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The effect of weather on the use of North American bicycle facilities: A multi-city analysis using automatic counts

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ABSTRACT

This study investigates the impact of weather on the use of urban bicycle facilities in Montreal, Ottawa, Vancouver and Portland, as well as on the Green Route in Quebec. This research makes use of long-term hourly and daily counts collected automatically using inductive loop detectors. The count data locations are organized into two groups – utilitarian and recreational. Using regression models with autoregressive and moving average (ARMA) errors, the direct impact and lagged effects of weather variables on hourly and daily bicycle counts are investigated. Among the main findings, temperature and humidity are positively and negatively associated with cycling, respectively, with a non-linear association in most cases. Precipitation has a significant negative impact on cycling flows, and its effect was observed to increase with rain intensity. Lagged effects of rain were also observed, such as the effect of rain in the previous three hours, rain in the morning only, and rain in the afternoon only. Furthermore, urban bicycle flows are more sensitive to weather on weekends than on weekdays, and recreational facilities are more sensitive than utilitarian facilities.

1. Introduction

In order to promote cycling and to accommodate the growing number of cyclists, many North American cities are investing in bicycle infrastructure (e.g., cycle tracks, bicycle lanes, bicycle parking) and implementing new policies and programs (e.g., bike sharing programs, traffic calming, bicycle integration with transit) (Pucher and Beuhler, 2011). As cities continue to invest and the number of cyclists grows, it is becoming increasingly necessary to study the safety, operations and planning of cycling facilities. This requires identifying the determinants of cycling activity across different cities and types of facilities. One topic that has been attracting more attention as of late is the relationship between weather and cycling.

Understanding the effect of weather on cycling ridership across different facilities is important for several reasons, as highlighted by Miranda-Moreno and Nosal (2011) and Thomas et al. (2012), among others. For instance, it will be essential for the development of methods to adjust brief cyclist data counts for weather, which is expected to increase the accuracy of cyclist exposure estimates, also known as the average annual daily bicyclists (AADB). AADB is used in a wide range of bicycle analyses (Sprinkle Consulting, 2011).

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Although several recent studies have been published on this topic (Lewin, 2011; Miranda-Moreno and Kho, 2012; Miranda-Moreno and Nosal, 2011; Rose et al., 2011; Thomas et al., 2012), there are several shortcomings in the literature. Most studies have used survey data, brief manual counts, or daily (aggregate) data, which cannot capture the effects of hourly (disaggregate) weather conditions, such as the effect of rain in the morning versus rain in the evening. Most past studies have either focused on one specific geographical area or a particular type of bicycle facility; few works have examined how the relationship between cycling and weather differs across cities or across different types of facilities. Very little research has examined the difference between the impact of weather on weekdays and the weekend, including lagged effects of weather.

This study will help address these shortcomings by using data from four North American cities – Montreal, Ottawa, Vancouver and Portland – and from a recreational bike network in Quebec, to develop hourly and daily cyclist ridership models. Regression with autoregressive moving-average (ARMA) errors is used to account for autocorrelation. In short, this work has the following two objectives: (i) to investigate the relationship between weather and hourly and daily cyclist volumes on utilitarian bicycle facilities, as well as how that relationship differs across cities, and (ii) to investigate the relationship between weather and hourly cyclist volumes on recreational facilities, as well as how that relationship differs from that of utilitarian facilities.

The following section presents a short literature review. Section 3 presents the methodology, including the data used and the analysis method. Section 4 presents the results, Section 5 presents a brief discussion, and Section 6 presents the conclusions.

2. Literature review

Though the relationship between cycling and weather has been studied directly as early as 1977 (Hanson and Hanson, 1977), there has more recently been an increase in research regarding the impact of weather on bicycle usage, and a wide range of data collection methods and statistical analyses have been utilized. Data collection methods include surveys as well as manual and automatic count data. For instance, Nankervis (1999a,b) used survey data and counts of parked bicycles on a university campus, Hanson and Hanson (1977) used travel survey data to estimate the daily cycling modal share, and more recently, Lewin (2011), Rose et al. (2011), and Thomas et al. (2012) used automatic long-term counts. Most studies incorporate data aggregated at the daily level, but more studies are emerging that use hourly cycle counts (Gallop and Tse, 2012; Miranda-Moreno and Nosal, 2011; Tin Tin et al., 2012). Regression models, with bicycle counts or the logarithm of bicycle counts modeled as a function of weather variables and various temporal fixed effects, make up the bulk of the statistical analyses (Brandenberg et al., 2007; Jaarsma and Wijnstra, 1995; Lewin, 2011; Miranda-Moreno and Nosal, 2011; Nankervis, 1999a,b; Rose et al., 2011; Thomas et al., 2012; Tin Tin et al., 2012).

In the literature, the two main weather determinants are temperature and rain, but others such as humidity and wind speed have been identified. In general, cycle counts increase with temperature. Though varying specifications make it difficult to compare directly across studies, an increase in temperature of one degree Celsius is generally associated with an increase in cycle counts of less than five percent (Tin Tin et al., 2012; Miranda-Moreno and Nosal, 2011). Two studies found the square of temperature to be insignificant when entered into a model with temperature, suggesting that the effect of temperature is linear (Tin Tin et al., 2012; Rose et al., 2011). However, Lewin (2011) and Miranda-Moreno and Nosal (2011) used binary variables to show that high temperatures are associated with a decrease in cycle counts, and Richardson (2000) observed a non-linear effect. Miranda-Moreno and Nosal (2011) found that increases in humidity are associated with decreases in cycling. Only one known study has utilized a thermal index to describe the perception of weather by cyclists (Brandenberg et al., 2007). Other variables that have been examined include hours of sunshine and wind speed (Thomas et al., 2012), and cloud coverage (Hanson and Hanson, 1977).

Regression models generally incorporate precipitation as a continuous variable, as the duration of precipitation (in hours), or simply as a binary variable. The effect of precipitation varies across locations, but in general, it was shown to have a smaller effect than temperature. Lewin (2011) found that rainfall in a day decreases the count by about 10% of the annual daily average, and Tin Tin et al. (2012) found that cycle counts decrease by 1.5% and 10.6% per millimeter of rain in a day and hour, respectively. Gallop and Tse (2012) found that rain one of the previous three hours can have an effect on cycle counts in the current hour comparable to or greater than rain in the current hour. Miranda-Moreno and Nosal (2011) confirm this, and found that rain in the morning can reduce cycling counts in the afternoon. These results suggest that lagged effects of precipitation can improve model fit, but they have been considered by no other known studies. Lagged effects of other weather variables have been examined, such as in the work by Jaarsma and Wijnstra (1995) which noted among other things that contiguous stretches of poor weather can lead to an extra boost in cycling when a day with good weather finally occurs.

In terms of the geographical areas, many of these studies are based in European, Australian, and recently, North American locations. Studies have typically only considered one region or city, with very few exceptions, such as the work of Rose et al. (2011)that included data from Portland, Oregon, USA and Melbourne, Australia. This study presents an aggregate (daily) ridership model to study the effects of weather on bicyclist volumes. As one of the main results, it is found that cyclists in the two cities (Melbourne and Portland) exhibit different sensitivities to weather.

While some studies make no distinction, several have examined the effects of weather on utilitarian and recreational cycling separately (Brandenburg et al., 2007; Hanson and Hanson, 1977; Richardson, 2000; Thomas et al., 2012). Brandenburg et al.