Truck Access into Roundabouts

Safety & Mobility Policy Advisory Committee

Driving Simulation Conclusions
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Phase I – Field Work

Field Evaluation

- Collected video data at six congested roundabout sites in OR/WA
- Transcribed heavy truck driver behavior
- Developed a dataset of 2,626 heavy truck observations
- 400 observations where trucks had to stop to reject a gap in circulating traffic
- Six common AASHTO classifications identified
  - WB-40, WB-50, WB-62, WB-67, WB-67D, WB-92D

Phase I Field Work – Gap Acceptance

Phase I – Microsimulation

VISSIM Simulation

- Calibrated and modeled to Sisters, OR site
  - US 20 and W Barclay Dr
- Four models were developed
- Assessment of two critical elements:
  - Heavy truck fleet composition
  - Method of unsignalized control
- Buses, pedestrians, cyclists were not included

Model 1: VISSIM default heavy vehicle fleet and “conflict area” yielding behavior
Model 2: VISSIM default heavy vehicle fleet and “priority rule” yielding behavior
Model 3: Heavy vehicle fleet observed in the field and “conflict area” yielding behavior
Model 4: Heavy vehicle fleet observed in the field and “priority rule” yielding behavior

Phase I VISSIM Model Selection

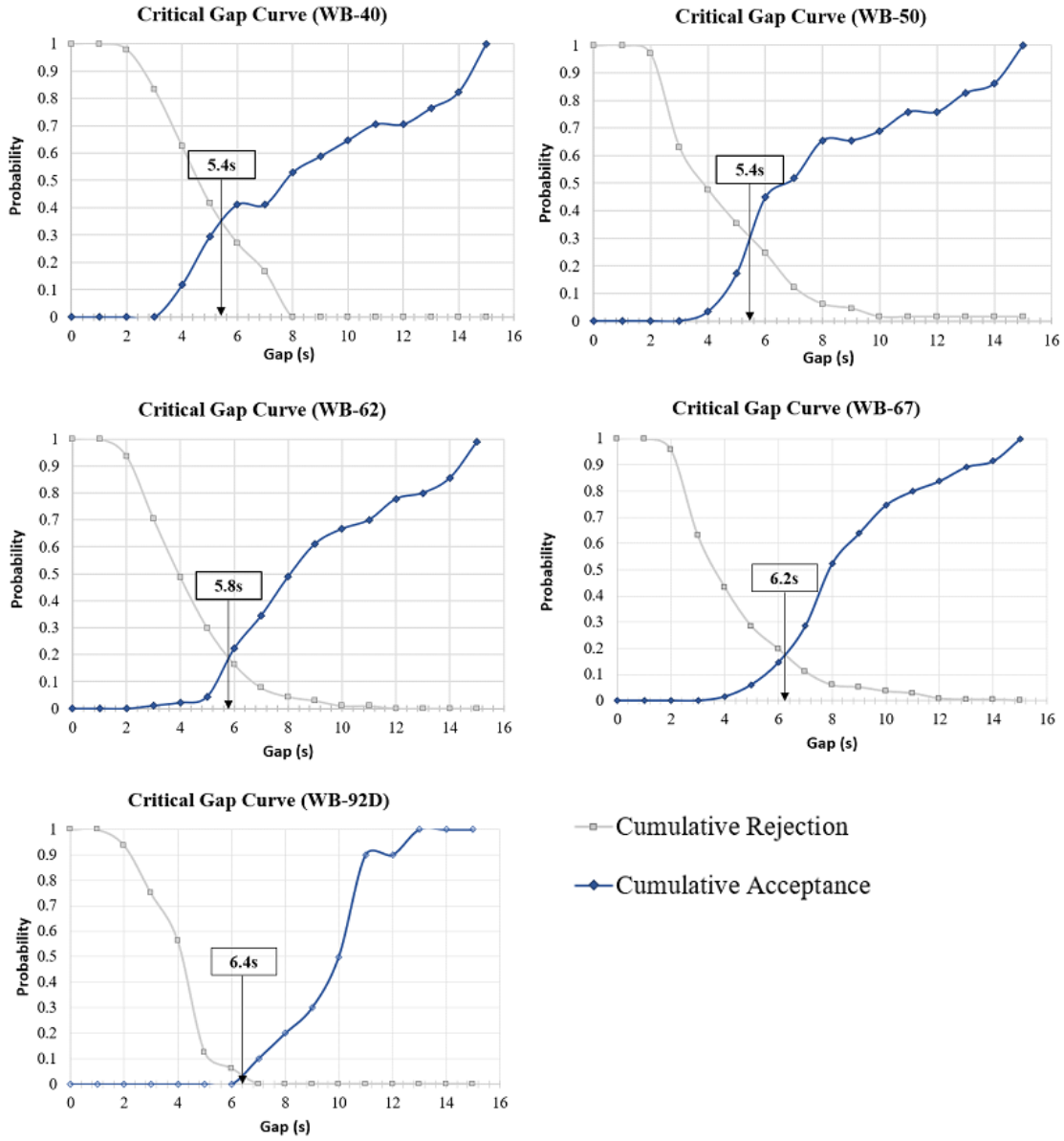
Phase I – Key Findings

Field Evaluation

- Observed **increase** in critical gap length as heavy truck size increases
- **WB-67** was the most common observed class
- Critical gap value(s) of **5.4 s – 6.4 s**

VISSIM Simulation

- Observed critical gap value(s) of **6.3 s** in the majority of simulation models
- Increasing volume and congestion led to an increase in **number of gaps rejected**
- Critical gap values ranged from **5.3 s – 7.4 s**



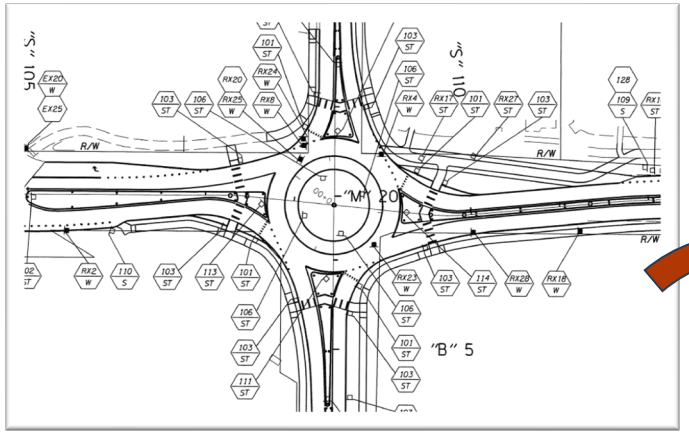
Critical Gap Observed in the Field

Overarching Connection Between Phase I & II

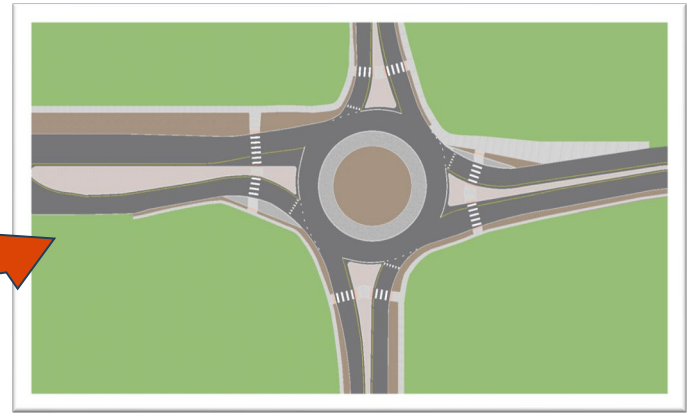
Problem Assessment	Identify field and VISSIM concerns from Phase I
Identification of Potential Solutions	Develop and test proposed solutions in a simulated environment
Perform testing with CDL drivers	Expose heavy truck drivers to scenarios and evaluate response
Evaluation and Recommendation	Provide recommendations regarding heavy truck access into congested roundabouts

Control Roundabout & Design Vehicle

- Entering/Exit geometry
  - Aligned with specifications and design drawings from as-built roundabout
- Congestion and volumetric loading
  - Entering and yielding behavior from field observations of ambient traffic
  - Gap length(s)
- Simulated vehicle (WB-67)
  - Turning radii
  - Trailer length/configuration
  - Acceleration and movement capabilities



Plan Drawing from As-Built



Design for Simulation

Independent Variables (IV)

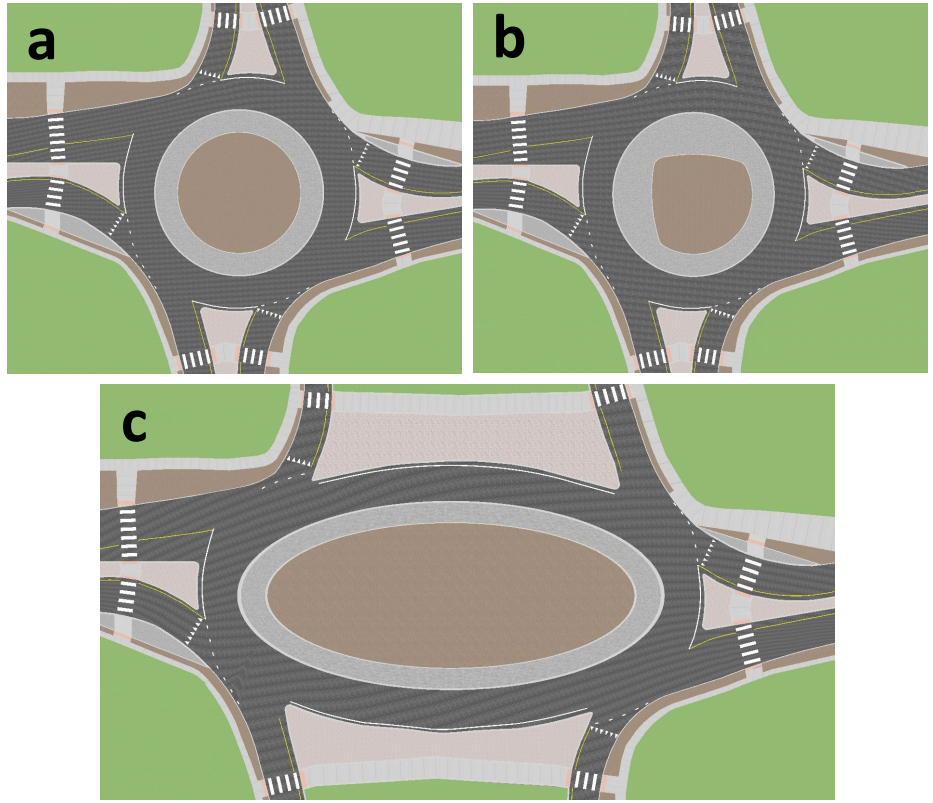
- Field and microsimulation findings guided certain variable level development
  - Critical gap length(s) and volumetric loading
- Four IV's of interest:
  - **Gap Length** in circulating traffic
  - **Volumetric Loading** at the intersection
  - **Geometric Configuration** of roundabout
  - **Roundabout Metering** as a TCD
- Geometric Configuration and Roundabout Metering were key considerations

Study Independent Variables

Variable	Number of Levels	Level Names
Gap Length	2	5.4 s
		6.4 s
Volumetric Loading	2	High
		Low
Geometry	3	Traditional
		Elliptical
		Tapered
Roundabout Metering	3	Meter Near
		Meter Far
		No Meter

IV: Geometry

- *Variations to some or all aspects of roundabout shape to provide changes in travel path*
- Three roundabout configurations included:
  - Traditional (a)
  - Tapered (b)
  - Elliptical (c)
- Traditional - Geocoded to match the field study site in Sisters, OR
  - From Phase I field work
- Tapered - Modifications made to the central island and inner truck apron
- Elliptical - Modifications to overall shape to create an elongated configuration

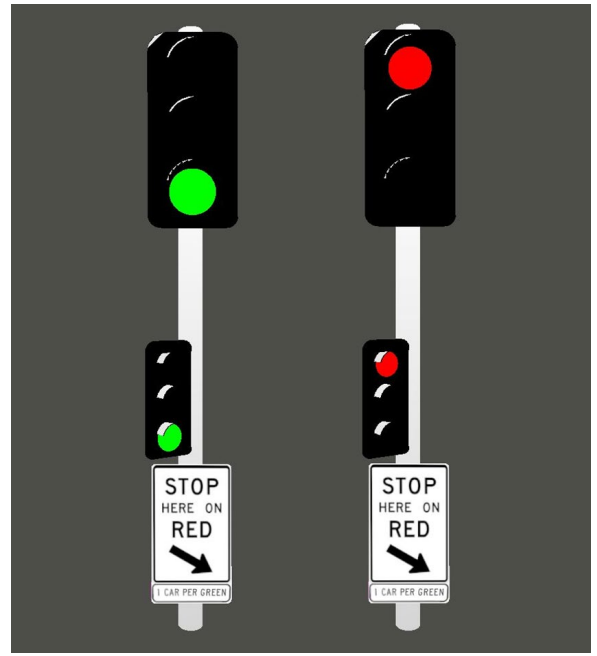


Geometry Measurements

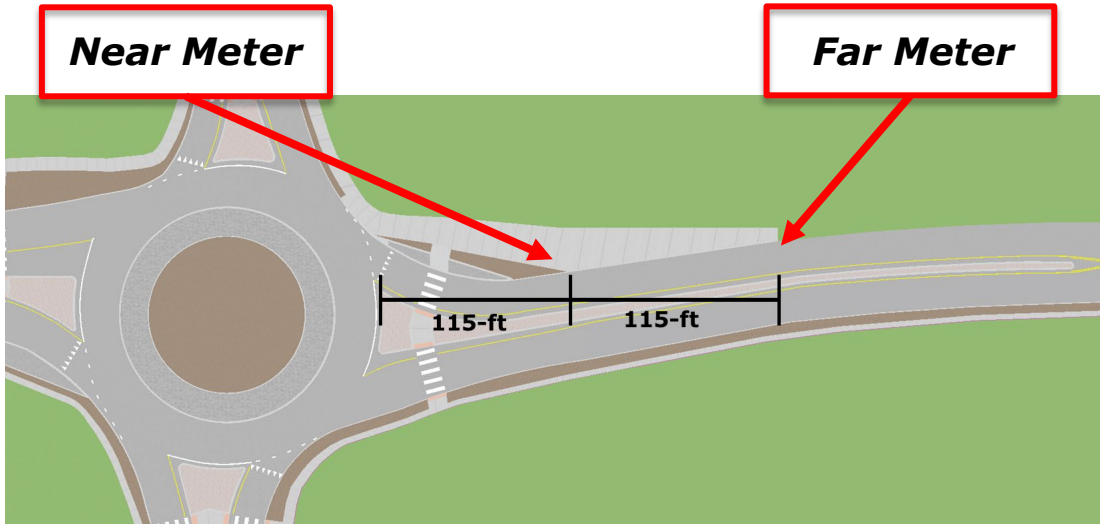
Geometry	ICD	Lane Width	Truck Apron Width
Traditional	155 ft	21 ft	14 ft
Tapered	155 ft	21 ft	Varies
Elliptical	Varies	21 ft	14 ft

IV: Traffic Control Device

- *Implementation of roundabout metering at distances along roundabout approach*
- Signal was designed in accordance with CalTrans Standards for ramp metering
  - 3-Section 12” upper signal head
  - 3-Section 8” lower signal head
  - Supplementary signage
- Near and Far variable levels
  - Near-Metering: **115-ft** from roundabout entrance
  - Far-Metering: **230-ft** from roundabout entrance



3-D Modeled Design



Equipment

- OSU Heavy Vehicle Driving Simulator
  - Quarter-cab steering operation station
  - Adjustable seat and mirrors
  - Faces three 60-inch high definition screens
  - 210° field-of-view
- Shimmer3 GSR+
  - Electrode sensors and device secured on participant
  - Bluetooth connectivity
- Tobii Pro Glasses 3
  - Four in-lens cameras
  - 16 illuminators
  - Front facing camera to capture 106° field-of-view

Equipment used for Testing Procedures

Participant Sample

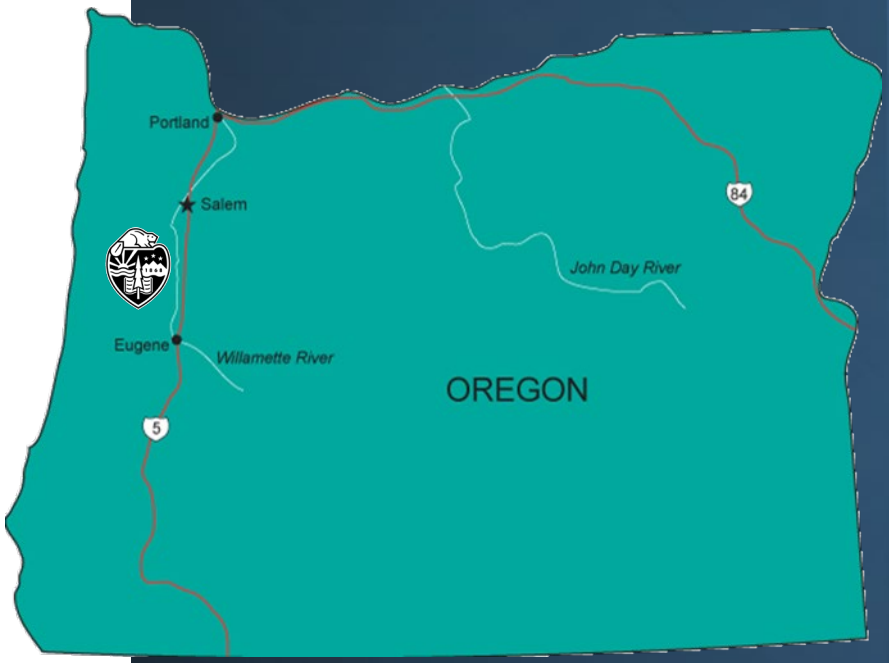
- Participants were invited to participate if they met three exclusionary criteria

  1. Must be at least 18 years of age

  2. Possesses a valid Commercial Drivers License (CDL)

  3. At least one year of commercial driving experience

- The final sample consisted of 41 Oregon heavy truck drivers spanning from Eugene to Portland
  - Wide range of experience: 1.5 years to 36 years (Mean = 12.5 years)
  - Over half of participants indicated they operate a heavy vehicle 5-7 days per week (57%)
  - 30% of participants responded they traverse roundabouts between 4-10 times per week
- Individuals were compensated $80 for participation



Positioning Results

- Average position for each participant individually across geometric configuration
- Measured from the centroid of the heavy truck
- Position assessed every 10-ft

Traditional

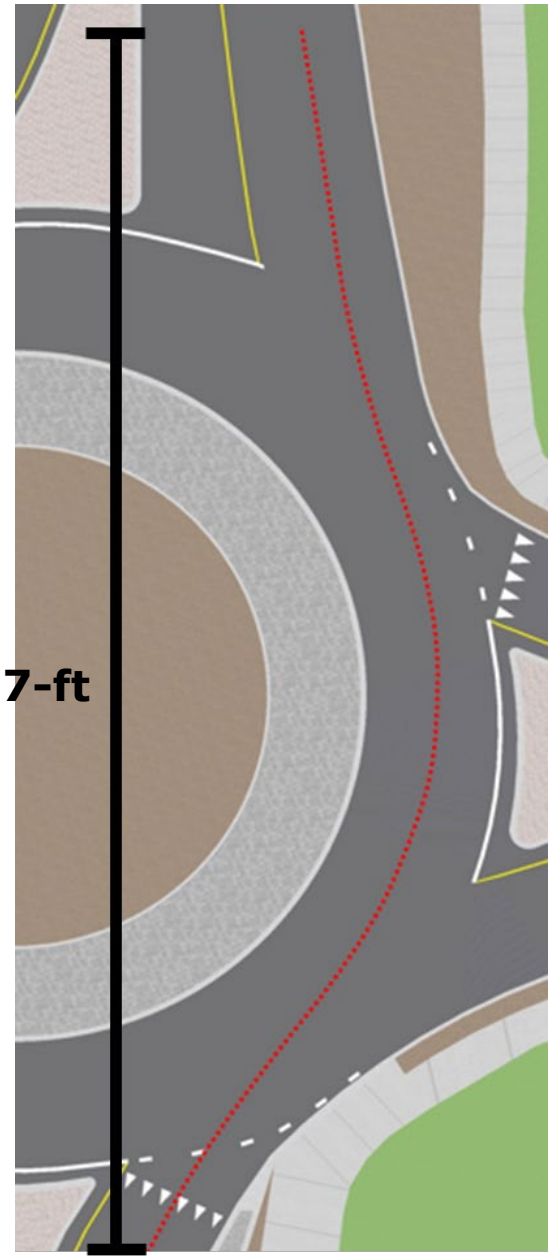
- Highest frequency use of inner truck-apron
- High density at beginning and end of traversal

Tapered

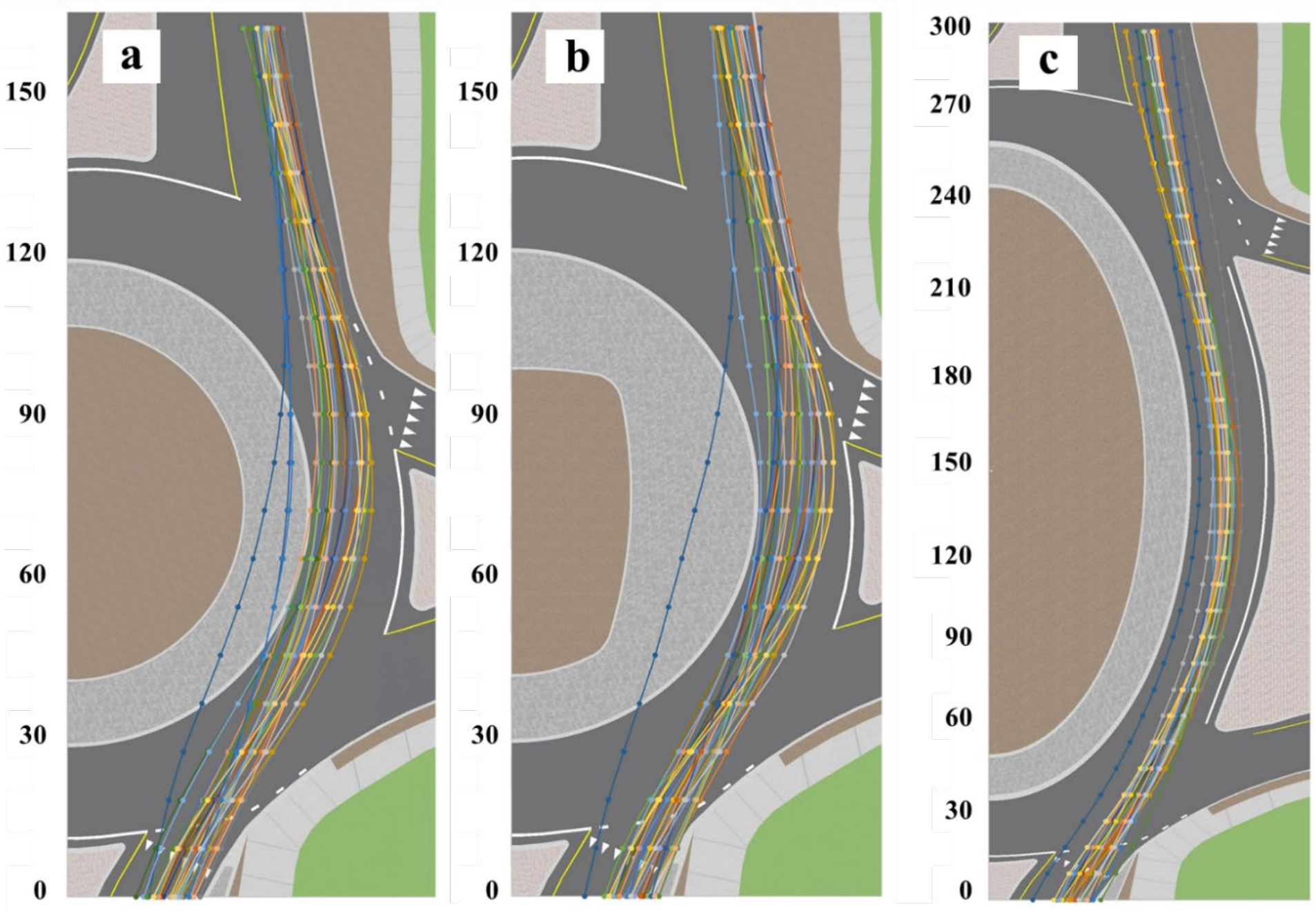
- Minimal use of inner truck apron
- Low density, high variations across participants

Elliptical

- Zero use of inner truck apron
- High density and uniformity throughout traversal



Roadway Centerline


a
150
120
90
60
30
0
b
150
120
90
60
30
0
c
300
270
240
210
180
150
120
90
60
30
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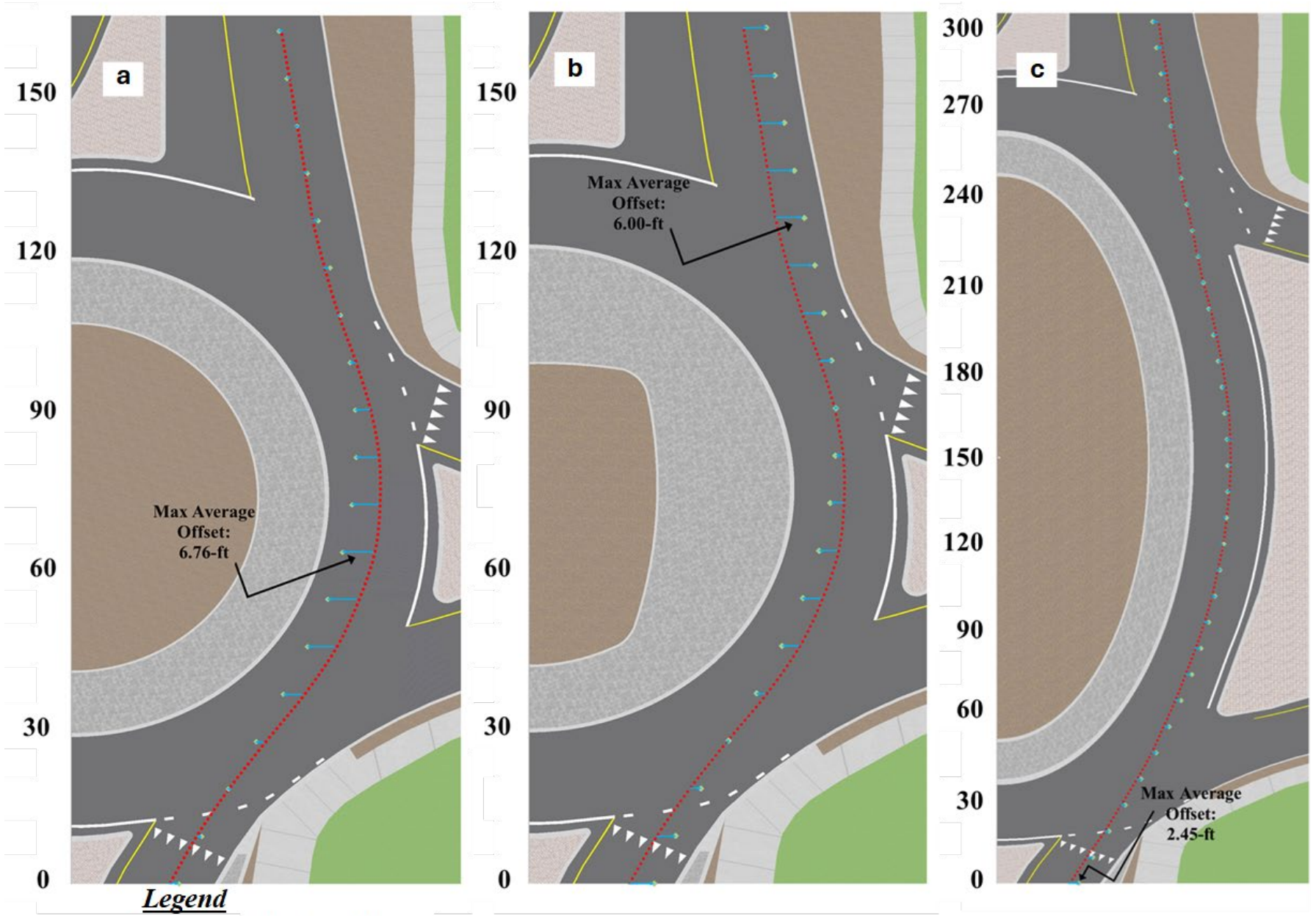
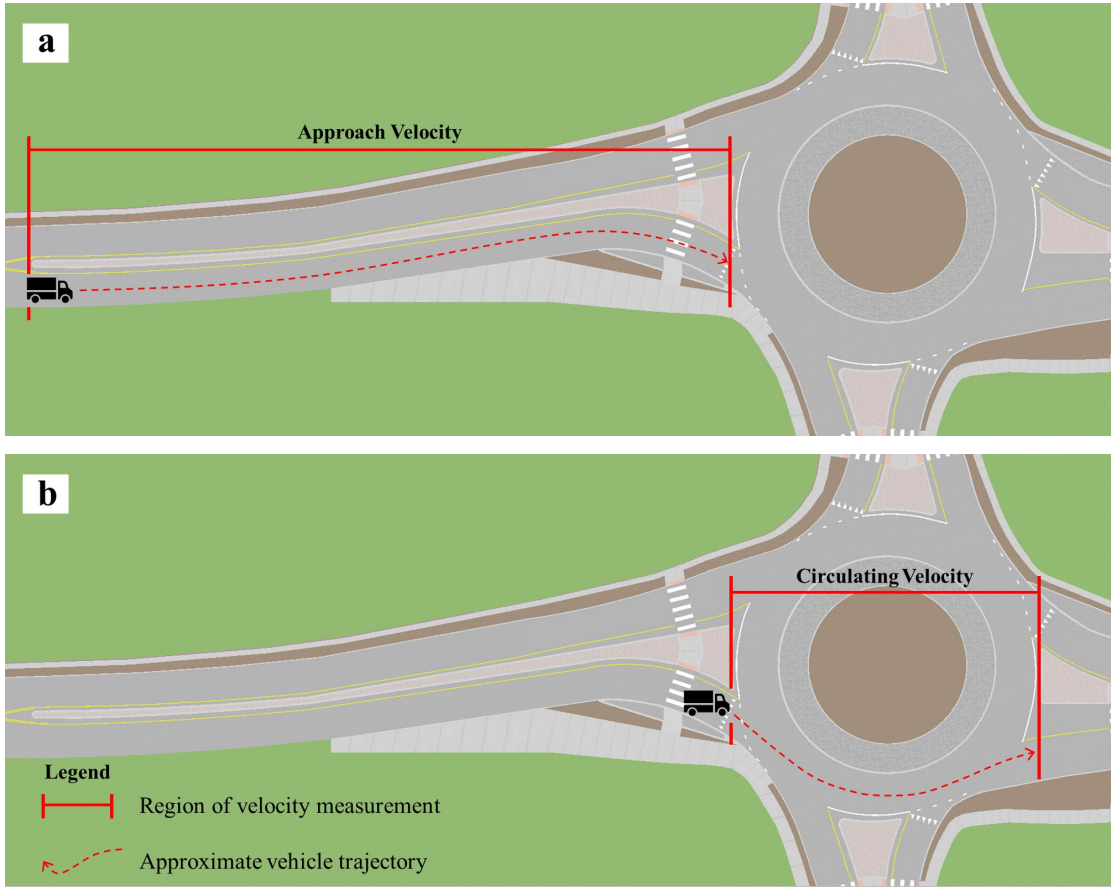

a
b
c
150
120
90
60
30
0
300
270
240
210
180
150
120
90
60
30
0
Max Average Offset: 6.76-ft
Max Average Offset: 6.00-ft
Max Average Offset: 2.45-ft
Legend
Center of lane
Average centroid position from all participants
Lateral distance from center of lane to average centroid of all participants

Velocity

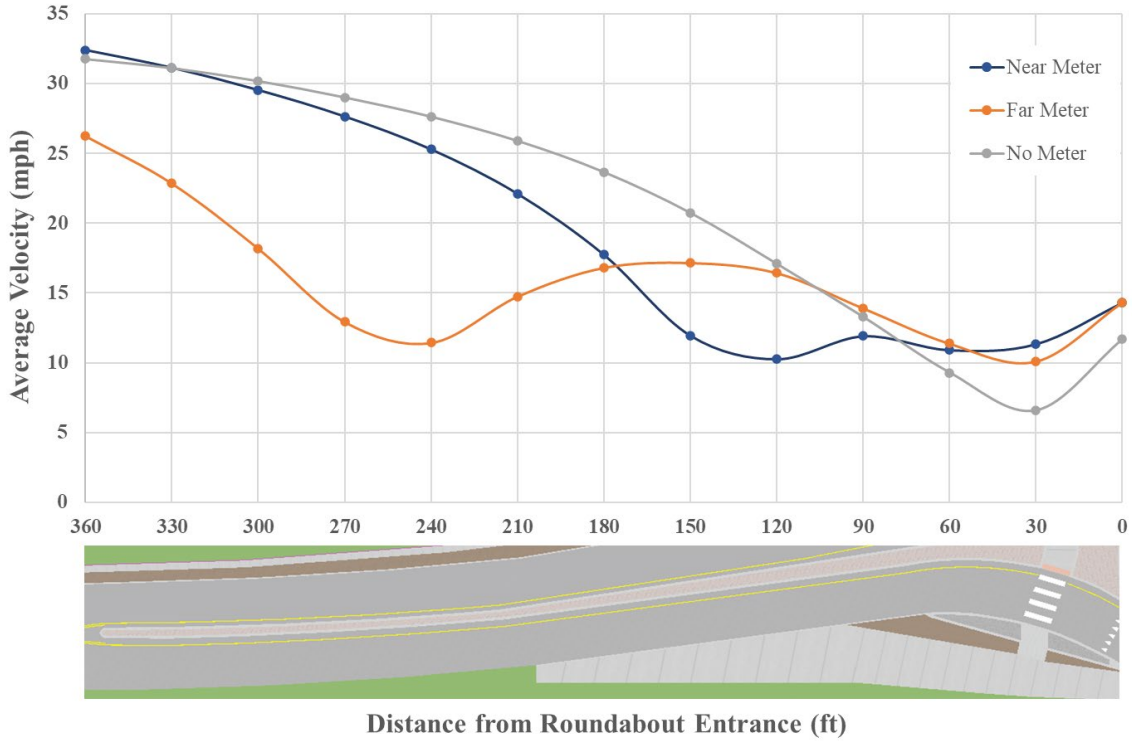
- Velocity was evaluated in two zones
  - (a) Approach velocity
  - (b) Circulating velocity
- Approach velocity segmented every 30-ft
  - Used for incremental velocity profile evaluation
- Circulating velocity was evaluated over the entire circulating roadway



Velocity Zones of Measurement

Approach Velocity

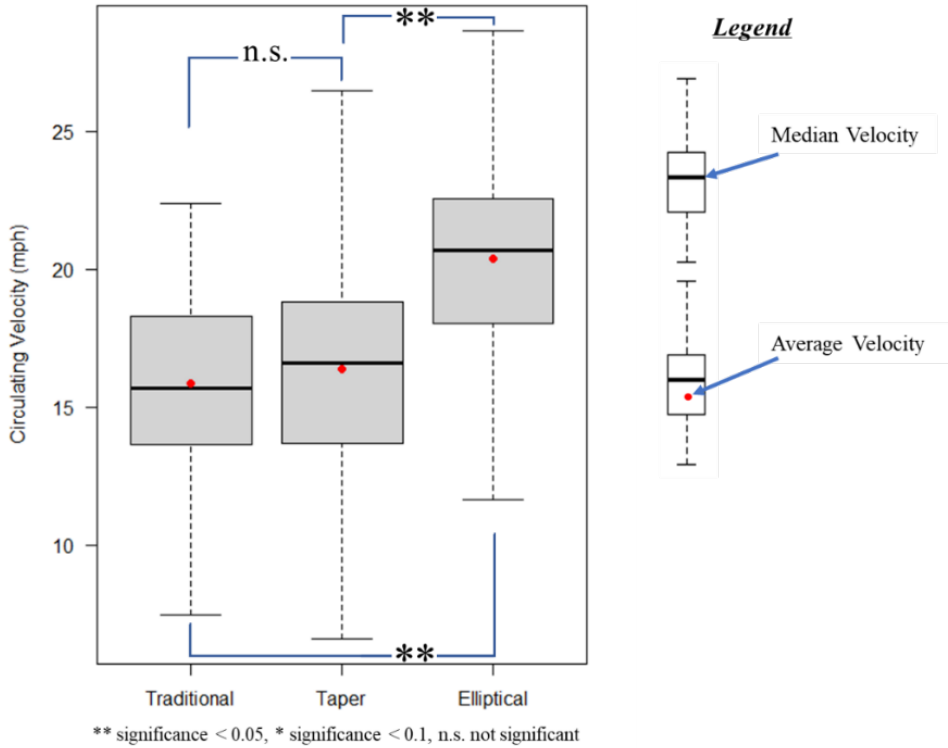
- Assessment of velocity based on location of roundabout metering
- Far (230-ft) meter had large variations
  - Constant acceleration/deceleration
- Near (115-ft) meter had relatively constant velocity after stop requirement
- No meter had constant deceleration until 30-ft
- All charts show a speed decrease 30-ft in advance of roundabout entrance



Average Velocity in Meter Scenarios

Circulating Velocity

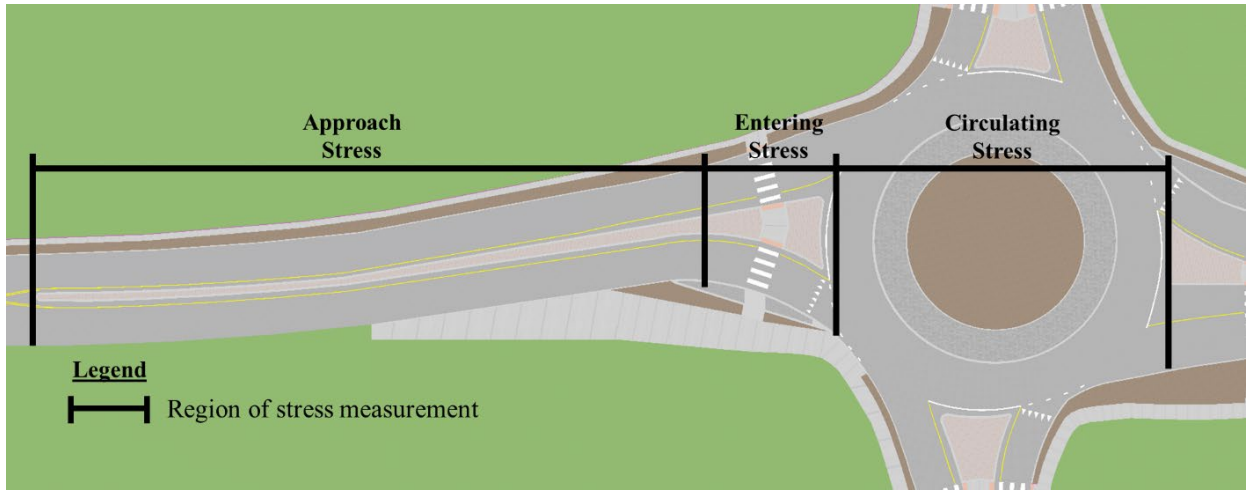
- Little to no difference in circulating velocity between traditional and tapered configurations
- Elliptical had the highest circulating velocity
  - Median = 20.70 mph
  - Mean = 20.38 mph
- Spread of data is consistent
- Tapered configuration had the most variability as indicated by the upper/lower bounds



Boxplot of Circulating Velocity by Geometry

Stress Response

- Three zones were identified to evaluate driver stress
  - On approach
  - While looking to enter
  - Once inside the roundabout
- Used performance measure “peaks/min”
  - Balances and accounts for duration of observation window
  - Allows comparisons to be drawn

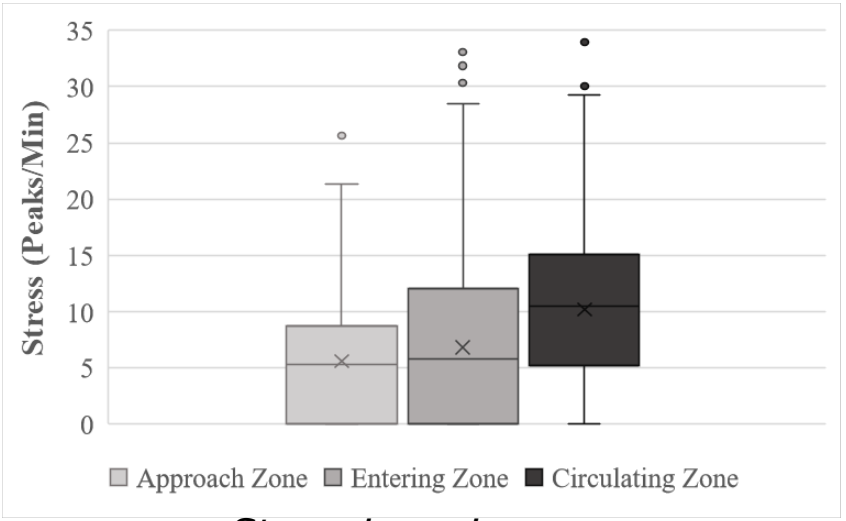


Stress Response Zones of Measurement

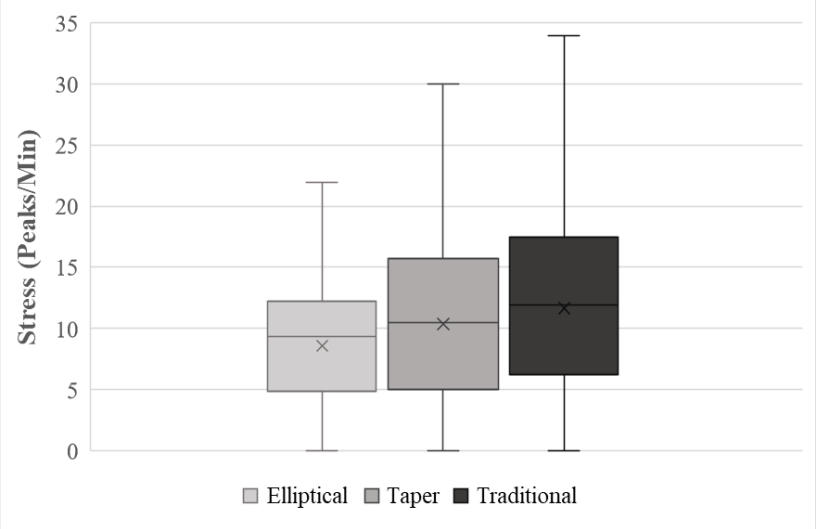
Stress Response Results

- Stress increased as participants traversed the different zones (averages)
  - Approach stress = 5.58 ppm
  - Entering stress = 6.91 ppm
  - Circulating stress = 10.20 ppm

- Geometric configuration may reduce stress once inside the roundabout (averages)
  - Elliptical circulating stress = 8.59 ppm
  - Tapered circulating stress = 10.37 ppm
  - Traditional circulating stress = 11.67 ppm



Stress in various zone



Circulating Stress by Geometry

Conclusions - Geometric Modifications

- Geometric modifications change heavy truck driver behavior and stress response when traversing congested roundabouts
- More modest (i) geometric modifications did not change response to the same degree as more comprehensive (ii) changes
  - (i) Traditional – Tapered
  - (ii) Traditional - Elliptical
- Driver position was in close alignment with lane center across elliptical traversal
  - May improve performance due to increased predictability and negotiations with other users
- Elliptical configuration was associated with the highest velocity (~4.0 mph) larger
  - Presents operational and safety concerns at adjacent legs and pedestrian crossings, respectively
- Stress response increased as drivers approached, entered, and circulated within the roundabout
  - Elliptical configuration reduced stress significantly over traditional and tapered designs

Conclusions – Traffic Control Devices

- Roundabout metering influences driver approach velocity and varies by distance placed in relation to the roundabout entrance
- Velocity results revealed that drivers reduce their speed ~30-ft in advance of the roundabout entrance
- Placing a roundabout meter too far from the roundabout entrance (i.e., 230-ft) results in large variations in approach tendencies
  - Constant acceleration and deceleration
- Near meter position (i.e., 115-ft) from roundabout entrance results in driver behavior that is relatively constant and for better judgement of available gap lengths
  - Did not require driver to make large accelerations at the end of approach to enter the roundabout
- The ideal distance between the roundabout meter and the roundabout entrance is dependent on context, should be similar to the near-meter scenarios (i.e., 115-ft) to achieve desired results in configurations like the one studied