Classification of Bicycle Traffic Patterns in Five North American Cities

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This study used a unique database of long-term bicycle counts from 38 locations in five North American cities and along the Route Verte in Quebec, Canada, to analyze bicycle ridership patterns. The cities in the study were Montreal, Quebec; Ottawa, Ontario; and Vancouver, British Columbia, in Canada and Portland, Oregon, and San Francisco, California, in the United States. Count data showed that the bicycle volume patterns at each location could be classified as utilitarian, mixed utilitarian, mixed recreational, and recreational. Study locations classified by these categories were found to have consistent hourly and weekly traffic patterns across cities, despite considerable differences between the cities in their weather, size, and urban form. Seasonal patterns across the four categories and in the cities also were identified. Expansion factors for each classification are presented by hour and day of the week. Monthly expansion factors are presented for each city. Finally, traffic volume characteristics are presented for comparison purposes.

As bicycle use and networks grow in size and complexity, there is a growing need to monitor and evaluate the characteristics of bicycle ridership at various locations over time. A full understanding of temporal cyclist ridership patterns can help municipalities in several ways:

1. Monitor the evolution of bicycle ridership on specific facilities (e.g., bicycle lanes or cycle tracks) or along corridors. Municipalities are often interested in quantifying the attractiveness of the bicycle infrastructure and how ridership is evolving over time.
2. Evaluate the impact of new bicycle infrastructure, programs, or policies to encourage cycling.
3. Collect data for traffic safety studies so design characteristics that may pose safety issues can be identified.
4. Identify current ridership patterns and predict future demand. This knowledge is useful for operating and maintaining bicycle facilities. Data on the distribution of hourly traffic can be used for timing traffic signals, assigning traffic patrols to certain times of day, and scheduling maintenance work.
5. Generate expansion factors to extrapolate manual short-term counts into average annual daily traffic, as is typically done for motor vehicle traffic. This is useful for a broad range of studies that require estimates of cyclist exposure in locations that lack permanent data collection.
6. Prioritize funding for new facilities according to predicted demand.

In response to these and other bicycle data needs, several North American cities and bicycle organizations have installed automated data collection technologies to collect continuous counts in specific locations. Despite the increase in data collection efforts in recent years, there is still little published work on the analysis of bicycle ridership patterns in North America. Practical experience and the few studies suggest that bicycle ridership patterns vary across cities and location types. For example, urban areas may have typical commuting patterns with distinct morning and afternoon peaks, or cold climate cities may have lower ridership during winter months. However, there is little previous research on these patterns (*1, 2*).

According to their use and ridership characteristics, bicycle facilities are often classified as either utilitarian (cycling done not mainly for fitness or recreation but as a means of transport) or recreational (leisure, social, and fitness activities). This classification may be overly simplistic because in most cases ridership is composed of a mix of users who have utilitarian and recreational purposes, independent of facility design. For instance, cycle tracks can be mainly utilitarian during the week but be heavily used on the weekend for recreational purposes, as has been documented (*1, 2*). Multiuse paths serve recreational bicyclists but are also used for trips to work and school and for many other utilitarian purposes (*3*). Bicycle volumes may also exhibit different patterns depending on the characteristics of a location rather than the specific facility type. This paper demonstrates that bicycle traffic patterns can be classified into four groups: primarily utilitarian, mixed utilitarian, mixed recreational, and primarily recreational.

Expansion factors are critical for extrapolating short-term counts into annual average daily traffic (AADT), as has been done for many years for motor vehicles (*4–7*) and which has many applications in active transportation research, such as bicycle safety, demand analysis, and pollution exposure (*8–10*). Classification is necessary for the proper application of expansion factors; for instance, applying expansion factors generated from utilitarian cyclist data to counts from a recreational location would produce biased estimates of AADT. Classification also helps in comparative analyses conducted across facilities, as well as in monitoring and detecting bicycle demand changes over time (*11, 12*). The justification of bicycle infrastructure is always easier when performance toward

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goals is demonstrated, in particular when funding is in question (*13, 14*). A point of reference (e.g., AADT) from similar facilities in other cities can help municipalities to fix their goals and evaluate their performance.

The objectives of this paper are threefold:

- Analyze bicycle traffic patterns with a unique database containing automatic hourly counts from locations in five North American cities (Montreal, Quebec; Ottawa, Ontario; and Vancouver, British Columbia, in Canada and Portland, Oregon, and San Francisco, California, in the United States) and along the Route Verte, a bicycle facility network spanning the Canadian province of Quebec.
- Present a general classification scheme for bicycle traffic patterns according to automated count data.
- Calculate expansion factors that are based on location type and region and calculate a set of simple performance measures for comparative analysis. Permanent locations with similar traffic patterns are grouped together and expansion factors are generated for expanding short-duration counts.

By including cities with a variety of bicycle facilities and location characteristics (such as weather, urban environment, and size), this study is expected to reach generalized conclusions for cycling conditions in North America.

STUDY LOCATIONS AND DATA COLLECTION

This study uses a unique cyclist-count database from a large set of automatic counting stations in five North American cities and along the Route Verte in Quebec. The Route Verte is operated by Velo Quebec (VQ), a nonprofit cycling advocacy and research organization. There are four locations in Montreal (referred to as Mon1 to Mon4), three in Ottawa (Ott1 to Ott3), one in Portland (Port), eight in San Francisco (SF1 to SF8), six in Vancouver (Van1 to Van6), and 16 along the Route Verte, located throughout suburban and rural Quebec (VQ1 to VQ16). The locations chosen for this study have some of the most extensive sets of automated bicycle count data in North America. General characteristics of the cities and the Route Verte are described in the following, and Table 1 presents a

TABLE 1 Bicycle Counter Locations

Region	Facility	Location	Facility Type	Average Daily Volume[a]	No. of Observations[b] (days)
Montreal, Quebec	Mon1	Maisonneuve at Peel	Cycle track	2,200	183
	Mon2	Maisonneuve at Berri	Cycle track	4,324	191
	Mon3	Brebeuf at Rachel	Cycle track	3,736	228
	Mon4	Berri at Maisonneuve	Cycle track	3,735	197
Ottawa, Ontario	Ott1	Ottawa River Path	Multiuse path	1,637	240
	Ott2	Colonel By Pathway	Multiuse path	832	240
	Ott3	Laurier	Segregated bike lanes	1,390	244
Portland, Oregon	Port	Hawthorne Bridge	Separated bikeway	4,869	244
San Francisco, California	SF1	Northpoint at Polk	Paired bicycle lanes	421	322
	SF2	Polk at Grove	Unidirectional bicycle lane	404	328
	SF3	Potrero at 23rd St.	Paired bicycle lanes	259	147
	SF4	Valencia at 14th St.	Paired bicycle lanes	2,475	182
	SF5	Seventh Ave. at Kirkham	Paired bicycle lanes	156	482
	SF6	Panhandle at Masonic	Multiuse path in park	3,452	175
	SF7	Lake at Arguello	Paired bicycle lanes	188	172
	SF8	Arguello at Lake	Paired bicycle lanes	511	172
Vancouver, British Columbia	Van1	Burrard St. Bridge	Bicycle lane separated path	3,004	335
	Van2	Canada Line Bridge	Bike and pedestrian bridge	336	383
	Van3	Cambie St. Bridge	Separated bikeway	990	332
	Van4	Central Valley Greenway at Rupert	Bicycle path	543	345
	Van5	Central Valley Greenway at Victoria	Bicycle path	805	344
	Van6	Ontario at 11th St.	Bicycle boulevard	788	332
Route Verte (various locations across Quebec)	VQ1	Métabéchouan	Asphalt bicycle path	232	492
	VQ2	Duschesnay	Gravel bicycle path	154	500
	VQ3	Quebec	Asphalt bicycle path	1,015	457
	VQ4	Lennoxville	Gravel bicycle path	207	458
	VQ5	Lévis	Asphalt bicycle path	1,034	444
	VQ6	Cabano	Gravel bicycle path	144	466
	VQ7	Saint Jean-sur-Richelieu	Asphalt bicycle path	200	518
	VQ8	Longueuil	Asphalt bicycle path	413	223
	VQ9	Cushing	Asphalt bicycle path	112	361
	VQ10	Laval	Asphalt bicycle path	590	492
	VQ11	Granby	Asphalt bicycle path	267	492
	VQ12	Mont-Rolland	Gravel bicycle path	359	448
	VQ13	Trois Rivières	Asphalt bicycle path	542	442
	VQ14	Victoriaville	Asphalt bicycle path	62	382
	VQ15	Gatineau	Asphalt bicycle path	34	496
	VQ16	Blainville	Asphalt bicycle path	135	399

NOTE: no. = number; st. = street; ave. = avenue.
[a]During study months (April to November).
[b]Observations are only during study months (April to November).

brief description of each specific counter location involved in the analysis.

Description of Study Areas

Montreal

Montreal experiences warm, often humid, summers and cold, snowy winters. Average daily high temperatures range from 27°C in July to –9°C in January. In Montreal, the average yearly water equivalent of all precipitation is roughly 980 mm, and the city receives roughly 220 cm of snow in an average year. Several of its bicycle facilities have been in use since the 1970s, and Montreal has recently constructed several new bicycle lanes and physically separated cycle tracks. For these, as well as many kilometers of multiuse paths in and around the city, Montreal has received accolades as a cycling city (*15*).

Ottawa

Like Montreal, Ottawa experiences hot, humid summers and cold, snowy winters. Ottawa experiences similar temperatures to Montreal. In Ottawa the average yearly water equivalent of all precipitation is roughly 944 mm, and the city receives roughly 212 cm of snow in an average year (*15*). Ottawa began constructing bicycle infrastructure in the 1970s with its Ottawa River Pathway. As of mid-2011, Ottawa had 341 km of multiuse pathways and 210 km of bike lanes.

Portland

Portland is characterized by a temperate climate with mild, wet winters and dry summers. Average high temperatures range from 8°C in January to 26°C in July. Rainfall averages 950 mm per year in downtown Portland (*16*). Portland's bridges act as feeders to carry commuters and students from neighborhoods east of the Willamette River into the downtown area and beyond, the Hawthorne bridge carrying more bicycle traffic than any other bridge in the city. Portland was described by one researcher to be "the American city that comes closest to implementing a truly comprehensive, well-integrated, long-term package of infrastructure, programs, and policies to promote cycling" (*17*).

San Francisco

San Francisco is known for mild temperatures year round, hilly topography, and frequent fog. Average high temperatures range from 14°C in December to 22°C in September in downtown, with average annual precipitation of 600 mm (*16*). San Francisco has the lowest rate of precipitation and the highest winter temperatures of the locations under study. The bicycle infrastructure in San Francisco includes roughly 37 km of separated bicycle paths and 72 km of on-street bicycle lanes (*18*). These facilities, as well as designated bicycle routes without any dedicated bicycle lanes, serve most of the spatially constrained city.

Vancouver

Vancouver has a temperate climate similar to Portland's. Located in the region with the warmest winters in Canada, Vancouver has high temperatures ranging from 6°C in January to 22°C in July. Also like Portland, Vancouver experiences rainy winters and relatively dry summers, averaging 1,155 mm of precipitation per year (*15*). Vancouver has a network of bicycle facilities that serve downtown, residential neighborhoods, and recreational destinations in and out of the city. In recent years, Vancouver has implemented bicycle-oriented traffic calming measures and has constructed new bicycle facilities.

Route Verte

The Route Verte (Green Route) is an extensive bicycle network spanning Quebec and is made up of more than 4,900 km of bikeways. This vast bicycle route, the most extensive in North America, includes a variety of facilities, such as multiuse paths, designated shared roadways, and paved shoulders. All Route Verte counting stations analyzed in this study are located on pathways in suburban or rural areas (*19*). The climate in each location is much like that of Montreal and Ottawa (*15*).

Collection of Cyclist Count Data

Data for the 37 permanent locations consist of disaggregated hourly bicycle counts collected with automatic inductive loop detectors embedded in the pavement of bicycle facilities. Previous studies showed that this equipment achieves high levels of accuracy (96% and more) (*20, 21*). The data were collected by the municipal planning departments of the cities under study, as well as by VQ. All data were collected between 2008 and 2011, and each facility provided at least one season of data. Some bicycle facilities in Montreal and Ottawa and along the Route Verte are not maintained during winter, so for consistency, this analysis incorporated data only from April through November (inclusive).

Before analysis, each data set was reviewed thoroughly for missing values, which can be caused by routine maintenance, counter malfunction, construction, or other factors. In addition, an effort was made to identify extreme values. For instance, large bicycle races or group rides on the Route Verte result in days with abnormally large total counts. Days with missing data or extreme values were excluded from the analysis of bicycle traffic patterns. Despite the high levels of accuracy, in-pavement loops do not count bicyclists with 100% accuracy. Although the count data presented here are not adjusted for undercounting, the counter technology used at all locations in this study is similar, and comparisons between sites are assumed to be consistent. However, if future validation studies show that accuracy varies by location, time, activity level, or other factors, some of the patterns identified in the analysis should be adjusted slightly.

METHOD OF ANALYSIS OF TRAFFIC PATTERNS

Definition of Standardized Indexes

Bicycle traffic patterns are analyzed with hourly and daily indexes, which express the average cyclist count for a given hour, day, or month as a percentage of the seasonal daily average (Equations 1 to 5). Because they are standardized for the seasonal average, the indexes facilitate comparisons of temporal profiles across facilities that exhibit differing absolute ridership levels. In the vehicular traffic literature, these indexes are typically referred to as expansion factors, and they can be used to convert brief manual cyclist counts into overall yearly averages.

Standardized Hourly, Daily, and Monthly Indexes

The standardized hourly, daily, and monthly indexes are defined as follows:

$$I_h = \left(\frac{\overline{v}_h}{\text{ADV}}\right) \tag{1}$$

$$I_d = \left(\frac{\overline{v}_d}{\text{ADV}}\right) \tag{2}$$

$$I_m = \left(\frac{\overline{v}_m}{\text{ADV}}\right) \tag{3}$$

where

I_h, I_d, I_m = standardized hourly, daily, and monthly indexes, respectfully;
$\overline{v}_h$, $\overline{v}_d$, $\overline{v}_m$ = seasonal (April to November) averages for given hour h, day of week d, or month m, respectively; and
ADV = $1/n \sum_{i=1}^{n} v_i$ = average daily volume over biking season or year, where v_i is total daily volume on day i and n is number of days in season or year.

Traffic Distribution Indexes

Traffic distribution indexes are used to quickly summarize the distribution of bicycle traffic throughout the day, week, or year and are defined as follows:

$$I_{\text{we/wd}} = \left(\frac{\overline{v}_{\text{we}}}{\overline{v}_{\text{wd}}}\right) \tag{4}$$

where $I_{\text{we/wd}}$ is the relative index of weekend versus weekday cycling traffic (WWI) and $\overline{v}_{\text{we}}$, $\overline{v}_{\text{wd}}$ are the seasonal average daily weekend and weekday traffic, respectively.

$$I_{\text{AM/mid}} = \left(\frac{\delta_i^{\text{AM}}}{\delta_i^{\text{mid}}}\right) \tag{5}$$

where

$I_{\text{AM/mid}}$ = relative index of morning (7:00 to 9:00) to midday (11:00 to 13:00) cycling traffic (AMI),
δ_i^{AM} = $\sum_{h=7}^{9} \overline{v}_h$, and
δ_i^{mid} = $\sum_{h=11}^{13} \overline{v}_h$.

Several intervals for the morning and midday hours were tested, and it was found that the preceding produced the clearest, most consistent results.

Classification of Bicycle Traffic Patterns

The bicycle traffic patterns were classified with the following procedure:

1. Identification of locations with utilitarian and recreational patterns. Equations 1 and 2 were used to compute the hourly, daily, and monthly indexes for each counter location. The values for each facility were plotted to graphically portray the hourly and daily profiles. Locations with either standard utilitarian or recreational traffic patterns were identified. For instance, typical utilitarian patterns consist of two peak traffic periods on weekdays (during the morning and evening commuting hours) and a higher proportion of traffic during the week than on the weekend. Standard recreational patterns consist of one midday or evening peak traffic period on weekdays and a higher proportion of traffic on weekends than during the week. This has been documented in recent bicycle studies (*1, 2, 22*). These patterns again are similar to those for highways (*4, 6*). The locations without typical utilitarian or recreational patterns were identified as mixed facilities.

2. Determination of confidence intervals for utilitarian and recreational groups. Data from the locations with standard utilitarian and recreational patterns were used to construct 95% confidence intervals with the mean and standard deviation of each hourly and daily index across all facilities in each group. For instance, the lower and upper limits for the hourly profile were estimated as $\overline{v}_h \pm 1.96(\sigma_h/\sqrt{n})$, where h ranges from 0 to 23. The confidence intervals were then superimposed on the hourly and daily profiles and used to validate the initial classifications made in Step 1. An iterative process was used to refine the confidence intervals and groups; if a location's hourly and daily profiles did not fit within the upper and lower limits of the confidence interval for utilitarian or recreational locations, that location was moved to the mixed category, and the confidence intervals were recalculated with the remaining locations. This was repeated until all facilities remaining in the utilitarian or recreational groups fit within the respective confidence intervals. Note that for a small number of locations, the hourly profile clearly exhibited a utilitarian or recreational pattern although one $\overline{v}_h$ value fell outside the confidence interval. In such cases, the location was not excluded from the confidence interval calculation.

3. Classification of mixed facilities. The patterns of the facilities that had been classified in the mixed category in the previous step are further analyzed in this step. Many of these locations exhibit similar patterns to the utilitarian or recreational locations despite not fitting completely into either. For instance, certain locations did not exhibit higher ridership during the week than on the weekend but did exhibit morning and evening commuting peaks. Other locations also did not exhibit higher ridership during the week than on the weekend but did exhibit one weekday peak, such as recreational facilities. Confidence intervals were constructed for these two subgroups and, again, the upper and lower confidence interval limits were then used to identify those locations with uncommon patterns. If the patterns of a location fell within the defined confidence intervals, the location was classified as either mixed utilitarian or mixed recreational. If not, the location was classified as an outlier with an anomalous classification. Locations that did not fall in any of these four categories were excluded from the calculation of the expansion factors.

The outlined procedure is illustrated in Figure 1 for the utilitarian and mixed utilitarian classifications. The same procedure was applied to arrive at the recreational and mixed recreational classifications.

RESULTS

This section provides the results of location classification with the described procedure. In addition to a discussion of the bicycle traffic classifications in the five study cities and on the Route Verte, this section presents expansion factors for use in practice.

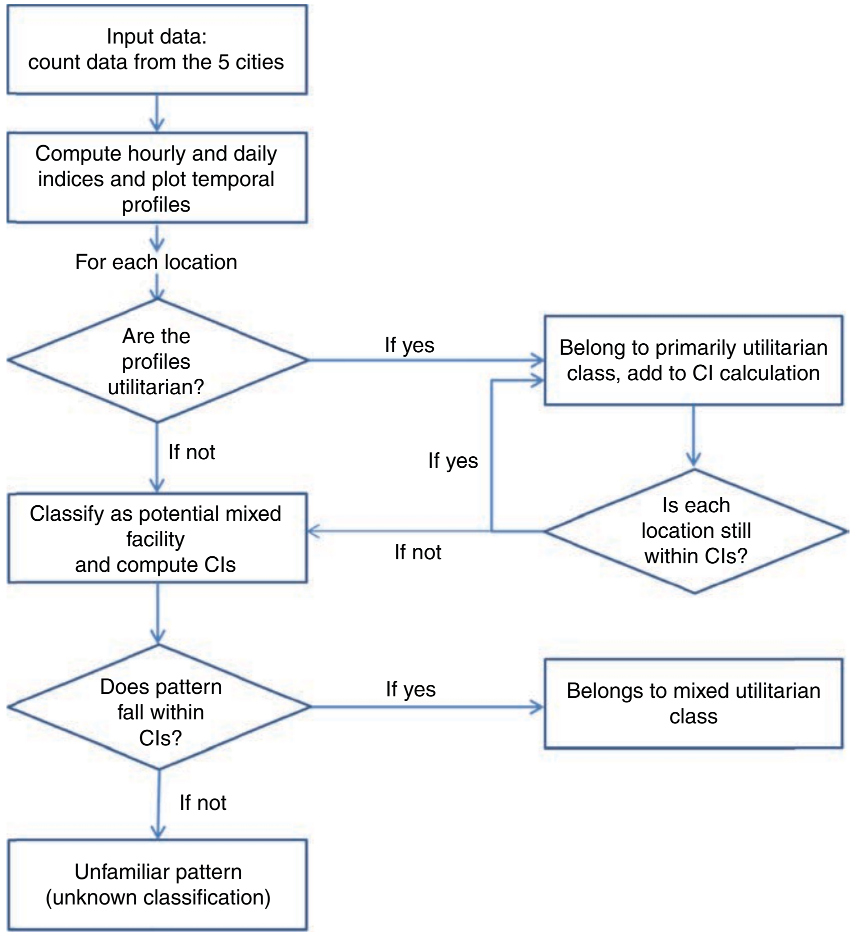


FIGURE 1 Classification of city counting locations (CI = confidence interval).

Traffic Ridership Analysis at City Locations

Following the procedure illustrated in Figure 1, the bicycle traffic patterns were calculated for each count location. Figures 2 and 3 show the average hourly profiles across 24 h for all the urban and Route Verte locations during weekdays and weekends, respectively. Figure 4 shows the daily profiles over the week for both urban and Route Verte locations. Figures 2, 3, and 4 include all the profiles from before the mixed facilities were separated and thus many facilities fall outside the confidence intervals.

With few exceptions, most of the locations in the five urban areas exhibit two pronounced peaks during the morning and evening commute times on workdays (Figure 2*a*). In addition, they have higher ridership during the workweek than on the weekend (Figure 4*a*). Locations with such patterns are classified as primarily utilitarian. Hourly and daily confidence intervals were estimated to validate the correct classification of each of these facilities, as illustrated in Figures 2, 3, and 4.

As explained in the previous section, facilities that do not fall within confidence intervals were grouped as locations with mixed patterns. The temporal profiles of these locations are reproduced separately in Figure 5, along with the mean profiles of the primarily utilitarian facilities, for clarity. With the exception of SF8, these locations maintain relatively consistent ridership throughout the week. However, all the hourly profiles of these locations still exhibit two distinct peaks during the workweek. This suggests that although the bicycle traffic on the weekend is as high as that on weekdays, these locations are still used heavily for commuting. These facilities are labeled mixed utilitarian.

The anomalous counter is SF8, which is located on the border of Presidio National Park, en route to the Golden Gate Bridge in California. Because of high tourist traffic to the bridge and park, SF8's daily profile is very similar to that of a recreational location. However, because of commuting traffic during the week, SF8 exhibits two distinct peaks during the workweek and has slightly higher noontime traffic. SF8 also exhibits a very recreational weekend hourly profile, with greater use occurring in the morning than the utilitarian average. Although this location is clearly mixed use, for consistency it is not included in the mixed utilitarian category.

Traffic Ridership Analysis at Route Verte Locations

With some exceptions, most of the suburban and rural count locations along the Route Verte exhibit only one midday or evening peak on both workdays and weekends (Figures 2*b* and 3*b*) as well as lower ridership during the workweek than on the weekend (Figure 4*b*). Locations exhibiting these patterns were classified as primarily recreational, as discussed in the methodology section. Again, following the procedure defined earlier, locations

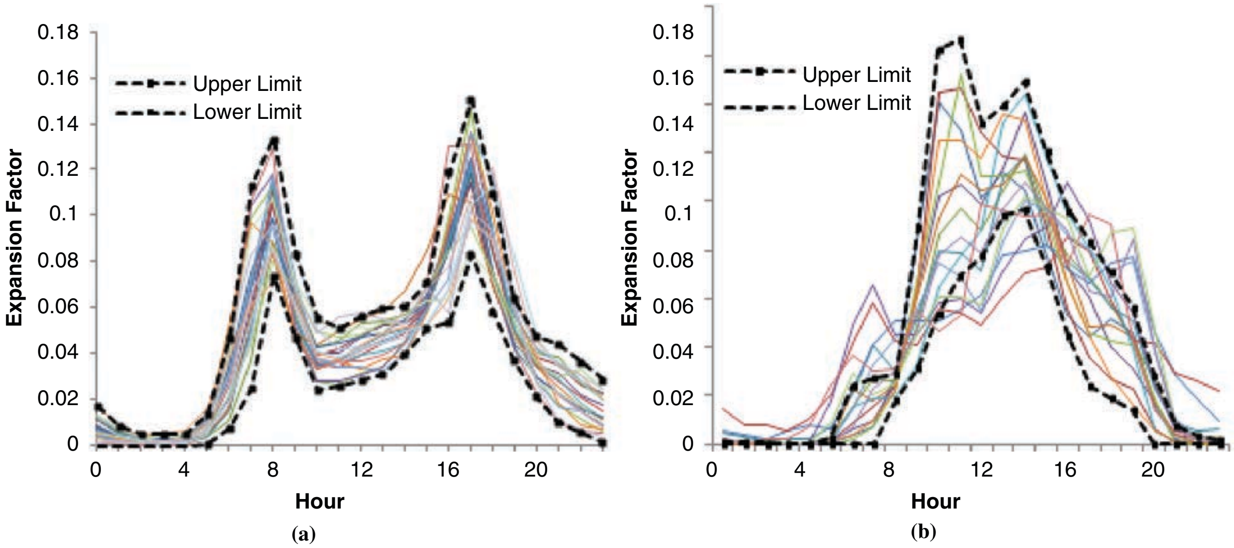


FIGURE 2 Weekday profiles for (*a*) urban locations and (*b*) Route Verte (Velo Quebec) locations.

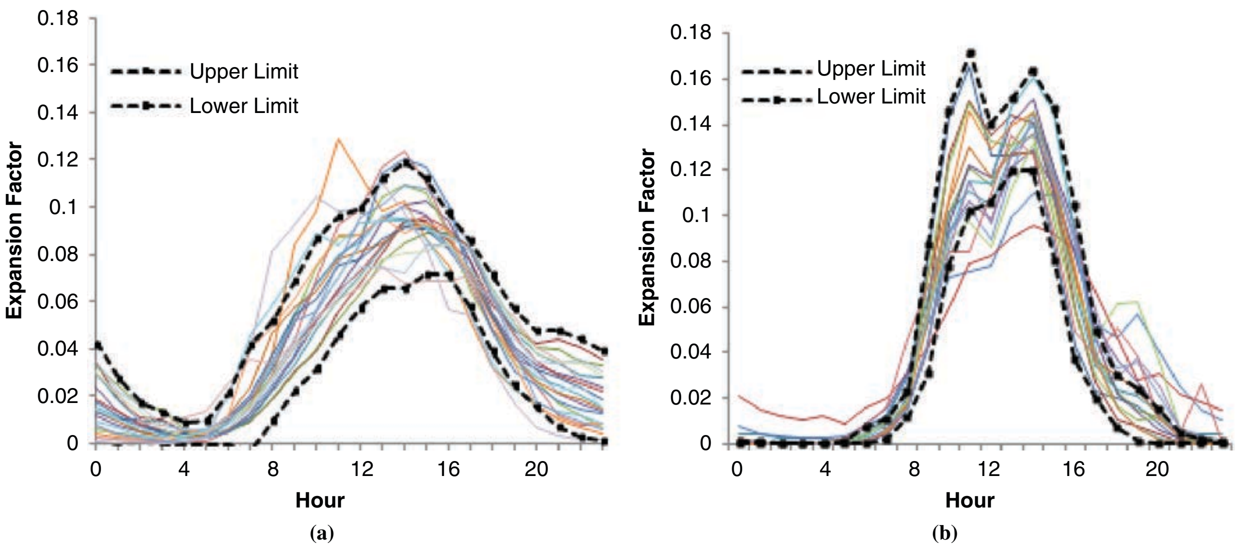


FIGURE 3 Weekend hourly profiles for (*a*) urban locations and (*b*) Route Verte (Velo Quebec) locations.

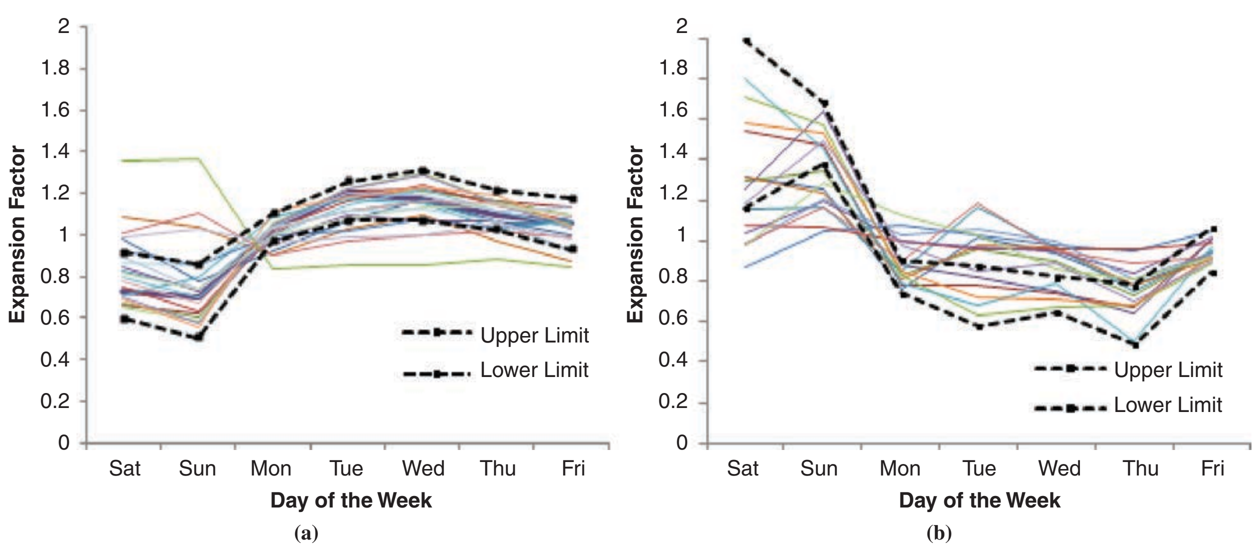


FIGURE 4 Daily profiles for (*a*) urban locations and (*b*) Route Verte (Velo Quebec) locations.

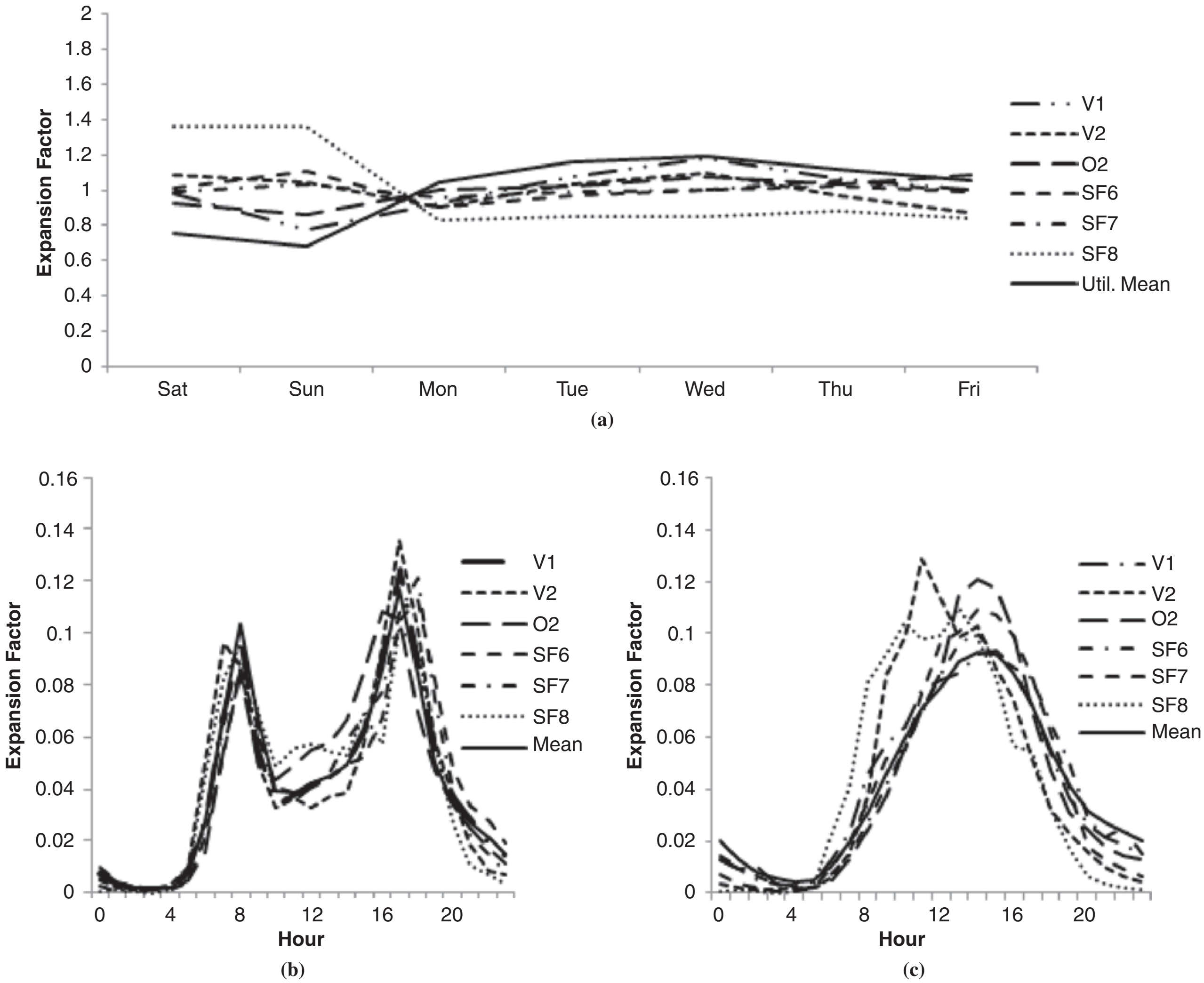


FIGURE 5 Mixed utilitarian (util.) daily and hourly profiles: (*a*) daily profile, (*b*) weekday hourly profiles, and (*c*) weekend hourly profiles.

that deviated from typical recreational patterns were singled out. For clarity their traffic patterns are presented in Figure 6. Like the mixed utilitarian locations, these locations maintain relatively consistent ridership throughout the 7 days of the week. However, although some may have a small morning peak, the hourly profiles do not exhibit two distinct commuting peaks. This suggests that although they may have relatively mixed use, they are used more heavily for recreational purposes. These facilities are labeled mixed recreational.

The mixed recreational locations have greater variability than the mixed utilitarian locations. Figure 6, *a* and *b,* presents the profiles of mixed recreational locations that exhibit higher WWI values (ranging from 1.34 to 1.51); Figure 6, *c* and *d,* displays the profiles of the mixed recreational locations that exhibit lower WWI values (0.96 to 1.20). The mixed recreational locations with higher WWI values more closely resemble primarily recreational facilities. However, those with lower WWI values appear more irregular. Although they do not exhibit two distinct peaks like the primarily utilitarian or mixed utilitarian facilities, they tend to exhibit a morning peak, suggesting more mixed use. It is possible that the variations in temporal profiles across mixed recreational locations can be explained by the locations characteristics, such as the surrounding land use, density, its proximity to attractions, town centers, and so on. For instance, two locations may experience roughly the same proportion of recreational and utilitarian use, but because one location is closer to town, it may get more use during the week, whereas the more remote locations are visited only for longer rides on the weekend. More specific categories that include such characteristics might be necessary. Until this can be investigated with geographic information system–based land use characteristics, the primarily recreational category was made to contain only those facilities with very high WMI values.

Seasonal Monthly Patterns Across Regions and Classifications

Hourly and daily patterns presented in Figures 2, 3, and 4 appear relatively consistent across regions; that is, primarily utilitarian locations in Vancouver exhibit hourly profiles very similar to those of primarily utilitarian facilities in Montreal. However, monthly patterns vary considerably across classifications and regions (Figure 7). Seasonal data from April through November show that Vancouver's utilitarian facilities retain higher ridership in November than both

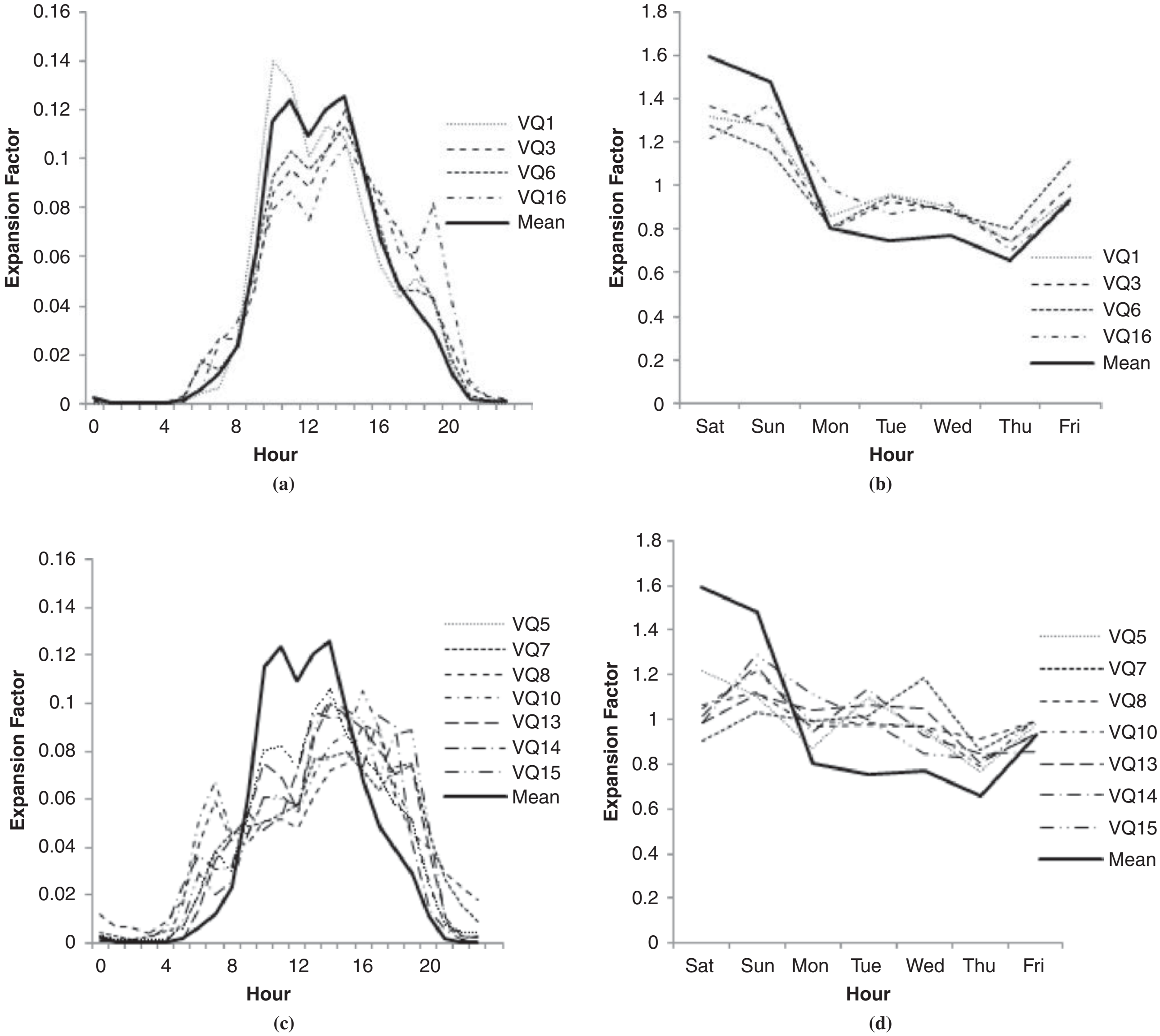


FIGURE 6 Traffic profiles for mixed recreational facilities: (*a*) weekday profile, mixed recreational locations, higher WWI; (*b*) daily profile, mixed recreational locations, higher WWI; (*c*) weekday profile, mixed recreational locations, lower WWI; and (*d*) daily profile, mixed recreational locations, lower WWI.

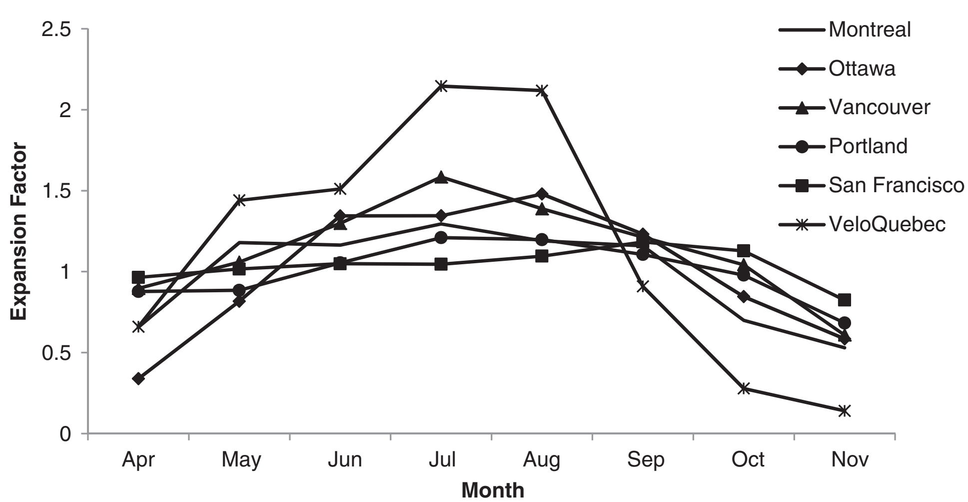


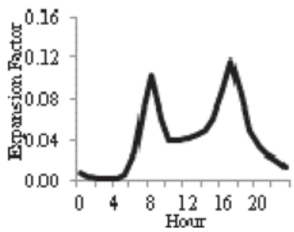
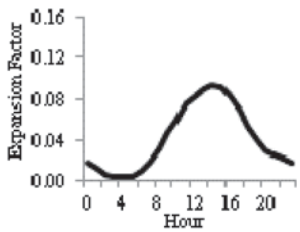
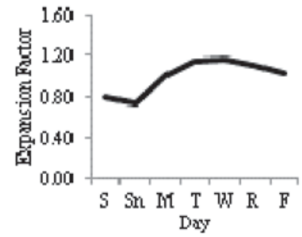
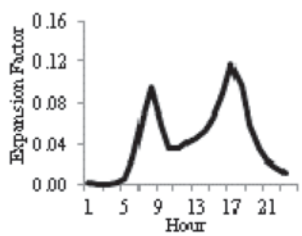
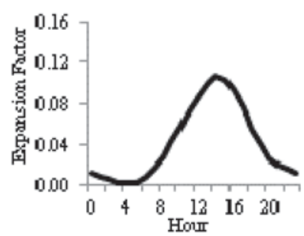
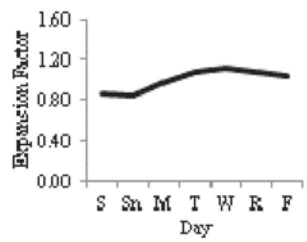
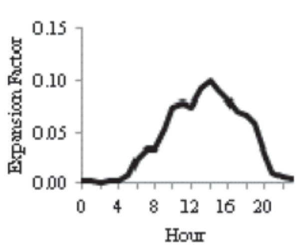
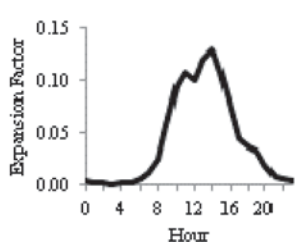
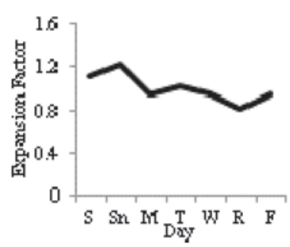
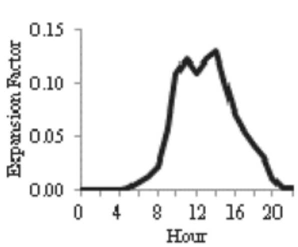
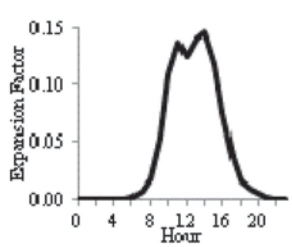
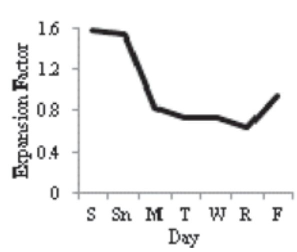
FIGURE 7 Monthly profiles for urban and Route Verte (Velo Quebec) locations.

Montreal and Ottawa, which suggests that because Vancouver has warmer winters, more of its utilitarian cyclists ride year-round. However, the Velo Quebec facilities, which share a climate similar to that of Montreal and of Ottawa, retain far less ridership in the winter than both cities, likely because recreational trips are more sensitive to cold weather.

Summary of Classification Groups

A summary of the classifications and their characteristics is provided in Table 2. The profiles are the mean values of the locations in each category. Although many bicycle counter locations can be classified into one of these four categories, differences can exist

TABLE 2 Summary of Bicycle Classifications

	Hourly Profile		
Type	Weekday	Weekend	Daily Profile
Primarily utilitarian			
	Utilitarian locations exhibit two distinct weekday peaks, much like automobile commuter patterns, and have much higher ridership during the week than on the weekend. The weekend profile builds smoothly to a single evening peak. In general, primarily utilitarian locations maintain the highest ridership in the winter.		
Mixed utilitarian			
	Mixed utilitarian locations still exhibit two peaks at the hourly level on weekdays, although the level of ridership between the peaks may be slightly higher than at primarily utilitarian locations. The difference between weekday and weekend ridership is much less pronounced and may even be negligible. Weekend ridership builds gradually to an evening peak, similar to primarily utilitarian locations. Mixed utilitarian locations may retain less ridership in the winter than primary utilitarian locations.		
Mixed recreational			
	Mixed recreational locations tend to maintain a consistent level of daily ridership throughout the week. However, unlike mixed utilitarian locations that of, their hourly profiles do not exhibit two distinct commuting peaks. Still, their early morning ridership during the workweek may be slightly higher than at primarily recreational locations. The daily profile may exhibit slightly higher ridership on the weekend. Ridership at these locations is generally considerably lower than primary utilitarian or mixed utilitarian locations in the winter.		
Primarily recreational			
	Primarily recreational locations are typically in parks or serve recreational areas. These locations exhibit considerably higher ridership on the weekend than during the week. The workweek hourly profile closely resembles the weekend profile, which increases steeply to and decreases steeply from a midday plateau. A slight dip around noon may be present as well. The decrease in ridership in winter is most significant at recreational locations.		

NOTE: Pictured profiles are mean values of facilities belonging to each classification.

across locations in the same category (particularly within the mixed groups), and some may not fit well into any category.

Expansion Factors for Extrapolating Manual Counts

For their use in practice, hourly and daily level expansion factors for the four classifications are computed for the four types of facility locations. Expansion factors were calculated with the traditional approach, as done for highways (*7*):

1. Aggregate hourly volumes into daily totals and calculate the overall average daily volume.
2. Calculate average daily total for each day of the week and for each month of the year. Then divide each daily average by the overall average to obtain the daily expansion factors. Similarly, divide the monthly average by the overall average to obtain monthly expansion factors.
3. Calculate average hourly totals for each hour of the day. Compute hourly expansion factors by dividing each hourly average by the overall average.

The estimated hourly and daily expansion factors for each facility type are presented in Tables 3 and 4. These values correspond to the graphical profiles presented in Table 2. Although these values are representative of each category, individual facility locations may exhibit slightly different behavior while conforming to the overall patterns of a given classification. Because monthly expansion factors vary so heavily across regions, in addition to across classifications, general monthly expansion factors for the four classifications are not feasible. Monthly expansion factors must be specific to a given climate and classification. Therefore, monthly expansion factors for the utilitarian facilities in each city, as well as for the recreational Velo Quebec facilities, are presented in Table 5.

Expansion factors are most applicable to primarily utilitarian and primarily recreational locations, as these locations exhibit the greatest consistency. Care must be taken to ensure that the factors are applied only to locations that exhibit the same patterns as the classification group being utilized. Mixed locations will require the greatest scrutiny.

Comparison of Bicycle Volume Patterns

In addition to the indexes that were calculated for the classification, the average daily volume was also computed for each facility. These values are reported in Table 6, along with the relative WWI and the relative AMI.

These comparisons show that traffic intensity can vary considerably between counting locations of the same type. For instance, the two top locations (Mon2 and Port) present daily volumes that are 10 times higher than counting locations in San Francisco. Much less variability is observed in the recreational group, which presents overall very low traffic intensity. However, as discussed earlier,

TABLE 3 Hourly Expansion Factors by Classification

Hour	Utilitarian	Mixed Utilitarian	Mixed Recreational	Recreational
0	0.007	0.006	0.007	0.000
1	0.004	0.003	0.005	0.000
2	0.002	0.002	0.004	0.000
3	0.001	0.001	0.004	0.000
4	0.002	0.003	0.006	0.000
5	0.006	0.008	0.012	0.002
6	0.025	0.032	0.028	0.011
7	0.072	0.074	0.040	0.015
8	0.114	0.089	0.039	0.026
9	0.064	0.051	0.047	0.064
10	0.037	0.037	0.065	0.114
11	0.037	0.041	0.065	0.118
12	0.042	0.043	0.060	0.104
13	0.044	0.047	0.086	0.111
14	0.048	0.052	0.093	0.119
15	0.061	0.069	0.081	0.093
16	0.093	0.098	0.076	0.067
17	0.118	0.122	0.070	0.051
18	0.077	0.087	0.064	0.045
19	0.046	0.053	0.063	0.037
20	0.033	0.036	0.036	0.016
21	0.027	0.024	0.018	0.004
22	0.019	0.015	0.014	0.001
23	0.014	0.011	0.010	0.001

TABLE 4 Daily Expansion Factors by Classification

Day	Utilitarian	Mixed Utilitarian	Mixed Recreational	Recreational
Saturday	0.70	1.00	1.02	1.35
Sunday	0.64	0.89	1.18	1.41
Monday	1.05	0.94	1.00	0.82
Tuesday	1.18	1.04	1.03	0.89
Wednesday	1.22	1.12	0.95	0.84
Thursday	1.14	1.02	0.85	0.72
Friday	1.08	0.99	0.97	0.97

TABLE 5 Monthly Expansion Factors by Region and Classification

	Utilitarian					
Month	Ottawa	Montreal	Vancouver	San Francisco	Portland	Velo Quebec
April	0.58	0.66	0.71	0.96	0.88	0.66
May	1.22	1.18	0.90	1.02	0.88	1.44
June	1.28	1.16	1.06	1.05	1.05	1.51
July	1.52	1.29	1.30	1.05	1.21	2.15
August	1.13	1.19	1.58	1.10	1.20	2.12
September	1.08	1.16	1.39	1.18	1.11	0.91
October	0.68	0.70	1.21	1.13	0.98	0.28
November	0.48	0.53	1.04	0.82	0.68	0.14

TABLE 6 Comparison of Bicycle Volume Patterns at Study Locations

Study Location	Rank (by AADT)	AADT	WWI	AMI
Utilitarian				
Port	1	4,869	0.54	1.68
Mon 2	2	4,021	0.56	1.26
Mon 3	3	3,553	0.65	1.66
Mon 4	4	3,267	0.72	1.63
SF 4	5	2,475	0.71	1.77
Mon 1	6	2,200	0.56	1.62
Ott 1	7	1,637	0.67	2.52
Ott 3	8	1,389	0.43	2.38
Van 3	9	990	0.61	2.05
Van 5	10	805	0.56	2.97
Van 6	11	788	0.72	2.17
Van 4	12	543	0.53	2.93
SF 1	13	421	0.77	2.62
SF 2	14	404	0.72	1.30
SF 3	15	259	0.65	1.53
SF 5	16	156	0.82	1.82
Mean	na	na	0.65	1.97
Mixed utilitarian				
SF 6	1	3,452	1.08	1.62
Van 1	2	3,004	0.84	1.76
Ott 2	3	832	0.85	1.16
SF 8	4	511	1.59	1.47
Van 2	5	336	1.1	2.17
SF 7	6	188	1.01	1.70
Mean	na	na	1.08	1.64
Mixed recreational				
VQ 5	1	1,034	1.25	0.48
VQ 3	2	1,015	1.51	0.35
VQ 10	3	590	1.20	0.85
VQ 13	4	542	1.08	0.63
VQ 8	5	413	1.14	0.88
VQ 1	6	232	1.47	0.32
VQ 7	7	200	0.96	0.71
VQ 6	8	144	1.34	0.32
VQ 16	9	135	1.47	0.44
VQ 14	10	62	1.20	0.53
VQ 15	11	34	1.20	0.44
Mean	na	na	1.26	0.54
Recreational				
VQ 12	1	359	2.13	0.24
VQ 11	2	267	1.81	0.33
VQ 4	3	207	1.77	0.32
VQ 2	4	154	1.88	0.27
VQ 9	5	112	2.26	0.26
Mean	na	na	1.97	0.28

NOTE: na = not applicable.

despite the large differences in volumes, there are consistent temporal patterns across these facilities and cities. The results of the study's classification also can be evaluated with WWI and AMI. These indexes are very similar across facilities of the same group, which shows the heterogeneity of traffic patterns within locations of the same group.

These simple indexes can be generated for monitoring the evolution and performance of facilities and bicycle use in general.

CONCLUSIONS AND FUTURE WORK

This paper presented a study of the temporal bicycle traffic patterns at 37 automatic counting locations on bicycle facilities in Montreal, Ottawa, Portland, San Francisco, and Vancouver, as well as at suburban and rural facilities along the Route Verte in Quebec. The study showed that most of the study locations can be classified into one of four groups: primarily utilitarian, mixed utilitarian, mixed recreational, and primarily recreational. Locations with primarily utilitarian patterns have typical weekday morning and afternoon commute peaks and a single peak during weekends. These patterns are very similar to those observed for motor vehicle traffic in urban arterials and highways. Mixed utilitarian locations exhibit two distinct commute peaks at the hourly level, but ridership between the peaks may be slightly higher than at primarily utilitarian locations. They also maintain a consistent level of ridership throughout the week, that is, daily volumes on weekends are as high as on weekdays. Recreational locations exhibit their highest proportion of traffic volumes around midday during both weekdays and weekends. Moreover, they exhibit higher ridership on the weekend than during the week. Finally, mixed recreational locations exhibit a consistent level of ridership throughout the week, like mixed utilitarian facilities. However, they do not exhibit two distinct commuting peaks during the workweek. As bicycle facilities become more recreational, the morning portion of the weekend hourly profile increases, whereas utilitarian facilities build to a gradual evening peak.

Within each of the four classifications, relative hourly and daily traffic patterns appear to be consistent across regions. However, local climate appears to have a considerable effect on the monthly profiles across cities. Utilitarian facilities in a city with colder weather retain lower ridership in the winter than those facilities in warmer cities. Furthermore, classifications appear to respond differently across seasons. Recreational locations retain far less ridership in winter than do utilitarian locations.

The consistency of temporal profiles across locations in the same classification suggests that general expansion factors can be applied to some bike facility locations. This paper reports expansion factors for each type of bicycle traffic classification. The expansion factors are expected to be useful for practitioners and researchers seeking to extrapolate manual counts into AADT estimates, a common need in planning and safety studies. In addition, several indexes were developed for comparing overall bicycle volumes and patterns of bicycling activity across locations. These measures can be used for comparative studies.

Future studies should explore more detailed measures of the built environment in the vicinity of count locations. It is likely that some of the variations in bicycle volume patterns within each general category are associated with immediate land use characteristics. More detailed measures will help further refine the comparison of bicycle ridership patterns across environments. In addition, winter data should be analyzed in a variety of locations for determining year-round bicycle volume patterns. Finally, changes in overall bicycle volumes and bicycle volume patterns over time can be investigated with a similar rich database of continuous counts from locations throughout North America.

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