



# Impacts of adverse weather on Arctic road transport



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## ABSTRACT

Arctic regions are geographically peripheral and characterized by cold climate, constantly changing weather conditions and strong seasonal variations. This article examines variations in road traffic volume due to adverse weather in an arctic region, a topic that has received little attention in the transportation literature. The subject of the case study is northern Norway's Saltfjellet mountain pass, which is part of European Highway 6 (Ev6). A succinct econometric structural equation model was used to test hypotheses regarding the impacts of fluctuations in temperature, precipitation and wind speed on passenger and freight traffic volumes. The findings indicate that there was some reduction in traffic volume during adverse weather, particularly with respect to passenger traffic. However, the day-to-day variations in traffic volumes were relatively low at the studied section of road, although it is known that generalized transport costs increase significantly in adverse weather due to delays related to poor driving conditions and closed roads. The studied region is rural with limited access to alternative routes or transport modes, thus making this portion of the road particularly important for the communities in the region. Hence, the road users have few other options than using this high-cost road in order to maintain their activities. The use of standardized parameters in transport models to predict the effect of adverse weather on traffic volume, would not be appropriate in the studied context. However, it is recommended that the benefits of reducing the extra costs that adverse weather impose on traffic are estimated and included in road-project assessment tools to capture the burden and strain imposed on road users. This to ensure that appropriate decisions are made regarding the development and improvement of transportation facilities, particularly in rural areas.

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## 1. Introduction

One of the main objectives of countries with long-term transport plans is to have efficient and reliable transportation systems (see, for instance, the *Norwegian National Transport Plan (2013)* and *National Plan for Sweden's Transport System (2010)*). However, extant literature indicates that transport systems are vulnerable to adverse weather,<sup>1</sup> as such conditions may reduce the efficiency and reliability of the system (Datla and Sharma, 2008; Keay and Simmonds, 2005; Khattak et al., 1998; Lam et al., 2008; Maze et al., 2006). To facilitate decision makers in improving the operations and maintenance of existing infrastructure and in planning new infrastructure and to identify adaptation and mitigation strategies to address weather-related problems of today and those of the future, it is critical to know and understand how weather conditions affect transportation (Jaroszowski et al., 2010, 2013). Many road sections in Norway are particularly vulnerable to adverse weather conditions because of the combination of challenging topography, vast mountain areas, deep fjords and adverse climatic conditions. A consensus among

climate researchers reveals that the global weather-related problems are not likely to diminish in the near future (Doran and Zimmerman, 2009). Moreover, they project that in Norway, the intensity and duration of precipitation are expected to increase, and while temperatures may increase and result in less snow in lower areas, it is expected that the mountain areas will still receive heavy precipitation in the form of snow during the winter months (NOU 2010: 10, 2010). The probability of an increased number of events with strong winds do also exists.

The aim of this article is to investigate the variability in road traffic volume under varied weather conditions on a rural road section, the Saltfjellet mountain pass, which is part of the main transport corridor of European Highway 6 (Ev6) that connects southern and northern Norway. A better understanding of how adverse weather impacts traffic in the rural context will help policy makers make better decisions regarding the development and improvement of transportation facilities in these areas. Only two alternatives exist to the part of Ev6 studied, and both have significantly higher transport costs. Similar to many other mountain passes, the Saltfjellet mountain pass is often affected by adverse weather that impairs driver ability and causes road closures, both of which increase travel time and thereby reduce arrival time reliability (Bardal and Mathisen, 2015). Assuming that drivers seek to minimize their transport costs, the hypothesis is that adverse weather

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<sup>1</sup> Adverse weather is defined as "atmospheric conditions at a specific time and place that are unfavorable to optimal traffic conditions" (El Faouzi et al., 2010).

conditions affect the number of drivers who choose to use this mountain pass. In addition, the literature indicates that various types of road transport respond differently to adverse weather (Button, 2010; De Jong et al., 2010; Graham and Glaister, 2004; Litman, 2013). Accordingly, the two research questions explored in this study are as follows:

1. How does adverse weather affect road traffic volume on the Saltfjellet mountain pass?
2. Do passenger and freight traffic volumes differ in their sensitivity to adverse weather on the Saltfjellet mountain pass?

Though the impact of weather on road transportation has been the subject of much research, the variations in context are limited. The majority of the extant studies have been conducted in densely populated areas where congestion and road capacity are the primary problems, while travel concerns in rural areas have received limited attention (Böcker et al., 2013). One important feature of rural areas is that they often lack, or have limited access to, alternative transport modes and routes. Therefore, interruptions in the available transport system may have substantial impacts on transport costs as well as on competition in the product, service and labour markets in these areas (Laird and Mackie, 2009). The climate zones covered in the literature are also limited. For example, all of the mountain passes in Norway have polar climates,<sup>2</sup> a climate zone that is virtually ignored in the literature (Böcker et al., 2013). Though roads in mountain areas in some other countries, such as the northern parts of the US, Canada, and some EU countries, experience similar winter problems, the areas are not classified as polar climates. In these cases, local knowledge of the relationship between transportation and weather conditions is essential because this relationship may differ extensively between locations (Böcker et al., 2013; Liu et al., 2014).

This article is structured as follows. In Section 2, the theoretical background and hypotheses regarding the relationships between traffic volume and adverse weather are provided. The case study and data are then described in Section 3. Section 4 presents the model, and Section 5 discusses the results. Concluding remarks and possible implications are provided in Section 6.

## 2. Factors affecting traffic volume

### 2.1. General theory

In this study, several factors are found to affect traffic volume (Button, 2010; Litman, 2013). Time costs and costs related to discomfort and risk are among the most important factors. These are followed by the high price and limited availability of other transport modes and routes at the section of road studied herein. Additionally, the amount and type of freight transport in the region and the quality of road maintenance and operations affect traffic volume on the studied mountain pass. It is expected that traffic volume will decrease when general transport costs increase (Button, 2010). Several studies have investigated the impact of adverse weather on generalized transport costs (Asensio and Matas, 2008; Bardal and Mathisen, 2015; Bates et al., 2001; Hagen and Engebretsen, 1999; Li et al., 2010; Sikka and Hanley, 2013; Tseng and Verhoef, 2008). The findings from these earlier studies form the basis for the relationships illustrated in Fig. 1.

Assuming that drivers act to minimize their generalized transport costs, we can expect different types of behavioural reactions to adverse weather. Adverse weather may affect trip generation, trip distribution, modal choice, route choice, temporal choice, and speed choice, all of which will cause variation in traffic volume (Koetse and Rietveld, 2009; Ortúzar and Willumsen, 2011). Husdal and Bräthen (2010) investigated

how production and transport companies managed uncertainties and disruptions in freight transport due to unforeseen events such as closed roads caused by adverse weather, flooding and avalanches. They found that the commodity owners attempt to reduce their risks by using regular routes and/or by using the same transport companies consistently, and the transport companies include the price of the risk in their cost calculations at the time the transport is ordered. Moreover, the transport companies attempt to reduce their risks by investing in suitable vehicles and equipment and by adding slack time into their schedules.

It is reasonable to expect freight transport is less sensitive to price changes than passenger transport on the mountain pass studied herein (Button, 2010; De Jong et al., 2010; Graham and Glaister, 2004; Litman, 2013). First, cancelling and postponing trips are not likely to be options for freight transporters who are obligated to meet delivery times. Second, it is more difficult for freight transporters to change transport modes or routes on short notice because of limited access to alternatives. Third, a large proportion of the passenger traffic on the Saltfjellet mountain pass is due to leisure activity. Fourth, according to Fuller's (2005) task-capability interface (TCI) model, freight transport drivers will, in general, possess higher capability levels because they are better trained and have more experience driving in adverse weather conditions. Thus, these drivers are better able to contend with challenging driving conditions than are private motor vehicle drivers, although the heavy vehicles may be more difficult to drive on icy roads compared to passenger cars. Finally, freight transport drivers may well have greater motivation than private motor vehicle drivers to complete the trip as quickly as possible due to tight time schedules (Fuller, 2005).

That the measured freight traffic volume is less sensitive to increases in generalized transport costs due to adverse weather is supported by the findings of several studies. For example, Maze et al. (2006, 2005) found in their study of northern Iowa that commercial trips were less likely to be affected by adverse weather conditions than were passenger trips. Cools et al. (2010a) explained that the heterogeneity in the effects of weather conditions on traffic between different locations on Belgium highways was due to the underlying differences in travel motives among drivers. For example, work-related traffic was less affected than leisure traffic. Datla and Sharma (2008) studied highways in Alberta, Canada, and found that commuter roads exhibited lower traffic reductions due to cold temperatures than did recreational roads.

### 2.2. Weather impact on traffic volume

Wind speed, temperature and precipitation (rain and snow) have been identified as important weather indicators affecting road transport (see e.g. Agarwal et al., 2005; Al Hassan and Barker, 1999; Bardal and Mathisen, 2015; Böcker et al., 2013; Clifton et al., 2011; Cools et al., 2010a; Datla and Sharma, 2008; Keay and Simmonds, 2005; Saneinejad et al., 2012), and the Norwegian Public Road Administration (NPRA) confirms that these are the most important weather variables affecting traffic at the Saltfjellet mountain pass (NPRA, 2012).<sup>3</sup>

An increase in precipitation is expected to cause a decrease in traffic volume (Al Hassan and Barker, 1999; Böcker et al., 2013; Datla and Sharma, 2008; Keay and Simmonds, 2005). As precipitation may reduce visibility and create challenging road surface conditions, some road users are expected to avoid using the mountain pass when precipitation increases, which can be measured as a decrease in traffic volume. Similarly, an increase in wind speed is expected to reduce traffic volume as strong winds may blow vehicles off the road or cause snowdrifts that may block the road and/or reduce visibility (Böcker et al., 2013; Cools et al., 2010a; Knapp et al., 2000; Maze et al., 2006).

Though the relationship between temperature and traffic volume is uncertain, it is postulated that cold temperatures may be associated

<sup>2</sup> According to the Köppen-Geiger classification (Böcker et al., 2013).

<sup>3</sup> Even though fog and clouds can affect traffic substantially in some geographical areas, fog and sky conditions do not normally cause problems for traffic in the context studied.

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