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Riders on the storm: Exploring weather and seasonality effects on commute mode choice in Chicago

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ABSTRACT

This paper separately analyzes the impacts of weather and seasonality on commute mode choice using a stated-preference (SP) survey. The study's twin objectives include quantifying the relative attractiveness of a flexible transit mode under adverse weather and analyzing the heterogenous impacts of seasonality and weather on different segments of the population. The survey was implemented during summer and winter months to analyze the impact of *seasonality* on commute mode choice. To analyze the impact of *weather* on commute mode choice, the survey randomly assigns respondents to a good or bad weather scenario. The three SP mode choice options are fixed-route transit, personal car, and a hypothetical flexible transit mode. The flexible transit mode allows travelers to wait for a transit vehicle at their origin point – an especially attractive feature on cold and/or snowy/rainy days. However, like with existing dial-a-ride services, travelers using the flexible transit service may experience detours between their pickup and drop-off locations. Several panel mixed-logit choice models that incorporate weather and seasonality were estimated using the SP survey data. The panel mixed-logit model form captures taste heterogeneity across respondents and correlation across multiple SP choice experiments from a single respondent.

Model estimation results indicate that relative to *good weather*, *summer days*, respondents were significantly more likely to choose traditional and flexible transit on *good weather*, *winter days*, and flexible transit on *bad weather*, *winter days*. Furthermore, the results show that the impacts of weather and seasonality on commute mode choice vary across the population. Most of the respondents had a lower (higher) propensity to choose the car (flexible transit) mode under bad weather than good weather. Conversely, car commuters, bicycle commuters, and baby boomers had a much higher propensity to choose the car mode under bad weather than good weather. Additionally, the results show that millennials had a much lower propensity to choose the car mode in the winter than the summer, whereas seasonality had little impact on the propensity of non-millennials to choose the car mode. The paper discusses the implications of these findings on the design of transit, flexible transit, and emerging mobility services, as well as the management of transportation systems and dissemination of information regarding alternative transport modes during adverse weather events.

1. Introduction

Weather impacts travelers' activity plans, locations, start times, and durations, which subsequently affect how much, where, how, and when travel occurs. Even for indoor activities, such as work inside an office, weather can still impact trip departure time, route choice, and mode choice, in addition to activity duration (through its impact on other activities during the day). Unlike other factors that impact travel behavior such as a road closure or a transit disruption, weather events can directly affect the behavior of all travelers in a geographical region simultaneously. In addition to its impact on traveler demand, adverse weather often degrades the performance of road networks and transit systems. Hence, even if the average per person impact of weather on travel behavior is small, the fact that it impacts all potential travelers and transportation infrastructure in a region simultaneously can result in a large net impact. Understanding demand shifts in adverse weather is especially important given the non-linear effects of both demand shifts and adverse weather events on the performance of roadway

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networks and transit systems.

Given the significant impact of commute trips on road network congestion and transit ridership, as well as the importance of mode choice on congestion levels, this study focuses on the impacts of weather and seasonality on *commute mode choice*. The study surveys travelers in the Chicago, Illinois area of the Midwestern United States. Chicago is a large metropolitan area with a relatively well-developed multimodal transport network, which experiences a full range of weather episodes and well-defined seasons during the year. In Chicago, the personal vehicle (henceforth 'car') mode and transit mode account for 60% and 27% of commute trips, respectively, making up the lion's share of all commute trips in the region (U.S. Census Bureau, 2015).

Adverse weather negatively impacts both commute modes in terms of the user experience. Precipitation reduces driver visibility, can increase travel times and travel time unreliability, and makes the roads less safe. Moreover, in the winter, car commuters need to clean snow off their car in the cold, and it can be more difficult to find a parking spot at home and work. For fixed-route/traditional transit commuters, walking to a transit stop and waiting in the cold and/or rain/snow is highly undesirable. Moreover, precipitation can increase transit travel times and transit travel time unreliability, especially for buses. The numerous and diverse negative impacts of adverse weather on both the traditional transit mode and the car mode for commuting motivate two research questions.

1. Would commuters find a hypothetical flexible transit mode an attractive commute option because it overcomes many of the negative aspects of the car and transit modes under adverse weather?

The main differentiating feature of the flexible transit mode, over the car and traditional fixed-route transit, is that it allows travelers to wait for a transit vehicle at their point of origin (e.g. at home, for the morning commute trip). This paper uses the term flexible transit to be as general as possible when referring to a mode that shares attributes with dial-a-ride transit services, shared-ride mobility services (e.g. UberPool and Lyft Line), and transit mainline feeder services. Between pickup and drop-off, a traveler's flexible transit vehicle may pick up and/or drop off several other travelers, affecting the total travel time the traveler experiences. In many instances, the flexible transit service may have a pre-defined geographical service region, and it may provide access to mainline rail transit.

The ability to wait inside one's point of origin, rather than at a transit stop for a transit vehicle, is a beneficial modal attribute in general but especially when there is precipitation, or it is cold outside. Hence, the flexible transit mode might be an attractive mode in the winter and during adverse weather. This is a particularly important research question, as adverse weather significantly decreases the performance of road networks (Frei et al., 2014). Hence, a mode shift away from cars toward flexible transit during adverse weather could benefit car and bus commuters via counter-balancing the negative impacts of adverse weather on road network performance by reducing demand for single-occupancy vehicle travel.

2. Do specific segments of the population prefer different commute modes under adverse weather?

Given the wide-ranging and complex ways in which adverse weather negatively affects both the traditional transit mode and the car mode, the impacts of adverse weather should differ across the population, reflecting travelers' heterogeneous travel circumstances and preferences. For example, some commuters may prefer waiting outside on a cold, snowy day for a few minutes for a bus, rather than clearing snow off their car or driving on snow covered roads. Conversely, others may prefer to experience lower visibility and more congestion inside a climate-controlled car, than wait outside in the rain at the bus stop. If there is significant heterogeneity, the ability to identify specific segments of the population in terms of their response to adverse weather would be quite useful when disseminating information about weather events and non-car travel options. Transportation managers could use this information to target specific population segments when instituting interventions that may decrease car usage during adverse weather events. For example, during heavy rain events, transit could be free to reduce traffic volumes and potential accidents on the roads; however, during severe weather events wherein a city might encourage residents to leave work early before a storm's arrival, the hours when transit is free could be limited to off-peak travel. These "free hours" could be communicated to travelers via television, radio, SMS and/or mobile application alert services.

To answer these two research questions, this study employs a stated-preference (SP) mode choice survey wherein specific weather descriptions are provided to respondents prior to the SP mode choice experiments. To answer the first research question, the SP mode choice experiments include a flexible transit mode along with car and traditional transit modes. To answer the second research question, the survey instrument collects information on the respondents' demographics, travel characteristics, and travel habits.

Notwithstanding the wide-ranging and substantial impacts of weather factors and seasonality on travel behavior, these relationships have been considerably under-researched in the transportation literature. The research presented herein provides several contributions, both methodological and substantive, to a relatively small but growing field of research exploring these relationships. First, the SP mode choice survey designed and conducted for this study is the first to explicitly include weather scenarios as contextual information for the respondents to consider in the choice experiments. This survey design enables the estimation of choice models to *quantify* the impacts of adverse weather on mode choice. Second, the SP choice experiments include *flexible transit* as a modal option. With the growth of emerging mobility services such as ridesharing, demand-responsive/-adaptive transit, and other hybrid travel modes, understanding the impacts of weather and seasonality on their ridership potential is especially valuable. Frei et al. (2017) briefly touch on these aspects, which are examined in much greater depth in this paper. Third, the study accounts for heterogeneity across respondent segments rather than assuming the impacts of weather and seasonality on commute mode choice are homogenous across the population.

Exploring and analyzing the impacts of weather and seasonality on specific *segments* of the population yields important findings that inform (i) the design of transit and emerging mobility services and (ii) the management of transportation systems. Given information about how different segments react to adverse weather, transportation planners and policy-makers can better allocate resources to provide travel alternatives during adverse weather events in specific neighborhoods. Additionally, transportation managers can use this information to target specific segments of the population when disseminating information about adverse weather events and the availability of non-car travel modes. Similarly, emerging mobility service and flexible transit providers can use this information to target specific market segments and design their services and infrastructure.

The remainder of the paper is structured as follows: Section 2 provides an overview of existing research examining relationships between weather, seasonality, and transportation, with a focus on travel behavior aspects. Section 3 describes the SP survey instrument. Section 4 provides summary statistics from the survey data. Section 5 presents a commute mode choice modeling framework and empirical choice model specifications. Section 6 presents and discusses empirical choice model results. Section 7 summarizes and concludes the paper.

2. Background

Recently, researchers have started to incorporate the impacts of weather on transportation network performance in traffic prediction