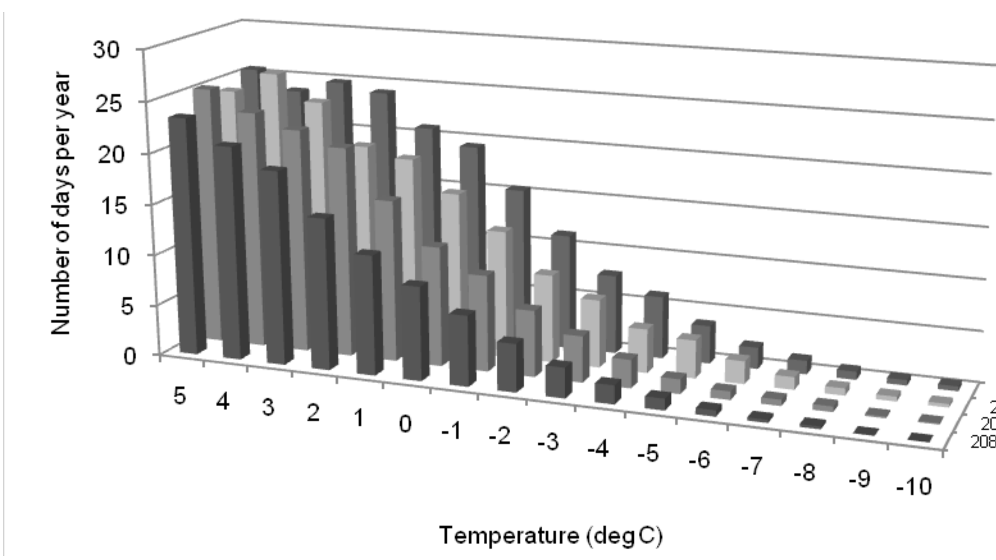

Figure 4. Number of days per year for each temperature degree ℜ 2080 ℜ 2050 ℜ 2020 ℜ BL

3.2 Future traffic accidents

In order to investigate how future accident numbers will change under the various climate scenarios, a simple relationship between the climate at Elmdon (DJF 2005-2006) and baseline accidents (DJF 2005-2006) was derived based on the ratio:

Number of accidents: Number of days per annum at the studied minimum. (1)

The result is produced for each temperature degree interval which can then be applied to the future climate scenarios to predict future accident numbers (Figure 5). Using this methodology, 2039 accidents would be predicted for the temporal analogue year DJF 2004-2005 which is close to the 2102 total recorded in the STATS-19 database.

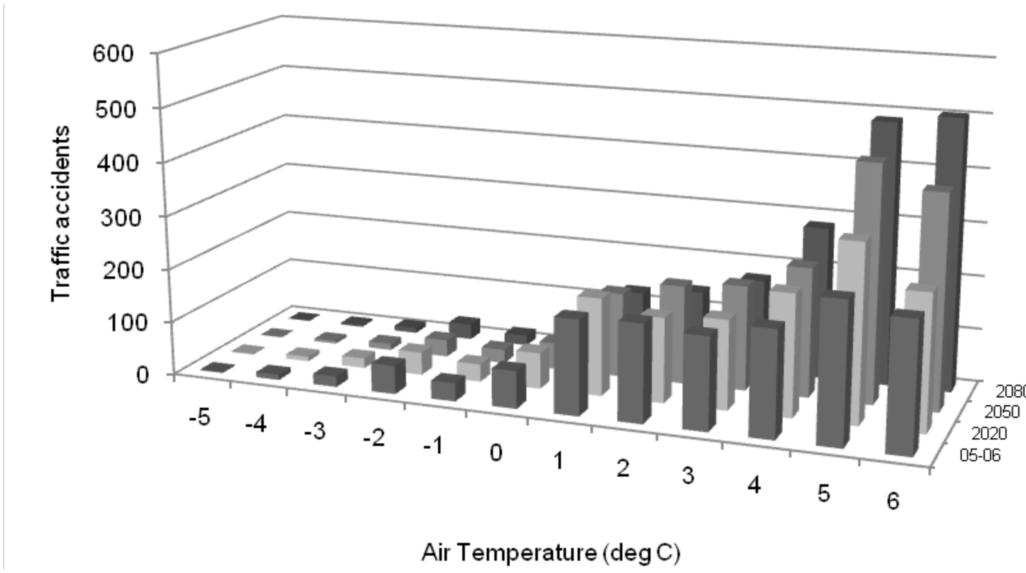

Figure 5. Amount of accidents in December to February for each temperature degree for actual amount of accidents and for three future scenarios ℜ 2005-2006 ℜ 2020 ℜ 2050 ℜ 2080

Based on this analysis, the reduction in the number of days below the 5°C threshold chosen to represent marginal nights will lead to a reduction in the number of traffic accidents that otherwise might have been caused by slippery winter roads. However, care must be taken when performing a projection of this nature as a major assumption is being made that the rate of accidents will remain constant over time. This is highly unlikely as improvements in vehicle technology and road safety are highly likely to continue to reduce accident numbers (Edwards, 1996). Indeed, to take this into account requires a far more sophisticated climate change impacts analysis (e.g. Jaroszweski et al, 2009). Furthermore, the projections made in this paper are highly subjective due to the uncertainty surrounding STATS-19 data and the climate models used by UKCIP. For these reasons, the 50% reduction in the total number of accidents by 2080 predicted in this paper is more than likely a conservative estimate.

4. Discussion

This study has identified that under UKCIP climate change scenarios there will be a significant change to the winters experienced in the West Midlands. Low freezing temperatures will become far less common and the winter season will be shorter. Using the methodology in this paper, it is hypothesised that this will in turn result in reduced numbers of road traffic accidents and also, in theory, the cost of winter maintenance.

Each year, the UK spends £482m on the winter road maintenance of the primary road network, plus a further £1069m on local roads (Department for Transport, 2009: http://www.dft.gov.uk). Approximately 30% of the road network in UK is treated on a regular basis (Handa et al., 2006), which in an average winter uses approximately 2 million tonnes of rock salt. The seven unitary authorities which comprise the West Midlands treat over 3700km on a night by night basis which equates to a total of 270 tonnes per treatment. Hence, based upon the analysis in this paper, a significant saving could be made on salting operations in the West Midlands by 2080.

However, in an environment of continual cost cutting, there could be a temptation to further increase these savings by vastly reducing winter maintenance budgets. If freezing temperatures are rarely experienced in the future, it may not be appropriate to operate a winter maintenance service (at least not at the level accustomed to). This complacency is already seen in the UK with snow related problems (e.g. Thornes, 2005; London Assembly, 2009), and the danger is that a similar situation will eventually occur with icy roads. As this paper has shown, it is not the coldest of nights which cause the problems (<0°C), it is the marginal nights (<5°C). Indeed, the number of marginal nights will not change significantly over the next century. In DJF 2005-2006 there were 82 marginal nights with a minimum temperature of 5°C or under. By 2080 this reduces to 65, but still means that a winter maintenance service will be required to secure the roads and reduce road accidents under the most dangerous of situations where surface temperatures hover above 0°C. To some extent this is also demonstrated by the use of DJF 2004-2005 as a temporal analogue where the increased temperatures experienced in that year made only a minor difference to accident numbers when compared with a baseline year (Figure 2). In effect, accident numbers were greater than predicted which underlines the need for caution when using temporal analogues to infer future climate change (e.g. Andersson and Chapman, 2010).

5. Conclusion

In summary, the number of frost days and the length of the winter season will reduce in the West Midlands. This will result in a reduction in the quantity of salt required to treat the roads and theoretically a near 50% reduction in the number of accidents caused due to slipperiness. However, there is a concern that this will lead to complacency. There is a danger that drivers will become less experienced with the conditions and that winter maintenance budgets will be significantly cut; a potentially lethal combination. As the number of dangerous marginal nights will stay roughly the same, it will remain essential to maintain a winter maintenance service over the next 80 years to prevent a significant increase in accident numbers due to winter weather.

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