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Let it rain: Weather effects on activity stress and scheduling behavior

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ABSTRACT

Travel and activity scheduling decisions largely depend on travelers' responses to prevailing trip conditions. These could be impacted by environmental situations, such as adverse weather, which can increase the variability in travel times, practical capacity and other system properties. Understanding and modeling the relationship between travel and activity decisions and adverse weather is important for devising and evaluating transportation management strategies that rely on adjustments and shifts in behavior. This study focuses on the impact of rainfall precipitation on activity decisions, more specifically the perceived stress underlying these decisions. In the current study, activity scheduling decisions for discretionary activities are examined under different rainfall levels, but given consistent data on other forms of precipitations, such as snow sleet or hail, this study could be extended to these cases. Activity stress is modeled under a discrete choice framework. The results show that the perceived activity stress differs under rainfall to some extent, depending on the number of activities in a traveler's activity queue, and the number of activities completed. The study also reveals that travel behavior may differ under rainfall, suggesting that travelers' may perceive information and uncertainty differently, relative to conditions with less variability in weather. Furthermore, issues concerning climatology data requirements for transportation models are discussed.

Introduction and background

The performance of transportation systems depends largely on travel and activity engagement and scheduling behaviors under different conditions and system performance levels, in addition to environmental conditions. Aside from its impact on the physical and operational aspects of transport systems, adverse weather also affects the system through its impact on users' travel decisions. Understanding and modeling the relationship between travel behavior and adverse weather is important for developing planning and operational strategies that rely on shifts and adjustments to these behaviors. Furthermore, in the context of sustainability and climate change, modeling this relationship may provide insight regarding the impacts of transportation and related climate policies that rely on interventions to transportation systems. This study focuses on the impact of rainfall on perceived activity stress that underlies activity scheduling and related travel decisions. Activity stress is modeled under a discrete choice framework, accounting for both activities that are completed and those in an activity queue.

The literature on adverse weather and traveler behavior has largely focused on the trip adjustments made when faced with these conditions, but not activity-related decisions. Common dimensions examined are departure time, mode and route choice, with studies showing that most travelers do make some kind of travel decision change under adverse weather (Khattak and de Palma, 1997; de Palma and Rochat, 1999; Aaheim and Hauge, 2005). Results of a detailed survey of commuters in Brussels reveal that even travelers with flexible work hours maintain regular schedules and make no travel changes, suggesting that changing departure times, modes or routes in response to bad weather may be influenced by habit or inertial effects (Khattak and de Palma, 1997). For users whose travel decisions are impacted by weather, a relatively high percentage indicates that departure time is more likely adjusted relative to route and mode choice (Mannering et al., 1995; Khattak and de Palma, 1997; de Palma and Rochat, 1999). This finding (higher likelihood of switching departure times than routes or modes) is consistent with other studies of traveler choice dynamics, in general situations that do not necessarily involve weather (Mahmassani, 1997). Preference in favor of adjusting departure times may reflect lower costs associated with searching for new alternatives. In the Brussels study, the large number of commuters with flexible work

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hours suggests that commuters prefer using this flexibility to select convenient beginning and end times.

Mode choice has also received significant attention in regards to adverse weather, primarily in Europe. In the Brussels study (Khattak and de Palma, 1997), the results show that although a high percentage (69%) stated they had access to secondary modes, only a small fraction (5%) of the respondents actually switched modes under bad weather, suggesting a low impact of weather on mode choice. Also, since only a small percentage of respondents used bicycles for commuting, these results suggest that the substitutability between car and transit is limited. One possible explanation is that transit and non-motorized modes may expose passengers to the elements. A study of mode choice comparing the winter versus summer months showed that a decrease in the number of bicycle trips in the winter was accompanied by a large increase in car use for commuting purposes (Bergstrom and Magnusson, 2003). However, these studies are based on stated preference data and may not represent actual behaviors. A revealed preference study of weather and travel habits in Bergen, Norway also suggests that the impact of weather on the substitution between public and private transport is relatively small (Aaheim and Hauge, 2005).

Although the impact of weather on travel behavior is significant, most research has focused on incorporating weather measurements, such as rainfall levels, into existing travel behavior models, and most of this work focuses on active transport. Weather is commonly incorporated through indicator variables (Winters et al., 2007). In a recent study Saneinejad et al. (2010) examined the impact of weather on active transportation using a disaggregate mode choice model estimated using travel activity data and corresponding historical hourly weather conditions in Toronto. This study addressed many of the gaps with previous studies by considering travel and weather at disaggregate level in terms of representation of weather and travel demand modeling. However, Saneinejad et al. (2010) included weather as indicator variables for different ranges based of arbitrarily chosen cutoffs, as opposed to ranges that travelers might intuitively perceive. Only a handful of studies consider rainfall or snow and their effect on pedestrian volumes (Aultman-Hall et al., 2009; Lam et al., 2014).

Recent interest in weather and travel is evident through a special section in the *Journal of Transport Geography* on the exposure to weather and implication on travel (Dijst et al., 2013). Topics covered ranged from the impact of weather forecasts (Coolsa and Creemersb, 2013) and projected weather conditions (Böcker et al., 2013), to the obstacles imposed by winter weather on the travel of elders (Hjorthol, 2013). Weather has also been investigated extensively with respect to traffic (Tsapakis et al., 2013) and the related topic of accidents and driver adaptation (Andreya et al., 2013; Jaroszweski and McNamara, 2014). In a series of studies aimed at incorporating the effect of weather in traffic modeling tools used in practice, Mahmassani et al. (2009) adapted a dynamic network modeling procedure to reflect the impact of weather on network performance, and investigated the contribution of demand management to alleviating the negative impact of severe weather (Kim et al., 2013); Frei et al. (2014) applied the framework to the Chicago network, in conjunction with the area's mode and departure time choice models, to examine the effect of specific demand management strategies in mitigating the impact of severe snow weather on network operations. The interest in weather and transportation is clear, with most studies interested in either behavioral changes or traffic related issues.

While the previous studies discussed have examined different travel choices in light of adverse weather, the literature on activity scheduling adjustments is virtually nonexistent. One possible explanation is the difficulty in obtaining good quality climate data over space for timeframes longer than a day. One study looking at the perception of weather information and beach trip decisions suggests that depending on the timeframe in which activities are planned, individuals make varying efforts to distort information regarding adverse weather (Adams, 1973). The study reveals that respondents with a high prior commitment to go to the beach reported a lower likelihood of rain, relative to respondents with lower prior commitment, with all individuals presented the same weather forecast. Also, individuals with lower prior commitment tend to cancel trips, relative to those with higher prior commitment, given the same forecasts. Although the study was based on stated behaviors, it still suggests that individuals are influenced by the priority or level of commitment to an activity in responding to weather forecasts. Similar findings would be expected if one has already purchased a ticket or made reservations for an activity threatened by bad weather.

Most studies found in the literature on the relationship between weather and travel behavior are stated preference studies. This reflects in part the difficulty in obtaining revealed travel behavior data in conjunction with actual weather conditions. Also, these studies focused more on travel decisions, such as departure time and mode choice, whereas the literature on activity scheduling adjustments to weather has been virtually nonexistent (Mahmassani et al., 2013). In addition to the difficulty in obtaining consistent weather information over the time frame of a day or longer, the variation of weather over space in conjunction with possible activity locations further complicates the problem. Behaviorally, there is also the issue of how individuals make assessment of weather conditions. From a tactical perspective, travelers may simply consider prevalent current conditions, but given access to ICT a more anticipatory decisions is possible.

Relative to the literature, this paper extends previous studies on weather and travel and activity decisions, by examining the effect of rainfall on activity scheduling. In particular, it focuses on the relationship between rainfall levels and activity stress which underlies and governs activity scheduling decisions. Observed rainfall levels from weather stations are linked to travel and activity decisions in a conventional household travel survey. One important issue that needs to be addressed first is the integration or inclusion of climatology data in activity-travel datasets. Estimating travel behavior models under different precipitation conditions requires information on actual conditions at activity locations. Typically, activity-travel surveys do not include information on prevailing weather, and precipitation data is collected independently of activity-travel data, and varies in accuracy both spatially and temporally. This study has implemented an approach for collating weather information from different weather stations and sources with activity diary data to address the questions of interest. Second, a modeling framework is presented to capture the effect of rainfall on activity stress, as a construct underlying traveler activity scheduling decisions, and applied to the above-mentioned data set to estimate the model parameters. Third, based on the estimation results, the importance of rainfall in perceived activity stress is examined. In particular, this study looks at the impact of completed activities and activities in queue on activity stress, considering also the rainfall condition at the time and location of the activities.

The next section discusses the modeling framework, starting with the rainfall data assembly process. This is followed by the estimation results and discussion focusing on the importance of weather conditions on travel. Concluding comments highlight the motivation for incorporating climatology data in activity and travel analysis.

Modeling framework

This section discusses the data assembly and modeling framework for estimating activity stress in relation to rainfall conditions, activities completed and those in queue. Data assembly will be