Using Signal Controllers To Count Bicyclists

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Oregon Transportation Research and Education Consortium (OTREC)
Agenda

• Motivation
• Methods
  • Video
  • Radar
  • Thermal cameras
  • Inductive loops
• Conclusions
• Future Research
Motivation
Why measure walking & biking?

If we don’t count it, it doesn’t count.
Why count walking & biking?

• Funding & policy decisions
• To show change over time
• Facility design
• Signal timing
• Validate regional models
• Planning (short-term, long-term, regional...)
• Economic impact
• Public health
• Safety
Traffic Monitoring Programs
Permanent Counters

Typically About 100

Legend
- Automated Traffic Recorder
Short Duration Count Sites

1000s or 10,000s

Can we apply these methods to bicycling?
Bicycle Counts

- **Permanent**: Hourly Counts 24/7
  - Infrared
  - Inductive Loop
  - Video Detection

- **Short duration**: One hour to one month
  - Infrared
  - Pneumatic Tube Counters
  - Video Image Recognition
  - Microwave
  - Radar
Can we afford it?

• Non-motorized traffic is more variable than motorized.
  – More continuous counters needed.
Variability – Motorized Traffic

Comparing Motorized Traffic with Non-Motorized in Suburban Denver

Source: CDOT 2013
Variability – Non-motorized Traffic

Comparing Motorized Traffic with Non-Motorized in Suburban Denver

Source: CDOT 2013
Can we afford it?

• Non-motorized traffic is more variable than motorized.
  – More continuous counters needed.

• Dense travel network.
Motor Vehicle Traffic Monitoring

Highways and Arterials
Bicycle and Pedestrian Traffic Monitoring

All Roads and Paths
Can we afford it?

• Non-motorized traffic is more variable than motorized.
  – More continuous counters needed.

• Dense travel network.

• For 100 permanent stations: $100,000 to $1M
  • Plus short duration count stations and staff time
Can we find another way?

• Use existing signal detection equipment?
  – Existing equipment at thousands of locations state-wide!
  – Negligible additional cost to collect counts
  – But not every location has the right equipment
But...

• Can we detect it?
• If we can detect it, can we count it?
• If we can count it, should we include it in our travel monitoring program?
Methods
Measures of Accuracy

• Assume manual count is correct

• % Bikes Counted
  \[
  \text{% Bikes Counted} = \frac{\text{Detector Count}}{\text{Manual Count}}
  \]

• Mean Absolute Percent Error (MAPE)

  \[
  \text{MAPE} = \frac{1}{m} \sum_{i=0}^{m} \frac{|\text{Detector Count}_i - \text{Manual Count}_i|}{\text{Manual Count}_i}
  \]

  Where \(m\) = number of bins
  \(i\) = counting variable
Video
Video Detection - Denver

Iteris – installed in 2011
Iteris SmartCycle

- Video detection system
- Being tested in Portland

Source: Portland Bureau of Transportation
Radar

Sensys MicroRadar

Results from Christine Kendrick, Peter Koonce, and Mark Haines, City of Portland
Sensys Networks WVDS Equipment
Sensor Placement

~19' to curb

~5' from car

~11' from curb
Overcounts Bikes

• 138 bike detections vs. 71 actual bikes
  – Misclassifies cars as bikes
  – Misclassifies pedestrians as bikes
  – Almost doubles bike count
    • Gives 190% of actual bike count
      (% Bikes Counted = 190%)

• More research needed!

Results from Christine Kendrick, Peter Koonce, and Mark Haines, City of Portland
Thermal Camera

Results from Christine Kendrick, Peter Koonce, City of Portland
Example of Counting
Example of Counting
Example of Counting
Example of Counting
Results

• Overcounting (% Bikes Counted= 126%)
• If extra counts occur, a bicyclist is more frequently counted twice compared to three or five times
• Counting affected detection presence.

Christine Kendrick and Peter Koonce, City of Portland
Inductive Loops
Inductive loop counters in bike lanes
Automated Bicycle Counts - Portland

- Inductive loops are most common
  - Stop Bar Loop
  - Advance Loop

- Conditions that have to be met
  - Presence of bicycle lane
  - Presence of advance loop in bike lane
  - Presence of individual loop wire
Verification of Bicycle Counts

- Verification is needed to ensure accuracy
  - Undercounting bicycles
  - %Bikes Counted 97%, 87%
  - Error (MAPE) 17%, 18%

N Wheeler Ave., N. Williams Ave and N. Winning Way 3-leg intersection
Portland – Lovejoy at NW 9\textsuperscript{th} Ave

- Highly Accurate

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Manual Counts</td>
<td>126</td>
</tr>
<tr>
<td>Detector Counts</td>
<td>124</td>
</tr>
<tr>
<td>% Bikes Counted</td>
<td>98%</td>
</tr>
<tr>
<td>Error (MAPE)</td>
<td>1%</td>
</tr>
</tbody>
</table>

Source: James Lindsey
Boulder – 20th St. NB

- Slight over detection

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Manual Counts</td>
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<td>Detector Counts</td>
<td>285</td>
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<tr>
<td>% Bikes Counted</td>
<td>102%</td>
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<tr>
<td>Error (MAPE)</td>
<td>10%</td>
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</table>
Oregon DOT Study

- Southbound Hall Boulevard to Tigard Library

- Loop at stop bar

- Second loop approximately 50 feet from stop bar

- Loops in Series

- Note worn bike lane stripe
## Loop Accuracy

10 hours with highest volumes: 6 to 11 and 2 to 7

<table>
<thead>
<tr>
<th>Video Counts</th>
<th>Loop Detections</th>
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</thead>
<tbody>
<tr>
<td>NB to Beaverton:</td>
<td>30</td>
</tr>
<tr>
<td>SB to Tigard:</td>
<td>35</td>
</tr>
<tr>
<td>EB to Portland:</td>
<td>10</td>
</tr>
<tr>
<td>WB to Sherwood:</td>
<td>28</td>
</tr>
<tr>
<td>*<em>32</em></td>
<td>*<em>66</em></td>
</tr>
<tr>
<td><strong>253</strong></td>
<td><strong>45</strong></td>
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</tbody>
</table>

*32 and 66 are the sum of two loops; the actual number of vehicles or bicycles that were detected at each loop on Hall is not known*. 
Overall Accuracy

- NB to Beaverton: 107% *
- SB to Tigard: 189% *
- EB to Portland: 2530%
- WB to Sherwood: 161%

* Based on 32 and 66 detections (see previous slide, the sum of two loops), the actual number of vehicles or bicycles that were detected at each bicycle loop on Hall is not known.
Summary: Bicycle Loops

• The location of loops is very important.

• Clearly, getting the right sensitivity is important to obtain accurate counts.

• TESTING is not optional!!!
Conclusions
<table>
<thead>
<tr>
<th>Signal Detection Technology</th>
<th>% Bike Counted</th>
<th>Mean Absolute Percent Error (MAPE)</th>
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</thead>
<tbody>
<tr>
<td>Video</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar Kendrick 2014</td>
<td>190%</td>
<td></td>
</tr>
<tr>
<td>Thermal Camera (Phase 3) Kendrick 2014</td>
<td>126%</td>
<td>21%</td>
</tr>
<tr>
<td>Thermal Camera (Phase 4) Kendrick 2014</td>
<td></td>
<td>26%</td>
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<tr>
<td>Inductive Loop (City of Portland) Kothuri 2012</td>
<td>97%, 87%</td>
<td>17%, 18%</td>
</tr>
<tr>
<td>Inductive Loop (City of Portland) Lindsey 2014</td>
<td>98%</td>
<td>1%</td>
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<tr>
<td>Inductive Loop (City of Boulder) Nordback 2011</td>
<td>102%</td>
<td>10%</td>
</tr>
<tr>
<td>Inductive Loop (Oregon DOT) Figliozzi 2014</td>
<td>107%, 189%, 2530%, 161%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Conclusions

Can we detect it?
  • Sometimes.

If we can detect it, can we count it?
  • Maybe, but overcounts common.

If we can count it, should we include it in our travel monitoring program?
  • You be the judge!
Future Research

• Oregon DOT to study loop configurations

• Portland Bureau of Transportation to study
  • Loops to distinguish between cyclist and vehicles
  • Video detection

Source: Alexandra Frackelton
Questions?

Krista Nordback
Nordback@pdx.edu
503-725-2897
The TMG 2013 Approach

- Inventory & QA/QC
- Permanent Count Program
- Short Duration Count Program
- Apply Factors

Annual Average Daily Bicycle or Pedestrian Traffic
National Bicycle and Pedestrian Documentation Project

Manual Counts:
2 hours
5 to 7pm
Tues, Wed, or Thurs in mid-September

http://bikepeddocumentation.org/
Passive Infrared Counters
The Problem

Cities and Counties

Ped/Bike counts live here and die here.

State Agencies

Some ped/bike counts live here.

Federal (FHWA)

No ped/bike counts live here.
The Solution

Cities and Counties

State Agencies

Federal (FHWA)

bike counts

bike counts

TMAS
Preliminary Site Prep

- Field testing of loop detectors
- Tiffany Slauter support
- 4 approaches
- Light activation when a bicycle is on the loop

Sensitivity was increased
- Initial sensitivity: switches 1 and 2 on
- After adjustment: most loops with 1, 2, 4, and 8 ON
Pilot Study

- Northbound Hall Boulevard to Beaverton

- Loop at stop bar
- Second loop approximately 50 feet from stop bar
- Loops in Series, counted twice in 2070 data
Pilot Study

• Eastbound - 99W to Portland

• Right turn pocket

• Single Loop before turn pocket
Pilot Study

• Westbound - 99W to Sherwood

• Single Bicycle Loop
Bike Loop Locations
Loop Accuracy: overcounting

\[
\% \text{ Error} = \frac{\#\text{loop} - \#\text{video}}{\#\text{video}}
\]

- NB to Beaverton: 1474 %
- SB to Tigard: 1169 %
- EB to Portland: 5413 %
- WB to Sherwood: 2180 %

Eastbound - 99W to Portland
Overall Accuracy

<table>
<thead>
<tr>
<th>High Sensitivity</th>
<th>Medium Sensitivity</th>
</tr>
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<tbody>
<tr>
<td>• NB to Beaverton : 1574 %</td>
<td>107 % *</td>
</tr>
<tr>
<td>• SB to Tigard: 1269 %</td>
<td>189 % *</td>
</tr>
<tr>
<td>• EB to Portland: 5513 %</td>
<td>2530 %</td>
</tr>
<tr>
<td>• WB to Sherwood: 2280 %</td>
<td>161 %</td>
</tr>
</tbody>
</table>

Accuracy did improve, but there may be a high correlation between traffic and detections (especially on 99W and in general with right turn volume)

* Based on 32 and 66 detections (see previous slide, the sum of two loops), the actual number of vehicles or bicycles that were detected at each bicycle loop on Hall is not known.
Analysis - Bicycle Loops

- Bike volumes counted for 6 days before/after sensitivity change
- Ratios presented below are daily AFTER/BEFORE loop counts

<table>
<thead>
<tr>
<th>DOW</th>
<th>99W Eastbound Portland</th>
<th>Hall Southbound Tigard Library</th>
<th>99W Westbound Sherwood</th>
<th>Hall Northbound Beaverton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturday</td>
<td>3.88</td>
<td>3.88</td>
<td>11.53</td>
<td>3.88</td>
</tr>
<tr>
<td>Sunday</td>
<td>3.14</td>
<td>4.01</td>
<td>13.39</td>
<td>3.93</td>
</tr>
<tr>
<td>Monday</td>
<td>3.44</td>
<td>4.22</td>
<td>10.75</td>
<td>4.46</td>
</tr>
<tr>
<td>Tuesday</td>
<td>2.79</td>
<td>4.24</td>
<td>8.99</td>
<td>3.40</td>
</tr>
<tr>
<td>Wednesday</td>
<td>2.75</td>
<td>4.83</td>
<td>11.32</td>
<td>3.42</td>
</tr>
<tr>
<td>Thursday</td>
<td>2.98</td>
<td>3.69</td>
<td>11.62</td>
<td>3.89</td>
</tr>
<tr>
<td>Averages</td>
<td><strong>3.17</strong></td>
<td><strong>4.15</strong></td>
<td><strong>11.27</strong></td>
<td><strong>3.83</strong></td>
</tr>
</tbody>
</table>
### Analysis - Bicycle Loops

**99W and Hall 2070 Bicycle Inductive Loop Counts**

Friday, 8/23/2013, when sensitivity of the loops was changed

![Graph showing bicycle volume changes](image)

- **EB 99W - BIKE**: 99W-Eastbound-Portland
- **SB Hall - BIKE (x2)**: Hall- Southbound-Tigard
- **WB 99W - BIKE**: 99W-Westbound - Sherwood
- **NB Hall - BIKE (x2)**: Hall- Northbound- Beaverton

**Sensitivity Change**
Analysis- Bicycle Loops

• Clearly, getting the right sensitivity is important to obtain accurate counts

• Sensitivity was subsequently adjusted: only switches 2 and 8 set to ON (1 and 4 off)

• We recorded another 24 hour video session from 9 AM 10/24 to 9 AM 10/25
Recommendations: Bicycle Loops

- Minor approach: split input loop at the stop bar and detection
- Create buffer for bicyclists and keep vehicles away from bicycle loops
- Bicyclist confusion: add sign to wait for green
- Improve bicyclist safety perception, how?

Source: NACTO Design Guide
Portland Loop Accuracy

N Wheeler Ave., N. Williams Ave and N. Winning Way 3-leg intersection
Bicycle Usage Trends

Inbound Bicycle Counts

Outbound Bicycle Counts

Kothuri, Reynolds, Monsere, and Koonce, 2012
Portland – Winning at Wheeler NB/SB

- Undercounting slightly

<table>
<thead>
<tr>
<th></th>
<th>NB</th>
<th>SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Counts</td>
<td>128</td>
<td>118</td>
</tr>
<tr>
<td>Detector Counts</td>
<td>112</td>
<td>115</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>88%</td>
<td>97%</td>
</tr>
</tbody>
</table>

David Urowsky – Portland Department of Transportation
1. Round corners of acute angle sawcuts to prevent damage to conductors.

2. Install 3 turns when only one Type D loop is on a sensor unit channel. Install 5 turns when one Type D loop is connected in series with 3 additional 8 in x 8 in (64 in²) loops on a sensor unit channel.

NOTES:

1. THE CONTRACTOR SHALL INSTALL THE LOOP DETECTORS ON THE TOP OF THE PREPARED BASE FOR THE SIDEWALK.

2. THE LOOPS SHALL BE WRAPPED BASED ON THE WRAPPING DETAIL AROUND WOOD STAKES OR REINFORCING STEEL AS SHOWN.
Use AADT to Estimate VMT

Sum \((\text{AADT} \times \text{Segment Length})\) over network to compute Vehicle Miles Traveled (VMT)
Signal Timing

Results

- Overcounting (% Bikes Counted = 126%)
- If extra counts occur, a bicyclist is more frequently counted twice compared to three or five times
- Counting affected detection presence.

Christine Kendrick and Peter Koonce, City of Portland
Video Data Results

Fifteen Hours of Images: 872 observations

- Yes: 265
- Maybe: 123
- No: 484

QC: Matching with SNAPS Report & Reviewing Images

- Yes: 259
- Maybe: 105
- No: 508

259 Events = 71 Bikes + 178 Vehicles + 10 Pedestrians
### Results: Total Detections
(detection= timestamp)

<table>
<thead>
<tr>
<th></th>
<th>SNAPS Non-Detects</th>
<th>SNAPS Detections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Video Non-detects</strong></td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td><strong>Video Detections</strong></td>
<td>15</td>
<td>244</td>
</tr>
</tbody>
</table>

- Total Events Observed on Video: 259
- Total Events Detected by sensor: 264
Results: Total Detections

SNAPS reports show a higher number of detections than actual events occurred:

- 20 Detections not observed in video

Why:
- False positive detections of bikes
- Counting a bike or car more than once
- Counting a misclassification more than once

Fifteen events observed in the video that did not correspond to any detection events by the sensor

- 13 possible missed bikes - more details later
- 2 missed cars
Results: Detection Classifications

<table>
<thead>
<tr>
<th>Video hours</th>
<th>Total events SNAPS</th>
<th>Bike events SNAPS</th>
<th>Any events SNAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>264</td>
<td>138</td>
<td>126</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Video hours</th>
<th>Total events video</th>
<th>Bike events video</th>
<th>Vehicle events video</th>
<th>Ped events video</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>259</td>
<td>71</td>
<td>178</td>
<td>10</td>
</tr>
</tbody>
</table>

- Sensor shows a higher number of bike detections than actual bikes:
  - 138 SNAPS bike events versus 71 video bike events
- Why:
  - Misclassifications (cars as bikes, peds as bikes) + false positive detections of bikes

- SNAPS show a lower number of any or vehicle events than actual vehicles
  - Misclassifications
Error Types

1) Vehicle detected as a bike: 50 instances
   - Vehicle travels in middle of SE 16th
   - Vehicle makes a wide right turn or short left turn
   - Smart or small car
   - Vehicle reverses a little bit
   - Parked vehicle leaves

2) False Positive for bikes: 19 instances
   - Vehicle is waiting to turn off of 16th and just outside of detection zone
   - Parked vehicle door activity
   - One instance of a bicycle detection with no one near or in the detection zone
3) Missed bike: 13 instances

- Subjective to decide if bike was correctly aligned in the detection zone due to camera angle and movement of bicyclists

- We were conservative when observing video to record a bicyclist as a definite yes observation meaning the bicyclist should have been detected by the sensor

- We had many “maybe” classifications and these were qc’ed when matching the SNAPs results with the video timestamps

- After QC: 13 events where bikes were observed in the video but not detected by SNAPS
  - 9 could have been going too fast or only clipped back corner
  - 2 occurred when there was a bike and car in the zone together
  - 2 that bike seemed to be in correct position but no detection by sensor
Error Types

4) Pedestrian as a bike: 10 instances
   - 10 Pedestrians observed in video: walking or jogging through the zone or getting into a car
   - 1 Time a ped was observed moving through zone but not detected by sensor (90% chance a pedestrian will be detected as a bike)

5) Missed vehicle: 2 instances
   - Two vehicles traveling slightly towards the middle of SE 16th
     - This type of movement was typically detected as a bike

6) False Positive for a vehicle: 1 instance
   - Vehicle was waiting to turn off of 16th just outside of detection zone

7) Motorcycle as a bike: 1 instance
   - We have not seen a bike detection system yet that can differentiate between bikes and motorcycles. This is not counted in the error totals in the rest of results.
## Table 1 Error Occurrences for Each Sample Hour

<table>
<thead>
<tr>
<th>Date</th>
<th>Time of sample hour</th>
<th>Total events Video</th>
<th>Total events SNAPS</th>
<th>Vehicle as a bike</th>
<th>Ped as a bike</th>
<th>False Positive Bike</th>
<th>False Positive Vehicle</th>
<th>Missed Bike</th>
<th>Missed Vehicle</th>
<th>Total # of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/24/2013</td>
<td>0800 PST</td>
<td>13</td>
<td>13</td>
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<td></td>
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<tr>
<td>6/24/2013</td>
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<td>13</td>
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Results:
- 82% Successful bike detection rate based on a total of 13 missed bikes.
- However, it was subjective at times to determine if bicycle correctly moved through detection zone.
- Even after watching video multiple times, 9 bikes potentially moved too quickly or only clipped back corner so could be a yes or a maybe.