AUTOMATED INTERSECTION VOLUME COUNTS USING EXISTING SIGNAL CONTROL DEVICES

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Outline

- Introduction (loop detector and volume application)
- Present status (detectors accuracy)
- Modifying detector counts (micro and macro)
- Estimating intersection turning volumes from traffic signals data
- Using stop-bar detector information to determine turning movement proportions in shared lanes
- Recommendations (appropriate condition of loops and middle intersection detectors)
Loop Detector

- Electronics units (card file format)
- Controller cabinet
- Lead-in conduit
- Pullbox
- Conduit-to-curb run
- Shielded lead-in cable
- Splice in pullbox
- Twisted wire to suppress electrical interference

(1 ft = 0.305 m)
Volume Applications

- Intersection operational analyses
- Traffic safety studies
- Travel demand modeling
- Identifying critical flow time periods
- ...
Collecting intersection Volume in Nevada

- Manual
  - Expensive
  - Time assuming
  - Not continuous

- Automatic using loops
  - Low accuracy
Outline

Introduction (loop detector and volume application)

Present status (detectors accuracy)

Modifying detector counts (micro and macro)

Estimating intersection turning volumes from traffic signals data

Using stop-bar detector information to determine turning movement proportions in shared lanes

Recommendations (appropriate condition of loops and middle intersection detectors)
Accuracy of present detectors

There is advanced detector but spliced to stop bar detectors.

Sparks/Prater, Sparks, NV

Kietzke/Moana, Reno, NV
Loop Detector Layout

PLAN VIEW

- Pull Box
- Curb, gutter pan lip or pavement edge
- Stop bar or back of crosswalk
- * Omit back loops on through, if advance loops are present
## Loop Detector Data

### Volume Report

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Detector 9</th>
<th>Detector 10</th>
<th>Detector 11</th>
<th>Detector 12</th>
<th>Detector 5</th>
<th>Detector 6</th>
<th>Detector 7</th>
<th>Detector 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/12/2013 6:00:00AM</td>
<td>29</td>
<td>33</td>
<td>45</td>
<td>41</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6/12/2013 6:15:00AM</td>
<td>26</td>
<td>36</td>
<td>39</td>
<td>37</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6/12/2013 6:30:00AM</td>
<td>33</td>
<td>32</td>
<td>57</td>
<td>53</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6/12/2013 6:45:00AM</td>
<td>46</td>
<td>67</td>
<td>89</td>
<td>87</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Accuracy of present detectors

Kitzke/Moana Northbound

Volume

6:45 7:00 7:15 7:30 7:45 8:00 8:15 8:30 8:45 9:00 9:15 11:00 11:15 11:30 11:45 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45 15:00 15:15 15:30 15:45 16:00 16:15 16:30 16:45 17:00 17:15 17:30 17:45 18:00

- Detector
- Base
Accuracy of present detectors

Kitzke/Moana Southbound

Volume

- Detector
- Base

Time:
- 6:45
- 7:00
- 7:15
- 7:30
- 7:45
- 8:00
- 8:15
- 8:30
- 8:45
- 9:00
- 9:15
- 10:45
- 11:00
- 11:15
- 11:30
- 11:45
- 12:00
- 12:15
- 12:30
- 12:45
- 13:00
- 13:15
- 13:30
- 13:45
- 14:00
- 14:15
- 14:30
- 14:45
- 15:00
- 15:15
- 15:30
- 15:45
- 16:00
- 16:15
- 16:30
- 16:45
- 17:00
- 17:15
- 17:30
- 17:45
- 18:00
Accuracy of present detectors

Kitzke/Moana Eastbound

Volume

- Detector
- Base

Time:
- 6:45
- 7:00
- 7:15
- 7:30
- 7:45
- 8:00
- 8:15
- 8:30
- 8:45
- 9:00
- 9:15
- 9:30
- 9:45
- 10:00
- 10:15
- 10:30
- 10:45
- 11:00
- 11:15
- 11:30
- 11:45
- 12:00
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- 12:45
- 13:00
- 13:15
- 13:30
- 13:45
- 14:00
- 14:15
- 14:30
- 14:45
- 15:00
- 15:15
- 15:30
- 15:45
Accuracy of present detectors

Kitzke/Moana Westbound

Volume

Detector
Base
Accuracy of present detectors
Accuracy of present detectors
Accuracy of present detectors

Sparks/Prater Southbound - Through

- Detector
- Base
Accuracy of present detectors

Sparks/Prater Southbound - Left

Volume

6:45 7:00 7:15 7:30 7:45 8:00 8:15 8:30 9:00 9:15
11:00 11:15 11:30 11:45 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45
15:45 16:00 16:15 16:30 16:45 17:00 17:15 17:30 17:45 18:00

- Detector
- Base
Accuracy of present detectors

Sparks/Prater Eastbound - Through

Volume

Detector
Base

6:45 7:00 7:15 7:30 7:45 8:00 8:15 8:30 8:45 9:00 9:15 9:30 9:45 10:00 10:15 10:30 10:45 11:00 11:15 11:30 11:45 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45 14:00 14:15 14:30 14:45 15:00 15:15 15:30 15:45 16:00 16:15 16:30 16:45 17:00 17:15 17:30 17:45 18:00
Accuracy of present detectors

Sparks/Prater Eastbound - Left

Volume

- Detector
- Base
Accuracy of present detectors

Sparks/Prater Westbound - Through

- Detector
- Base

Volume

6:45 7:00 7:15 7:30 7:45 8:00 8:15 8:30 8:45 9:00 9:15 11:00 11:15 11:30 12:00 12:15 12:30 12:45 13:00 13:15 13:30 13:45 15:45 16:00 16:15 16:30 16:45 17:00 17:15 17:30 17:45 18:00
Accuracy of present detectors
Accuracy

\[ MAPE(\%) = \frac{\sum_{i=1}^{n} \left| \frac{D_i - B_i}{B_i} \right|}{n} \]

\[ RMSE = \sqrt{\frac{\sum_{i=1}^{n} (D_i - B_i)^2}{n}} \]

Where:

MAPE: Mean Absolute Percentage Error
RMSE: Root Mean Squared Error
\( D_i \): the detector data value
\( B_i \): the reference (base) data value
\( n \): the total number of intervals
Accuracy of present detectors

Kitzke/Moana

- Northbound
- Southbound
- Eastbound
- Westbound

MAPE
RMSE
Accuracy of present detectors
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- Recommendations (appropriate condition of loops and middle intersection detectors)
Kietzke/Moana, Volume
Sparks/Prater, Volumes

Scatterplot of SB-T-B vs SB-T-D, SB-L-B vs SB-L-D, WB-T-B vs WB-T-D, W

- SB-T-B*SB-T-D
- SB-L-B*SB-L-D
- WB-T-B*WB-T-D
- WB-L-B*WB-L-D
- NB-T-B*NB-T-D
- NB-L-B*NB-L-D
- EB-T-B*EB-T-D
- EB-L-B*EB-L-D
Proposed Process to Improve Accuracy

Whenever we collect manual data for an intersection we can also do:

- Collecting data from loop detectors (Volume, occupancy, and speed)
- Making a model based on our manual and detectors data
- Calculating the accuracy of our model for using in future
The Model

- Manual count = $f\text{(detector volume, speed, and occupancy)}$
Making the Model

- **Regression**
  - User must specify the structure of the model

- **Genetic Programming**
  - GP automatically evolves both the structure and the parameters
What does GP do?
What does GP do?

![Diagram showing geometric patterns]

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>y</td>
<td>z</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>5.830952</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>16.12452</td>
</tr>
<tr>
<td>18</td>
<td>2</td>
<td>18.11077</td>
</tr>
<tr>
<td>32</td>
<td>11</td>
<td>33.83785</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>15.6205</td>
</tr>
<tr>
<td>21</td>
<td>6</td>
<td>21.84033</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>8.062258</td>
</tr>
</tbody>
</table>

**Simplified overall GP expression:**

```
psqroot(square(x1) + square(x2)) - --------- + ------
4.075 square(x2 - 8.483) 4.89 x1 1.232
```

```
How GP Works?

- GP is based on evolution process, (cross over, mutation, and elitism)
- We can use ready applications
GPTIPS
# Models (Reno)

<table>
<thead>
<tr>
<th>Approach</th>
<th>Regression Models</th>
<th>GP Models</th>
<th>GP vs Reg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td>R-squared</td>
<td>Model</td>
</tr>
<tr>
<td>NB</td>
<td>$NBB = -1.2 + 1.07 ; NBD + 0.144 ; NBO^*$</td>
<td>0.885</td>
<td>$NBB = -4NBD^{1.3} / 10^{1.5}$ + 0.02NBD$^{1.2}$ − 0.6NBD + 59.9</td>
</tr>
<tr>
<td>EB</td>
<td>$EBB = 10.7 + 1.04 ; EBD + 0.336 ; EBO$</td>
<td>0.879</td>
<td>$EBB = 3.3EBD - 2.5EBO$ − 0.02EBD×EBO + 0.02EBO$^{1.2}$ + 53.2</td>
</tr>
<tr>
<td>SB</td>
<td>$SBB = 8.7 + 1.04 ; SBD + 0.170 ; SBO$</td>
<td>0.646</td>
<td>$SBB = -8SBD^{1.3} / 10^{1.5}$ + 0.04SBD$^{1.2}$ − 4.3SBD + 0.15SBO + 253</td>
</tr>
<tr>
<td>WB</td>
<td>$WBB = 107 +$</td>
<td></td>
<td>$WBB = 8WBO - 0.13WBD$</td>
</tr>
</tbody>
</table>
Accuracy of Models, Reno

Kietzke/Moana

Original MAPE
Regression MAPE
GP MAPE
Accuracy of Models, Sparks

![Bar chart showing the accuracy of models for different directions and lanes at Sparks/Prater. The chart compares Original MAPE and Regression MAPE.](chart.png)
Potential Applications

A large majority of signalized intersections operate under some form of actuated control, in that intersection approaches (or lanes) have some type of inductive loops.

<table>
<thead>
<tr>
<th>Loop Detector Attributes</th>
<th>Reno</th>
<th>Sparks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of intersections controlled by the responsible agency</td>
<td>238</td>
<td>108</td>
</tr>
<tr>
<td>Number of intersections with detection type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loops</td>
<td>132 (Some Intersections have both Loops and Video)</td>
<td>45</td>
</tr>
<tr>
<td>Video</td>
<td>74</td>
<td>62</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td>32</td>
<td>-</td>
</tr>
</tbody>
</table>
Errors using inadequate data are much less than those using no data at all.

Charles Babbage in 1860

Considered “father of the computer”
Micro Analysis

- High resolution data
- Internet search, ITE forum, contacting vendors, …
Outline

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Recommendations (appropriate condition of loops and middle intersection detectors)
Case Study: Incentive

Mean Absolute Percentage Error

Counts from loop detectors are not reliable in Reno and Sparks, NV

Kietzke and Moana, Reno, NV

Sparks and Prater, Sparks, NV
Research Question

Can turning volumes be estimated based on signal information without using loop detector data?
Methodology

Modeling the intersection in VISSIM

Developing a code in COM interface (VISSIM tool) with different parameters

Making a prediction model for the data
## Signal Information from VISSIM Simulation

<table>
<thead>
<tr>
<th>Cycle No</th>
<th>Green Time</th>
<th>Volume per Cycle</th>
<th>Hourly Volume</th>
<th>Side Street Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.6</td>
<td>12</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>20.7</td>
<td>12</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>20.7</td>
<td>12</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>20.7</td>
<td>12</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>19.4</td>
<td>10</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12373</td>
<td>18.6</td>
<td>8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>12374</td>
<td>14.8</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>12375</td>
<td>13</td>
<td>6</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Making the Model

Regression
• User must specify the structure of the model

ANFIS
• Adaptive Neuro-Fuzzy Inference System
Crisp (a) and fuzzy (b) sets of ‘tall men’
<table>
<thead>
<tr>
<th>Hedge</th>
<th>Mathematical expression</th>
<th>Graphical representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A little</td>
<td>$[\mu_A(x)]^{1.3}$</td>
<td></td>
</tr>
<tr>
<td>Slightly</td>
<td>$[\mu_A(x)]^{1.7}$</td>
<td></td>
</tr>
<tr>
<td>Very</td>
<td>$[\mu_A(x)]^2$</td>
<td></td>
</tr>
<tr>
<td>Extremely</td>
<td>$[\mu_A(x)]^3$</td>
<td></td>
</tr>
<tr>
<td>Very very</td>
<td>$[\mu_A(x)]^4$</td>
<td></td>
</tr>
<tr>
<td>More or less</td>
<td>$\sqrt{\mu_A(x)}$</td>
<td></td>
</tr>
<tr>
<td>Somewhat</td>
<td>$\sqrt{\mu_A(x)}$</td>
<td></td>
</tr>
</tbody>
</table>
| Indeed        | $2[\mu_A(x)]^2$ if $0 \leq \mu_A \leq 0.5$  
                 | $1 - 2[1 - \mu_A(x)]^2$ if $0.5 < \mu_A \leq 1$  |
Fuzzy rules

If x is A
Then y is B

For example:

Rule 1:
IF Green time is > 30 sec AND It is during peak-hour
THEN “traffic_volume” is high

Rule 2:
IF Green time is < 10 sec
THEN “traffic_volume” is low
Fuzzy inference

- A process of mapping from a given input to an output, using the theory of fuzzy sets
- Mamdani-style inference
- Sugeno-style inference

Fuzzification, Rule evaluation, Aggregation of the rule outputs, Defuzzification
Fuzzy inference: Mamdani-style inference
Fuzzy inference: Sugeno-style inference
Neural network
Adaptive Neuro-Fuzzy Inference System (ANFIS)
Modeling
Case Study Intersections
Results

![Graph showing ANFIS improvement over regression percentage for different phases and times.]
ANFIS advantages and disadvantages

- Needs additional effort for learning the ANFIS concept 😞
- Needs more data records to have better training and data preparation
- More flexibility for modeling complex data sets
- More accuracy especially when data pattern is not clear
- Ready toolbox in MATLAB 😊
So far, thank you for not being like these!

Any comment or question?
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Present status (detectors accuracy)

Modifying detector counts (micro and macro)

Estimating intersection turning volumes from traffic signals data

Using stop-bar detector information to determine turning movement proportions in shared lanes

Recommendations (appropriate condition of loops and middle intersection detectors)
Using Stop-bar Detector Information to Determine Turning Movement Proportions in Shared Lanes
What is the current practice?

In this method we need:
- Stop–bar detector data
- Exit detector data
- Traffic signal data

Input Detections: 1, 3
Output Detection: 5, 6

Possible Matches for 6:
1->6 Northbound Right Turn
3->6 Southbound Left Turn

Possible Matches for 5:
3->5 Southbound Through
Stop-bar Detector Data

- Aggregated
- High Resolution
## Detector Data, Aggregated

### Volume Report

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Detectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/12/2013</td>
<td>9  10  11  12  5  6  7  8</td>
</tr>
<tr>
<td>6:00:00AM</td>
<td>29  33  45  41  0  0  0  0</td>
</tr>
<tr>
<td>6:15:00AM</td>
<td>26  36  39  37  0  0  0  0</td>
</tr>
<tr>
<td>6:30:00AM</td>
<td>33  32  57  53  0  0  0  0</td>
</tr>
<tr>
<td>6:45:00AM</td>
<td>46  67  89  87  0  0  0  0</td>
</tr>
</tbody>
</table>
Stop-bar Detector Data

- Aggregated
- High Resolution
Detector Data, High Resolution

Detector #8 on at 08:09:15.012; Vacant time is 7.902s

08:09:15.012, D8 on, 7.902s

08:09:15.481, D8 off, 0.468s

08:09:16.761, G3 off, 29.389s

08:09:16.761, Y3 on, 179.021s

08:09:17.620, D9 on, 2.686s

Green Phase #3 off at 08:09:16.761; Green duration time is 29.389s

08:09:15.012, D8 on, 7.902s

08:09:18.823, D10 off, 0.671s

08:09:20.244, Y3 off, 3.482s

08:09:21.649, D22 on, 80.953s

08:09:22.008, D22 off, 0.359s

08:09:23.242, G1 on, 172.806s

Yellow Phase #3 off at 08:09:20.244; Yellow duration time is 3.482s

Green Phase #1 on at 08:09:23.242; Red duration time is 172.806s
Collecting intersection Volume in Nevada

- Manual
  - Expensive
  - Time assuming
  - Not continuous

- Automatic using loops
  - Not possible in shared lanes
Determine Turning Movement Proportions at Signalized Intersections with Shared Lanes

| Departure detector | Only high resolution data  
|                    | Both stop bar and departure detectors in addition to signal information are necessary |
| Network Equilibrium (NE) | Aggregated or high resolution data |
| Volume and Queue Length of Shared Lanes (VQ) | 1 min aggregated data or high resolution data |
| Flow Characteristics of Shared Lanes (FC) | Only high resolution data |
| Observed proportions in the field (OP) | Aggregated or high resolution data |
### Determine Turning Movement Proportions at Signalized Intersections with Shared Lanes

<table>
<thead>
<tr>
<th>Category</th>
<th>Data Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Departure detector</strong></td>
<td>• Only high resolution data</td>
</tr>
<tr>
<td></td>
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<tr>
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</tr>
<tr>
<td><strong>Observed proportions in the field (OP)</strong></td>
<td>• Aggregated or high resolution data</td>
</tr>
</tbody>
</table>
Network Equilibrium (NE)

\[ WT_i^t = -NL_i^t - SR_i^t + WR_j^{t+\Delta t} + WT_j^{t+\Delta t} + WL_j^{t+\Delta t} - \delta_{ij}^t \]
## Determine Turning Movement Proportions at Signalized Intersections with Shared Lanes

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</tr>
<tr>
<td><strong>Observed proportions in the field (OP)</strong></td>
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Volume and Queue Length of Shared Lanes (VQ)

\[ r_{s,a}^t = \frac{v_s^t}{v_a^t} \]

\[ r_{r,t}^t (\text{or } r_{l,t}^t) = \frac{v_r^t (\text{or } v_i^t)}{v_t^t} \]

\[ r_{r,t}^t (\text{or } r_{l,t}^t) = f(r_{s,a}^t) \]
Determine Turning Movement Proportions at Signalized Intersections with Shared Lanes

- Departure detector
  - Only high resolution data
  - Both stop bar and departure detectors in addition to signal information are necessary

- Network Equilibrium (NE)
  - Aggregated or high resolution data

- Volume and Queue Length of Shared Lanes (VQ)
  - 1 min aggregated data or high resolution data

- Flow Characteristics of Shared Lanes (FC)
  - Only high resolution data

- Observed proportions in the field (OP)
  - Aggregated or high resolution data
Flow Characteristics of Shared Lanes (FC)

\[ P(t \downarrow i, r) \text{ or } P(t \downarrow i, l) = f(h \downarrow i, hf \downarrow i, cp \downarrow i, ct \downarrow i, cf \downarrow i) \]
# Determine Turning Movement Proportions at Signalized Intersections with Shared Lanes

<table>
<thead>
<tr>
<th>Method</th>
<th>Data Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure detector</td>
<td>- Only high resolution data</td>
</tr>
<tr>
<td></td>
<td>- Both stop bar and departure detectors in addition to signal information are necessary</td>
</tr>
<tr>
<td>Network Equilibrium (NE)</td>
<td>- Aggregated or high resolution data</td>
</tr>
<tr>
<td>Volume and Queue Length of Shared Lanes (VQ)</td>
<td>- 1 min aggregated data or high resolution data</td>
</tr>
<tr>
<td>Flow Characteristics of Shared Lanes (FC)</td>
<td>- Only high resolution data</td>
</tr>
<tr>
<td>Observed proportions in the field (OP)</td>
<td>- Aggregated or high resolution data</td>
</tr>
</tbody>
</table>
## Considerations

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departure detector</td>
<td>Not applicable in Nevada</td>
</tr>
<tr>
<td>Network Equilibrium (NE)</td>
<td>Significant trip generator between intersections</td>
</tr>
<tr>
<td>Volume and Queue Length of Shared Lanes (VQ)</td>
<td>Downstream intersection</td>
</tr>
<tr>
<td>Flow Characteristics of Shared Lanes (FC)</td>
<td>Not applicable if left turn is not protected</td>
</tr>
<tr>
<td></td>
<td>Pedestrian</td>
</tr>
<tr>
<td></td>
<td>Turning radius</td>
</tr>
<tr>
<td>Observed proportions in the field (OP)</td>
<td>High variances in different hours, days, weeks, or seasons</td>
</tr>
</tbody>
</table>
Which method?

1- NE (if there is not significant trip generator between intersections)
2- Departure Detectors (if high resolution data and departure detectors are available)
3- VQ (if at least 1 minute aggregate data is available)
4- FC (if high resolution data is available)
5- OP (if none of above methods are available)
Calculating the proportion of turning volume based on NE method

Obtaining data from shared lane

Can NE be applied?

Yes

No

Is high resolution data available?

Yes

No

Is any same-direction adjoining lane?

Yes

No

Calculating the proportion of turning volume based on VQ method

Calculating the proportion of turning volume based on FC method, and add all red time actuations to right turn if the shared lane is not NTOR or left turn shared lane. Also divide the first vehicles at the queue and all green time arriving vehicles (which their headway is not significantly associated to turning movement) between through and turning movement based on vehicles in queue during red time.

Does turning radius make headway significantly associated to turning movement?

Yes

No

Calculating the proportion of turning volume based on CS method

2014 Fall Transportation Conference
Making the Models

For VQ and FC methods we need to make models. To make models we used:

- **Regression**
  - User must specify the structure of the model

- **Genetic Programming**
  - GP automatically evolves both the structure and the parameters
```r
# Ex06_02
# Computing a regression

# Load data file about Google searches by state
google <- read.csv("google_correlate.csv", header = T)
names(google)

reg1 <- lm(data_viz ~
            degree + stats_ed + facebook + nba + has_nba + region,
            data = google)

summary(reg1)
```

```r
> google <- read.csv("google_correlate.csv", header = T)
> names(google)

[1] "State" "state_code" "data_viz" "facebook"
[5] "nba" "has_nba" "degree" "stats_ed"
[9] "region"
> reg1 <- lm(data_viz ~
+ degree + stats_ed + facebook + nba + has_nba + region,
+ data = google)
```
Accuracy

- \( MAPE(\%) = \frac{\sum_{i=1}^{n} |D_i - B_i|}{n} \)

MAPE: Mean Absolute Percentage Error

- \( D_i \): the detector data value
- \( B_i \): the reference (base) data value
- \( n \): the total number of intervals
Case Study Intersections

9th St. and Sierra St.

8th Street and Center Street

N McCarran Blvd and Clear Acre Ln
Sample of data collected for VQ method

<table>
<thead>
<tr>
<th>TIME INTERVAL (1 MINUTE)</th>
<th>SHARED LANE VOLUME $v_s^t$</th>
<th>ADJOINING LANE(S) VOLUME $v_a^t$</th>
<th>RATIO OF SHARED LANE TO ADJOINING LANES $r_{s,a}^t$</th>
<th>NO. OF RIGHT TURNS $v_r^t$</th>
<th>RATIO OF RIGHT TURNS $r_{r,t}^t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>25</td>
<td>0.24</td>
<td>3</td>
<td>0.50</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>18</td>
<td>0.39</td>
<td>5</td>
<td>0.71</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>13</td>
<td>0.46</td>
<td>4</td>
<td>0.67</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>21</td>
<td>0.86</td>
<td>18</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>16</td>
<td>0.44</td>
<td>5</td>
<td>0.71</td>
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</tbody>
</table>
Sample of data collected for FC method

<table>
<thead>
<tr>
<th>CYCLE&lt;sub&gt;cni&lt;/sub&gt; NO.</th>
<th>HEADWAY &lt;i&gt;h_i&lt;/i&gt;</th>
<th>FRONT CAR HEADWAY &lt;i&gt;hf_i&lt;/i&gt;</th>
<th>CAR POSITION &lt;i&gt;cp_i&lt;/i&gt;</th>
<th>CAR TYPE &lt;i&gt;ct_i&lt;/i&gt;</th>
<th>FRONT CAR TYPE &lt;i&gt;cf_i&lt;/i&gt;</th>
<th>TURNING DIRECTION &lt;i&gt;td_i&lt;/i&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>c</td>
<td>c</td>
<td>T</td>
</tr>
<tr>
<td>1</td>
<td>2.24</td>
<td>2.24</td>
<td>2</td>
<td>c</td>
<td>c</td>
<td>R</td>
</tr>
<tr>
<td>1</td>
<td>2.31</td>
<td>4.55</td>
<td>3</td>
<td>t</td>
<td>c</td>
<td>T</td>
</tr>
<tr>
<td>1</td>
<td>3.01</td>
<td>5.32</td>
<td>4</td>
<td>c</td>
<td>t</td>
<td>T</td>
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</tbody>
</table>
## Models

<table>
<thead>
<tr>
<th>MODELLING METHOD</th>
<th>N MCCARRAN BLVD/ CLEAR ACRE LN</th>
<th>9TH ST/ SIERRA ST</th>
<th>8TH ST/ CENTER ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>GP</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Analytical Calculation</td>
<td>Not applicable due to un-controlled south bound right turn</td>
<td>$ER_i^t = -SR_j^t - ST_j^t + ST_i^t + WL_i^t$</td>
<td>Not applicable due to downstream un-signalized intersection</td>
</tr>
<tr>
<td>Regression</td>
<td>Not applicable because the adjoining lane is also shared lane</td>
<td>Not applicable due to no existing same-direction adjoining lane</td>
<td>$r_{r,t} = 0.2 + 0.6 r_{s,a}^t$</td>
</tr>
<tr>
<td>VQ</td>
<td>Not applicable due to no existing same-direction adjoining lane</td>
<td>Not applicable due to no existing same-direction adjoining lane</td>
<td>$r_{r,t} = 4.55 + 2.5 r_{s,a}^t - 3.75 e^{-r_{s,a}^t} + 0.25 r_{s,a}^t^2$</td>
</tr>
<tr>
<td>GP</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Analytical Calculation</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Regression</td>
<td>$P(t_i) = \frac{e^{12.6 - 3.6h_i}}{1 + e^{12.6 - 3.6h_i}}$</td>
<td>$P(t_r) = \frac{e^{9.2 - 2.7h_i}}{1 + e^{9.2 - 2.7h_i}}$</td>
<td>$P(t_r) = \frac{e^{6 - 1.8h_i}}{1 + e^{6 - 1.8h_i}}$</td>
</tr>
<tr>
<td>GP</td>
<td>$P(t_i) = -3 + 2.8 \sqrt{</td>
<td>h_i - 3.8</td>
<td>} + 0.1 e^{h_i} - 0.1 h_i^2$</td>
</tr>
<tr>
<td>Analytical Calculation</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
# Results

<table>
<thead>
<tr>
<th>MODELLING METHOD</th>
<th>INTERSECTION</th>
<th>TURNING RADIUS (FT)</th>
<th>TIME INTERVAL</th>
<th>MAPE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOW CHARACTERISTIC S (FC)</td>
<td>8th St and Center St</td>
<td>16</td>
<td>Vehicle by Vehicle</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hourly Average</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9th St and Sierra St</td>
<td>35</td>
<td>Vehicle by Vehicle</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hourly Average</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>McCarran Blvd and Clear Acre Ln</td>
<td>100</td>
<td>Vehicle by Vehicle</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hourly Average</td>
<td>27</td>
</tr>
<tr>
<td>VOLUME AND QUEUE (VQ)</td>
<td>8th St and Center St</td>
<td></td>
<td>Vehicle by Vehicle</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hourly Average</td>
<td>4</td>
</tr>
<tr>
<td>NETWORK EQUILIBRUM (NE)</td>
<td>9th St and Sierra St</td>
<td></td>
<td>Vehicle by Vehicle</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hourly Average</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Regression</th>
<th>GP</th>
<th>Analytical Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8th St and Center St</td>
<td>20</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>9th St and Sierra St</td>
<td>21</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>McCarran Blvd and Clear Acre Ln</td>
<td>28</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>8th St and Center St</td>
<td>17</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>9th St and Sierra St</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Results

Mean Absolute Percentage Error (MAPE) percent

- Regression MAPE
- GP MAPE
- Analytical MAPE

Flow Characteristics (FC):
- 8th St and Center St
- 9th St and Sierra St
- McCarran Blvd and Clear Acre Ln

Volume and Queue (VQ):
- 8th St and Center St
- 9th St and Sierra St

Network Equilibrium (NE):
- Volume and Queue (VQ)
Outline

- Introduction (loop detector and volume application)
- Present status (detectors accuracy)
- Modifying detector counts (micro and macro)
- Estimating intersection turning volumes from traffic signals data
- Using stop-bar detector information to determine turning movement proportions in shared lanes
- Recommendations (appropriate condition of loops and middle intersection detectors)
Using Existing Loops at Signalized Intersections for Traffic Counts
Various applications of single loops
Various applications of two loops
Various applications of four loops
Sequential four loop configuration and expected accuracy
Middle-Intersection Detectors (MID)

\[ S11_t = \begin{cases} 
  \text{WBL if } (M_{41}^{t+\Delta t}S_{11} - M_{41} + \delta) \text{ and } (M_{21}^{t+\Delta t}S_{11} - M_{21} + \delta) \\
  \text{WBT if } (M_{41}^{t+\Delta t}S_{11} - M_{41} + \delta) \text{ and } (M_{11}^{t+\Delta t}S_{11} - M_{11} + \delta) \\
  \text{WBR if } (M_{31}^{t+\Delta t}S_{11} - M_{31} + \delta) 
\end{cases} \]
Stop bar detector \( j \) on leg \( i \)
Middle-intersection detector \( j \) on leg \( i \)
Possible movements
Movement path
Getting counts from middle-intersection detectors

Starting from the time that the first S detector is activated,

\[ k = k + \Delta t \]

Constructing the \( S^2 \) functions of MID activations in the range of valid interval

Determine the turning movement

Adding 1 to the turning counts of approach \( i \)

Deleting the activated records of selected movement

Are all \( S^2 \) records used?

Yes

Are all MID activations used?

Yes

Counts

Using Failed Activation Algorithm

No

Are all MID activations used?

Yes

Counts

No

Are all MID's used?

Yes

Counts

No

Are all MID's used?

No

Dividing 1 between all movements that may have activated these detectors

Adding 1 to the selected turning movement

Sorting the remaining \( M_{ij} \) based on time of activation

\[ m = 1 \]

\[ m = m + 1 \]

Making the matrix \( M^n = [M_{ij} + M_{ij}^{n-1} + \ldots + M_{ij}^{1}] \)

\( n \) is the maximum number of middle-intersection detectors that can be activated by a movement

Is any movement possible between a consecutive subset of matrix \( M^n \)?

Yes

Is the time between first and last array of this subset matrix reasonable?

Yes

Extracting the correct movement based on time of activations, position of MIDs and direction of movements in street

No

Dividing 1 between all movements that may have activated this detectors

No

Counts

Yes

Counts
Case Study for MID
A sample of VISSIM output for phases 4

<table>
<thead>
<tr>
<th>SG4*</th>
<th>S41**</th>
<th>M41</th>
<th>M42</th>
<th>M43</th>
<th>S42</th>
<th>M22</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
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</table>
Thank you

Any comments or questions?

*If we have data, let’s look at data. If all we have are opinions, let’s go with mine!*

Jim Barksdale, former Netscape CEO