NCHRP 3-65: Applying Roundabouts in the United States

Preliminary Findings

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AASHTO Subcommittee on Design, Chicago, IL

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KITTELSON & ASSOCIATES, INC.
TRANSPORTATION PLANNING/TRAFFIC ENGINEERING

Bhagwant Persaud, Canada
David Harkey, USA
George Mason University, USA
McDonald & Partners, UK
Rensselaer Polytechnic University, USA
Rod Troutbeck, Australia
Ruhr-University Bochum, Germany
University of Idaho, USA

Topics of Discussion

- **Project panel and team**
- **Project need and objective**
- **Preliminary findings**
  - *Safety*
  - *Operations*
  - *Design*
- **Anticipated products**

Project panel

- Beatriz Caicedo-Maddison, Florida DOT (chair)
- Maria Burke, Texas DOT
- Jerry Champa, California DOT
- Leonard Evans, Science Serving Society
- Steve King, Kansas DOT
- Robert Limoges, New York State DOT
- Richard Long, Western Michigan University
- Ron Pfefer, HSM liaison
- Brian Walsh, Washington State DOT
- Mohsin Zaidi, City of Kansas City, MO
- Joe Bared, FHWA
- Hari Kalla, FHWA
- Rich Cunard, TRB
- Ray Derr, NCHRP

Project team

- **P.I.: Lee Rodegerdts (KAI)**
  - *(Bruce Robinson, Co-P.I. Emeritus)*

- **USA**
  - ***Kittelson & Associates, Inc.***
  - ***University of Idaho***
  - ***Rensselaer Polytechnic Institute***
  - ***George Mason University***
  - ***David Harkey***
  - ***John Mason***

- **Australia**
  - ***Rod Troutbeck***
- **Canada**
  - ***Bhagwant Persaud***
- **Germany**
  - ***Werner Brilon***
- **United Kingdom**
  - ***Richard Hall***

U.S. practice relies heavily on the experience from other countries.

- Current U.S. procedures depend on international methods without having U.S. data for calibration
- Use of roundabouts in the U.S. may differ from that experienced in other countries

Overview of research tasks

1. Summarize Existing Relationships
2. Model Formulation
3. Data Collection Plan
4. Interim Report
5. Execute the approved data-collection plan
6. Inventory U.S. Roundabout Sites
7. Operational Performance Methods
8. Safety Performance Methods
9. Design Criteria
10. Final Report
11. Prepare marketing materials

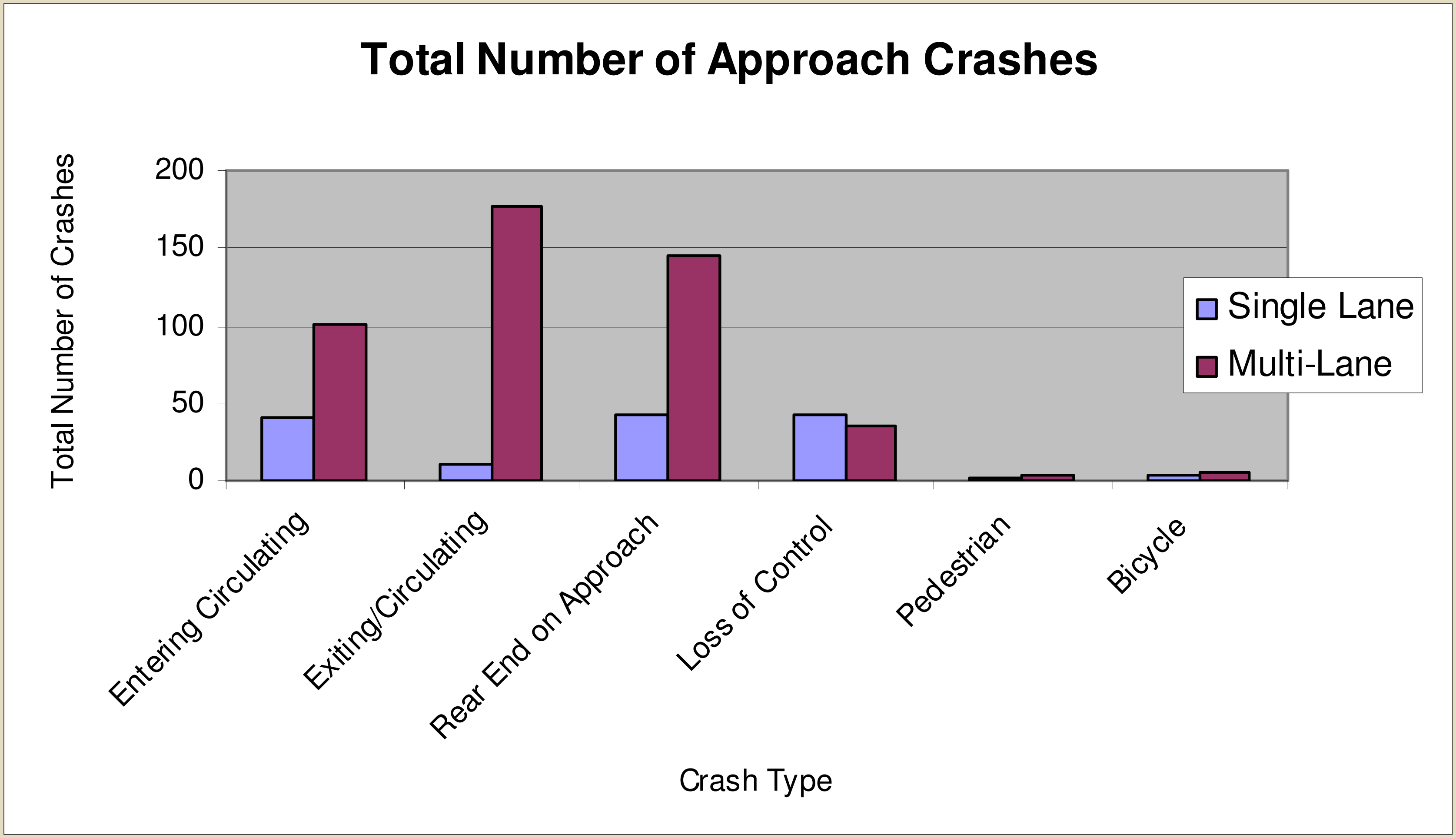
Preliminary Safety Findings

- Roundabout-level accident models
- Approach-level accident models
- Before-after study of intersections converted to roundabouts

Roundabout-Level Crash Prediction

- **Used for comparing performance to other intersection types**
- **Baseline prediction on which approach-level CMFs could be applied**
- **Form: Crashes = $\alpha(AADT)^{\beta}$**
- **Factors affecting coefficients:**
  - *Number of lanes*
  - *Number of approaches*

Approach-Level Crash Data (139 approaches)



% change in crashes from candidate approach level models per unit change in variable

Variable	Entering/ Circulating	Exiting/ Circulating	Approach
Entry Radius (ft.)	1% reduction		
Entry Width (ft.)	5% increase		
Approach Half Width (ft.)			3% increase
Inscribed Circle Diameter (ft.)		2.2% increase	
Central Island Diameter (ft.)	0.5 to 0.8% reduction	1.4% increase	
Circulating Width (ft.)		12% increase	
Angle To Next Leg (degree)	3% reduction		

Before-After Results – All Sites (55)

	All	Injury
Crashes recorded in after period	*726*	*72*
EB estimate of accidents expected after without roundabouts	*1122*	*296*
Reduction (Standard error)	*35.4 % (3.4)*	*75.8 % (3.2)*

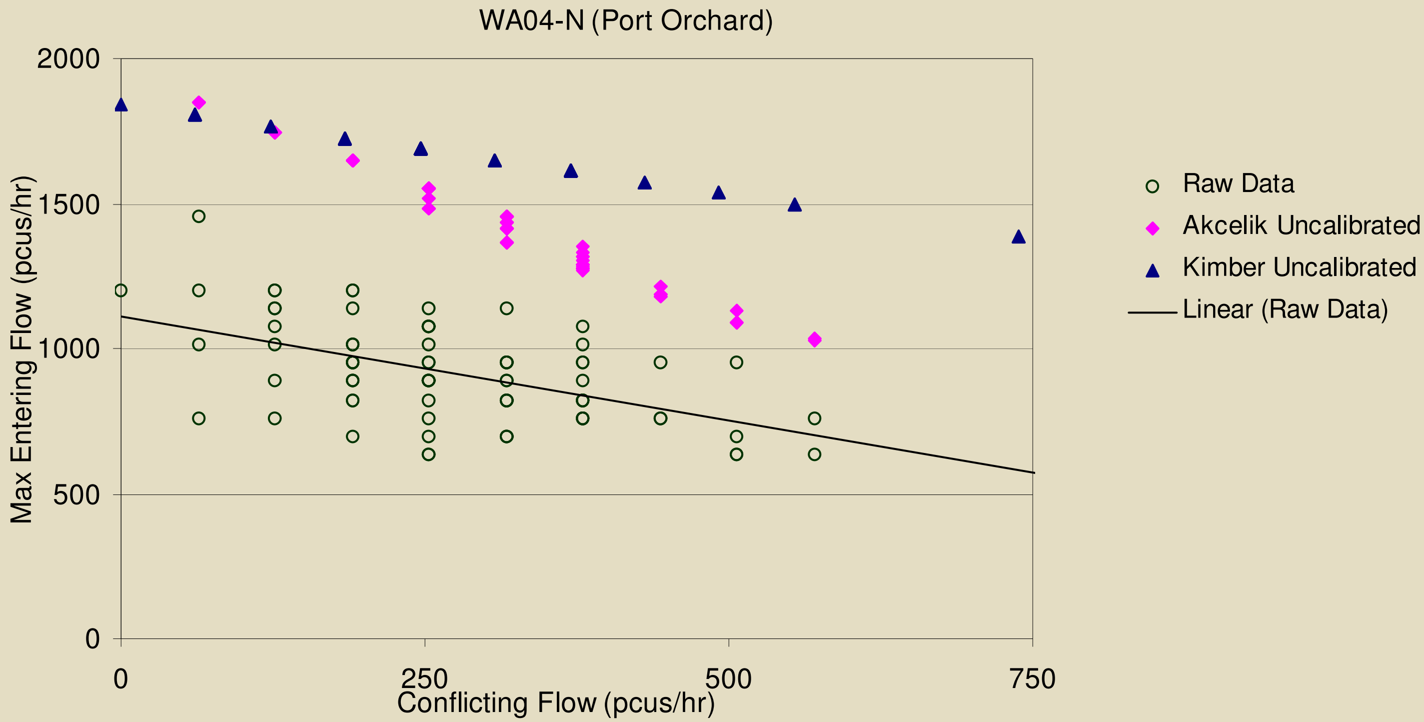
CONTROL BEFORE	*All*	*Injury*
SIGNALS (9)	*48%*	*78%*
TWO WAY STOP (34)	*44%*	*82%*
ALL-WAY STOP (10)	*Insignificant increase*	

Preliminary Operations Findings

- Analysis of existing models
- Driver behavior and effect of geometry
- HCM recommendations

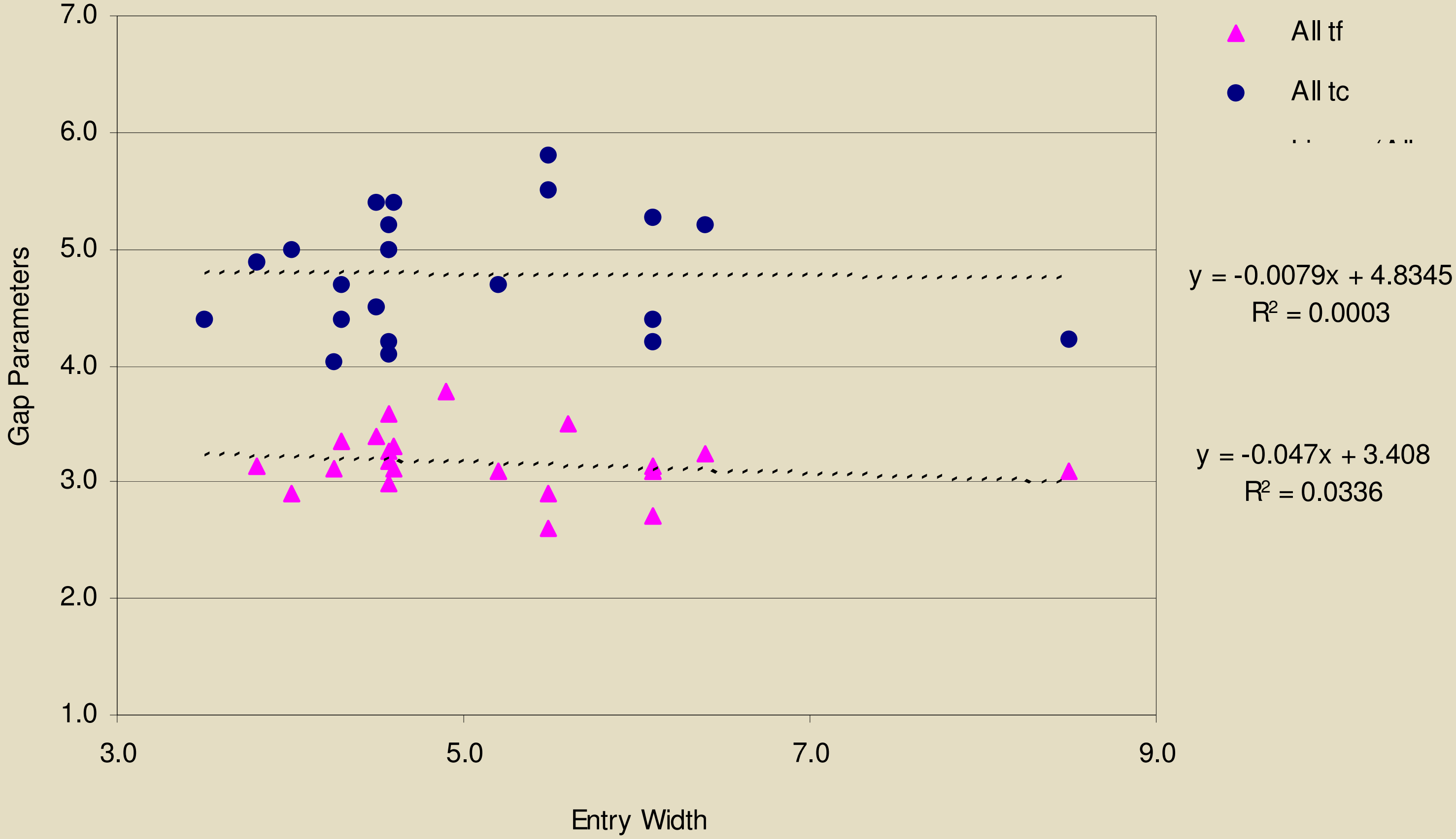
Analysis of Existing Models

- All international models (including SIDRA and RODEL) predict capacities higher than observed



Influence of Flow & Geometry on Driver Behavior

- Entry lane width = entry width / # lanes

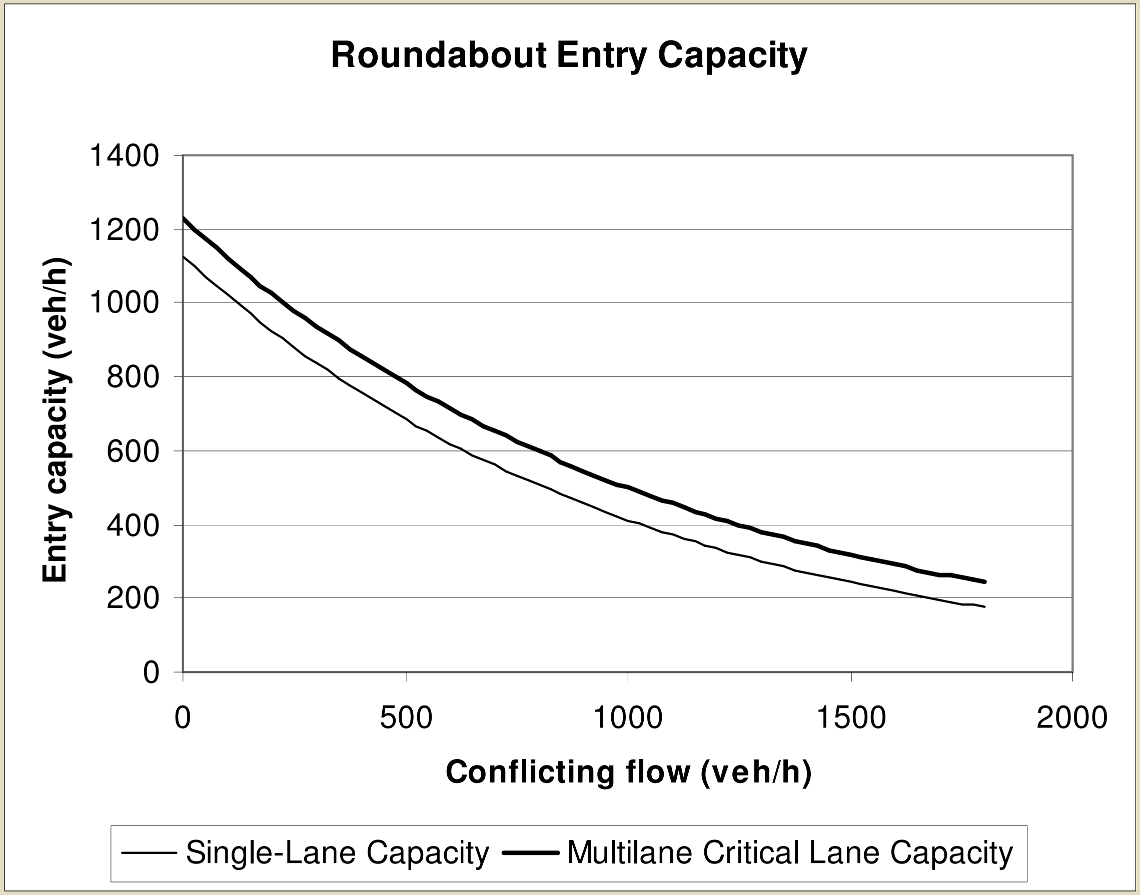


Multilane Modeling Issues

- **Several sites exhibit strong queuing in only one lane**
- **Possible causes:**
  - Turning movement effects
  - Lane use assignment (or lack thereof)
  - Geometric effects (vehicle path overlap)
  - Driver unfamiliarity
- **Model intended to allow designer to capture these first-order effects apparent in U.S. data**

Proposed HCM Capacity Models

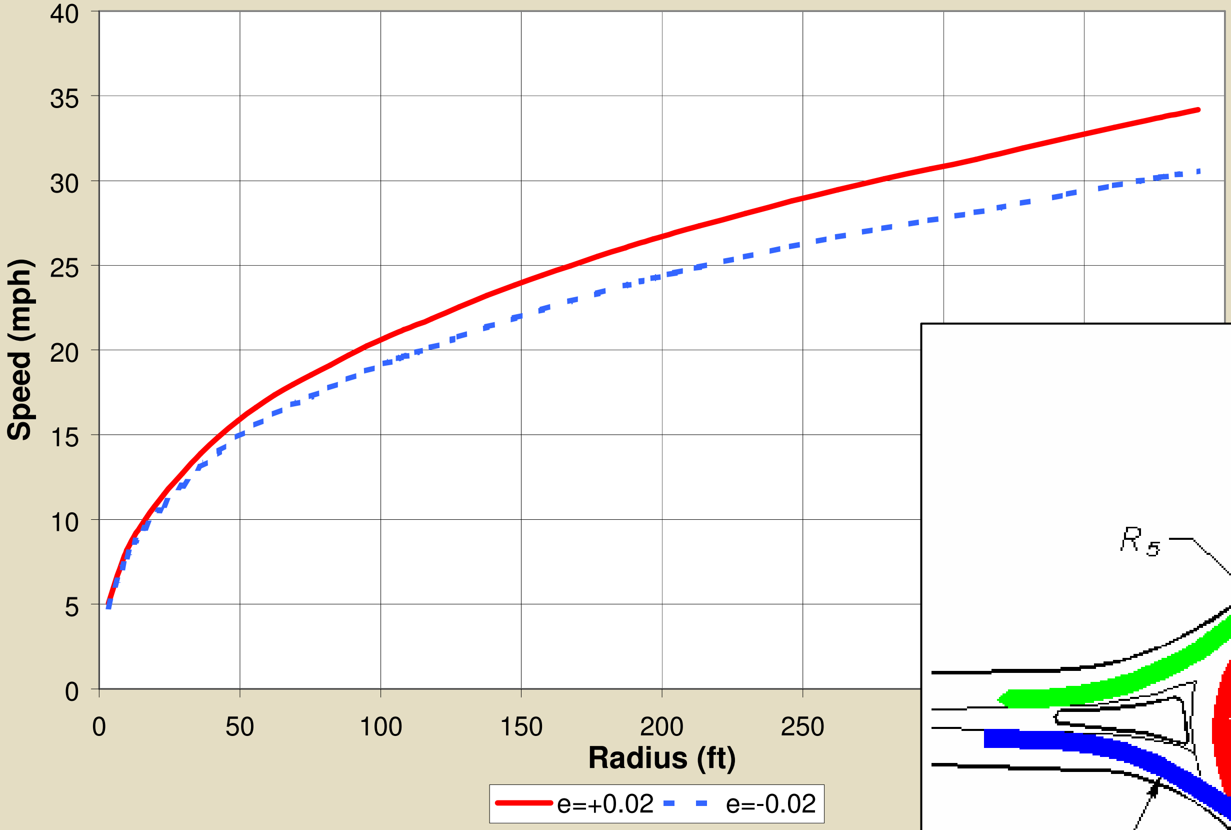
- **Single-lane: Current HCM model with new t_c, t_f**
- **Multi-Lane: Exp. regression model for critical lane**

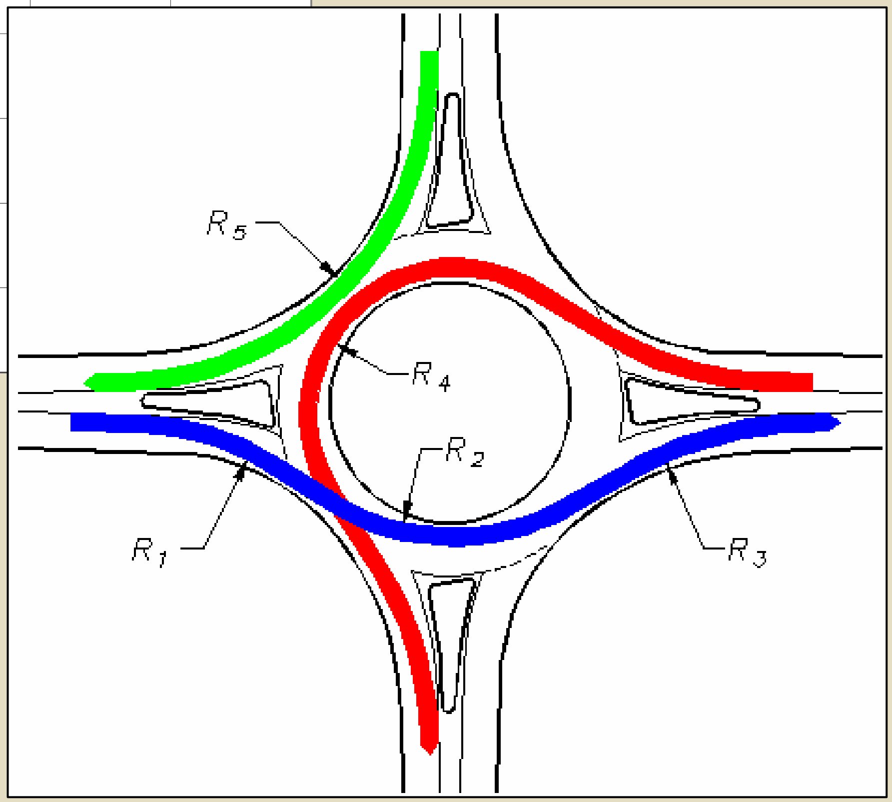


Preliminary Design Findings

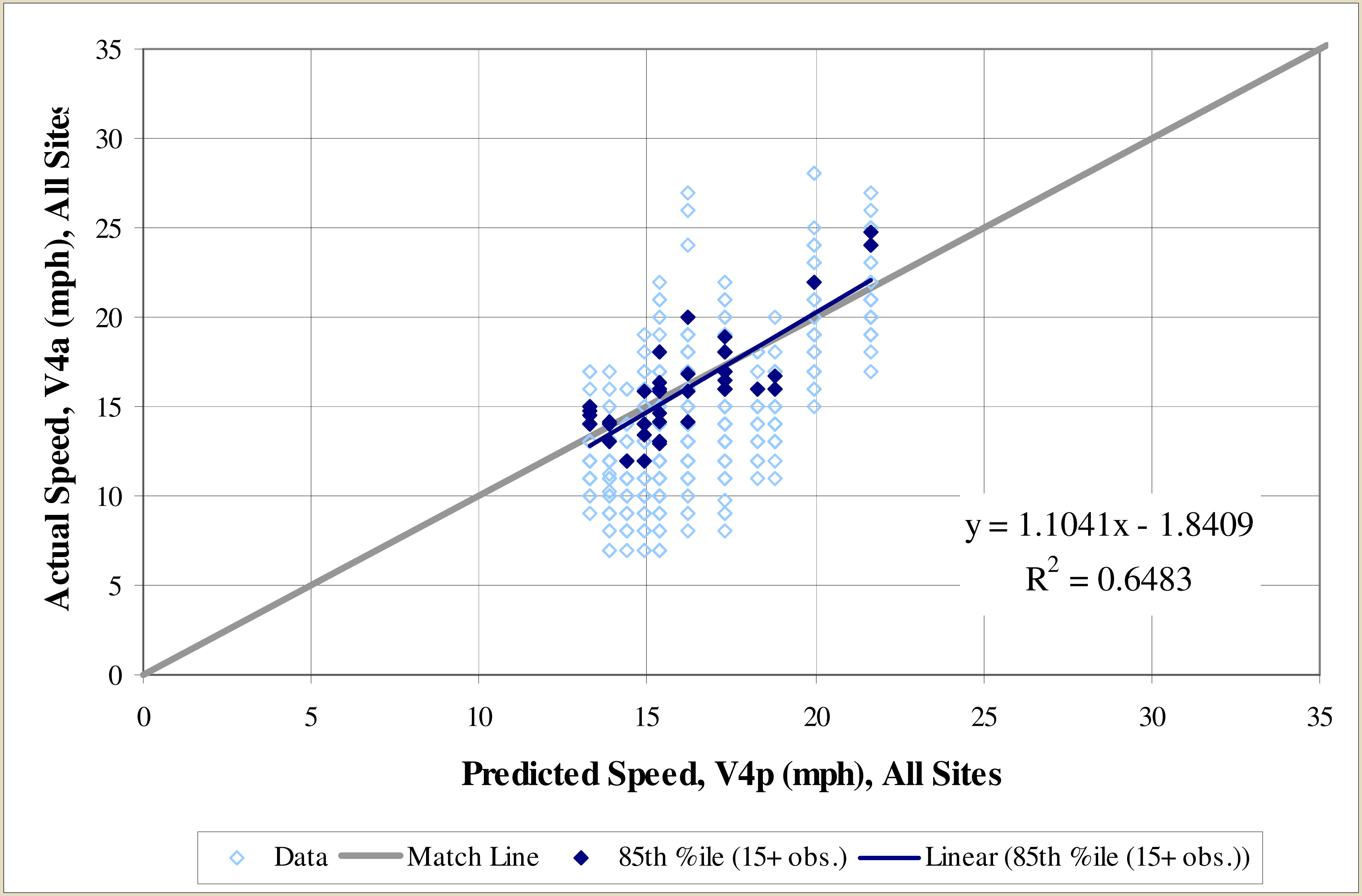
- Design speed modeling
- Other design findings for motor vehicles
- Pedestrian and bicycle observations

Current FHWA speed prediction method is based on AASHTO speed-radius function.

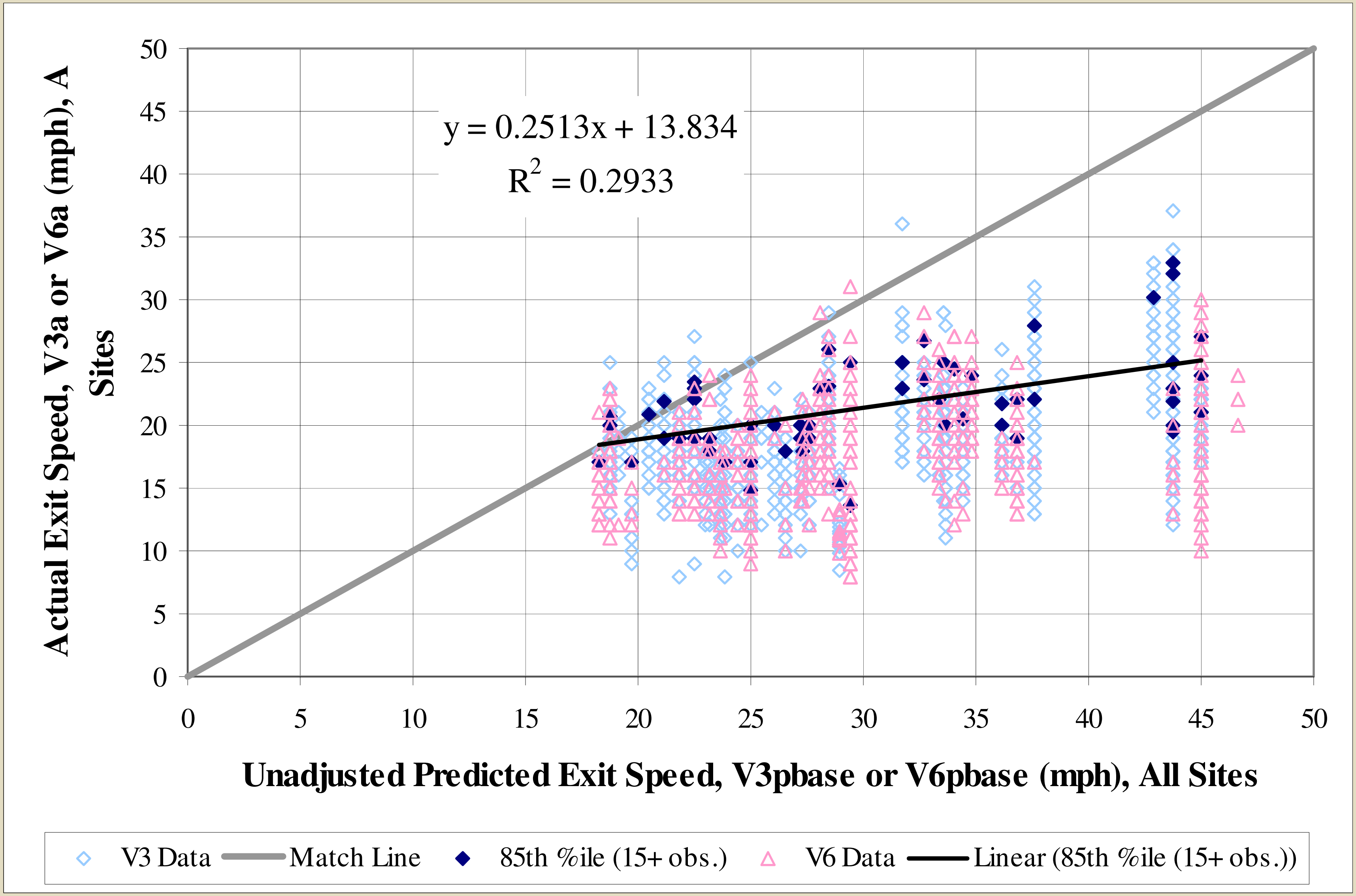




Design speed modeling:
V4, Left-turn circulating speed (all sites)



Design speed modeling: Exit speed (all sites), unadjusted



Proposed exit speed equation

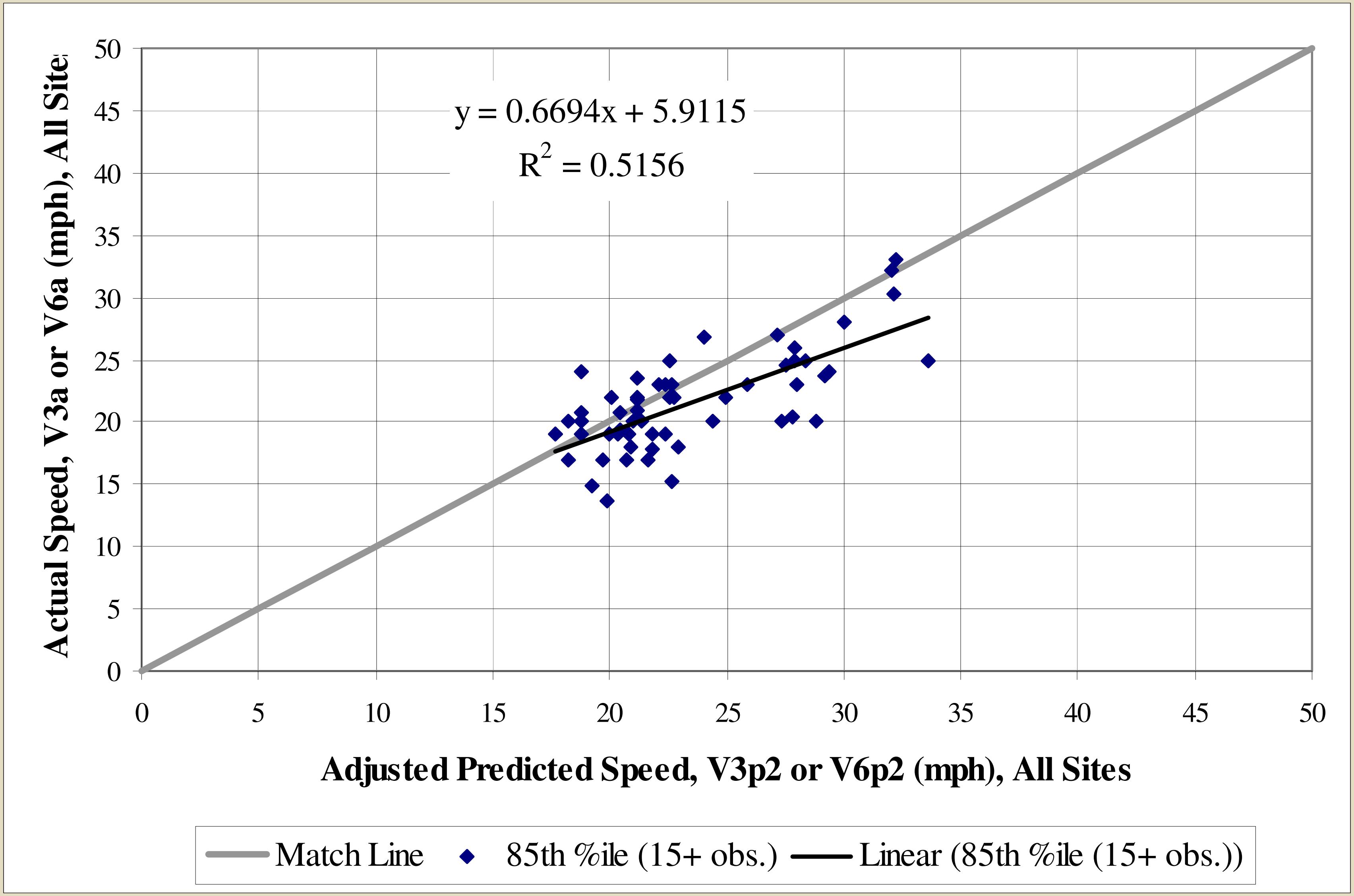
$$V_3 = \min\left\{ \begin{array}{c} V_{3pbase} \\ \\ \frac{1}{1.47}\sqrt{(1.47V_2)^2 + 2a_{23}d_{23}} \end{array} \right\}$$

Speed where exit radius is limiting factor

Speed where circulating speed and acceleration distance is limiting factor

- where:
- V_3 = V_3 speed, in mph
- V_{3pbase} = V_3 speed predicted based on path radius, in mph
- V_2 = V_2 speed predicted based on path radius, in mph
- a_{23} = acceleration along the length between the midpoint of V_2 path and the point of interest along V_3 path = **6.9 ft/s^2**
- d_{23} = distance between midpoint of V_2 path and point of interest along V_3 path, in ft

Design speed modeling: Exit speed (all sites), adjusted



Implications for design

- **Tangential or nearly tangential exits do not appear to cause excessive vehicle exit speeds if the following conditions are met:**
  - *The speed of circulation (V2 and V4) is kept low*
  - *The distance between the start of the exit path and the point of interest (e.g., crosswalk) is kept short*
- **Similar prediction adjustment for entry speeds**
- **Entry speed appears to be limited by drivers' anticipation of the speed needed for circulation**
  - *However, recommend continued reliance on entry path curvature as a primary method to control entry speed*

Entry width and lane width

- **Narrow lane widths (entry and circulating) at multilane roundabouts appear to have a detrimental effect on safety**
- **Entry width:**
  - *Aggregated entry width (number of lanes) has a clear safety and operational effect*
  - *Variations of lane width appear to be second-order effects*

Multilane roundabout issues

- Higher crash frequencies and crash rates than single-lane roundabouts
- Vehicle path overlap, poor striping apparent contributors
- Anecdotal evidence suggests that their correction can substantially improve safety performance

Example: Clearwater Beach, FL, before and after design modifications

Photo: Bruce Robinson

Before (2001)

Photo: Lee Rodegerdts

After (2005)

Non-motorized users

- **Examination of observed field behaviors for two groups:**
  - *Pedestrians*
  - *Bicyclists*
- **Pedestrian data:**
  - *10 approaches at 7 sites; 769 events*
- **Bicyclist data:**
  - *14 approaches at 7 sites; 690 events*
- **Geographic diversity:**
  - *California, Florida, Maryland, Nevada, Oregon, Utah, Vermont, Washington*

How do motorists behave when encountering pedestrians?

- **Motorists failing to yield to pedestrians**
  - *All sites: 30 percent*
  - *Entry leg: 23 percent*
  - *Exit leg: 38 percent*
  - *1-lane approaches: 17 percent*
  - *2-lane approaches: 43 percent*

How do pedestrian behaviors at roundabouts compare to other forms of control?

Crossing control	Percent of "normal" crossings	Percent of non-yielding vehicles
Uncontrolled	70%	48%
Roundabout	85%	32%
Signal-controlled	90%	15%
Stop-controlled	100%	4%

Anticipated products

- Final report
- Draft Highway Capacity Manual procedure
- Components compatible with a possible Highway Safety Manual procedure
- Updated design research for use in future updates to FHWA Roundabout Guide, AASHTO Green Book
- Data that is accessible for future research
- Problem statement(s) for continued research
- Anticipated completion: December 2005

Questions?

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Photo: Lee Rodegerdts