

# Road Surface Characteristics and Accidents

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# Factors Affecting Accident Rate

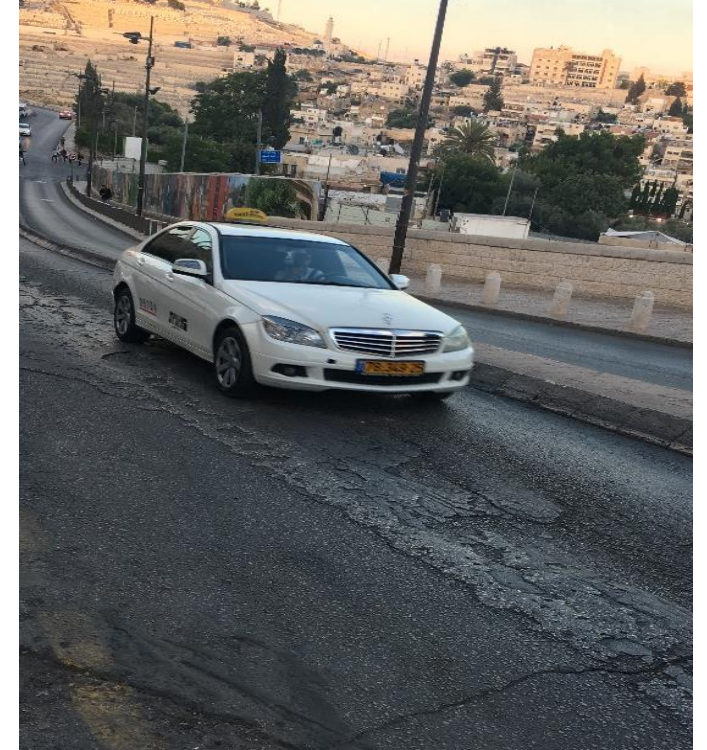
- Human factors ←
- Vehicular causes
- Environmental conditions
- Roadway geometry
- Traffic volume
- Pavement condition
- Combinations



- Although pavement condition is not a major factor, the exact role of this factor is not well understood

# Roughness and Rutting

- Directly affect ride quality
- Indirectly contribute to driver distraction, vehicle operation, and accidents
- Can cause vehicles to lose control when braking or turning, especially under adverse environmental conditions
- Can be exaggerated when human factors, such as distraction, alcohol, stress, physical deficiency and age exist



# Roughness

- Deviations of pavement surface from a true plane surface that affect vehicle dynamics, ride quality, dynamic loads, and drainage
- Roughness may result in:
  - ❖ decreasing contact area between tires and pavement, resulting in lowering brake friction
  - ❖ vehicle instability due to different friction forces on both sides of vehicle
  - ❖ vehicle bouncing and possibly losing loads



# Rutting

- Permanent deformation in the wheel path
- Rutting may result in:
  - ❖ exert extra effort needed to get out from the wheel path, resulting in uncontrolled lateral vehicle movement
  - ❖ water accumulates in the rut, resulting in hydroplaning and loss of vehicle control

# Problem Statement

- Many studies dealing with effect of skid resistance on safety
- Limited studies focusing on effect of roughness or rutting on safety
- Need for roughness and rut depth thresholds below which pavement-related accidents can be reduced

# Objectives

- To investigate the relationship between accident rate and both IRI and rut depth
- To determine the IRI and rut depth thresholds that correlate to an increased accident rate

# Literature Review

- Studies suggest that roughness and rutting can be contributing factors for traffic safety and crash occurrence
- Studies suggest that pavement roughness has good correlation with crash rate and crash severity
- The contribution of rut depth to traffic safety is not well defined



## Literature Review (Cont.)

- One study recommended  $IRI \leq 120$  in./mile
- One study showed an increase in crash rate where the rut depth  $\geq 0.4$  inches
- No guidelines to assist highway maintenance authorities to maintain their pavement at a certain level in order to minimize crash occurrences

# Data Collection

- National Highway Performance Monitoring System (HPMS) and open source state data
- 3 states in different geographic locations and climatic conditions (AZ, NC, MD)
- Interstate, U.S. and State roads
- 2013 - 2015
- Accident data [frequency, severity, weather, cause (if known)]
- Pavement conditions (IRI, rut depth)
- Traffic data (AADT)

# Roughness and Rutting Measuring Devices

State	Roughness measuring device	Rutting measuring device
Arizona	Profilometer	Profilometer
North Carolina	Profiler	Profilometer
Maryland	Automatic Road Analyzer (ARAN)	ARAN

# Example: ADOT Profilometer



# Summary of IRI (in./mile) in Different States

State (Year)	Mean	Standard Deviation
AZ (2013)	72	31
AZ (2014)	72	33
NC (2015)	102	43
MD (2014)	133	87

# Summary of Rut Depth (in.) in Different States

State (Year)	Mean	Standard Deviation
AZ (2014)	0.06	0.05
NC (2015)	0.14	0.06
MD (2014)	0.15	0.05



# Difference Among States

- IRI and rut depth values are different
- Reasons for the differences
  - ❖ actual differences in pavement conditions
  - ❖ types of data measured
  - ❖ measuring equipment
  - ❖ processing methods
  - ❖ sampling methods
  - ❖ number of runs of measuring devices



# Crash Severity Levels

Severity Level	Arizona	North Carolina	Maryland
1	Damage w/o injury	Damage w/o injury	Property damage
2	Minor injury	Injury level C	Physical injury
3	Non-incapacitating injury	Injury level B	
4	Incapacitating injury	Injury level A	
5	Fatality	Fatality	Fatality

# Data Processing

- Data were sorted and separated for each year/state
- Crash data and PMS data were matched and merged together on the basis of location using SQL (Structured Query Language)
- In AZ and NC, data were matched using name and milepost. In MD, data were matched using GIS coordinates (latitude and longitude)
- Microsoft Excel was used to perform further analysis

## Data Processing (Cont.)

- Crashes caused by snow or factors other than road condition (if known) were removed
- In AZ and NC PMS data were provided for each mile post, but in MD every 0.1 miles. To maintain uniformity, one mile segments were used in all states
- Accident severity levels were separated and related to IRI or rut depth

# Summary of Crash Data

State (Year)	All Severities	Severity Level 1	Severity Level 2	Severity Level 3	Severity Level 4	Severity Level 5
Arizona (2013)	31,514	21,748	4,473	4,149	838	306
Arizona (2014)	32,570	22,809	4,454	4,296	767	243
North Carolina (2015)	97,612	67,601	20,625	6,702	835	601
Maryland* (2014)	807	607	204			-

\*Partial crash data were obtained from Maryland

# Crash vs. Non-Crash Segments

- Crash segments represent 37-48 percent of the total length of the network
- Average roughness and rutting values of crash and non-crash segments are close to each other
  - ❖ The reason could be that roughness and rutting are not the only factors affecting crashes. Other factors include traffic volume, other pavement distresses, etc.



# Crash Rate

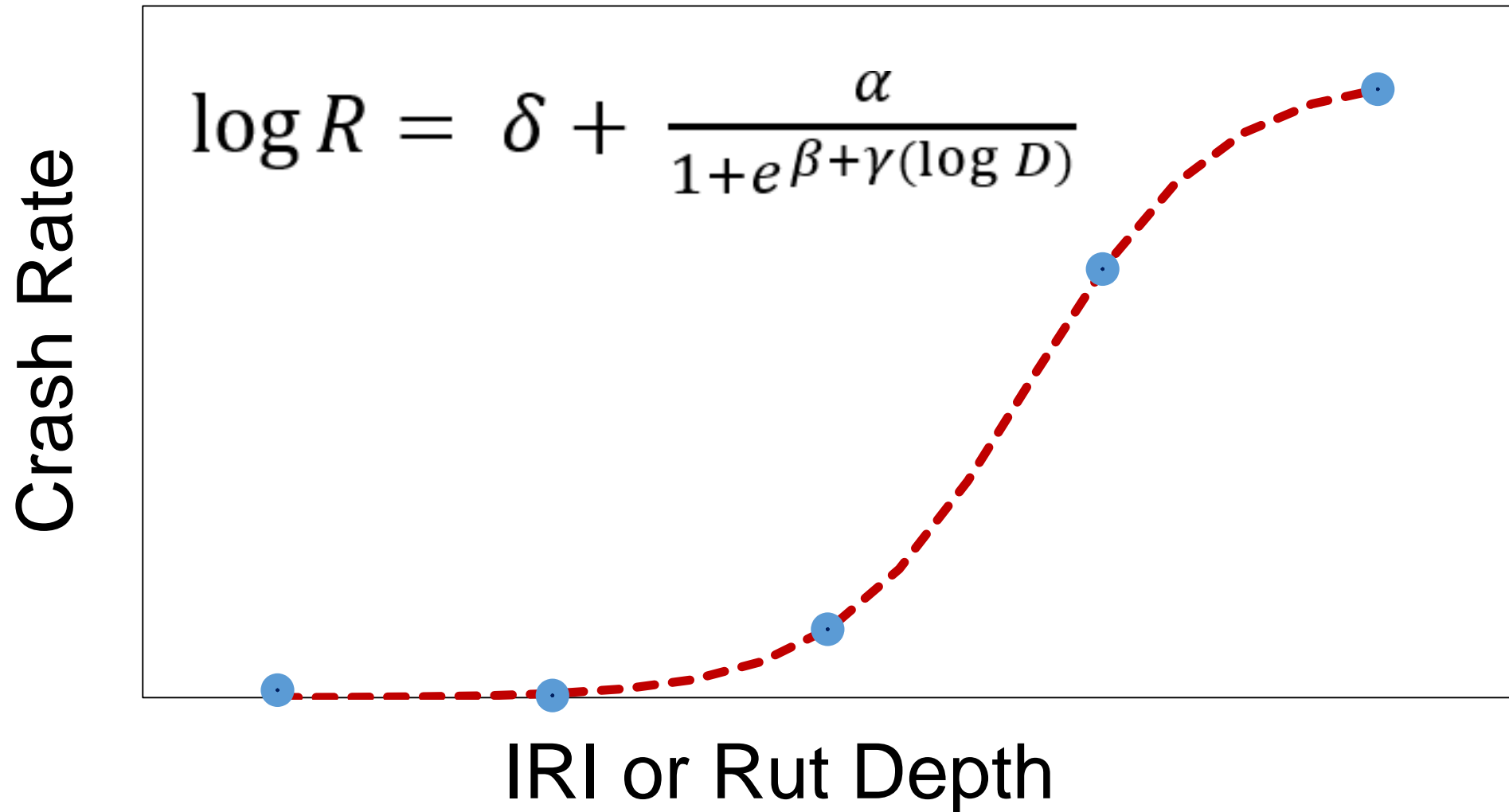
- IRI values were broken down to categories of 50 in./mile
- Rut depth values were broken down to categories of 0.1 in.

$$\text{➤ } R = \frac{C \times 100,000,000}{AADT \times 365 \times Length \times No. of Years}$$

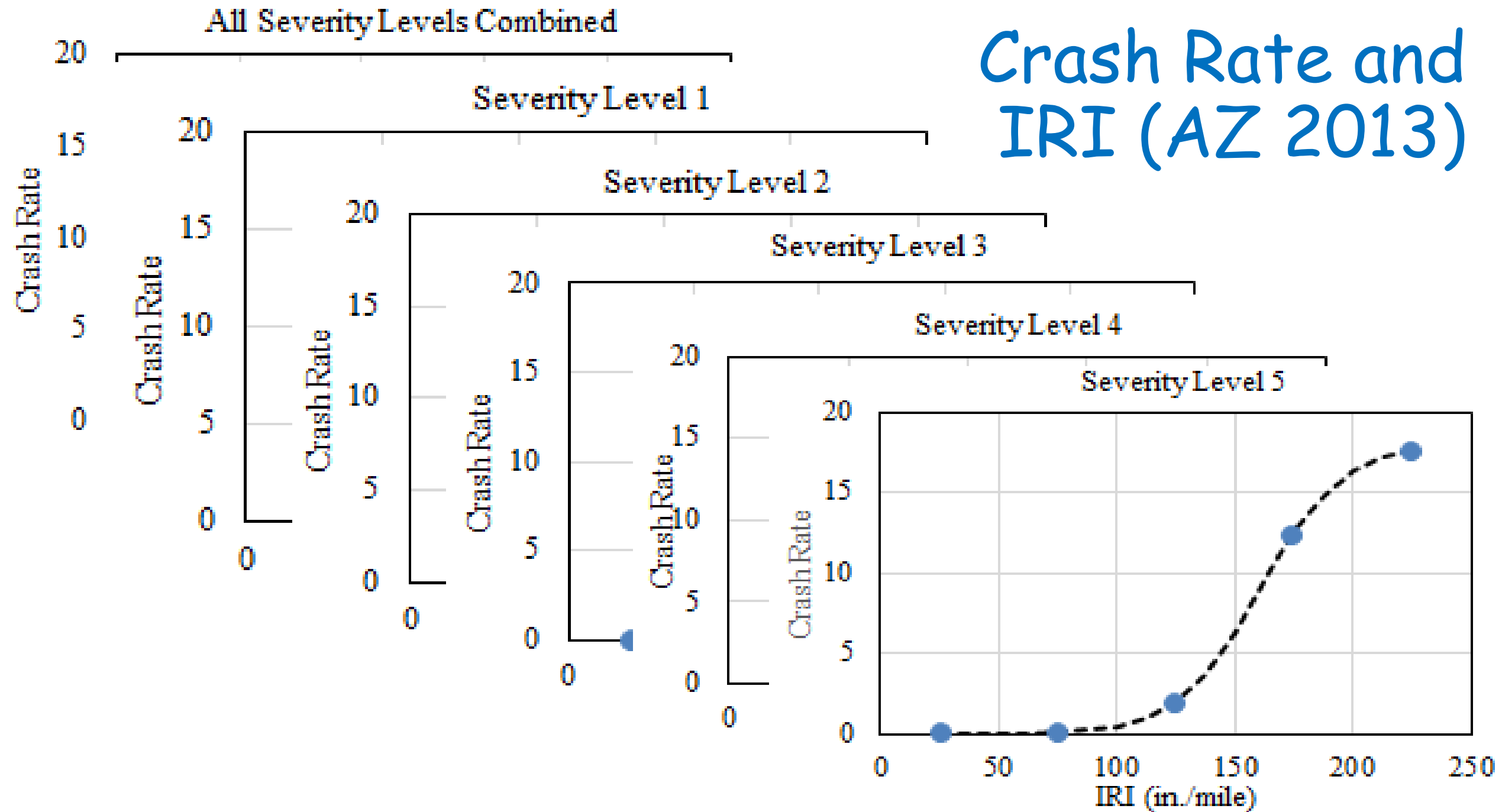
where R = Crash rate per 100 million vehicle-miles of travel

# Ride Quality Analysis

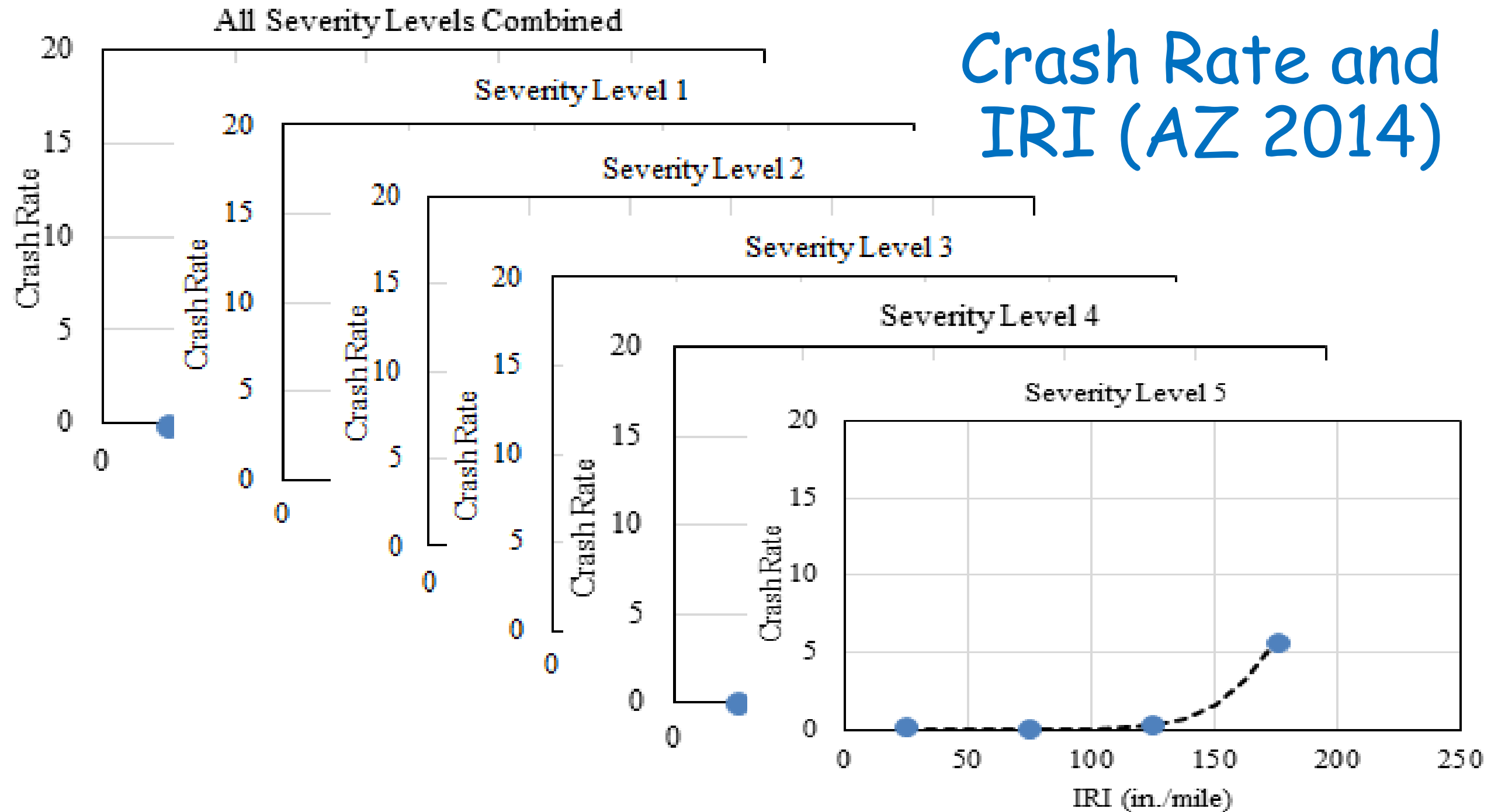
## ➤ Sigmoidal function



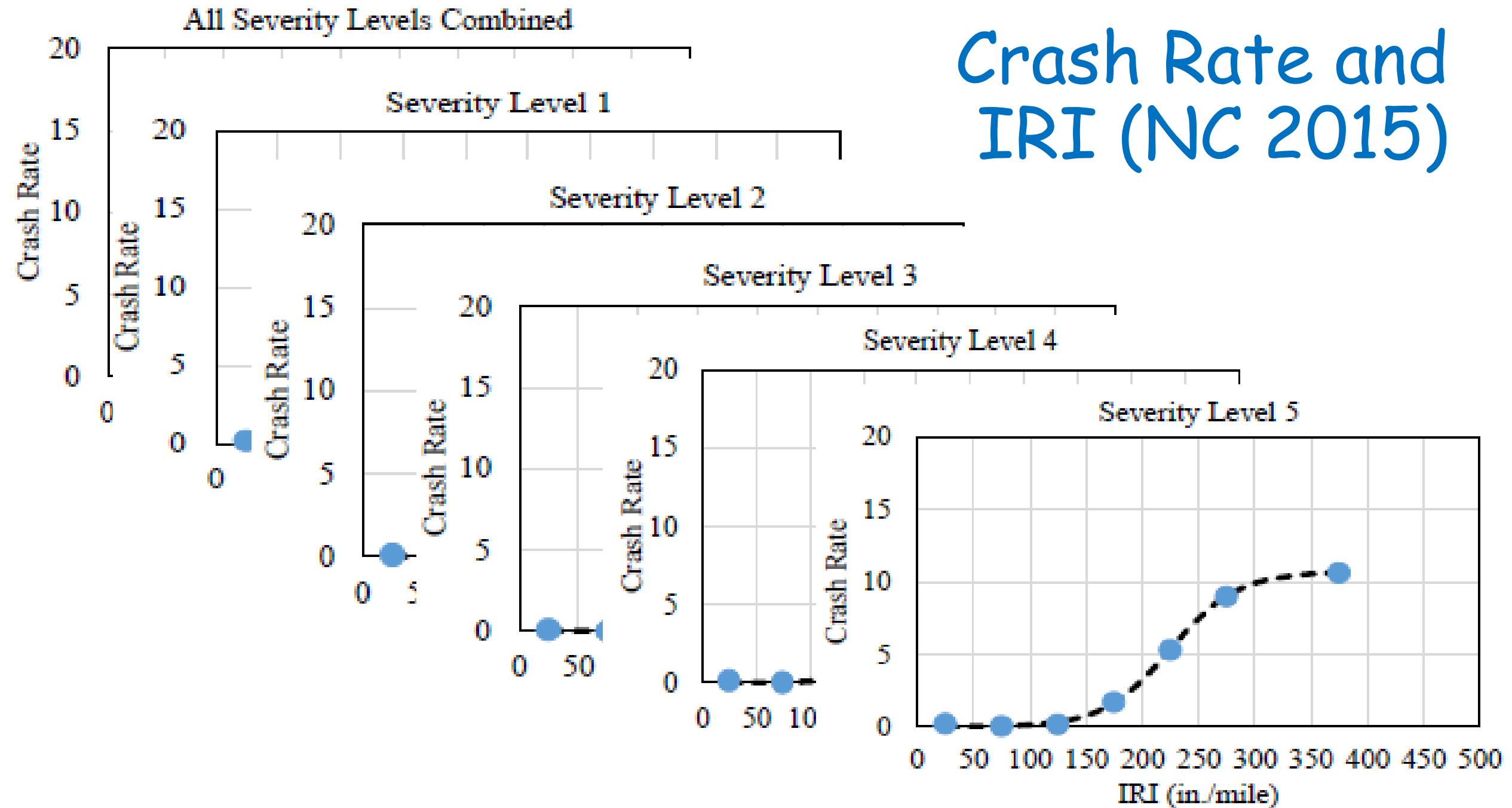
# Crash Rate and IRI (AZ 2013)



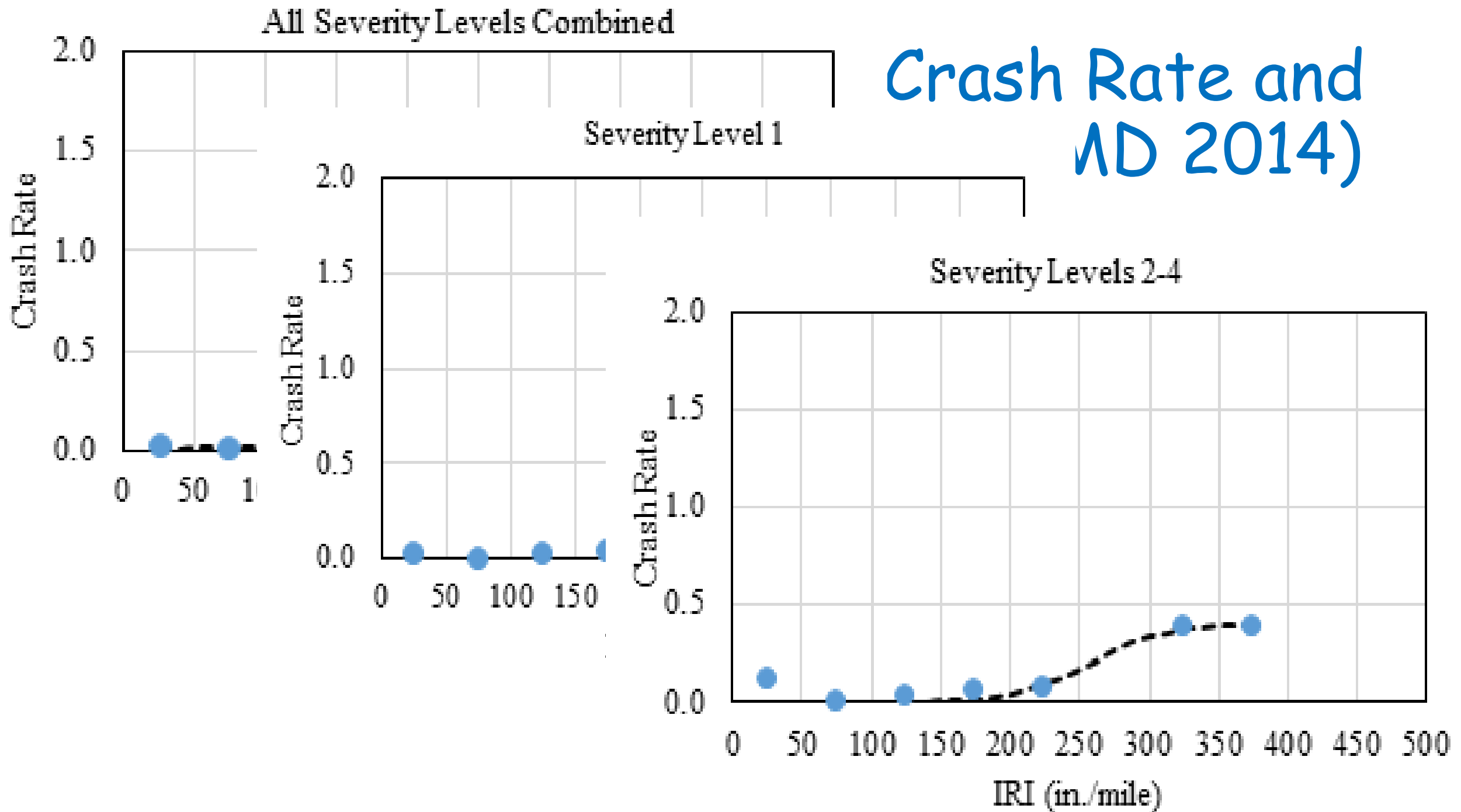
# Crash Rate and IRI (AZ 2014)



# Crash Rate and IRI (NC 2015)

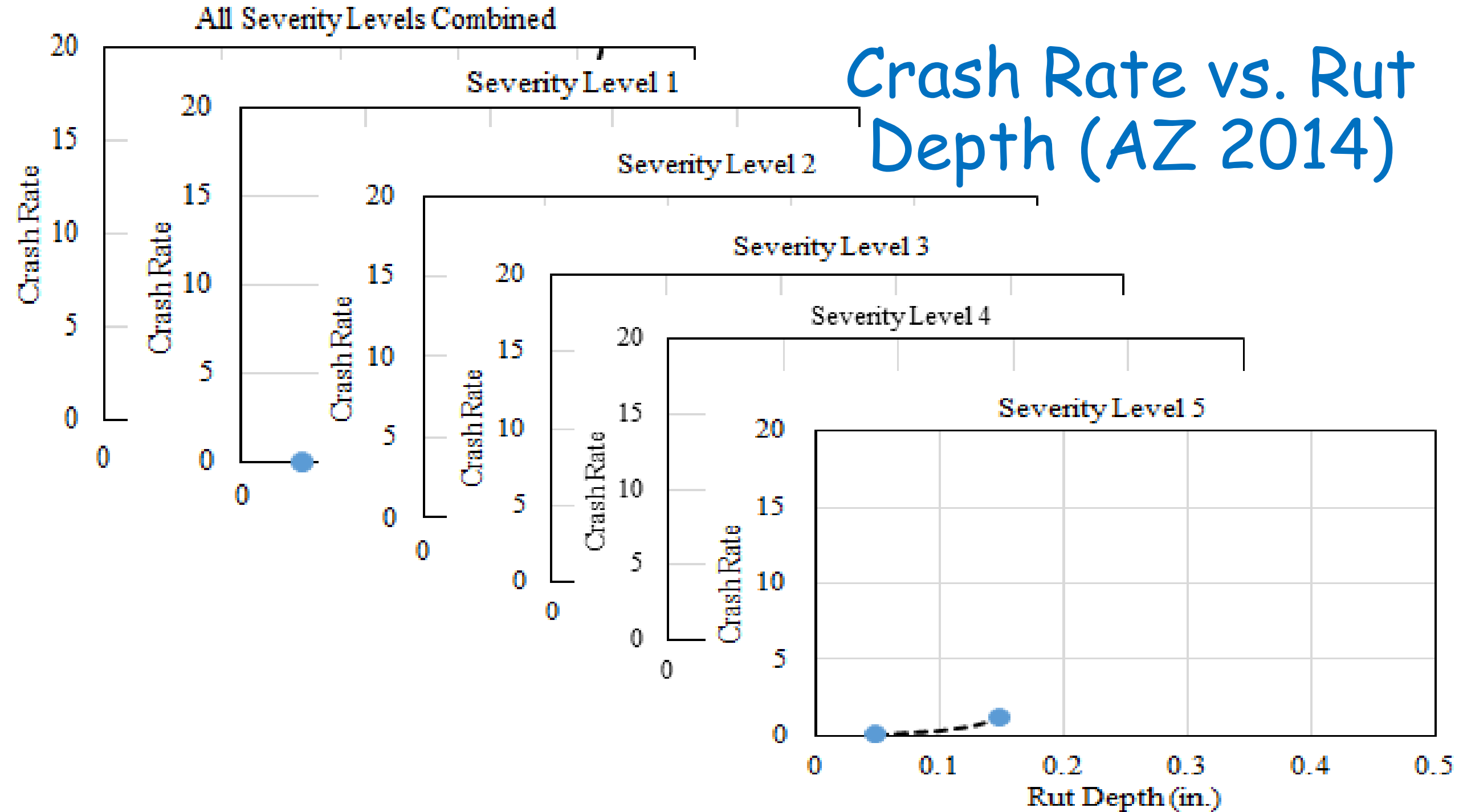


# Crash Rate and AD 2014)

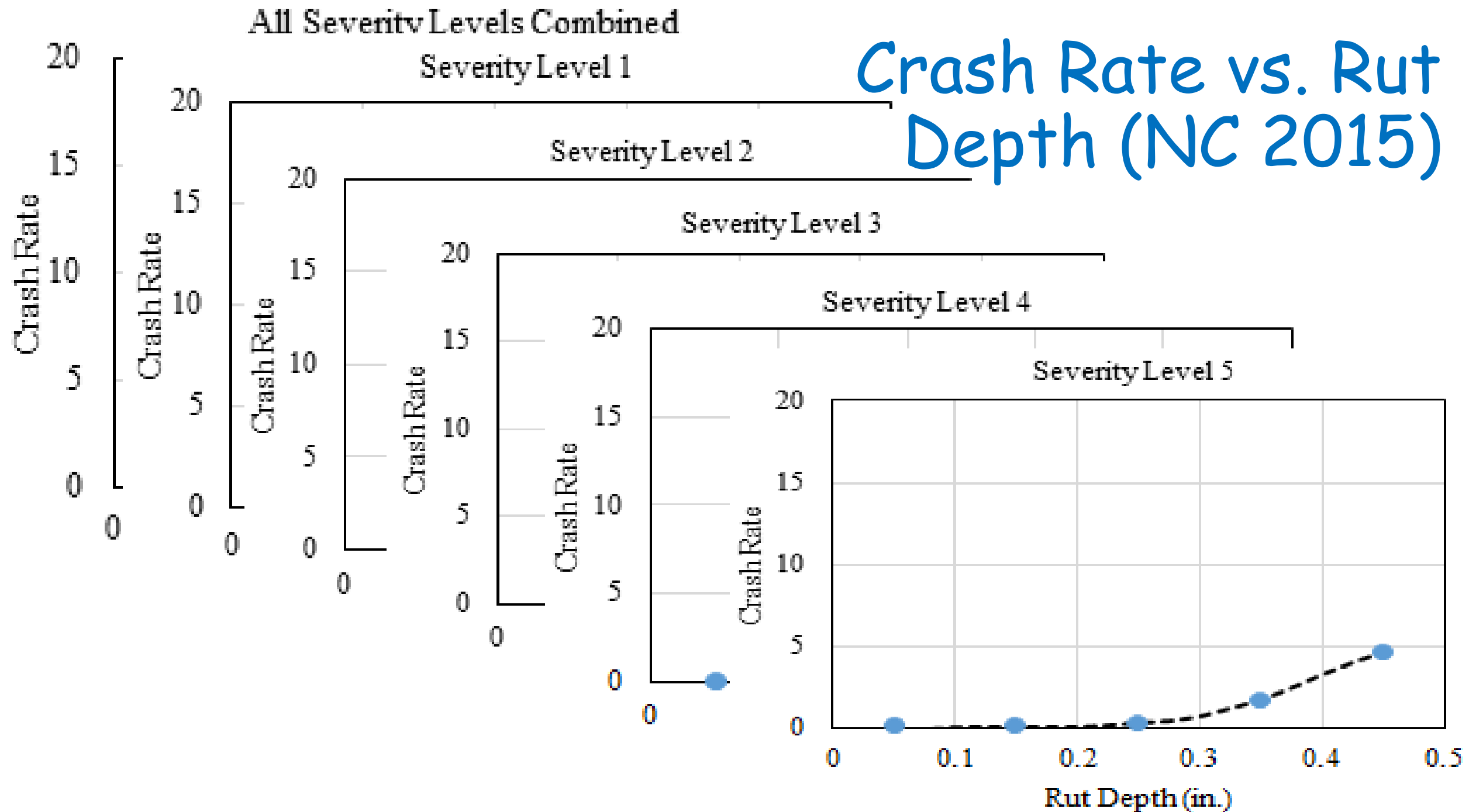




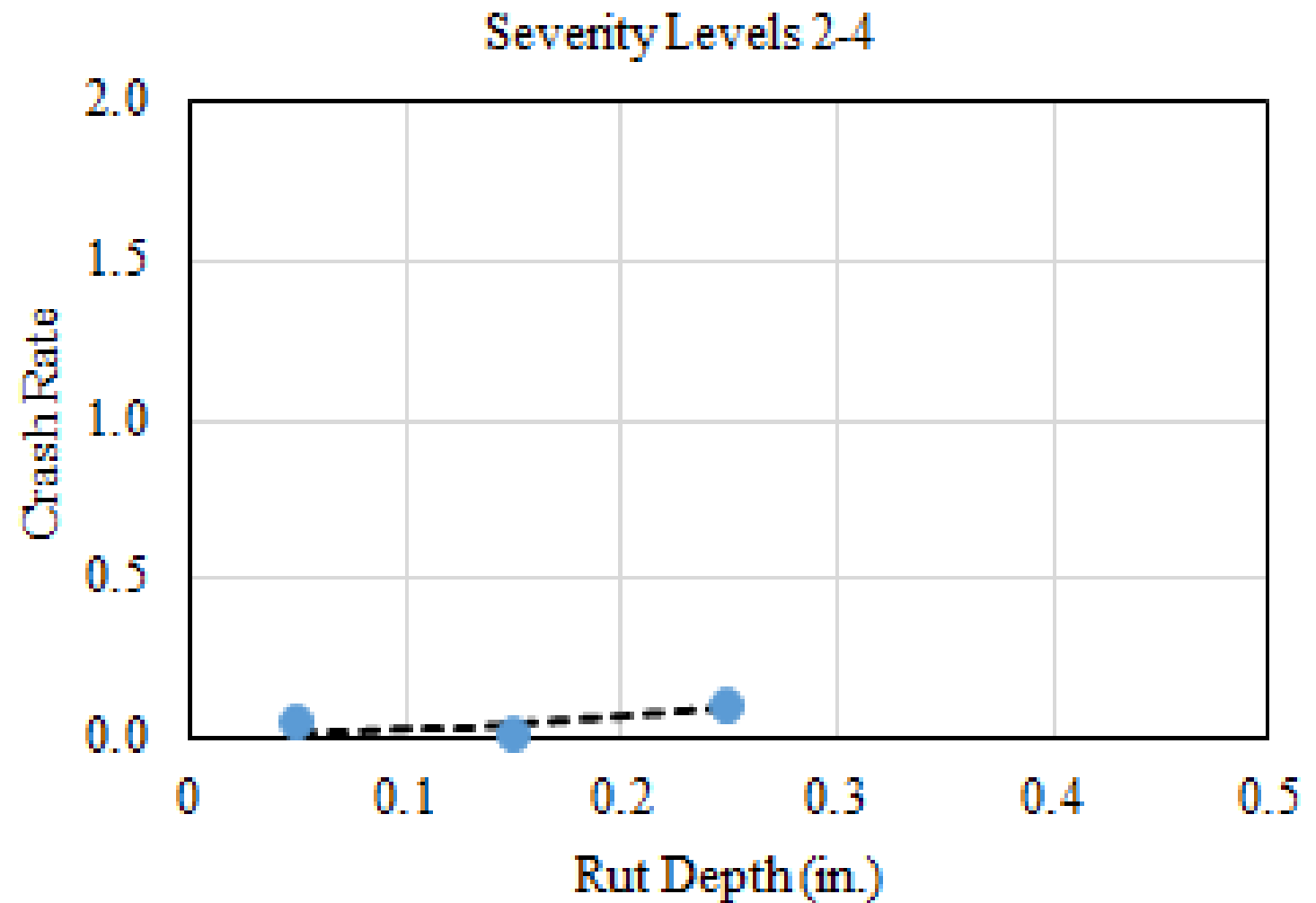
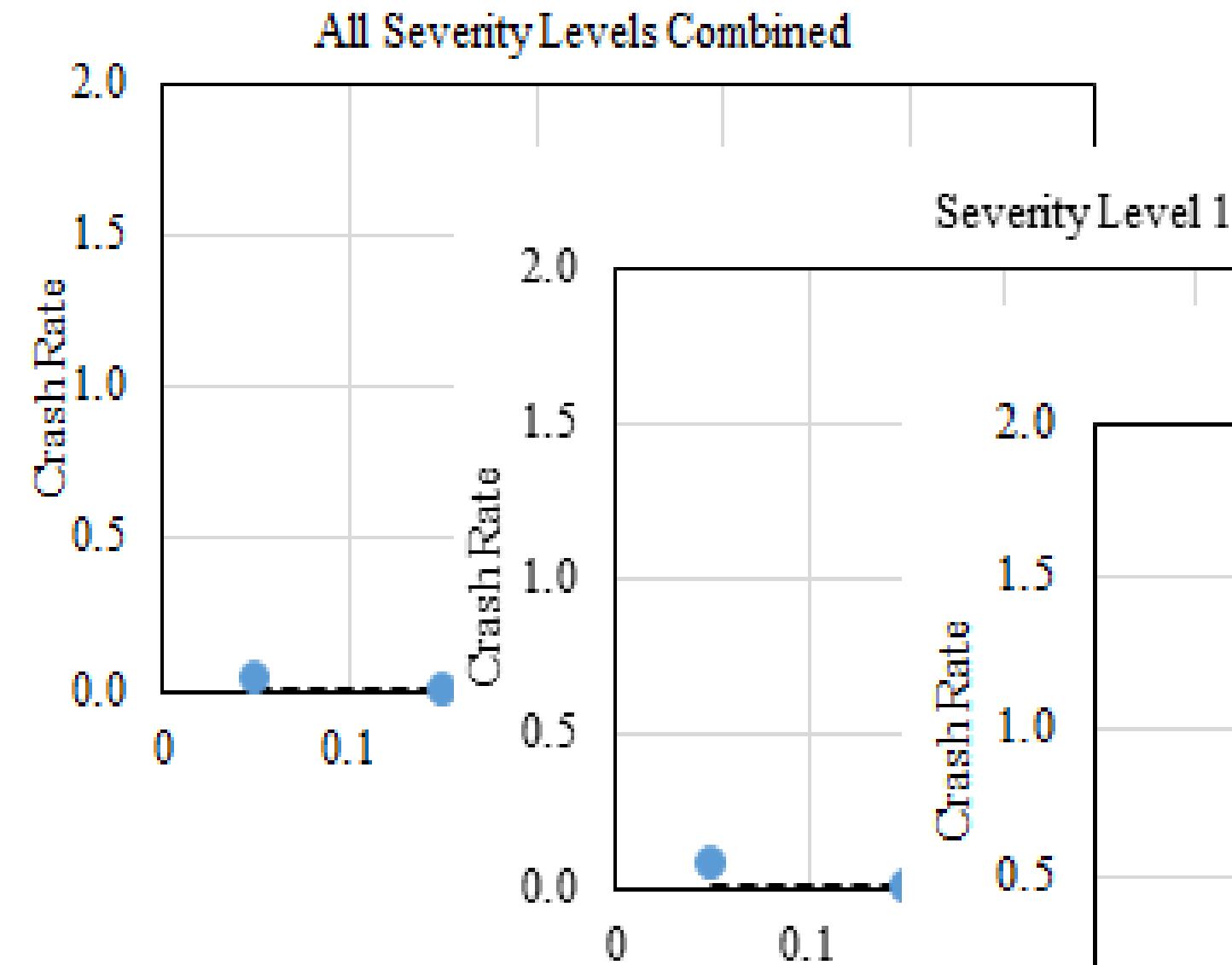
# Crash Rate vs. Rut Depth (AZ 2014)



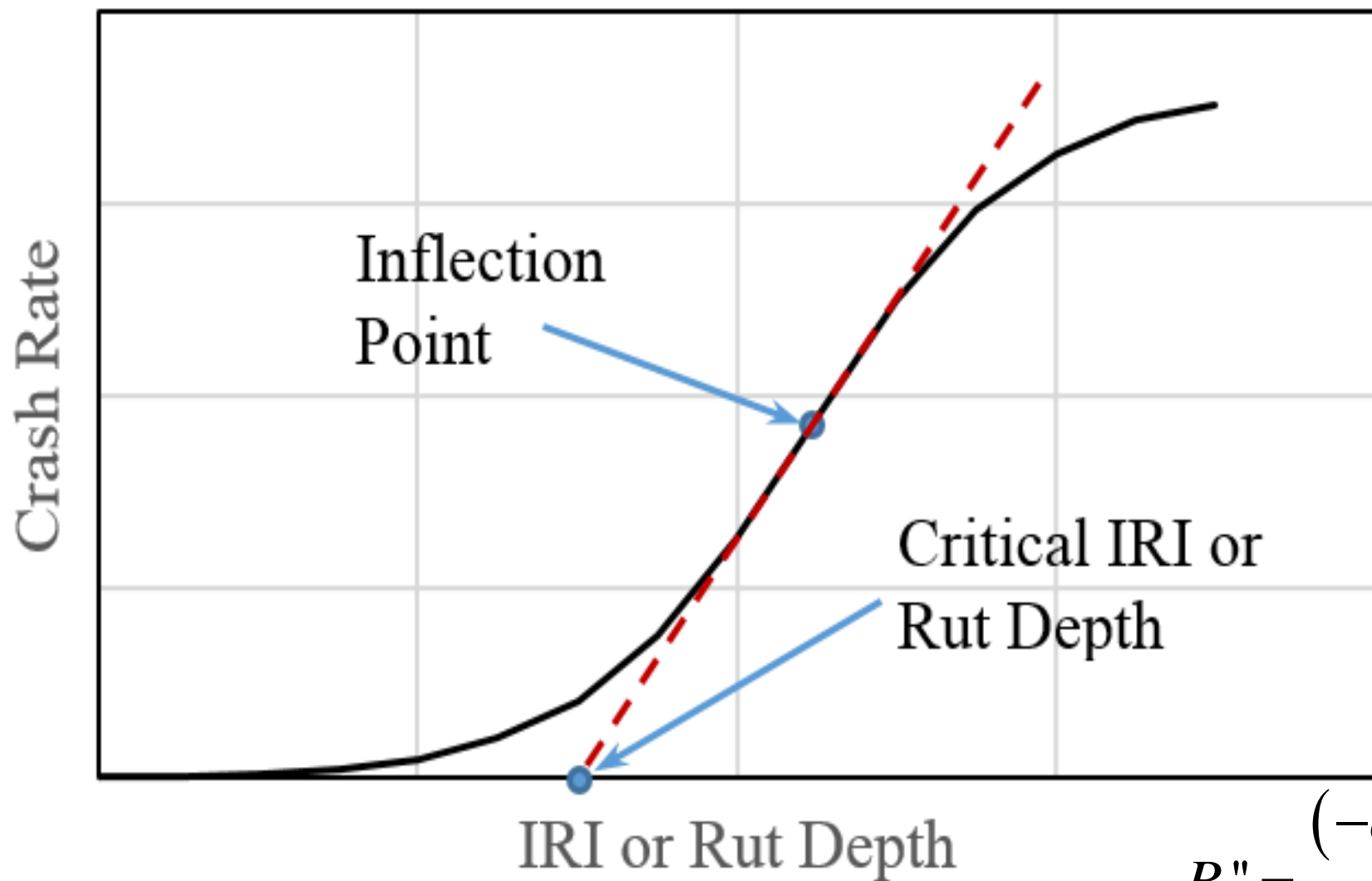
# Crash Rate vs. Rut Depth (NC 2015)



# Crash Rate vs. Rut Depth (MD 2014)



# Critical Pavement Condition



$$R' = \frac{\alpha \times \beta \times e^{(D \times \beta + \gamma)}}{(e^{D \times \beta} + e^{\gamma})^2}$$

$$R'' = \frac{(-\alpha \times \beta)^2 \left[ (e^{D \times \beta} - e^{\gamma}) (e^{(D \times \beta + \gamma)}) \right]}{(e^{D \times \beta} + e^{\gamma})^3}$$

# Critical IRI and Rut Depth Values

State	Year	Critical IRI (in./mile)	Critical Rut Depth (in.)
Arizona	2013	192	---
	2014	152	0.35
North Carolina	2015	268	0.35
Maryland	2014	208	0.4
<b>Average</b>		<b>210</b>	<b>0.4</b>

# Conclusions

1. IRI and rut depth values of crash and non-crash segments were close to each other. This suggests that ride quality and rutting are not the only factors affecting crashes.
2. Crash rate does not increase up to a certain IRI value, above which crash rate starts to increase. This phenomenon occurred for different crash severity levels.



## Conclusions (Cont.)

3. Similar to ride quality, crash rate does not increase up to a certain rut depth value, above which crash rate starts to increase. This phenomenon occurred for different crash severity levels.
4. The critical IRI values above which crash rate starts to increase varied from one state to another due to factors such as measurement equipment, data processing methods, sampling method, or number of runs of measuring devices, etc.

## Conclusions (Cont.)

5. The average critical IRI value for all three states above which crash rate starts to increase is 210 inches/mile.
6. The average critical rut depth value above which crash rate starts in increase was almost the same for all three states with an average value of 0.4 inches.
7. These threshold values can assist highway authorities in maintaining pavement at a certain level in order to minimize crash occurrences

