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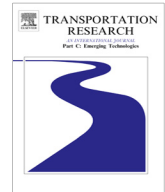
Impacts of weather on public transport ridership: Results from mining data from different sources

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ABSTRACT

The existing studies concerning the influence of weather on public transport have mainly focused on the impacts of average weather conditions on the aggregate ridership of public transit. Not much research has examined these impacts at disaggregate levels. This study aims to fill this gap by accounting for intra-day variations in weather as well as public transport ridership and investigating the effect of weather on the travel behavior of individual public transit users. We have collected smart card data for public transit and meteorological records from Shenzhen, China for the entire month of September 2014. The data allow us to establish association between the system-wide public transit ridership and weather condition on not only daily, but also hourly basis and for each metro station. In addition, with the detailed trip records of individual card holders, the travel pattern by public transit are constructed for card holders and this pattern is linked to the weather conditions he/she has experienced. Multivariate modeling approach is applied to analyze the influence of weather on public transit ridership and the travel behavior of regular transit users. Results show that some weather elements have more influence than others on public transportation. Metro stations located in urban areas are more vulnerable to outdoor weather in regard to ridership. Regular transit users are found to be rather resilient to changes in weather conditions. Findings contribute to a more in-depth understanding of the relationship between everyday weather and public transit travels and also provide valuable information for short-term scheduling in transit management.

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1. Introduction

Transportation is an activity that has to be exposed to outdoor environment where weather is a major defining factor. Weather conditions impact both the performance of transportation systems and the travel behavior of passengers. Bad weather conditions may degrade the level of service of transportation systems (Hofmann and O'Mahony, 2005); likewise, different weather conditions may influence passengers' choice of departure time and transport mode or even whether or not to conduct a trip at all (De Palma and Rochat, 1999). Accordingly, two major themes of studies on the impact of weather on transportation can be identified. The first stream of studies investigate the influence of weather on the performance of transport systems including infrastructure performance (Koetse and Rietveld, 2009), road capacity and vehicle moving speed (Kyte et al., 2001; Smith et al., 2004) and disruptions in the transport systems caused by adverse weathers (Hofmann and

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O'Mahony, 2005). The second stream of studies has focused on the impact of weather on the travel behavior of passengers. These include studies on the impact of weather conditions on travel demand (Cools et al., 2010), modal shift (Heinen et al., 2010; Koetse and Rietveld, 2009), and route and destination choices (Cools et al., 2010). These studies have covered different weather elements and targeted various transport modes and systems. Studies have investigated the link between the seasonal fluctuation of temperature and the shift pattern of transport mode (Muller et al., 2008); the association between vehicle traffic volume and weather conditions such as coldness (Tang and Thakuriah, 2012) and snow and heavy wind (Maze et al., 2006). The influence of weather on the usage of active transport modes including cycling has also attracted quite some research attention (Nankervis, 1999; Bergström and Magnusson, 2003; Brandenburg et al., 2004).

The influence of weather on public transportation, on the other hand, has received relatively less attention. One of the reasons could be that the effect of weather on public transit is more complex than private and non-motorized transport modes. Transit riders are subject to the weather effect in a similar way like active transport mode users on the way to/from transit facilities and private transport mode users when on-board the vehicle (Guo et al., 2007). In addition, bad weather may reduce the desire to travel in general and, in turn, demand for public transit; it may also divert the travel demand from other transport modes (e.g., cycling) to public transit (Khattak, 1991). Probably constrained by the availability of data, the existing studies on the weather influence on public transit have mainly focused on the effect of average weather conditions on the aggregate ridership of public transit on daily basis (e.g., Guo et al., 2007; Stover and McCormack, 2012). As a result, these studies do not account for intra-day variations in weather as well as ridership and thus fail to establish direct links between weather conditions and demand for public transit at finer temporal scales. In addition, they do not investigate the effect of weather on the travel behavior of individual public transit users. Exploring the impact of weather on public transit at fine-grained temporal and spatial scales would be not only of great importance to our understanding of the relationship between weather and travel behavior but also very helpful for developing short-term transit management measures to enhance resilience to weather changes.

This study aims to fill these research gaps and enrich the existing literature with more findings on the influence of weather on public transportation. We have collected smart card data for public transit and meteorological records from Shenzhen, China for the entire month of September 2014. The data allow us to establish association between the system-wide public transit ridership and weather condition on not only daily, but also hourly basis and for each metro station. In addition, with the detailed trip records of individual card holders, the travel pattern by public transit can be constructed for each card holder and this pattern can be linked to the weather conditions he/she has experienced. Multivariate modeling approach is applied to analyze the influence of weather on public transit ridership and the travel behavior of regular transit users. Results show that some weather elements are more influential than others on public transportation. Metro stations located in urban areas are more vulnerable to bad weather with regard to ridership. Regular transit users are found to be rather resilient to changes in weather conditions. Findings of this study contribute to a more in-depth understanding of the relationship between weather and travel by public transit and also provide valuable information for short-term scheduling in transit management.

The remainder of this paper is organized as follows. Section 2 reviews related studies and provides the literature background for the present study. Section 3 introduces the data and the study area. Analytical approaches are also elaborated on in Section 3. Section 4 presents and discusses the analysis results and research findings. Section 5 summarizes the research findings and points out future research directions.

2. Related works

The transportation impacts of weather have received substantial research attention. Studies have investigated the influence of weather types (e.g., snowy or rainy day) and elements (e.g., wind, temperature, and precipitation) on various aspects of transportation including system-wide performance and trip-making behavior of travelers. In this section, we shall review the relevant studies, outline the major findings and identify the research gaps.

2.1. Impact of weather on traffic and urban transportation

A number of studies have examined the impact of weather on urban transportation systems and travel demand and different weather elements have been reported to have different effects. Several studies have found negative effect of precipitation, either snow or rainfall, on outdoor activity and travel demand (Spinney and Millward, 2011; Chan and Ryan, 2009; Tucker and Gilliland, 2007). In addition, total traffic volume on urban highways and intra-urban roads are reported to be reduced by snow (Call, 2011; Datla and Sharma, 2010) or rainfall (Al Hassan and Barker, 1999; Keay and Simmonds, 2005). Other studies have reported opposite results where rainfall or snow increased motorized travel volume (Aaheim and Hauge, 2005; Saneinejad et al., 2012). Temperature and wind are other elements that are frequently examined. Colder weather are found to be associated with decreasing travel volumes (Shih and Nicholls, 2011; Tang and Thakuriah, 2012; Datla and Sharma, 2010). Wind is found to have both negative effect (Maze et al., 2006) and positive effect (Saneinejad et al., 2012) on car use or car traffic in different scenarios.

Compared to motorized travel modes, active modes including cycling and walking are considered more heavily affected by weather as the travelers would be entirely exposed to outdoor environment. For example, in terms of temperature