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Data and Bicycle and Pedestrian Demand

AN INTERIM SYNTHETIC APPROACH FOR ESTIMATING PEDESTRIAN VOLUMES IN SMALLER COMMUNITIES

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ABSTRACT

As multimodal transportation infrastructure becomes common, planners need estimates of non-motorized travel demand in order to evaluate investment choices. Just as transportation agencies rely on established motor vehicle traffic monitoring programs to identify auto-oriented improvements, agencies are beginning to recognize the necessity of a parallel non-motorized traffic monitoring program. For rural communities with limited resources, however, the cost of establishing such a program may be prohibitive.

Accordingly, this paper reports on the development of a relatively simple approach to estimate daily pedestrian volumes using publicly available data: population density, speed limits, number of lanes, traffic volumes, and national household survey results. A comparison of forecast and observed volumes at 30 sites throughout smaller Virginia locations (Charlottesville, Harrisonburg and Roanoke) shows that the approach yields a median error of 254 pedestrians per day. Further, the paper illustrates how a modest amount of additional data can improve the accuracy of the estimates: for example, by using thirty 2015 observations of pedestrian travel to supplement the 2009 NHTS, the median error improved to 230 pedestrians per day. The approach also demonstrates that the variables used therein are reasonable; for example, the model shows that as speed limits drop from 45 mph to 25 mph, one would expect the number of pedestrians to increase by a factor of about 3.1.

To be clear, this approach will not replace a full count program for those jurisdictions that can afford one. However, it may be useful for smaller localities who are considering incremental improvements to counting methods or which need to quickly obtain pedestrian count estimates for a large number of links. The paper illustrates how to develop the estimation approach through geographic information systems (GIS), how to calibrate estimations to a target area, and the accuracy one might expect from using this method.

Keywords: Pedestrian counts, Traffic counts, Programming (planning), Pedestrians, Bicyclists, Traffic

surveillance

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INTRODUCTION

There is a growing need to make evidence-based choices for transportation investment, particularly for non-motorized travel. Especially in large urban locations, such as Arlington (Virginia) and San Diego (California), agencies have begun to routinely collect bicycle and pedestrian count data (*1*,*2*). At the federal level, both the FHWA and the National Highway Traffic Safety Administration initiated a Bicycle-Pedestrian Count Technology Pilot Project in 2015; the effort is intended to collect more and better data on pedestrian and bicyclist activity to support planning and investment decisions as well as targeted safety improvements (*3*). Just as agencies routinely collect motorized vehicle data that can be used to evaluate the need for candidate transportation improvements, nonmotorized count data can be used in prioritization processes as well.

Rural locations and smaller urban areas, however, face unique challenges for estimating pedestrian volumes. Planning and transportation agencies in such locations may not have sufficient resources to establish a nonmotorized count program. Whereas state transportation agencies usually have a functional unit that can at least obtain vehicle volumes on a few major roadways such as interstates and state arterials, localities may not have procedures in place to count bicyclists and pedestrians on the many smaller facilities where pedestrians are likely to travel. This situation arose in Virginia where, in 2015, the application of a statewide process for prioritizing candidate transportation improvements across different modes required estimates of demand. For many measures, the statewide traffic count program easily provided the necessary information; Virginia has over a half-century of experience in operating a motorized vehicle count program. Some measures, however, required estimates of nonmotorized traffic volumes, and except in a few urban locations, no pedestrian count data were available. This paper illustrates how to respond to that challenge in order to estimate pedestrian volumes statewide, especially in rural areas, in the absence of data collection resources.

Accordingly, this paper reports on a three-stage approach for estimating pedestrian volumes. The first stage uses National Household Travel Survey data and motorized traffic volumes to obtain an estimate of pedestrian traffic on each Virginia link. The second stage forecasts the estimated volumes based on the density of the link's designated census tract. The third stage modifies estimated volumes based on each link's appeal to pedestrians (using link speed limit and number of lanes) and then specifies calibration parameters based on observed pedestrian count data in three small and medium-sized Virginia cities: Charlottesville, Harrisonburg, and Roanoke. Because many localities may have to implement such a process from scratch, the paper first describes the preliminary data acquisition and synthesis process.

LITERATURE REVIEW

A considerable amount of recent research has been devoted to establishing long-term formal count programs for nonmotorized road users. Examples are the *Guidebook on Pedestrian and Bicycle Volume Data Collection (4),* FHWA's *Traffic Monitoring Guide (5),* TRB's *Monitoring Bicyclist and Pedestrian Travel Behavior – Current Research and Practice (6), and Estimating Bicycling and Walking for Planning and Project Development: A Guidebook (7).* Collectively, these resources indicate technologies useful for performing counts, techniques for converting spot counts to annual counts, and a rationale for estimating bicycling and walking demand as part of regional, corridor, or project-level analyses. Research has also addressed specialized topics within the framework of establishing a count program, such as count site selection (*8*), design hour (*K*) factors (*9*), and technologies for data collection such as signal controller infrastructure (*10*).

Formal count programs have been launched in a few states. The Minnesota Bicycle and Pedestrian

Counting Initiative is a collaborative, statewide effort to encourage and support non-motorized traffic monitoring by local, regional, and state governments and nonprofit organizations (*11*); Washington (*12*) and North Carolina (*13*) have also initiated statewide count programs to evaluate the utility of new facilities, identify frequently used routes, and calculate mode share. In Virginia, local and regional count programs are run by Arlington County (*1*), the Charlottesville-Albemarle Metropolitan Planning Organization (*14*), and the Roanoke Valley Transportation Planning Organization (*15*). Organizationally, the collection of nonmotorized counts has proceeded in a different manner than for motorized counts: whereas the latter are typically managed through a statewide program with a single set of standards for how these counts are performed, the former is a collaborative effort with diverse entities collecting these data.

While the aforementioned literature is helpful for establishing a formal program, small jurisdictions with limited resources that are not covered by a regional or statewide nonmotorized count program—as well as state DOTs without established nonmotorized count programs—do not have a way to quickly estimate pedestrian and bicycle volumes.

PURPOSE AND SCOPE

This paper illustrates an approach for quickly estimating pedestrian volumes in the absence of an established count program and quantifies the accuracy of that approach, comparing forecast to observed volumes. The scope of the approach is limited to steps that can be applied within approximately eight weeks using publicly available data.

METHODS

Four iterative steps were used to implement an interim approach for forecasting pedestrian volumes:

- Preliminary data acquisition and synthesis to support Stages 1-3
- Stage 1: Estimate pedestrian volume based on average daily (motor vehicle) traffic (ADT) alone
- Stage 2: Adjust pedestrian volume based on population density
- Stage 3: Adjust pedestrian volume based on speed limit, number of lanes, and local counts

Preliminary Data Acquisition and Synthesis

The synthesis of data required two major steps: a*cquire data* and *cleanse data*. For data acquisition, three key sources were of interest.

1. *A recent VDOT data set with strong coverage but limited detail*. VDOT's Master Linear Referencing System (LRS) contains the location, length, and route number for each roadway network segment maintained by VDOT (*16*,*17*). It consists of 70,735 roadway segments and includes individual line segments such as ramps or, in the case of divided highways, one segment for each direction of travel.

2. *A recent VDOT data set with less coverage but detailed data*. VDOT's Statewide Highway information Planning System (SHIPS) database contains attributes of interest to planners, such as the number of lanes, speed limit, indication of whether a transportation project will be built at this location, and forecast speed twenty years in the future. However, this data source contains information only for most functionally classified roadways maintained by VDOT; consequently, it does not contain detailed data for small local facilities (such as a residential cul-de-sac), and it consists of centerline segments only (e.g., it excludes ramps and, in the case of divided highways, has only one segment). Consequently, it has about a third (24,019) of the segments available in the former layer. (These data are available internally; VDOT (*18*) describes the types of data available in this database.)

3. *A less recent non-VDOT data set with strong coverage and strong detail*. A layer from the Virginia Geographic Information Network (VGIN) (*19*) consists of 619,997 segments. It has some commonality with the first layer in that it contains ramps and, for a divided highway, it would contain two features: one for each direction of travel. It also has some commonality with the second layer: it has some attributes that represent speed limit, pavement width, and average annual daily traffic (i.e., the numbers of vehicles expected for an average 24-hour period). However, it does not contain all planning data elements found in the second layer: crash data and forecast speed limits are missing).

Figure 1 contrasts the three data sources for a small city in central Virginia. Data source 1 has good coverage but lacks key data elements, such as speed limit, that may affect a route's attractiveness to pedestrians. Data source 2 has these data but lacks many of the smaller facilities, such as collector roads, that pedestrians tend to use. Data source 3 has good coverage (as with data source 1) and some detail (as with data source 2), but is slightly older and is a compilation of several sources.

Figure 1. Links with Updated Detailed Planning Level Data are in Green (Data Source 2). (Left: Red links are in Data Source 1. Right: Purple links are in Data Source 3).

Ideally, the most credible data set would consist of all segments for which detailed planning data were available (e.g., data source 2) combined with additional segments from data source 3 and 1 as appropriate. Unfortunately, there was not a single attribute that could be used to indicate whether a given line segment was common to both layers; further, because data source 3 is an aggregation of networks from multiple organizations, there were some imperfections in the alignment of the layers. Accordingly, a trial-and-error procedure was developed based on the portion of the network shown in Figure 1. Table 1 summarizes this procedure, which was then applied to the statewide network.

Steps 6 and 7 in Table 1 illustrate the type of procedures used to determine attribute values from these layers; for example, to determine the expected speed of vehicles on a roadway section, some links have the speed limit whereas other links have a value that appears to be based on modeling. On average, for every segment from the VDOT layer with detailed planning data (data source 2), there were almost 20 segments from data source 3 with limited planning data; the combined layer has a total of 491,924 segments. The procedure is not perfect (e.g., a few crossovers on Interstate highways will remain), but it generally provides a workable base roadway network layer that can be used to determine facilities on which pedestrians may travel.

Table 1. Methodology for Developing a Single Pedestrian-Oriented Roadway Network Layer

Step	Description	Result
1	Query the VGIN layer (data source 3) to identify those facilities that (1) do not have a VDOT route number or are functionally classified as a local road, and (2) are neither ramps nor primary routes	Layer 1
2	Create a 10-foot buffer around the VDOT layer (data source 2)	Layer 2
3	Identify those segments from Layer 1 that are contained by Layer 2.	Layer 3
4	Erase (from Layer 1) those segments that are in Layer 3. The result is a layer of VGIN centerline segments that are not within the VDOT layer.	Layer 4
5[a]	Merge Layer 4 and the VDOT layer, which yields a pedestrian-oriented planning layer	Layer 5
6[a]	Replace null values with zero (e.g., select records where "SPEED" is null and replace with zeroes, then repeat for VDOT_SPD and POSTED_SPEED_LIMIT	Layer 5 (modified)
7[a]	Create a new field called OurSpeed and calculate it in Python as the maximum value of SPEED, VDOT_SPD, and POSTED_SPEED_LIMIT. (For the speeds that are still zero, use the modeled speed "FORECAST_YR_0_AVG_SPEED" as the speed.) For the 266 remaining links (about 0.05% of the total), a speed of 26 mph is assigned (close to the default value of 25 but 1 mph higher should these links need to be re-identified.)	Final network layer

[a] This type of processing is repeated for other attributes that are common to data sources (2) and (3) such as lane counts, pavement width, 24-hour volume, and jurisdiction in which the road segments are located.

Stage 1: Estimate Pedestrians Based on ADT Alone

The Stage 1 model requires just a few calculations: determine vehicle-miles traveled (VMT) for each census tract (*20)*, determine average trip length for driving and pedestrian trips from National Household Travel Survey (NHTS) data (*21*), and then determine a factor to convert ADT to pedestrians per day.

- *Obtain total VMT for every Census tract.* VMT is the product of ADT and segment length. For example, for one particular Census tract there were 70 segments with ADT from as low as 0 to as high as 47,000, and the length for each segment ranged from less than a tenth of a mile to 0.86 miles. Multiplying each segment length by its ADT and then summing for the entire tract suggests a total of 130,321 VMT per day for that particular tract.

- *Estimate average trip length for driving trips and pedestrian trips.* The 2009 NHTS indicated that the total private vehicle trips in Virginia were 8,219 million trips (per year), which divided by 365 days yields 22.518 million trips per day. If we divide VDOT's daily VMT (estimated as 221.28 million in 2013) *(20)* by these 22.518 million trips, we obtain an average trip length of 9.8 miles. (As a check, the 2009 NHTS reports the average private driving trip length in Virginia to be 9.3 miles). The average walk trip length, according to NHTS, is 0.84 miles for Virginia.

- *Determine a factor to convert ADT to pedestrian trips*. According to the NHTS, Virginia saw 986 million walking trips per year, which equates to 2.701 million trips per day. These walking trips, with an average length of 0.84 miles, generated 2.266 million person-miles traveled (PMT) per day (see Equation 1). To convert from VMT and PMT to vehicle and pedestrian counts, we use the private vehicle VMT of roughly 221.28 million vehicle miles per day and presume that the paths people walk on are the same length as the paths vehicles take.

$$\frac{\text{Statewide Walk PMT}}{\text{Statewide Drive VMT}} = \frac{2.266\text{ million}}{221.28\text{ million}} = \frac{(\text{Peds})(\text{Sidewalk Length})}{(\text{ADT})(\text{Roadway Length})} = \frac{1\text{ pedestrian}}{98\text{ vehicles}} \quad \text{(Eq. 1)}$$

Equation 1 shows that, assuming that all roads are equally attractive for pedestrians and that the data from the 2009 NHTS (*21*) and the 2013 VMT are accurate (*20*), for every pedestrian we would see 98 vehicles. The calculations also assume that the lengths of paths taken by pedestrians are the same as the length of roadway facilities. For pedestrian trips, one way to address this assumption is to remove facilities that do not have pedestrians from Equation 1. For example, of the 221.28 million VMT in Virginia, almost a third (66.58 million VMT) were on Interstates, which typically do not have pedestrian or bicycle traffic, although some do have well-used adjacent trails. Accordingly, assuming that the length of non-Interstate roads is equal to the length of the walking areas, Equation 1 is modified, resulting in 1 pedestrian for every 68 vehicles.

$$\frac{\text{Statewide Walk PMT}}{\text{Statewide Drive VMT}} = \frac{2.266\text{ million}}{154.7\text{ million}} = \frac{(\text{Peds})(\text{Sidewalk Length})}{(\text{ADT})(\text{Roadway Length})} = \frac{1\text{ pedestrian}}{68\text{ vehicles}}$$

Stage 2: Estimate Pedestrian Volume Based On Population Density

The second stage of this process estimates a pedestrian volume based on the population density (*22*) where a roadway is located. For example, consider the density of 2,000-3,999 people per square mile where there are 252 million walk trips and 1,886 million private vehicle trips; the ratio of these suggests 7.5 driving trips per pedestrian trip. Given trip lengths of 0.84 pedestrian miles per pedestrian trip and 9.84 miles per vehicle trip, unit cancellation (see Equation 2) suggests that multiplying ADT by 0.0114 will yield the number of pedestrians.

$$\left(\frac{0.84\text{ pedestrian miles}}{\text{pedestrian trip}}\right)\left(\frac{\text{pedestrian trip}}{7.5\text{ vehicle trips}}\right)\left(\frac{\text{vehicle trip}}{9.83\text{ vehicle miles}}\right) = \frac{0.0114\text{ pedestrians}}{\text{vehicle}} \qquad \text{(Eq. 2)}$$

Because Virginia stakeholders were concerned that NHTS data might not be valid for that purpose due to small sample sizes, Table 2 shows the 95% confidence intervals for the percentage of trips by walking at eight different density levels. Note that there is not a meaningful difference between the confidence intervals for the first two density levels; however, at higher densities some differences are clearly significant. For example, the percentage of trips that are pedestrians at densities of 2,000-3,999 people per square mile (9.1%-13.2%) is clearly different from the percentage of such trips at a density below 100 people per square mile (5.0%-8.6%).

Table 2. Confidence Intervals for Pedestrian Trips Based On the NHTS

Density (people/mile^2)	Walk Trips (millions)	Private Vehicle Trips (millions)	Driving Trips / Pedestrian Trips	To get pedestrians, multiply ADT by: (Pedestrian Multiplier)	95% Confidence Interval (Walk Trips)
0-99	112	1,476	13.2	0.00647	5.0%-8.6%
100-499	94	1,250	13.3	0.00642	5.0%-8.3%
500-999	77	815	10.6	0.00806	5.7%-10.8%
1,000-1,999	97	979	10.1	0.00846	7.0%-10%
2,000-3,999	252	1,886	7.5	0.01140	9.1%-13.2%
4,000-9,999	261	1,642	6.3	0.01357	10.7%-14.9%
10,000-24,999	70	162	2.3	0.03688	15.1%-36.7%
25,000-999,999	23	9	0.4	0.21810	31.0%-73.5%

Stage 3: Estimate Pedestrian Volume Based On Density, Speed Limit, and Number of Lanes

The third stage of this process modifies the estimated volumes based on each link's appeal to pedestrians as shown in Equation 3. For example, if higher speeds greatly deter pedestrians from using a facility, then one would expect the adjustment factor alpha to be relatively large. If higher speeds did not affect pedestrian use, one would expect alpha to be zero. Further, during this third stage, one can adjust the pedestrian multipliers (originally derived in Table 2) to minimize the difference between the forecasted pedestrian volume and the observed pedestrian volume if actual counts are available.

$$\text{Pedestrians}_{\text{i}} = \text{Census Tract ADT} * \text{Peds Multiplier} * \frac{(\text{Link ADT})\left((1/\text{Speed}_{\text{i}})^{\alpha} + (1/\text{Lanes}_{\text{i}})^{\text{b}}\right)}{\sum_{\text{i}}^{70} (\text{Link ADT}_{\text{i}})\left((1/\text{Speed}_{\text{i}})^{\alpha} + (1/\text{Lanes}_{\text{i}})^{\text{b}}\right)} \quad \text{(Eq. 3)}$$

RESULTS AND DISCUSSION

Calibration of Equation 3 yielded logical values where alpha = 1.93 (for the inverse of speed) and beta = 32 (for the inverse of the number of lanes). This means that according to the stage 3 model, a 10% decrease in speed will increase the number of pedestrians by about 22%. (The impact of changes in the number of lanes is less pronounced with this particular data set because so many of the facilities were either two- or four-lane roads, although conceptually, the result indicates that as the number of lanes increases, the appeal of a facility for pedestrians should drop.)

A key question is the accuracy of the approach. A comparison of forecast pedestrian volumes and observed pedestrian volumes at 30 different intersections was performed, and Table 3 shows the results. For example, the first site was an intersection located in Charlottesville where each of the intersecting roads had a speed limit of 25 mph; however, one road had four lanes (two in each direction) and the other had two lanes (one in each direction). The Stage 3 approach yielded a forecast of almost 52 pedestrians on one link and 15 on the other link, leading to an intersection count of 67 pedestrians. While a 24-hour count was not available at that intersection, a shorter-term count had been performed, and this shorter count was expanded to a 24-hour count using hourly and monthly expansion factors recommended by the National Bicycle and Pedestrian Demonstration Project (*23*), which yielded a 24-hour observed volume of 502. Treating this as ground truth, Table 3 shows that the forecast volume (67 vehicles) differed from the observed volume (502 vehicles) by 87%; because this was an underestimate, the error of 435 vehicles is negative.

Table 3 is instructive in several regards. First, although there is some random variation, a majority of the sites show a negative error, suggesting that the approach tends to underestimate the number of pedestrians. Out of a total of over 28,000 pedestrians that were observed, slightly less than a third (8,173) were forecast. One possible explanation is the age of the survey data from NHTS (2009); a second possibility is that there are factors besides those in the model that account for higher pedestrian use than what is forecast.

Second, a few sites have much larger errors than the remaining sites, which is why the mean error (an underestimate of 663) has a much greater magnitude than the median error (an underestimate of 223). Further, because the method overestimates the number of pedestrians for a few of the sites (notably sites 8, 18, 19, and 27), the mean error (where overestimates and underestimates cancel) is smaller than the mean absolute error (where overestimates and underestimates do not cancel).

Finally, while the percentage error by site can be informative in that it shows a relative accuracy, in a few cases it can be misleading. For example, the large percent error at site 13 (8 forecast pedestrians and 1 observed) yields an error of 702%; however, one might be more concerned with sites such as site 18, where the percent error is smaller (90%) but the over-forecast of 144 pedestrians could cause greater concern.

The underestimates of pedestrian volumes in Table 3 suggest that it may be possible to reduce the error by adjusting the pedestrian multiplier shown in Equation 1. In practice, this would occur if an agency applied the three-stage process that yielded the forecasts shown in Table 3 and then, as was done in Virginia, compared forecast to observed volumes at a few locations. One way to determine how to modify the pedestrian multiplier is to find a factor that, when applied to Equation 1, minimizes the mean absolute difference between the forecast and observed volumes. For this particular data set, that factor is 2.2: that is, multiplying the existing pedestrian multiplier by a factor of about 2.2 reduces the mean absolute error from 747 to 636, with a reduction in the median error from 254 to 230. Further, such a change results in the total forecast pedestrians being approximately 63% of the observed pedestrians—a substantial improvement over the performance shown in Table 3.

Table 3. Initial Performance of the Three-Stage Approach at 30 Sites

Location	Site	Speed[a]	Lanes[a]	Forecast Volume	Obs. Volume	Error	|Error|	Percent Error	|Percent Error|
Charlottesville	1	25/25	4/2	67	502	-435	435	-87%	87%
Charlottesville	2	25/25	2/2	172	681	-509	509	-75%	75%
Charlottesville	3	25/25	2/2	6	199	-193	193	-97%	97%
Charlottesville	4	35/25	2/2	63	697	-634	634	-91%	91%
Charlottesville	5	25	2	959	1,827	-868	868	-48%	48%
Charlottesville	6	25/25	1/2	2,582	7,633	-5,051	5,051	-66%	66%
Charlottesville	7	25/40	2/4	466	1,011	-545	545	-54%	54%
Charlottesville	8	35/25	2/2	887	257	630	630	245%	245%
Charlottesville	9	35/25	2/2	12	177	-165	165	-93%	93%
Charlottesville	10	25/25	2/2	119	7,613	-7,494	7,494	-98%	98%
Roanoke	11	35/45	2/4	38	17	21	21	123%	123%
Roanoke	12	25/35	2/2	7	25	-18	18	-72%	72%
Roanoke	13	25/35	2/4	8	1	7	7	702%	702%
Roanoke	14	30/25	2/2	78	102	-24	24	-24%	24%
Roanoke	15	35/25	2/3	306	305	1	1	0%	0%
Roanoke	16	20/20	2/4	56	340	-284	284	-83%	83%
Roanoke	17	25/30	2/2	295	2,083	-1,788	1,788	-86%	86%
Roanoke	18	25/25	2/2	305	161	144	144	90%	90%
Roanoke	19	25/25	2/2	274	152	122	122	80%	80%
Roanoke	20	35/30	2/2	176	1,592	-1,416	1,416	-89%	89%
Harrisonburg	21	25/55	2/4	88	18	70	70	386%	386%
Harrisonburg	22	25/55	2/3	95	18	77	77	430%	430%
Harrisonburg	23	55/25	2/2	104	367	-263	263	-72%	72%
Harrisonburg	24	55/40	2/2	337	725	-388	388	-54%	54%
Harrisonburg	25	25/25	2/2	161	147	14	14	10%	10%
Harrisonburg	26	25/25	2/2	210	468	-258	258	-55%	55%
Harrisonburg	27	35/25	2/2	221	55	166	166	302%	302%
Harrisonburg	28	25/35	2/2	61	431	-370	370	-86%	86%
Harrisonburg	29	25/25	2/2	7	257	-250	250	-97%	97%
Harrisonburg	30	25/45	2/4	15	211	-196	196	-93%	93%
Mean						-663	747	28%	130%
Median						-223	254	-61%	86%

[a] For intersection count sites, the speed and number of lanes of both streets are separated by a slash (/).

Table 4 shows the impact of performing this adjustment to the Stage 3 model and for comparison purposes also shows the error that would have resulted from stopping at either Stage 1 (e.g., using a single factor to convert from ADT to pedestrians) or Stage 2 (e.g., using density alone without any roadway attributes). In addition to the four goodness of fit measures (error, absolute error, percent error, and median percent error), Table 4 also shows the portion of total observed pedestrians that were forecast. Not surprisingly, the results show that accuracy generally improves with each stage; however, it was surprising to the research team that the use of density (Stage 2) did not show more of an improvement relative to Stage 1. However, this finding could change with newer data sources (e.g., the forthcoming NHTS update). That said, for agencies who are considering adopting this approach but who have very limited resources, it may be productive to either simply perform Stage 1 (which can be completed within a couple of hours) or perform Stage 3.

Table 4. Accuracy of Approach By Stage

Stage [a]	Statistic	Error	|Error|	Percent Error	|Percent Error|	Percent of Total Pedestrians Forecast
1	Mean	-760	825	153%	244%	19%
	Median	-202	209	-53%	79%	
2	Mean	-785	826	44%	143%	16%
	Median	-219	228	-60%	86%	
3	Mean	-663	747	28%	130%	29%
	Median	-223	254	-61%	86%	
3 +Calibration	Mean	-345	636	178%	247%	63%
	Median	-12	230	-15%	83%	

[a] Stage 1 uses a single value to convert ADT to pedestrians; Stage 2 includes density only; Stage 3 incorporates roadway information, and Stage 3 +Calibration incorporates actual volume counts from 30 sites.

Certainly these results show the limits of an approach that does not entail collection of detailed pedestrian counts, as other factors (besides density, speed limits, and the number of lanes) are likely to influence the likelihood of pedestrians using a facility. However, the results also suggest that for agencies that can collect a modest amount of data, it may be possible to gain substantial accuracy. For example, by collecting some additional pedestrian counts, the median error (where positive and negative errors cancel) is about 12 pedestrians per day. Further, a paired t-test shows that, for three of the goodness of fit measures (error, percent error, and absolute percent error), the errors that result from the calibration in Stage 3 are significantly better than when density alone is used.

CONCLUSIONS

1. *This approach for forecasting pedestrian volumes based on density, speed limit, and number of lanes has a median absolute error of 254 pedestrians over a 24-hour period without any calibration based on actual counts.* If pedestrian counts can be obtained, however, such that the variable Stage 1 Pedestrian Estimate in Equation 3 can be adjusted to improve model fit, then the median absolute error drops to 230. Further, this local calibration results in the total forecast pedestrians being 63% of the observed forecast pedestrians, whereas this percentage was 29% without the calibration.

2. *The three-stage approach suggests that two variables—speed limits and number of lanes—nominally improve accuracy relative to using density alone.* If the calibration based on actual counts noted in conclusion 1 is used, this difference is statistically significant for the error (p=0.03), percent error (p<0.01), and absolute percent error (p=0.02). The improvement is nominal, but not significant (p=0.35), for the absolute error: density alone gives an average error of 826, whereas the improved model gives a mean error of 636.

3. *As expected, the stage 3 approach shows that lower speed limits and a lower number of lanes are*

associated with higher pedestrian volumes. For example, based on the model, a decrease in the speed limit from 45 mph to 25 mph increases the forecast number of pedestrians by a factor of about 3.1.

4. *In the creation of planning-oriented data sets suitable for estimation of pedestrian volumes, analysts should keep in mind that there are two fundamental differences compared to data sets suitable for estimating vehicle volumes*.

    - *Better data are available for the facilities where pedestrians do not travel.* Virginia, as is the case with many transportation agencies, provides more detailed geometric and operational data such as current traffic volumes, forecast volumes, shoulder widths, and the location of future investments for roads oriented towards motorized vehicles than for lower-speed local streets that may attract more pedestrian traffic.

    - *Short-term pedestrian counts, which are expanded to estimate average daily pedestrian volumes, are collected by different organizations such as localities and volunteer groups—not a single agency with dedicated staff.* By contrast, spot counts used to estimate average daily traffic volumes are usually collected by a single organization—the state DOT.

RECOMMENDATION

1. *Localities that have no pedestrian count data should consider using the Stage 3 approach developed here in order to estimate pedestrian volumes*. The Stage 3 approach provides additional accuracy relative to the earlier stages, but at an additional time cost. (This cost was roughly 400 additional person-hours at the state level but may be less if performed by an individual locality.) In the future, it may be useful to investigate whether better data sets allow density alone to provide more accurate forecasts than those given here. (Stage 2 can be applied with approximately 80 hours of work using data such as that shown in Table 1, which states or localities can update using the 2014 National Household Travel Survey when those results are made available.)

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