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Impact of weather on urban transit ridership

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ABSTRACT

Utilizing daily ridership data, literature has shown that adverse weather conditions have a negative impact on transit ridership and in turn, result in revenue loss for the transit agencies. This paper extends this discussion by using more detailed hourly ridership data to model the weather effects. For this purpose, the daily and hourly subway ridership from New York City Transit for the years 2010–2011 is utilized. The paper compares the weather impacts on ridership based on day of week and time of day combinations and further demonstrates that the weather's impact on transit ridership varies based on the time period and location. The separation of ridership models based on time of day provides a deeper understanding of the relationship between trip purpose and weather for transit riders. The paper investigates the role of station characteristics such as weather protection, accessibility, proximity and the connecting bus services by developing models based on station types. The findings indicate substantial differences in the extent to which the daily and hourly models and the individual weather elements are able to explain the ridership variability and travel behavior of transit riders. By utilizing the time of day and station based models, the paper demonstrates the potential sources of weather impact on transit infrastructure, transit service and trip characteristics. The results suggest the development of specific policy measures which can help the transit agencies to mitigate the ridership differences due to adverse weather conditions.

1. Introduction

From a transportation agency's perspective, weather conditions are considered exogenous factors which indirectly influence the demand for transit. For example, Khattak and Palma (1997) have shown that weather potentially affects a traveler's decision regarding mode choice and route choice while impacting the total trip duration. Similarly, adverse weather conditions also directly influence the availability and the quality of transit service. Weather can affect the total trip duration by increasing the access time, transfer time and the normal trip duration and also by causing schedule disruptions (Hofmann and O'Mahony, 2005). Adverse weather conditions can change the service frequency (Chung, 2013) or in the case of extreme events result in service cancellation (Katz, 2011; Flegenheimer, 2013). Such weather conditions modify the trip characteristics significantly enough to alter normal ridership levels (Changnon, 1996). This often results in reduced transit usage along

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with substantial revenue losses for transit agencies (Changnon, 1996; Cravo and Cohen, 2009). Given the financial difficulties generally faced by transit agencies, there is a need to investigate policies to minimize all types of revenue losses. For the case of adverse weather, policy makers need transit ridership models to identify the remedies and evaluate alternatives.

This paper extends the currently available limited body of research to understand the effects of weather on transit ridership. As a case study, the paper examines the impact of weather on the Metropolitan Transportation Authority-New York City Transit (MTA-NYCT) subway ridership. Two years of ridership data from the MTA-NYCT and weather data from National Oceanic and Atmospheric Administration (NOAA) and Weather Underground website were combined to model the relationship among variables with ordinary least square (OLS) regression. While past studies have demonstrated the adverse impact of weather on transit ridership; this paper contributes uniquely in the following ways:

(i) Use of detailed ridership data: Currently, all existing studies make use of daily ridership values and aggregated weather conditions to explain ridership variation. This paper utilizes hourly ridership and hourly weather data to model the weather effects. Further, we compare the results of both daily and hourly ridership models and discuss their applicability for policy making; a comparison not yet made to the authors' knowledge. This segregation of ridership models allows a better examination of the weather impacts based on trip purpose; a topic which has been studied in detail for car based private travelers but has not received much attention for transit dependent population.
(ii) Investigation of station types: The effect of weather conditions on a passenger waiting inside an underground subway station is different than the one waiting at outdoor platforms and bus stops. Under adverse weather conditions, many factors such as station accessibility, proximity and station's weather protective features may influence transit riders' trip decisions. There is no quantitative study which compares this disparity of weather impact on transit ridership based on such station types. We develop separate regression models for elevated and non-elevated stations and investigate the weather impacts. Additionally, we investigate the role of connecting bus service routes in maintaining stable station ridership under adverse weather conditions.

The paper starts with a short review of the research literature. This is followed by a description the data and methodology adopted to analyze the weather impacts. The case study for MTA-NYCT transit ridership is then presented followed by the model results. The paper concludes by summarizing key findings and a discussion of their implications for research and policy.

2. Literature review

2.1. Impact of weather on travel demand

The impact of weather conditions on travel demand has been well studied for highway traffic with conditions such as rain, snow, fog and wind and weather intensity levels reportedly affecting traffic demand, traffic safety and traffic flow relationship (Maze et al., 2006). Adverse weather conditions have been noted to cause highway capacity reduction (Smith et al., 2004); affect travel decisions regarding service mode, departure time and route choice (Khattak and Palma, 1997; Palma and Rochat, 1999), and impact traffic volumes and flows (Hassan and Barker, 1999; Keay and Simmonds, 2005; Cools et al., 2010a). The effect on travel behavior and thus travel demand has been observed to depend upon the type of weather (Cools et al., 2010b), day of week and trip purpose (Chung et al., 2005), and time of day (Hanbali and Kuemmel, 1993). Strong winds, low temperature, precipitation and winter months have resulted in mode shift from bicycle to car and transit while the reverse was found to be true for high temperatures (Sabir et al., 2008; Sabir et al., 2010). Inclement weather conditions such as low temperatures, strong wind and precipitation have led to reduced bicycle usage (Emmerson et al., 1998; Sabir et al., 2008; Miranda and Nosal, 2011) and pedestrian traffic volumes in dense downtown environments (Hall et al., 2009; Attaset et al., 2010). In an active mode choice study in Toronto, Canada, wind speed and precipitation was found to affect cyclists more than pedestrians with younger individuals and females' mode choices being more affected by colder temperatures (Saneinejad et al., 2012). A recent review of past weather impact studies on daily travel activities (or trip purposes) concluded that the existing studies lacked cohesiveness based on methodology, context and behavioral backgrounds and thus presented an incomplete and fragmented picture of the impact of weather on travel behavior (Böcker et al., 2013). In Netherlands, using revealed preference data from Dutch national household survey Creemers et al. (in press) recently studied the weather impacts on trip motives and modal choices by developing two respective MNL-GEE models. They found that thermal component (represented by thermal index); aesthetical component (fog, cloud cover) and physical component (precipitation) of weather were significant in both models. Model parameter estimates also suggested significant differences in the impact of weather conditions when different time scales were considered (e.g. daily versus hourly based analysis). Seasonality of weather conditions also played a significant role in explaining the variability in daily travel behavior which underlines the importance on including the effects of seasonality in analysis of weather impacts.

In brief, the impact of weather on travel demand is complex. Along with the commuter's socio-economic characteristics, weather condition type and intensity, combined with temporal factors (time of day, day of week, seasonality), scale of analysis (daily versus hourly) and trip purpose/daily activities influence commuter's travel mode decisions as well as their non-motorized travel times.