Methods and Technologies for Pedestrian and Bicycle Volume Data Collection

NCHRP 7-19

SafeTREC seminar

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NCHRP 7-19 Research Team

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- University of Wisconsin—Milwaukee
- UC Berkeley, SafeTREC
- Toole Design Group
- McGill University
- Quality Counts, LLC
Presentation Overview

- Introduction
- State of the Practice
- Counting Program Overview
- Testing Approach and Findings
- Guidebook Walkthrough
- Final Remarks
Project Purpose

- Address lack of pedestrian and bicycle volume data
- Assess data collection technologies and methods
- Develop guidance for practitioners
Early Findings

- Counting programs and current count practices
  - Limited established count programs in the U.S., but lots of interest
  - Need and desire for guidance
  - Manual counts most common in current practice
Early Findings

- **Correction and extrapolation factors**
  - **Correction factors** adjust counts to eliminate inaccuracies due to data collection technology used
  - **Extrapolation factors** is an area of needed research
    - Temporal
    - Land use
    - Weather
    - Demographics
Early Findings

- Multimodal data used for a number of purposes:

- Before/after studies of new infrastructure
- Project prioritization
- Tracking increases/decreases in activity over time
- Network modeling and/or estimating ADT
- Risk/exposure analysis
- Other

![Bar Chart](chart.png)
Early Findings

**Count technologies**

- Automated count technology is growing rapidly
- Manufacturers of automated count technologies tend to be from outside of the U.S.

*Source: MetroCount*
NCHRP 7-19 Survey Findings

- There is no standard approach for initiating a count program
- Practitioners are looking for more guidance
  - Choosing devices
  - Selecting locations
  - Count intervals and duration
  - Temporal/seasonal adjustments
Barriers to Collecting More Data

- Lack of staff time or volunteer interest
- Funding limitations/cutbacks
- Lack of technological tools to collect data
- Lack of organizational interest or defined need...
- Lack of knowledge of topic
- No, we currently collect as much volume data...
- Not confident in the accuracy of current count...
- Other
- Potential for unexpected results

[Bar chart showing number of responses for bicycles and pedestrians]
Challenge: Site/Mode characteristics

Motor vehicle data collection
- Widely collected
- Easy to track vehicle movements
- Predictable patterns and routes
- Years of trend data to analyze

Bicycle and pedestrian data collection
- Sparsely collected
- Difficult to track and tabulate movements
- Unpredictable paths of travel
- Weather and seasonal impacts
- Lack of historical data
Motor Vehicle Data Collection

Constrained; somewhat predictable
Bicycle Data Collection

Constrained environments easy to monitor

Complex environments harder to define
Pedestrian Data Collection

Constrained environments easy to monitor

People tend to make their own path
Case Study: Arlington County, VA

Arlington County’s automated bicycle and pedestrian count program

- First counter Custis Trail Fall 2009
- Now 30 Stations
- Automatic uploads to central server
- Web based “dashboard”
- Recently installed real-time “totem” counter display

Statistics and graphics courtesy of David Patton
Bicycle & Pedestrian Planner, Arlington County Division of Transportation
Arlington County – Daily Trip Behavior

Typical weekday pattern of bicycle traffic on the Custis Trail

Typical weekend pattern of bicycle traffic on the Mount Vernon Trail
Arlington County – Weather Impacts

Effect of rainy weather on bicycle travel

Impact of un-cleared heavy snow on bicycle travel

Effect of rainy weather suppressing bicycle transportation, Tuesday, October 18 - Wednesday, October 19, 2011

Impact of un-cleared heavy snow transportation on Custis Trail due to uncleared heavy snow

Figure 3

Figure 4
Arlington County – Trend over time

Forty one months of bicycles on the Custis Trail, November, 2009 – March 2013

(February 2010 saw exceptionally heavy snow fall; low bars in October – November 2012 attributable to battery failure)
COUNT PROGRAM OVERVIEW

Planning
Implementation
Institutionalize Pedestrian & Bicycle Data

- A multimodal transportation system requires collecting data for all modes of transportation.
Institutionalize Pedestrian & Bicycle Data

- A multimodal transportation system requires collecting data for all modes of transportation
- Establish baseline for pedestrian & bicycle safety, infrastructure, volumes, etc.

We need these data fields!
Pedestrian & Bicycle Count Program Overview

- Chapter 3 of NCHRP 07-19 Guidebook
  - Plan the count program
  - Implement the count program
- Complements Chapter 4
  FHWA TMG

Traffic Monitoring Guide
Updated April 2013
Plan the Count Program

- Specify the data collection purpose
- Identify data collection resources
- Select count locations & determine timeframe
- Consider available counting methods
Show progress toward walking and bicycling goals
Minneapolis, MN

Figure 1 - Daily bicycle and pedestrian trips at annual benchmark locations. From 2007 to 2013, the number of bicyclists counted increased 76% and the number of pedestrians increased 24%.

Source: City of Minneapolis Pedestrian & Bicycle Count Report, 2013
Account for exposure when analyzing pedestrian or bicycle safety (risk)
Oakland Reported Intersection Pedestrian Crashes (1996-2005)

Absolute number of crashes suggests safety problem is in downtown Oakland
Oakland Estimated Intersection Pedestrian Crash Risk

But the highest risk per pedestrian crossing is along major arterial roads.
Document improvements in pedestrian and bicycle safety after investments are made
Bicycling activity went up; bicycle crash risk went down

Show that streets are used by many types of travelers, not just cars
This map shows mode shares at select locations where data for all transportation modes was available. Data at one location along the Midtown Greenway and one location along the U of M Transitway are provided for comparison. The count location number is listed on each chart.

Each chart is scaled to the total travelers at each location. Larger charts represent a higher number of total travelers and smaller charts represent a lower number of total travelers. Due to the geographic concentration of some data points, charts are not always placed directly above the location.
UC Berkeley Campus Periphery
Mode-share for Intersection Counts

2-hour Intersection Count for all modes

- Street
- Periphery Study Area

- 2,000
- Bicycle
- Pedestrian
- Cars

Pedestrian counts represent different 2-hour periods between 5 a.m. and 6 p.m. on various weekdays with different days in season. All counts were from between 6/26 and 10/28, so weather was assumed to be normal. No adjustments have been made for variations in volumes by time of day or day of week. Counts sourced from UC Berkeley SafeTREC Periphery Study (2014). Multiple counts have been taken at some locations; so, labeled represents the average count at those sites.
Understand the impacts of weather
Weather Data

The effect of various weather conditions on bicycling and walking levels has not been determined for Minneapolis. However, the following graph, showing daily bicycling traffic on the Midtown Greenway and daily weather conditions during a 30-day sample, suggest the general effect of temperature and precipitation on bicycling levels.

Source: City of Minneapolis Pedestrian & Bicycle Count Report, 2010
Quantify the number of bicyclists who don’t use trails when they are not plowed

Saturday, February 6 - Friday, February 19, 2010, zero bicycle transportation on Custis Trail due to uncleared heavy snow
Plan the Count Program

- Specify the data collection purpose
- Identify data collection resources
- Select count locations & determine timeframe
- Consider available counting methods
Data Collection Resources

- Automobile traffic monitoring program → Transportation monitoring program
- Grants (public health)
- Even with minimal dedicated budget, agencies can:
  - Organize volunteers
  - Creating partnerships with other agencies and organizations (universities, non-profits)
  - Piggyback on motorized counting
Plan the Count Program

- Specify the data collection purpose
- Identify data collection resources
- **Select count locations & determine timeframe**
- Consider available counting methods
## Count Locations & Timeframe

- **Common strategy: Manual + Automated**

<table>
<thead>
<tr>
<th>Count Duration</th>
<th>Geographic Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>Automated</td>
</tr>
<tr>
<td>Short-Term</td>
<td>Manual</td>
</tr>
</tbody>
</table>

- **A Few Locations**
- **Many Locations**
Factor Groups

- Sites with similar pedestrian or bicycle activity patterns (often have similar nearby land uses)

Photos by Robert Schneider, UW-Milwaukee
Bicycle Patterns from Six Cities: Utilitarian Factor Group

Source: Miranda-Moreno et al. (2013)
Bicycle Patterns from Six Cities: Recreational Factor Group

Source: Miranda-Moreno et al. (2013)
Plan the Count Program

- Specify the data collection purpose
- Identify data collection resources
- Select count locations & determine timeframe
- Consider available counting methods
Manual Counts

- Most common type of counting, to date
- Capture many different locations
- Record pedestrian & bicyclist characteristics
- Can count roadway crossings
- Expensive
- Short-counts may not expand accurately
Manual Counts

Photo by Robert Schneider, UW-Milwaukee
Identify Sites Appropriate for your Specific Counting Method

- Most technologies count screenlines...few methods can count roadway crossings
- Know the type of data that you will be getting

Photos by Robert Schneider, UW-Milwaukee
Implement the Count Program

- Obtain necessary permissions
- Procure counting devices
- Inventory and prepare devices
- Train staff
- Install and validate devices
- Calibrate devices
- Maintain devices
- Manage count data
- Clean and correct count data
FIELD TESTING

Testing Plan

Technologies and Site Locations

Evaluation Method and Criteria

Data Analysis

Findings
Testing Plan

- Focus on testing and evaluating commercially available automated technologies
- Assess type of technology as opposed to a specific product
- Cover a range of facility types, mix of traffic, and geographic locations
- Evaluate accuracy through the use of manual count video data reduction
Technologies and Site Locations

- **Technologies**
  - Passive infrared
  - Active infrared
  - Pneumatic tubes
  - Inductive loops
  - Piezoelectric
  - Radio beam
  - Combination of technologies

- **Site Locations**
  - Portland, OR
  - San Francisco, CA
  - Davis, CA
  - Berkeley, CA
  - Minneapolis, MN
  - Washington, D.C.
  - Arlington, VA
  - Montreal, Canada
San Francisco, CA

- Fell Street Bicycle Lane
  - Passive Infrared
  - Pneumatic Tubes
  - Inductive Loops
Minneapolis, MN

- Midtown Greenway multiuse path
  - Active Infrared
  - Passive Infrared
  - Radio Beam
  - Inductive Loops
  - Pneumatic Tubes
# Summary of Data Collected

<table>
<thead>
<tr>
<th>Condition</th>
<th>Passive Infrared</th>
<th>Active Infrared</th>
<th>Pneumatic Tubes</th>
<th>Inductive Loops</th>
<th>Inductive Loops (Facility)</th>
<th>Piezoelectric</th>
<th>Radio Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hours of data</td>
<td>298</td>
<td>30</td>
<td>160</td>
<td>108</td>
<td>165</td>
<td>58</td>
<td>95</td>
</tr>
<tr>
<td>Temperature (°F) (mean/SD)</td>
<td>70 / 15</td>
<td>64 / 26</td>
<td>71 / 9</td>
<td>73 / 12</td>
<td>71 / 17</td>
<td>72 / 10</td>
<td>74 / 10</td>
</tr>
<tr>
<td>Hourly user volume (mean/SD)</td>
<td>240 / 190</td>
<td>328 / 249</td>
<td>218 / 203</td>
<td>128 / 88</td>
<td>200 / 176</td>
<td>128 / 52</td>
<td>129 / 130</td>
</tr>
<tr>
<td>Nighttime hours</td>
<td>30</td>
<td>3</td>
<td>10</td>
<td>13</td>
<td>19</td>
<td>15.75</td>
<td>3.5</td>
</tr>
<tr>
<td>Rain hours</td>
<td>17</td>
<td>0</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Cold hours (&lt;30 °F)</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hot hours (&gt;90 °F)</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Thunder hours</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Data Analysis

- Three methods used to analyze data:
  1. Graphical analysis
  2. Accuracy calculations
  3. Development of correction functions
Graphical Analysis

![Graphical Analysis Diagram](image)

- **Overcounting**
- **Undercounting**
- "Perfect accuracy" line
Accuracy Calculations

\[ \text{APD} = \frac{1}{n} \sum_{t=1}^{n} \frac{A_t - M_t}{M_t} \]

\[ \text{AAPD} = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{A_t - M_t}{M_t} \right| \]

\[ r = \frac{\sum_{t=1}^{n} (M_t - \bar{M})(A_t - \bar{A})}{\sqrt{\sum_{t=1}^{n} (M_t - \bar{M})^2} \sqrt{\sum_{t=1}^{n} (A_t - \bar{A})^2}} \]

Where \( A_i \) is the automated count in period \( i \) and \( M_i \) is the manual count in period \( i \)
Correction Functions

- Functions for each technology/product
- Manual Count = f(Automated Count, Env. Factors)
  \[ V = \beta_1 \ast A + \beta_2 \ast A^2 + \beta_3 \ast A \ast T + \beta_4 \ast A \ast R \]
- Estimated using ordinary least squares regression
- Models compared using Akaike Information Criterion (AIC)
Why Correct Counts

Raw Estimation Data

Raw Validation Data
Why Correct Counts

Corrected Estimation Data

Corrected Validation Data
Evaluation Method and Criteria

- **Accuracy**: automated count data vs. “ground-truth” volumes
  - Video-based manual counts
  - Interrater reliability tested

- **Ease of installation, maintenance requirements, cost, flexibility of data, etc.**
Video Data Collection

- Camera installed with counters for ~5 days
- Second deployment targeting desired conditions
- ~3k hours of video collected
Passive Infrared (IR)

- Detect pedestrians and cyclists by infrared radiation (heat) patterns they emit
- Passive infrared sensor placed on one side of facility
- Widely used and tested

Source: Ciara Schlichting, Toole Design Group
Passive Infrared

- Easy installation
- Mounts to existing pole/surface or in purpose-built pole
- Potential false detections from background
- Possible undercounting due to occlusion
Passive Infrared Findings

- APD = -8.75%, AAPD = 20.11%, \( r = 0.9502 \)
- Differences between products
- Correction function:
  \[ V = 1.137 \times A \]
  \[ V = 1.313 \times A - 3.995 \times \frac{A^2}{10^4} \]
- Accuracy not affected by high temperatures
Active Infrared (IR)

- Transmitter and receiver with IR beam
- Counts caused by “breaking the beam”

Source: Steve Hankey, University of Minnesota
Active Infrared

- APD = -9.11%; AAPD = 11.61%; r = 0.9991
- Single device tested – accurate and highly precise
- Correction Functions:
  \[ V = 1.139 \times A \]
  \[ V = 1.413 \times A + 0.868 \times \frac{A^2}{10^4} - 3.93 \times 10^{-3} \times A \times T \]
Pneumatic Tubes

- One or more tubes are stretched across roadway or path
- When a bicycle rides over tube, pulse of air passes through tube to detector

Source: Karla Kingsley, Kittelson & Associates, Inc.
Pneumatic Tubes

- Tested BSCs – bicycle specific counters
- Primarily tested tubes on multi-use paths and bicycle lanes
- Issues with site on 15th Avenue in Minneapolis
Pneumatic Tubes

- Fairly high accuracy at very high volumes
- Site and device specific effects
- Accuracy rates not observed to decline with aging tubes
- Correction function:
  \[ V = 1.135 \times A \]
Radio Beam

- Transmitter and receiver emit a radio signal that detect a user when the beam is broken
- Not previously tested in literature
- Some devices count bikes and peds separately

Source: Karla Kingsley, Kittelson & Associates, Inc.
Radio Beam

- Product B higher accuracy
- Product A – low precision and lower accuracy
- Occlusion errors
- Temperature, lighting, rain issues
Inductive Loops

- Generate a magnetic field that detect metal parts of bicycle passing over loop
- In-pavement or temporary loops (on surface)

Source: Katie Mencarini, Toole Design Group
Inductive Loops

- Permanent (in ground) or temporary (on surface)
- Bypass errors
  - Cyclists passing outside bike lane
  - Loops leaving gaps in detection zone
Inductive Loops

- APD = 0.55%; AAPD = 8.87%; r = 0.9938
- Errors with age of loops not detected
- No substantial difference between permanent and temporary loops
- Correction Function: $V = 1.050 \times A$
Inductive Loops

- Need to mitigate bypass errors
Piezoelectric Sensor

- Emit an electric signal when physically deformed to detect bicyclists
- Typically embedded in pavement across travel way

Source: MetroCount
Piezoelectric Strips

- APD = -11.36%; AAPD = 26.60%; r = 0.6910
- Tested one existing device, due to difficulties procuring equipment
- Caution – data from single device not installed by research team
- Correction Function: 
  \[ V = 1.059 \times A \]
Research Conclusions

- **Factors influencing accuracy**
  - Proper calibration and installation
  - Occlusion
  - Vendor differences

- **Factors not found to influence accuracy**
  - Age of inductive loops or pneumatic tubes
  - Temperature (except possibly active IR)
  - Snow/rain (limited data)
Research Conclusions

- Automated counter accuracy:

<table>
<thead>
<tr>
<th>Device</th>
<th>Undercounting Rate</th>
<th>Total Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive Infrared (2 products)</td>
<td>8.75%</td>
<td>20.11%</td>
</tr>
<tr>
<td>Active Infrared</td>
<td>9.11%</td>
<td>11.61%</td>
</tr>
<tr>
<td>Pneumatic Tubes</td>
<td>17.89%</td>
<td>18.50%</td>
</tr>
<tr>
<td>Radio Beam</td>
<td>18.18%</td>
<td>48.15%</td>
</tr>
<tr>
<td>Inductive Loops</td>
<td>0.55%</td>
<td>8.87%</td>
</tr>
<tr>
<td>Piezoelectric Strips</td>
<td>11.36%</td>
<td>26.60%</td>
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</table>
GUIDEBOOK WALKTHROUGH

Purpose
Organization
Guidebook (NCHRP Report 797)

Organization

Quick Start Guide
1. Introduction
2. Non-Motorized Count Data Applications
3. Data Collection Planning and Implementation
4. Adjusting Count Data
5. Sensor Technology Toolbox

Case Studies

Appendices

Manual Pedestrian and Bicyclist Counts: Example Data Collector Instructions
Count Protocol Used for NCHRP Project 07-19
Appendix D. Day-of-Year Factoring Approach
2. Non-Motorized Count Applications

- Measuring facility usage
- Evaluating before-and-after data
- Monitoring travel patterns
- Safety analysis
- Project prioritization
- Multimodal modeling

For each application:
Details
Case Studies

3. Data Collection Planning & Implementation

- Covers:
  1. Planning the count program
  2. Implementing the count program

- Provides examples, detailed guidance, checklists

Source: Tony Hull, Toole Design Group.
4. Adjusting Count Data

- Sources of counter inaccuracy
- Measured counter accuracy
- Counter correction factors
- Expansion factors
- Examples applications

Occlusion error
5. Treatment Toolbox

- Description
- Typical application
- Level of effort
- Strengths
- Limitations
- Accuracy
- Usage

Sidebar with quick facts

PASSIVE INFRARED SUMMARY

Maximum user volume:
Provides consistent results up to 600 users per hour; counts can be corrected at higher volumes.

Detection zone width:
<20 feet

Typical count duration:
Can be used for both short-term counts and permanent installations

Typical equipment cost (2013):
$1,000–3,000

Relative preparation cost:
Medium (may require permitting)

Typical installation time:
<30 minutes for temporary installations, longer for permanent installations involving installing posts

Typical data collector training time:
<30 minutes

Relative hourly cost:
Low, equipment costs are spread over a large number of data-collection hours

Mobility:
Very good, equipment can be readily removed and taken to a new site
Suggested Research

- Additional testing of automated technologies
  - Technologies not tested or underrepresented
  - Additional sites and conditions

- Extrapolating short-duration counts to longer-duration counts

- Adjustment factors for environmental factors
Questions?

- Contact Information
  - Frank Proulx / fproulx@berkeley.edu