DESIGN, OPERATIONS AND SAFETY OF HIGH SPEED APPROACH RURAL ROUNDBOUTS

Purdue Road School
March 9, 2016

James Tobaben, P.E., PTOE & David Church, P.E., PTOE
WSP / Parsons Brinckerhoff
OUTLINE

- Kansas Roundabouts (History)

- High Speed Approach Roundabouts
  - K-68 & Old KC Road – Paola, KS

- Current Design Philosophy

- Recently Opened High Speed Approach Roundabouts
  - US-77 & US-56 – Marion, KS

- Additional High Speed Approach Rural Roundabouts
  - US-77 & US-166 – Arkansas City, KS
  - US-400 & K-47 – Fredonia, KS
KANSAS ROUNDABOUTS (HISTORY)

- Mid-1990’s, Jim Tobaben (then State Traffic Engineer for KDOT) brought the concept to Kansas after a trip to Maryland (Tom Hicks)
- First modern roundabout in Kansas was installed in 1997
- Candlewood & Gary (two-collector roads) in Manhattan, KS
HIGH SPEED APPROACH RURAL ROUNDABOUTS

- Existing – 8
- Under Design - 0
- Planned / Under Consideration – 2

- Why install?
  - Safety, Safety, Safety!
  - Reduced High Crash Locations
RESEARCH VALIDATES SAFETY BENEFITS OF RURAL ROUNDABOUTS

- Reviewed before & after crash data at 19 high speed approach rural roundabouts
  - Total Crashes: 63% reduction
  - Injury Crashes: 88% reduction
  - Angle Crashes: 91% reduction
- Research performed by Hillary Isebrands, PE, PhD (FHWA) & Shauna Hallmark, PhD (Iowa State University)
- Developed Crash Mitigation Factors (CMF) for the AASHTO Highway Safety Manual
Existing High Speed Rural Roundabouts in Kansas

- K-68 & Old KC Road, Miami County, KS
- US-400 & K-47, Fredonia, KS
- US-77 & US-166, Arkansas City, KS
- US-69 Alt., K-66
- Wichita
- Tulsa

© 2016 Europa Technologies
© 2016 Google Image Landsat
Imagery Date: 4/9/2013   36°23'31.94" N   98°01'07.51" W   elev 1517 ft   eye alt 460.33 mi
Typical Signing Plan –
High Speed Approach Rural Roundabout
K-68 & OLD KC ROAD

- Two way stop
- 1996 identified as a high crash location
- Converted to 4-way Stop in 1998 (temp).
- Roundabout opened in November 2001
- Five legs / Concrete
- Cost $2.5 million
ACCIDENT SUMMARY

<table>
<thead>
<tr>
<th>No. of Accidents</th>
<th>Study Period</th>
<th>Contributing Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal - 0</td>
<td>1/1/93 to 7/1/96</td>
<td>Dry, Wet, Water Const.</td>
</tr>
<tr>
<td>Personal Injury - 8</td>
<td></td>
<td>Snow/Ice, Slippery, Unknown</td>
</tr>
<tr>
<td>Property Damage - 9</td>
<td></td>
<td>Alcohol Intake 1</td>
</tr>
<tr>
<td>Total - 17</td>
<td></td>
<td>Accident Factor (AF)</td>
</tr>
</tbody>
</table>

Injury Record
Fatalities - 0
Personal Injuries - 25

3 of 37 accidents mentioned that traffic next to them was partly the cause of the accident.

K-68

ACCIDENT RATE

\[
\text{Fatality Rate} = \frac{17 \times 10^3}{365\text{Yrs.} \times 365\text{(ADT)}} = 20.3
\]

LEGEND

Fatality - Uninvolved
Personal Injury - Vehicle
Property Damage - Pedestrian
Fixed Object

DATE (TIME) ROAD COND. (LIGHT COND.) ACTION
1/1/8 (1100) I I A, J, M

COLLISION DIAGRAM

KANSAS DEPT OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING

BY A.J.M.

DRIVER ACTION

A. Illegal or Unsafe Speed
B. Impeding Traffic
C. Following Too Close
D. Improper Overtaking
E. Improper Turn
F. Improper Start, Stop, Park
G. Traffic Control Violation Signs
H. Traffic Control Violation Lights
J. Fail to Yield R/W
K. Drove Left of Center
L. No or Improper Signal
M. Careless - Inattention
N. Avoid Vehicle, Object, Ped.
65 mph Approach on K-68; 55 mph on Old KC Road
K-68 & Old KC Road

AADT = 6,900 vpd (20% trucks)
**Accident Summary**

No. Of Accidents:
- Fatal: 0
- Personal Injury: 0
- Property Damage: 8

**STUDY PERIOD**

Jan 2002 to Dec 2006

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**COLLISION DIAGRAM**

*KANSAS DEPT. OF TRANSPORTATION*

*BUROU OF TRAFFIC ENGINEERING*

**CONTRIBUTING FACTORS**

<table>
<thead>
<tr>
<th>ROAD SURFACE COND.</th>
<th>LIGHT COND.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dry</td>
<td>1. Daylight</td>
</tr>
<tr>
<td>2. Wet</td>
<td>2. Dawn/Dusk</td>
</tr>
<tr>
<td>3. Water Const.</td>
<td>3. Dark, LTG.</td>
</tr>
<tr>
<td>4. Snow/Ice</td>
<td>4. Dark, NO LTG.</td>
</tr>
<tr>
<td>5. Slippery</td>
<td>5. Unknown</td>
</tr>
<tr>
<td>6. Unknown</td>
<td></td>
</tr>
</tbody>
</table>

**Alcohol Intake**

1. Accident Factor (AF)
2. Not an AF
3. Unknown if AF

- 09/13/02 (1710) Dry (Day) J, H
- 11/20/03 (1654) Dry (Day) J, M
- 09/18/05 (1512) Dry (Day) J

**Accident Rate**

\[
\text{Critical Rate} = \frac{\# \text{ Acc.} \times 10^2}{(365 \times \text{Yrs.} \times \text{ADT}) \times (365 \times 5 \times 3110)} = 14.095
\]

**LEGEND**

- Fatality
- Personal Injury
- Property Damage
- Fixed Object
- Uninvolved
- Vehicle
- Pedestrian
- Pedestrian

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**K-68 & Old KC Road**

**COUNTY:** Miami  
**DATE:** 04/05/2007  
**COMPLETED BY:** Cheryl Lambrecht

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**DRIVER ACTION**

A. Illegal or Unsafe Speed
B. Impeding Traffic
C. Following Too Close
D. Improper Overtaking
E. Improper Turn
F. Improper Start, Stop, Park
G. Traf. Control Viol'n. Lights
H. Traf. Control Viol'n. Signs
J. Fail to Yield R/W
K. Drove Left of Center
L. No or Improper Signal
M. Careless- Inattention
N. Avoid Vehicle, Object, Ped.
O. Bad Lane Change
### K-68 & Old KC Road
(Before and After Crash Data)

<table>
<thead>
<tr>
<th>Years</th>
<th>Crashes</th>
<th>Injuries</th>
<th>Property Damage Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995-2000</td>
<td>33</td>
<td>42</td>
<td>17</td>
</tr>
<tr>
<td>2001-2006</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>% Change</td>
<td>-73%</td>
<td>-100%</td>
<td>-53%</td>
</tr>
</tbody>
</table>

Source: K-TRAN: KSU-02-4 “Operational Performance of Kansas Roundabouts: Phase II”
PAOLA

Percentage Change in Measures Of Effectiveness Between AWSC and Roundabout

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Measures of Effectiveness</th>
<th>AWSC</th>
<th>Roundabout</th>
<th>%change</th>
<th>Significantly Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>95% Queue Length (ft)</td>
<td>92</td>
<td>21</td>
<td>-77.2</td>
<td>YES</td>
</tr>
<tr>
<td>2</td>
<td>Ave. Intersection Delay (sec)</td>
<td>19.0</td>
<td>5.5</td>
<td>-71.1</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>Max. Approach Delay (sec)</td>
<td>41.5</td>
<td>6.5</td>
<td>-84.3</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>Proportion Stopped</td>
<td>0.98</td>
<td>0.35</td>
<td>-64.3</td>
<td>YES</td>
</tr>
<tr>
<td>5</td>
<td>Max. Proportion Stopped</td>
<td>0.80</td>
<td>0.23</td>
<td>-71.3</td>
<td>YES</td>
</tr>
<tr>
<td>6</td>
<td>Degree of Saturation</td>
<td>0.537</td>
<td>0.155</td>
<td>-71.1</td>
<td>YES</td>
</tr>
</tbody>
</table>

Source: K-TRAN: KSU-02-4 “Operational Performance of Kansas Roundabouts: Phase II”
K-68 & Old KC Road
(Long Splitter Islands)
WIND TURBINE FARMS FACILITATE TRANSPORTATION OF LARGE COMPONENTS

- Wind Turbine Components:
  - Wind Blades – 150 Ft each
    - Transported in pairs
  - Tower Sections – 65 ft to 75 ft
    - Transported in four sections

- Challenge to Transport
  - N/S US-highways to and through Kansas
  - Roundabouts seen as “obstacles” to route around
K-68 Roundabout Accommodates “Superload”!

Source: KDOT, District Four (Mike Stringer)

- Three leg braided intersection
- 2001 identified as a high crash location
- Roundabout opened in April 2006
- Three legs / Concrete
- Cost $2.4 million
(Previous Geometry)
### ACCIDENT SUMMARY

<table>
<thead>
<tr>
<th>NO. of ACCIDENTS</th>
<th>STUDY PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal 1</td>
<td>1-1-98 to 12-31-00</td>
</tr>
<tr>
<td>Personal Injury 1</td>
<td></td>
</tr>
<tr>
<td>Property Damage 5</td>
<td></td>
</tr>
<tr>
<td>Total 7</td>
<td></td>
</tr>
</tbody>
</table>

Injury Record
- Fatalities
- Personal Injuries

### CONTRIBUTING FACTORS

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<td>2. Dawn/Dusk</td>
</tr>
<tr>
<td>3. Water Cond.</td>
<td>3. Dark, Lt.</td>
</tr>
<tr>
<td>5. Slippery</td>
<td>5. Unknown</td>
</tr>
<tr>
<td>6. Unknown</td>
<td></td>
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<td>Alcohol Intake</td>
<td></td>
</tr>
<tr>
<td>1. Accident Factor (AF)</td>
<td></td>
</tr>
<tr>
<td>2. Not an AF</td>
<td></td>
</tr>
<tr>
<td>3. Unknown if AF</td>
<td></td>
</tr>
</tbody>
</table>

### ACCIDENT RATE

\[
\frac{(#\text{Acc})(10^7)}{(365)(\text{Yrs})(\text{ADT})} = \frac{1 \times 10^7}{365 \times (3)(5530)} = 1.15
\]

Fatality Rate = Crashed Rate: 9.86

### DRIVER ACTION

- A. Illegal or Unsafe Speed
- B. Impeding Traffic
- C. Following Too Close
- D. Improper Overtaking
- E. Improper Turn
- F. Improper Start, Stop, Park
- G. Traf. Control Viol'n. Lights
- H. Traf. Control Viol'n. Signs
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### COLLISION DIAGRAM

KANSAS DEPT. OF TRANSPORTATION
BUREAU OF TRAFFIC ENGINEERING

DATE (TIME) ROAD COND. (LIGHT COND.) ACTION
1/1/8 (1100) I I A, J, M

COUNTY: KANSAS DATE: 1-1-01
BY: D.M.

REV'D 9/88
65 mph Approach on US-169; 60 mph on US-59
AADT = 5,845 vpd (20% trucks)
Rear tire tracks over central island

Rear tire tracks over outside curb
US-50 & US-77

- Two way stop
- High crash location
- Converted to 4-way Stop (temp).
- Roundabout opened in September 2006
- One roll-over crash
- Five legs / concrete
- Cost $3.2 million
55 mph Approach on US-50; 65 mph on US-77 (from the west)
US-50 & US-77
AADT = 4,800 vpd (50% trucks)
See Typical Median Approach Details Sheet 70.

NOTE: For Roundabout Pavement Marking Details See Sheet 73

Music by Judas Priest – Heading Out to the Highway (Live), (Metal Works ’73 – ’93)
“Ballet Midwest” Presents ....

**CURRENT DESIGN PHILOSOPHY**

- **Design Resources:**
  - State/Local Roundabout Design Guide

- **Design Philosophy**
  - “Left-Offset” on Approach
  - Accommodate WB-67
  - Try to Accommodate Oversized Loads
- US-50 and US-281 Intersection
- Two-Way Stop Controlled
- North-South on US-281
- 65 MPH Speed Limits
- Multiple recent injury and fatality crashes
Excellent candidate intersection for roundabout installation:
- Good sight distance
- Minimal grade across intersection
- Minimal ROW Constraints
- Roads meet at 90° Angles
Aerial Image Source: Google Earth
© WSP, Parsons Brinckerhoff, 2016
Steps to Lay Out a Left-Offset Rural High-Speed Roundabout
Step 1: Determine Inscribed Circle Diameter & Roundabout Center

Ø 180'
Step 2: Offset lines for inside circulating lane edge of pavement (EOP) and offset lines for inside and outside EOP for entry lanes.
Step 3: Fillet between circulating lane and exiting lane EOP. These lines become the exiting lane EOP.
Step 4: Offset inside exiting lane EOP. This distance will set the minimum splitter island width.
Step 5: Draw a line from left of the center of the circle, tangent to the offset line from Step 4. This line becomes the left EOP for the entry lane.
Step 6: Offset tangent drawn in Step 5. This line becomes the right EOP for the entry lane.
Step 7: Fillet EOP lines from Step 4 and 5 with circulating lane and entering lane EOP lines.
Step 8: Lay out shifting taper from beginning of curve from Steps 3 and 7 that begins furthest from roundabout (furthest east on this leg) per MUTCD guidelines.
Step 9: Offset for back of curbs and truck apron
Step 10: Fillet curbs to create splitter island
Step 11: Trim out construction lines for gore markings
Step 12: Repeat for other four legs and fillet between entry & exit radii
Design Checks--Design Vehicle:
Check turning movements for design vehicle for all movements of all legs. Typically will be WB-67 for rural roundabouts.
Design Checks--Fastest Path: Check for each movement of each entry per NCHRP 672.

- R2 = 19 MPH
- R5 = 23 MPH
- R1 = 24 MPH

- R3 = 28 MPH*
- R4 = 17 MPH

Aerial Image Source: Google Earth
© WSP | Parsons Brinckerhoff, 2016
*Note that R3 is usually a very large radius with left-offset entry roundabouts--utilize Equation 6-4 from NCHRP 672 based on vehicle acceleration for better exit speed estimate.*
Design Checks--Sight Triangles: Check all stopping and intersection sight triangles per NCHRP 672.
Often desirable to accommodate Oversized / Overweight (OSOW) vehicles in rural roundabouts. It is possible to accommodate these vehicles.
OSOW Vehicle Option for Wind Turbine Through Movement

External Mountable Truck Aprons

Expanded Internal Mountable Truck Apron

Aerial Image Source: Google Earth
© WSP | Parsons Brinckerhoff, 2016
Wind Turbine Vehicle Tracking: 180' Blade (Utilizing Rear Wheel Steer)
Wind Turbine Vehicle Tracking: 88' Upper Tower Section
Wind Turbine Vehicle Tracking: 78' Lower Tower Section
US-77 & US-56

- Two way stop (US-56)
- Recently identified as a high crash location
- Converted to 4-way Stop (temp)
- Included by-pass lanes for oversized loads (new)
- Roundabout opened in December 2015
- Four legs / Concrete
- Cost $5.4 million
US-77 & US-56

- Still under construction (outside of roundabout)
- By-pass lanes coned off (temp)
- 4,000 vpd / 35% trucks
- Approach speeds:
  - 65 mph US-56
  - 65 mph US-77
US-75 & K-268 / K-31

- Two way stop (K-268/K-31)
- High crash location
- Converted to 4-way Stop (temp).
- Roundabout opened in mid-2015
- Four legs / concrete
- Cost $2.5 million
65 mph Approach on US-75; 65 mph on K-268 / K-31
US-75 & K-268 / K-31
ADT = 8,600 vpd (10% trucks)
Roundabout Easily Accommodates Wind Tower Equipment Transport

Source: https://www.youtube.com/watch?v=ePoSzrwfez0
US-75 & K-268 / K-31

- August 5, 2015 - Truck Overturns
- Driver not injured
Roundabout Saves Lives in NE Kansas!

Music by Bon Jovi – It’s My Life (Crush), 2000
US-77 & US-166, Arkansas City, KS
US-400 & K-47, Fredonia, KS
Roundabouts Reduce High Crash Locations in Rural Areas!

Music by Bruce Springsteen – Thunder Road (Born to Run), 1975
THANKS FOR YOUR TIME AND ATTENTION

- Questions?

- Open invitation to visit our roundabouts

- Happy to coordinate with KDOT to give you a tour of these locations