Design and Maintenance Considerations for Buggies
Jay Grossman, Valparaiso University
Charlie McKenzie, Elkhart County Highway Department
Design and Maintenance Considerations for Buggies

- Background (need)
- Community Input
- Maintenance
- Dedicated Lanes
- Needs
- Intersection Design
Background: Elkhart County

The Amish Way of Life

Home-sown vegetables filling their barns, horses, oxen, and sheep grazing in the rich soil, and a simple, close-knit lifestyle. Amish people pride themselves on remaining close to the traditions of their ancestors.

History

Amish Country Community

Find that the Amish in Northern Indiana to be friendly and hospitable—one of many reasons why travelers are attracted to the Deming Sheds. Please do not disturb these people in their annual sale day, and keep these traditions in mind.
Why

Amish Population by State 2015

Source: Reddit user Mainstay17 via vividmaps.com
Source: https://wisevoter.com/state-rankings/amish-population/
US Counties Ranked by **Percentage** of Population of Amish Adherents (2010)

Table 2: Top 10 Amish-Inhabited Counties by Percent of Total Population, 2010

<table>
<thead>
<tr>
<th>Ranking</th>
<th>County</th>
<th>State</th>
<th>Adherents</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Holmes County</td>
<td>Ohio</td>
<td>17,654</td>
<td>41.7%</td>
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<tr>
<td>2</td>
<td>LaGrange County</td>
<td>Indiana</td>
<td>14,011</td>
<td>37.7%</td>
</tr>
<tr>
<td>3</td>
<td>Adams County</td>
<td>Indiana</td>
<td>6,343</td>
<td>18.5%</td>
</tr>
<tr>
<td>4</td>
<td>Davis County</td>
<td>Iowa</td>
<td>1,355</td>
<td>15.6%</td>
</tr>
<tr>
<td>5</td>
<td>Douglas County</td>
<td>Illinois</td>
<td>2,361</td>
<td>11.8%</td>
</tr>
<tr>
<td>6</td>
<td>Daviess County</td>
<td>Indiana</td>
<td>3,708</td>
<td>11.7%</td>
</tr>
<tr>
<td>7</td>
<td>Vernon County</td>
<td>Wisconsin</td>
<td>2,786</td>
<td>9.4%</td>
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<tr>
<td>8</td>
<td>Geauga County</td>
<td>Ohio</td>
<td>8,537</td>
<td>9.1%</td>
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<td>9</td>
<td>Hart County</td>
<td>Kentucky</td>
<td>1,646</td>
<td>9.0%</td>
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<tr>
<td>10</td>
<td>Moultrie County</td>
<td>Illinois</td>
<td>1,260</td>
<td>8.5%</td>
</tr>
</tbody>
</table>

Source: IBRC, using Religious Congregations and Membership Study data

Source: https://www.incontext.indiana.edu/2012/nov-dec/article2.asp
### Indiana Counties Ranked by **Total** Amish Adherents (2010)

<table>
<thead>
<tr>
<th>Rank</th>
<th>County</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>LaGrange County, IN</td>
<td>14,011</td>
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<td>Adams County, IN</td>
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</tr>
<tr>
<td>3</td>
<td>Elkhart County, IN</td>
<td>6,244</td>
</tr>
<tr>
<td>4</td>
<td>Daviess County, IN</td>
<td>3,708</td>
</tr>
<tr>
<td>5</td>
<td>Allen County, IN</td>
<td>3,466</td>
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<tr>
<td>6</td>
<td>Kosciusko County, IN</td>
<td>2,277</td>
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<tr>
<td>7</td>
<td>Marshall County, IN</td>
<td>1,413</td>
</tr>
<tr>
<td>8</td>
<td>Parke County, IN</td>
<td>1,105</td>
</tr>
<tr>
<td>9</td>
<td>Jay County, IN</td>
<td>1,024</td>
</tr>
<tr>
<td>10</td>
<td>Noble County, IN</td>
<td>1,006</td>
</tr>
</tbody>
</table>

Source: The Association of Religion Data Archives

### Indiana Counties Ranked by **Percentage** of Population of Amish Adherents (2010)

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<td>4</td>
<td>Parke County</td>
<td>1,105</td>
<td>6.4%</td>
</tr>
<tr>
<td>5</td>
<td>Jay County</td>
<td>1,024</td>
<td>4.8%</td>
</tr>
<tr>
<td>6</td>
<td>Switzerland County</td>
<td>469</td>
<td>4.4%</td>
</tr>
<tr>
<td>7</td>
<td>Martin County</td>
<td>412</td>
<td>4.0%</td>
</tr>
<tr>
<td>8</td>
<td>Elkhart County</td>
<td>6,244</td>
<td>3.2%</td>
</tr>
<tr>
<td>9</td>
<td>Marshall County</td>
<td>1,413</td>
<td>3.0%</td>
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<tr>
<td>10</td>
<td>Orange County</td>
<td>593</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

Table 3: Top 10 Amish-Inhabiting Counties in Indiana by Percent of Total Population, 2010

**Provided by**
InContext is an award-winning publication from the Indiana Business Research Center at Indiana University’s Kelley School of Business.

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Community Input

• Amish Safety Committees
  • Annual meetings held with Sheriff, Commissioners, County Engineer, and MPO
  • Review safety issues, current/future projects
  • Review buggy registration process and fees
Horse Drawn Vehicle Ordinance

• Registration is required by law
• Funds road repairs caused by horse drawn vehicles
• Support from Safety Committee
• Logistics
  • Annual fee ($100, automatic increase annually)
  • Mail in (with fee) and in person options for registration / payment
  • Enforcement???
Elkhart County issues more than 5000 buggy plates each year

Generates nearly $500k in annual fees
Outreach is important!
Maintenance: Horse trough paving

Horse troughs: areas of increased wear of pavement from horse hooves

- Drainage issues
- Pavement fatigue
- Operational effects on motor vehs and buggies - safety
Maintenance: Horse trough paving

Horse troughs: Eventually will lead to fatigue cracking, further infiltration, potholes, and base failure.

Drill Tec – carbide and tungsten dressed for traction

Wearing of horse running path through HMA surface
Maintenance: Horse trough paving

- Why not change horse shoe dressing?
  - Met with Amish Safety Committee and local farriers
  - Not against change, but change is slow
  - Enforcement is not realistic
  - Traction is critical, especially during winter
  - Preference was to pay for damages
Horse trough paving

Thin HMA lift filling in trough
Extends life of pavement
Horse trough Paving

Depending on severity, spot paving may only be necessary. Often we will address edge / cross slope issues at the same time.
Horse trough Paving

- Fill "troughs"
- Re-establish cross slope if necessary
- Apply chip seal
- Extends life of pavement
Dedicated Lanes

• Primary concern is safety
  • Eliminate speed differential and passing
  • Corridors with high mixed use traffic

• $25M invested since 2010
Dedicated Lanes

• Typical Section
  • 12' lanes, 8' shoulders (buggy lane)
Dedicated Lanes

- Keep in mind, the shoulder is being used as a lane
- Acceleration / Deceleration
- Merging with through lane
- Transitions at ends of project and intersections
Dedicated Lanes

CR 16 (2010)

Wearing of horse running path in lane

CR 38 – (2016)
Dedicated Lanes

CR 38 (2021)

CR 38 – (2023)
Dedicated Lanes

Open to local traffic for one day

CR 40 – (2023)
Research Needs

• LTAP Synthesis Study - ongoing
• Maintenance
  • Methods
    • Tack / no tack
    • Mill it out? Wedge over?
  • Cost / benefit
• Materials
  • Optimal HMA design
  • Rubberized? Fibers?
Research Needs

- Design
  - Capacity
    - What is the impact to highway capacity of buggy traffic?
  - Geometry
    - What are the design guidelines for buggies?
  - Volume thresholds
    - When should designers consider buggy design guidelines?
    - How do we count buggy traffic at scale?
- Upcoming LTAP Research Project
Intersection Design
Intersection Sight Distance

Review

Figure 9-17. Departure Sight Triangles for Intersections

Source: AASHTO
Intersection Sight Distance

Review

Decision Point (Driver Location) distance from edge of Major Road travelled way = **14.5 ft (21.9 m)**

Driver Eye Height (passenger car) = **3.5 ft (1.1 m)**
**Intersection Sight Distance**

Review

Table 9-6. Time Gap for Case B1, Left Turn from Stop

<table>
<thead>
<tr>
<th>Design Vehicle</th>
<th>Time Gap ((t_g)) (s) at Design Speed of Major Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
<td>7.5</td>
</tr>
<tr>
<td>Single-unit truck</td>
<td>9.5</td>
</tr>
<tr>
<td>Combination truck</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Table 9-8. Time Gap for Case B2—Right Turn from Stop

<table>
<thead>
<tr>
<th>Design Vehicle</th>
<th>Time Gap ((t_g)) (s) at Design Speed of Major Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger car</td>
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</tr>
<tr>
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<td>8.5</td>
</tr>
<tr>
<td>Combination truck</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Based on Gap Acceptance Studies

Also for Crossing
Intersection Sight Distance

Review

\[ ISD = 1.47 \cdot V_{\text{major}} \cdot t_g \]

AASHTO Green Book Eq. 9-1

Where:

- ISD is in feet
- \( V_{\text{major}} \) is major road design speed in mph

Table 9-6. Time Gap for Case B1, Left Turn from Stop

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</tr>
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Figure 9-17. Departure Sight Triangles for Intersections
Adjustments for Buggies

Compared to vehicles in AASHTO studies, how do horse-drawn vehicles (buggies) compare?

- Stopping distance from EP of Main Line
- Driver Eye Height
- Gap Acceptance
**Stopping Position**

- Two-way stop controlled intersection
- 55 mph speed limit on mainline Less than 3% grade
- 12 days of video recorded
- 427 gaps observed

**Pavement markings** – distance from EP of Mainline
Histogram of measured driver stopping distances from the major road based on 118 measurements

Average: **27.2 ft (8.29 m)**
Min: 16 ft (4.9 m)
Max: 36 ft (11 m)
Std Dev: 4.6 ft (1.4 m)
N = 118
Driver Eye Height

Average: 70 in (5.83 ft, 1.78 m)
Std Dev: 1.25 in (3.2 cm)
Min: 68 in (173 cm)
Max: 72 in (183 cm)
N = 14
Gap Acceptance – Right Turns

Rejected Gaps: 20
Accepted Gaps: 36
Critical Gap: 13s
Gap Acceptance – Left Turns

Rejected Gaps: 111
Accepted Gaps: 73

Critical Gap: 12s
Gap Acceptance – Crossing

Critical Gap: 14s

Rejected Gaps: 63
Accepted Gaps: 70
## Gap Acceptance – Summary of Findings

<table>
<thead>
<tr>
<th>Minor Road Vehicle Movement</th>
<th>Left Turn</th>
<th>Crossing</th>
<th>Right Turn</th>
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<tbody>
<tr>
<td>Passenger Cars</td>
<td>7.5</td>
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</tr>
<tr>
<td>Horse-Drawn Vehicles</td>
<td>12</td>
<td>14</td>
<td>13</td>
</tr>
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Comparison of Current Time Gap Values for Intersection Sight Distance based on the AASHTO Green Book, and Estimated Values for Horse-Drawn Vehicles, in Seconds.
For left turns, 55 mph design speed, buggies are estimated to require:

\[
ISD = 1.47 \cdot V_{major} \cdot t_g
\]

\[
ISD = 1.47 \cdot 55 \text{ mph} \cdot 12 \text{ s} = 970.2 \text{ ft (295.7 m)}
\]

Compared to 606.4 ft (184.8 m) for passenger cars
(Or 768.1 ft for SU)
Design Example – CR 38 at CR 33

Two-way stop controlled intersection – designed using AASHTO Green Book ISD Criteria
Design Example – CR 38 at CR 33
Design Example – CR 38 at CR 33
NB Vehicle – Left Turn
Design Example – CR 38 at CR 33
NB Buggy – Left Turn

18’ 32’ 970’ 606’
Design Example – CR 38 at CR 33
SB Vehicle – Left Turn
Design Example – CR 38 at CR 33
SB Vehicle – Left Turn
Existing Cemetery with Retaining Wall
Design Example – CR 38 at CR 33
SB Buggy – Left Turn
Design Example – CR 38 at CR 33
Buggy – Left Turns
Minor Road Vehicle Movement

<table>
<thead>
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<th></th>
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<th>Right Turn</th>
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<td>14</td>
<td>13</td>
</tr>
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</table>

Available Revenue from Registrations vs. Horse Trough Repair Costs

Cumulative Percent of Gaps Accepted vs. Cumulative Percent of Gaps Rejected

Left Turns

Number of observations vs. Distance (ft)

Cumulative Percent of Gaps Rejected vs. Cumulative Percent of Gaps Accepted

Gap (m:s)