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Temporal trends and the effect of weather on pedestrian volumes: A case study of Montreal, Canada

Luis F. Miranda-Moreno *, Aleksiina Chapman Lahti

Department of Civil Engineering and Applied Mechanics, McGill University, 817 Sherbrooke Street West, Montréal, QC, Canada H3A 2K6

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ABSTRACT

This study examines the impact of weather on pedestrian activity, as well as the temporal trends of pedestrian flows in the city of Montreal, Canada. The direct and lagged effects of weather variables on hourly volumes are determined for the temperate and cold months, as well as for weekdays and weekends. Pedestrian hourly volumes are found to decrease in the winter. In downtown locations, there are three weekday pedestrian hourly peaks; a pattern distinctive from those observed in other surveys. Also, temperature, humidity, wind speed as well as direct and lagged effects of precipitation are the main factors affecting pedestrian activity. In winter, pedestrian flows are more sensitive to wind speeds and precipitation, and also during weekends than weekdays. Built environment plays a role not only in the magnitude but also in the temporal profile of pedestrian sidewalk activity. In comparison to bicycle ridership, pedestrian flows seem to be much less sensitive to weather.

1. Introduction

This paper investigates the impact of weather conditions on pedestrian volumes during temperate and winter months in a set of sidewalks in Montreal, Canada, and considers temporal patterns and variations across pedestrian counting locations at different built environments. It covers 12 consecutive months of hourly counts from a set of pedestrian sidewalks. The results are then compared to those from origin destination surveys and bicycle flows.

2. Data and modeling approach

Automatic hourly pedestrian counts were collected in five locations embracing two types of built environments: low pedestrian volumes with mixed residential–commercial areas and low residential density, and high volume locations in busy commercial-service areas with high residential density. Automatic counts were made using five identical Eco-Counter Pyro electric, double short-range sensors installed over twelve consecutive months, June 2010 to June 2011. Each counter was validated with manual counts at least three times during the year. It was found that their accuracy generally ranged from zero to under-counting of 20%, depending on the sensor in question. These results are deemed acceptable because the errors were fairly consistent for each counter over time.[1]

* Corresponding author. Tel.: +1514 398 6589.
E-mail address: luis.miranda-moreno@mcgill.ca (L.F. Miranda-Moreno).

[1] Some previous studies report lower errors (e.g., Aultman-Hall et al., 2009; Schneider et al., 2009), but this may be attributed to the sensors used being located on sidewalks with smaller pedestrian flows.

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A few extreme count values are removed – less than 0.2% of the data set – that are likely due to people (or heat emitting or reflecting objects) being idling for an extended period in front of the pyro electric lens. In these cases, the count was replaced with an interpolation of the counts in the hour prior and after the omitted period. The counting sites were selected carefully to obtain data from both residential neighborhoods and downtown areas. Of the counting locations, two are on popular streets in downtown Montreal, Sherbrooke and University Streets, and three on less busy, out of downtown, streets with moderate land use mixes.

The differences in the built environment was validated and integrated in the analysis using the classical land use mix index refereed as the entropy index. This index was measured within a 400 m radius around each counter. Counting locations were then grouped into two categories according to the entropy index: above and below 0.6. Sensor locations with an index greater than 0.6 were those sidewalks in downtown – in busy commercial-service streets with high-density residential buildings. Locations with an index less than 0.6 were those in mixed residential–commercial areas with low-density residential buildings (Miranda-Moreno and Fernandes, 2011).

Weather data were obtained from Environment Canada's McTavish weather station, located near McGill University; all pedestrian counters being located within 5 km of the station. The station provided hourly data for air temperature (°C), precipitation (0.1 mm increments), humidity (%), wind speed (km/h), and wind chill index. Missing values, which made up less than 1% of the dataset, were replaced with weather data from the Pierre Elliot Trudeau Airport weather station. Table 1 presents statistics.

Our modeling approach is similar to that applied to hourly bicycle counts by Miranda-Moreno and Nosal (2011). The overall modeling structure is $\log(y_{h,d,m,e}) = \beta X_{h,d,h} + \alpha X_{h-1,d,m} + \mu_h + \lambda_d + \gamma_m + \psi_e + \varepsilon_{h,d,m,e}$ where $y_{h,d,m,e}$ is for the counts in a given hour, day and month (h, d, m) in a given built environment e, $X_{h,d,m}$ stands for the weather variables (including temperature, precipitation, humidity, wind speed) and $X_{h-1,d,m}$ their lag effects. β and α are coefficients, with fixed parameters are μ_h, λ_d, γ_m, and ψ_e – for hour, day, month and site and $\varepsilon_{h,d,m,e}$, is the model error term representing unobserved heterogeneities. This can be independent or correlated and different error structures are used to investigate serial correlation. For parameter estimation, log-linear time-series regression models and regression models for count data were tested. Temporal correlation in error terms was explored using autoregressive models where the errors are allowed to follow different log-linear autoregressive moving-average specifications.

To investigate the differences in weather conditions between seasons, the analysis was split in winter months and temperate (spring–fall) months. Temperate months correspond to those in which the average monthly temperature was above zero degrees Celsius. In Montreal, these months are April through November. Conversely, the months where the majority of the recorded temperatures were below freezing were considered as winter months, namely, December through March. Days where a statutory Canadian holiday falling on a weekday are omitted, and when on a weekend are treated within the category of weekend. Additionally, given the considerable differences between patterns, weekdays and weekend days are analyses separately. Periods from 10 pm to 6 am are excluded because of very low count volumes or zero-counts.

3. Results

The distributions of the 24-h average hourly volumes during winter and temperate months are presented in Fig. 1. These distributions are shown separately for weekdays and weekends. Overall hourly volumes in the winter are lower than those observed during the temperate months – in particular, a major difference is observed between weekends. Despite the differences in magnitude, hourly trends follow a very similar pattern for both the temperate and the winter months. For instance, the weekday morning and afternoon peaks are very similar during both periods. In both seasons, weekend hourly flows are significantly lower than weekday hourly flows. Moreover, weekend flows follow a similar distribution to those for recreational vehicular travel, suggesting that weekend trips, as expected, are mainly non-work related, in both the winter and temperate months.

Temporal automatic count patterns were compared to those obtained from origin–destination survey data. Fig. 1 shows the distribution of trips reported by the Montreal 2008 origin–destination survey, specifically for neighborhoods where the

Table 1
Descriptive statistics of the variables.

Variable	Description	Mean	St dev	Max	Min
Counts	Pedestrians	130.49	127.2	767	0
Landuse	Land use index (0,1)	0.61	0.12	0.78	0.50
Temp	Temperature (°C)	6.74	11.6	33.5	−25.7
Temp2	Temperature squared	180.5	215.2	1122.2	0
Prec	Precipitation (0.1 mm)	1.79	8.38	250	0
Hum	Humidity (%)	67.14	17.16	99	19
Hum2	Humidity squared (%)	4801.6	2,284.0	9801	361
Winds	Wind speed (km/h)	7.02	2.96	28	0
Lag_prec	Precipitation in the previous hour [0,1]	0.04	0.20	1	0
Lag_prec2	Precipitation over the previous 2 h [0,1]	0.05	0.20	1	0