Methodology for Measuring the Ability of Convex Mirrors to Improve Rear Visibility

Dr. W. Riley Garrott

Elizabeth N. Mazzae

National Highway Traffic Safety Administration

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Outline of Presentation

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- Objectives of Study
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Introduction

- Cameron Gulbransen Kids Transportation Safety Act of 2007 requires NHTSA to revise FMVSS No. 111
  - ➢ Must expand rear visibility of vehicles to try to reduce backover crashes
  - ➢ Multiple methods for expanding rear visibility listed in act: additional mirrors, cameras, sensors, etc.
  - ➢ This study focused on additional mirrors as possible backover countermeasure

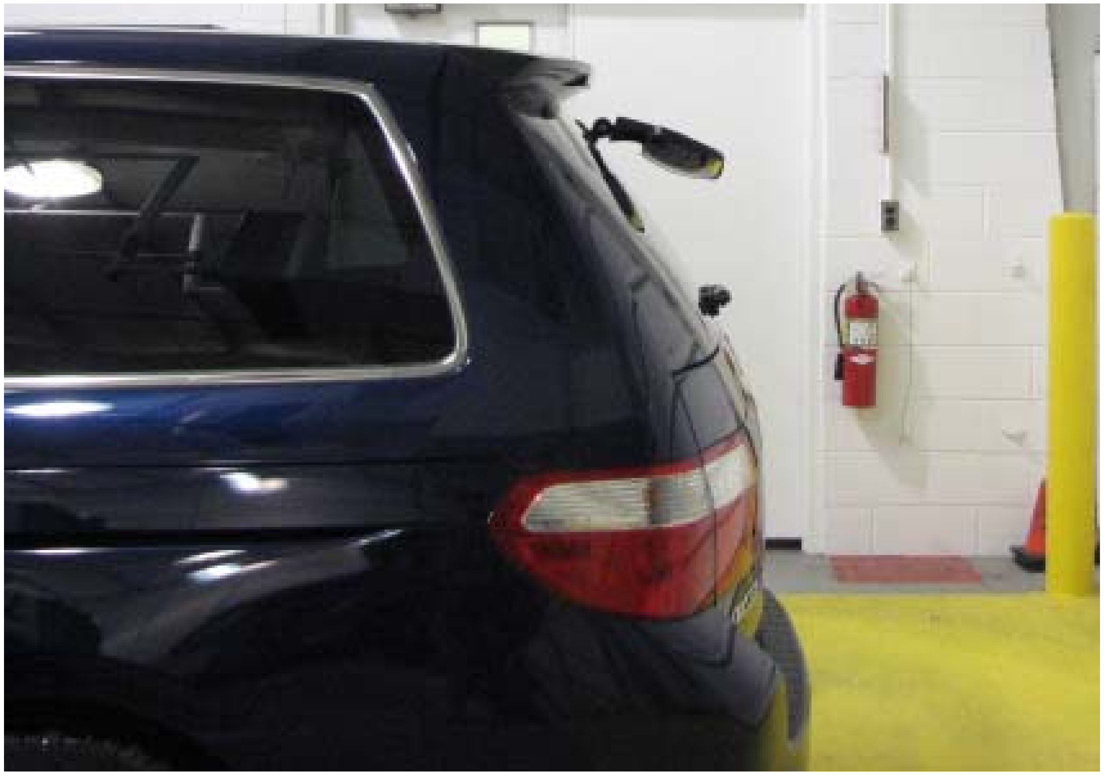
Objectives of Study

- What additional area behind vehicle does each mirror allow a driver to see?
  - What is each mirror's Field-of-View (FOV)?
- What is the quality of images seen in the mirror?
  - Measure minification and distortion at different locations in mirror's FOV
  - Talk focuses on image minification in mirror
- What is each mirror's potential for providing an appropriate FOV for reducing backover crashes?

Mirrors Evaluated

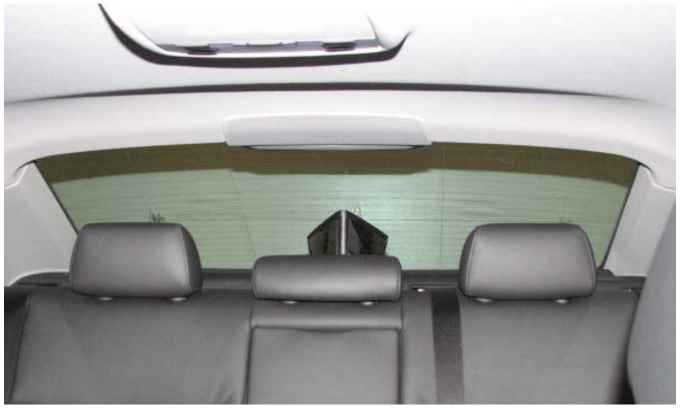
Three Types of Rear-Convex Mirrors

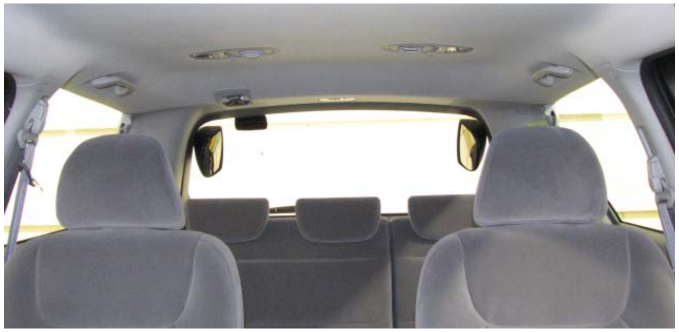
- Rear-mounted look-down mirror:
  - One rear look-down mirror evaluated
    - K Source C088 mounted on 2007 Honda Odyssey



Three Types of Rear-Convex Mirrors

- Rear cross-view mirrors:
  - Three rear cross-view mirrors evaluated
    - ScopeOut passenger car mirror mounted on BMW 330i
    - ScopeOut light truck mirror mounted on 2007 Honda Odyssey
    - Toyota 4Runner OE rear cross-view mirror





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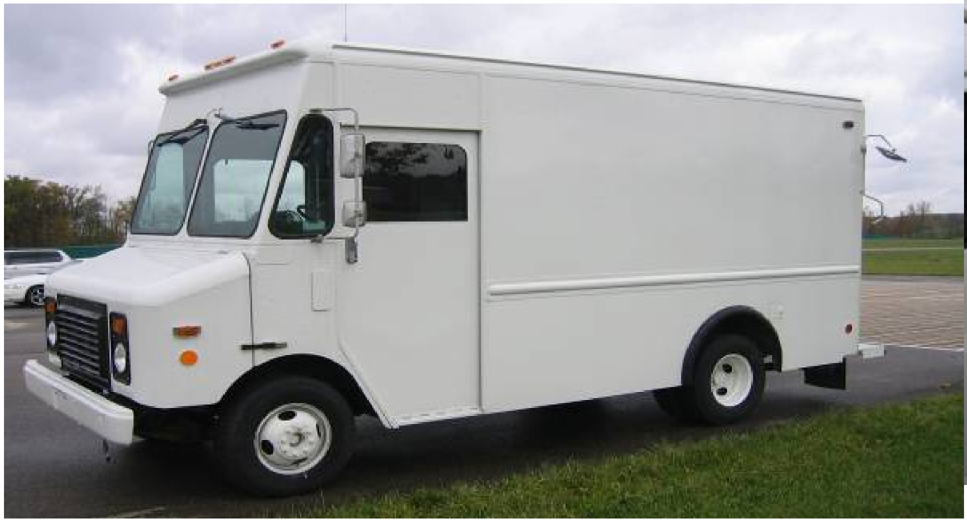
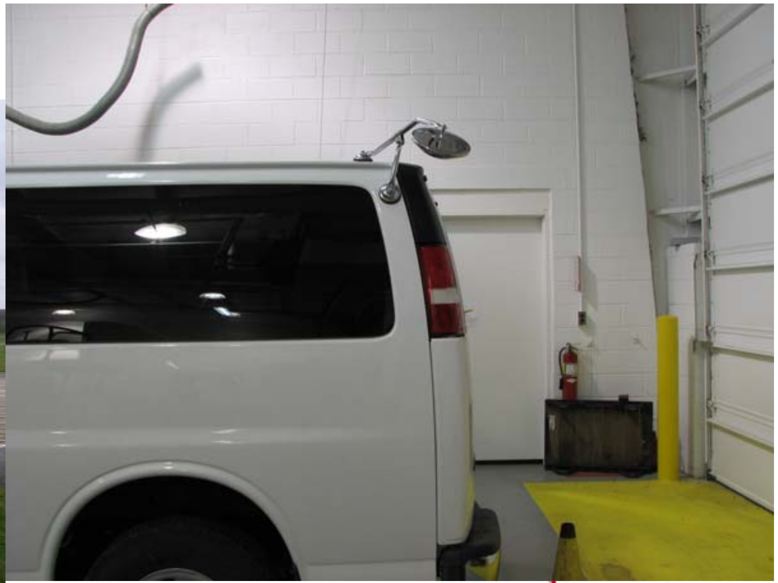
Three Types of Rear-Convex Mirrors

- Rear corner mirror:
  - Using data measured during earlier NHTSA study
  - Velvac RXV corner mirror evaluated
  - Using extrapolation and interpolation to account for size differences





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Mirror FOV Measurement Methodology

Mirror FOV Measurement Method

- Visual target was a 28-inch-tall traffic cone with a 3-inch in diameter red, circular reflector sitting atop it
- The combined height of the cone and reflector was 29.4 inches
  - According to CDC, simulates standing 1-year-old child

Mirror FOV Measurement Method

- Measurements performed using 50th percentile male driver
- Grid of 1 foot by 1 foot squares set up behind vehicle
  - Extends 50 feet behind vehicle, 25 feet to each side of vehicle
- Test object moved from square-to-square
  - In FOV if could see all of reflector

Mirror Minification Measurement Methodology

Mirror Image Quality Assessment

- Used method developed by Satoh
  - Quantitative measurements made of selected images
  - Satoh related quantitative measurements to subjective ratings of image quality
- Satoh's method was basis for school bus cross-view mirror compliance test in S9 and S13 of FMVSS 111
- Two aspects of image quality:
  - Distortion – How much apparent shape of objects changes when viewed in mirror
  - Minification – How large objects appear when viewed in mirror
    - Talk will focus on image minification

Measurement of Mirror Minification

- Used 1-year-old and 3-year old ATD's
- Pictures taken of ATD and "sizing object"
- Measurements made of apparent ATD size
- Apparent ATD size scaled using known size of "sizing object"
- Angle subtended at driver's eyes calculated using scaled apparent ATD size

Subjective Minification Ratings Versus Subtended Visual Angle

Level	Degree of Image Form	Degree of Image Size	Visual Angle θ (minutes)
5	Excellent	No Image small	
			50
4	Good	Small, but no problem	
			20
3	Fair	Small, but possible to judge	
			10
2	Poor	Small and hinders judgment	
			5
1	Very Poor	Impossible to judge	
			3
0	Impossible	Impossible	<3

Copied from the paper "Development of Periscope Mirror System" by Satoh, et al.

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FOV Estimation Methodology

General Idea for FOV Estimation

- Used Monte Carlo simulation
- Key assumptions:
  - ➢ Pedestrian is oblivious to backing vehicle
    - o Thought to frequently be case when backover crashes occur because otherwise move out of backing vehicles path
    - o No true for fallen or non-mobile pedestrians
  - ➢ Driver looks at rear-mounted convex mirror only one time, immediately prior to start of backing maneuver
    - o Currently lack data on driver usage of rear convex mirrors during backing to improve on this assumption

General Idea for FOV Estimation

- Simulated 110 by 70 foot grid of initial pedestrian locations
  - Grid extends back 90 feet from rear bumper, 20 feet forward from rear bumper and 35 feet to each side of vehicle centerline
  - Total of 7,700 one foot by one foot squares
- Probability of simulated backover crash calculated for each grid square
  - Ran 1,000,000 Monte Carlo iterations for each square
  - Due to left-right mirroring, have effectively 2,000,000 iterations per square

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FOV Estimation Data Source

- Information about vehicle backing behavior from NHTSA's On-Road Study of Drivers' Use of Rearview Video Systems study used for risk estimation
  - Naturalistic backing data collected for over 6,000 backing events by 37 drivers
  - Vehicle distance backed and backing speed data used by Monte Carlo simulation

Description of Vehicle for Simulation

- Distance Backed – Determined by random draw from Weibull distribution
  - Average Backing Distance – 33.8 ft
  - Maximum Backing Distance (approximate) – 303.2 ft
- Backing Speed – Determined by random draw from Weibull distribution
  - Minimum Backing Speed – 0.4 mph
  - Average Backing Speed – 2.24 mph
  - Maximum Backing Speed (approximate) – 7.76 mph
- Vehicle Width – Changeable simulation parameter

Description of Vehicle for Simulation

- Backing maneuvers frequently involve turning
- If distance backs more than 25 feet, high probability of turn. Assumed:
  - 40 % chance of turn to left
  - 20 % chance of straight back
  - 40 % chance of turn to right
- Turn begins after 25 feet of backing or 30 feet from end of back, whichever is more
- Vehicle turns up to 90° around 20 foot radius circle

Description of Pedestrian for Simulation

- Pedestrian Speed
  - 33 % of time pedestrian stationary
  - 67 % of time pedestrian moving is straight line at a speed determined by random draw from Weibull distribution
    - Minimum Pedestrian Speed – 0.52 mph
    - Average Maximum Speed – 2.964 mph
    - Maximum Backing Speed (approximate) – 7.52 mph
  - Above pedestrian speeds thought appropriate for 5- to 6-year-old child

Monte Carlo Simulation Normalization

- Backover crashes counted for each grid square
- Normalized crash counts by dividing by number of crashes counted for grid squares directly behind bumper in middle of vehicle
  - Gives relative probability of crash for each grid square
  - Since each grid square is subject to same imperfections, hope to substantially reduce effect of imperfections

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Summary

- Talk has discussed methods for:
  - Determining what can be seen in a rear convex mirror
  - Determining quality of image (minification only) seen in a rear convex mirror
  - Determining importance of being able to see various areas to left-rear, directly behind, and to right-rear of vehicle
- There is a need for data as to how drivers use rear-mounted convex mirrors

Questions?