



# Rail Transit Safety: An Empirical Evaluation

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## Measuring Safety Performance

American Public Transportation Association: Annual Rail Conference

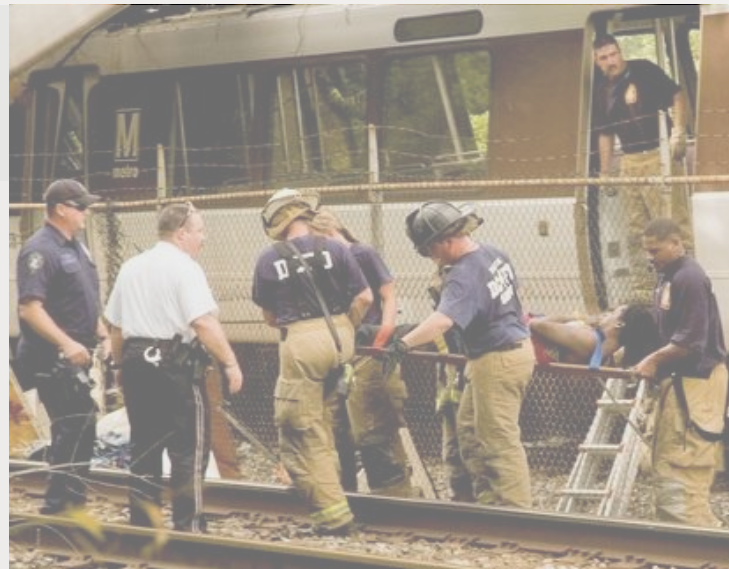
June 14, 2011 | 10:45 am | Ballroom Salon G | Marriott Copley Place | Boston MA

# Agenda



- Introduction
- How safe is rail transit?
- Rail transit incidents, injuries and fatalities
- Data and methodology
- Findings and discussion
- Concerning fatalities
- Conclusions





- **Introduction**
- How safe is rail transit?
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# Introduction

- The US rail transit industry has suffered recent rash of tragic and catastrophic accidents
  - May 2008
    - 49 hospitalized due to light rail accident
  - May 2008
    - operator killed and numerous passengers injured in another light rail accident
  - June 2009
    - Nine killed in a heavy rail collision
  - July 2009
    - 48 hospitalized after a light rail collision.

**Inevitable questions concerning safety of US rapid transit and light rail systems.**



# Regulatory Response

- December 8, 2009
  - US Department of Transportation Proposes Legislation to Improve Rail Transit Safety Oversight

DOT Announcement 193-09

*“More than 14 million passengers use our rail transit systems every weekday. Yet the responsibility to guarantee their safety is currently left to a patchwork of 27 state agencies with inconsistent standards, inadequate powers and insufficient staffing.”*

- Proposed to establish and enforce minimum Federal safety standards for rail transit systems to correct the status quo “resulting in a situation in which there are inconsistent practices and effectiveness.”



# Research Objective

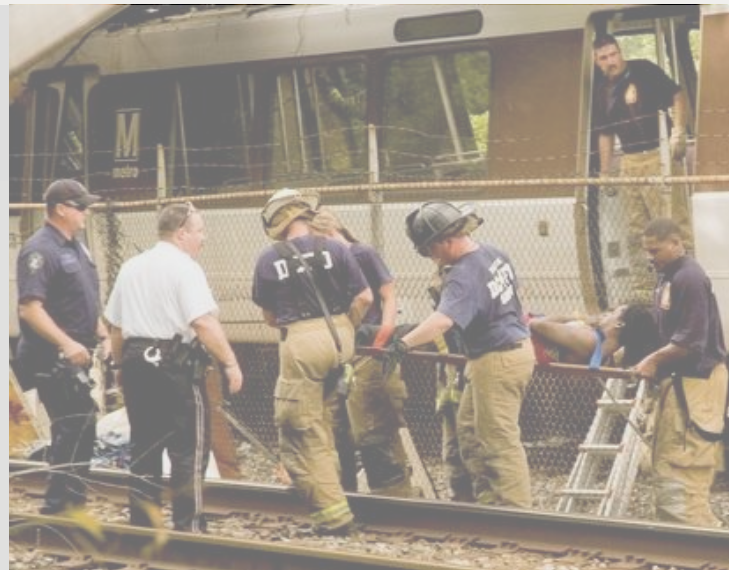
- Shed empirical light on the question of inconsistent safety among rail transit operations in the United States
- Safety is a very emotional topic, making it sometimes difficult to review dispassionately
- Accidents are thankfully rare and infrequent events
  - but clusters of accidents sometimes occur
- Is there a statistically significant pattern of inconsistent safety between agencies?
  - or was the rash of accidents simply bad luck?



# Problem Statements

- How safe is rail transit compared with other modes of transport?
- Are there statistically significant long term differences in safety records among US heavy rail and light rail agencies?



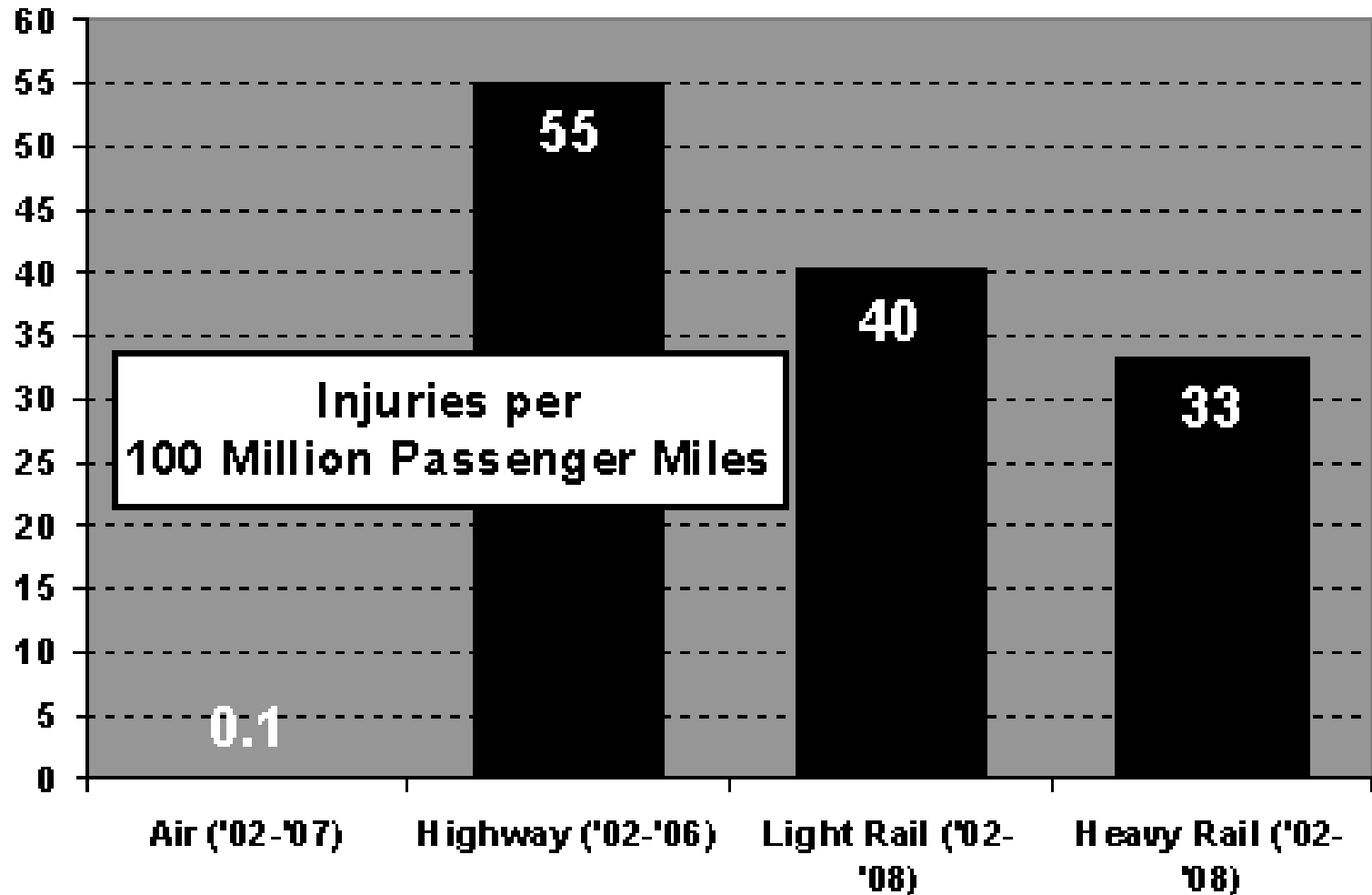


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# How safe is rail transit compared to other modes?

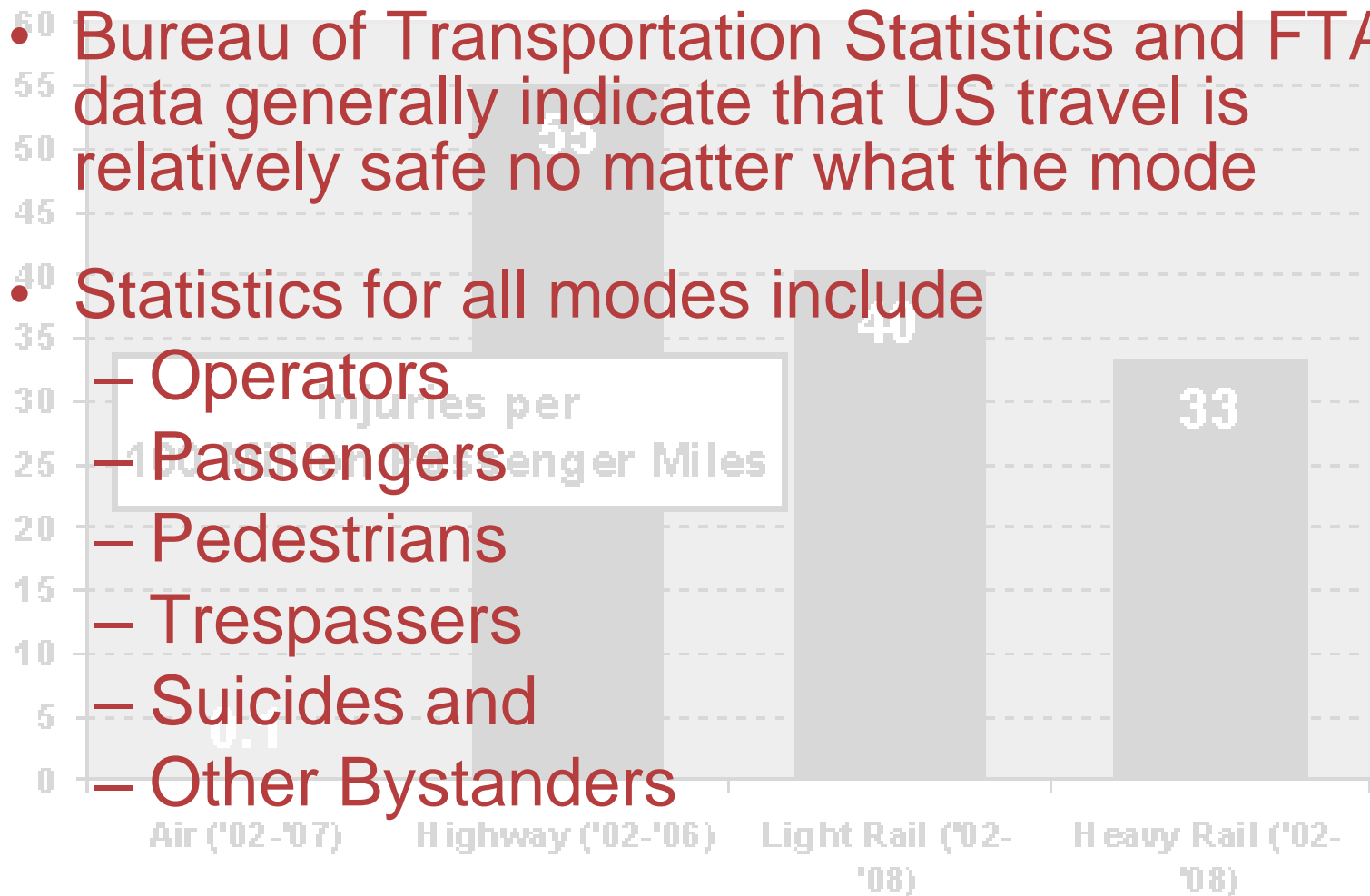


# How safe is rail transit compared to other modes?

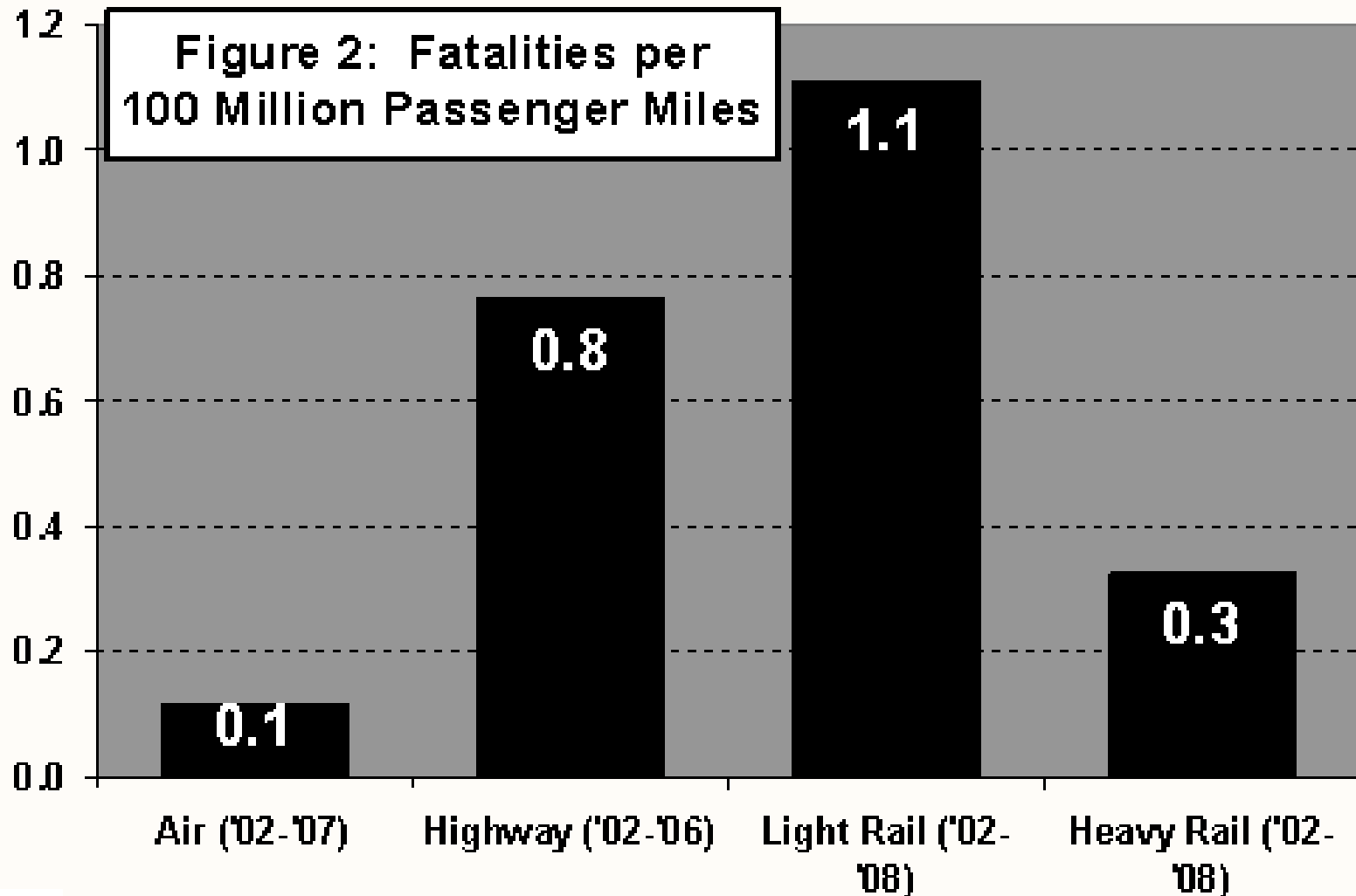
- Bureau of Transportation Statistics and FTA data generally indicate that US travel is relatively safe no matter what the mode

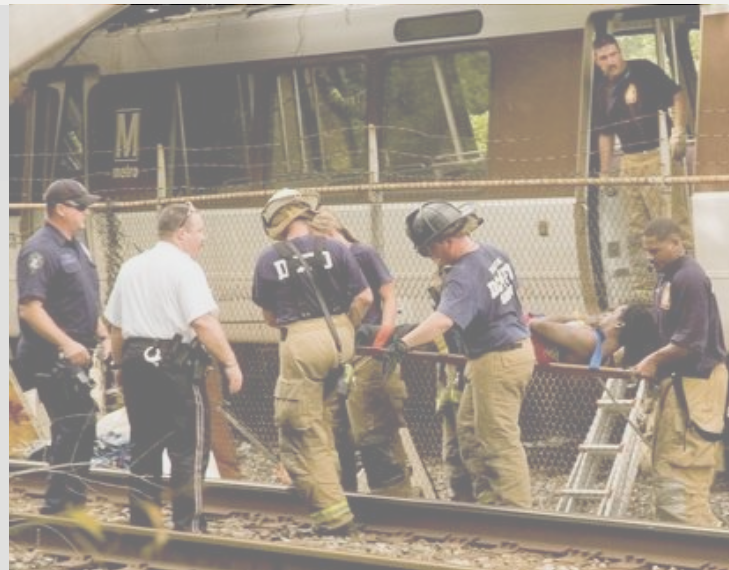
- Statistics for all modes include

- Operators
- Passengers
- Pedestrians
- Trespassers
- Suicides and
- Other Bystanders



# How safe is rail transit compared to other modes?





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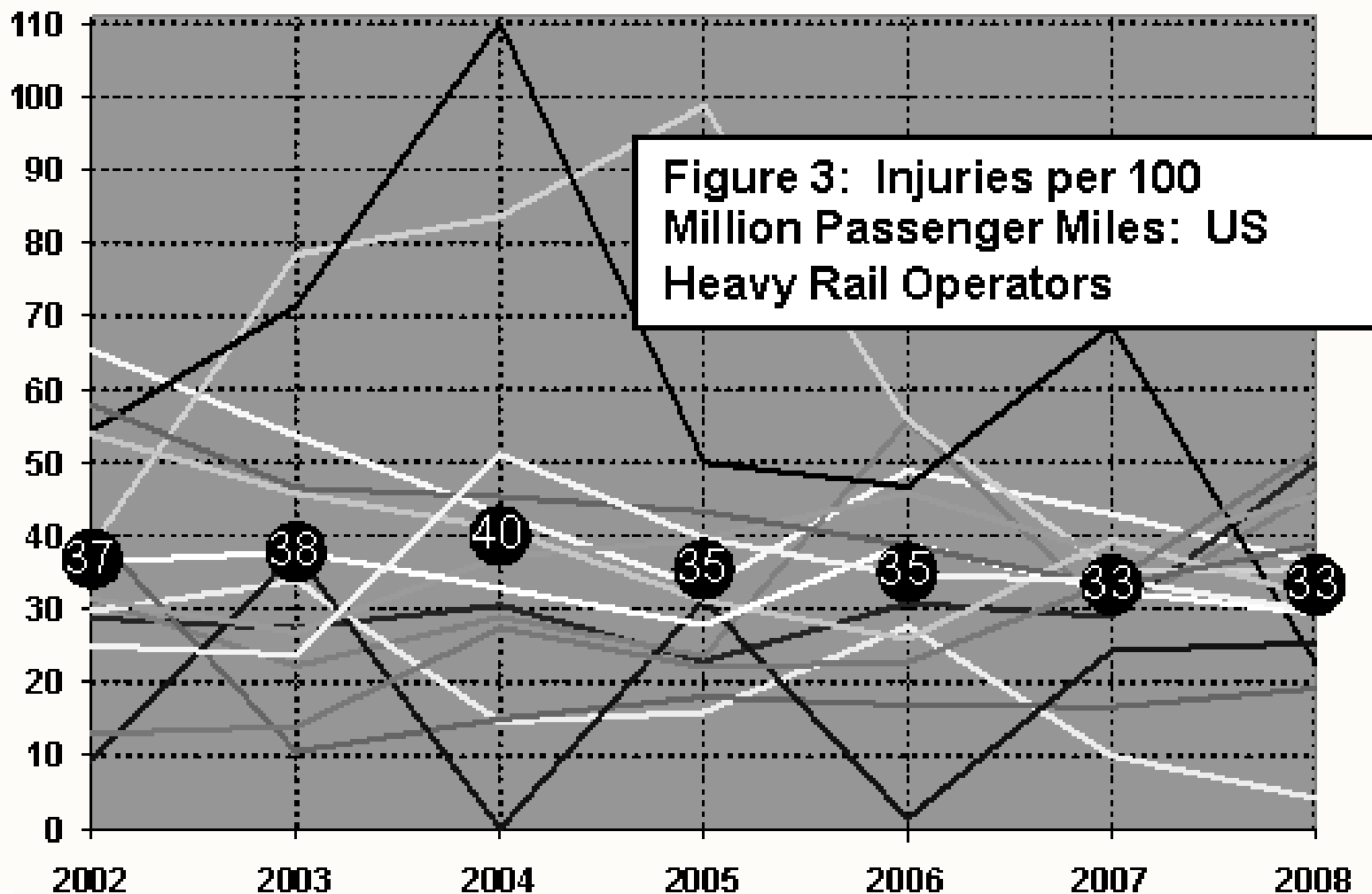
# A dispassionate statistical approach

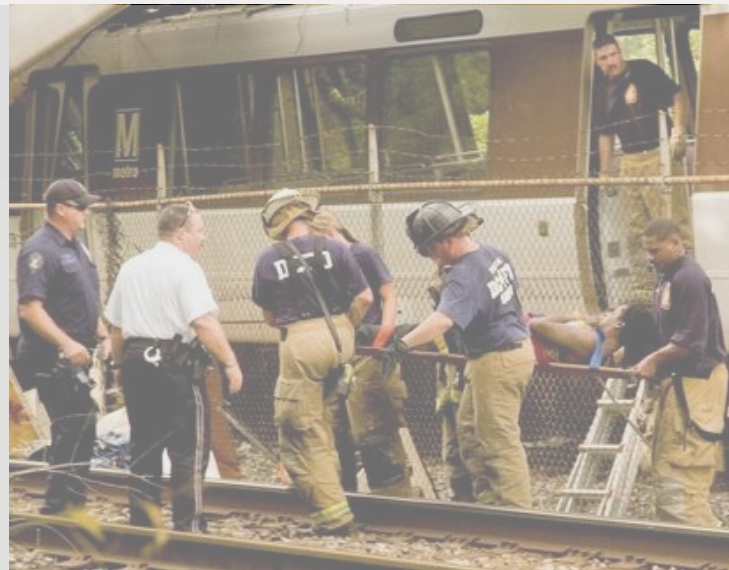
- Incidents (accidents), injuries and fatalities in rail transit are statistically uncommon events
- Actuarial sciences and the art of underwriting treat accidents as essentially random events occurring within a historical distribution of probabilities



# Injury rates vary substantially from year to year

## But are there **SIGNIFICANT LONG TERM DIFFERENCES**?





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# Data (2002-2008)

- FTA National Transit Database started collecting safety data in 2002
- Assume seven years data reflect true long term averages
- Considered only the largest and oldest systems
  - 14 heavy rail systems
  - 17 light rail systems
  - Smallest & newest light rail operations were excluded





# Data Definitions

- **Incidents** – include collisions, derailments, fires, and all other reportable incidents, such as slips and falls, electric shocks
- **Injuries** – include any physical damage or harm to persons as a result of an incident that requires immediate medical attention away from the scene
- **Fatalities** – include any death or suicide confirmed within 30 days of a reported incident. It does not include deaths in or on transit property that are a result of illness or other natural causes



# Heavy Rail Safety Summary

<b>TABLE 1. Heavy Rail Accidents 2002-2008</b>	<b>Incidents</b>	<b>Injuries</b>	<b>Fatalities</b>
Chicago Transit Authority	3,098	2,588	40
Greater Cleveland Regional Transit Authority	105	96	4
Los Angeles County Metropolitan Transportation Authority	492	425	10
Maryland Transit Administration	82	84	1
Massachusetts Bay Transportation Authority	2,264	1,761	18
Metropolitan Atlanta Rapid Transit Authority	1,394	1,347	6
Miami-Dade Transit	380	332	13
MTA New York City Transit	27,494	19,211	174
MTA Staten Island Railway	116	110	4
Port Authority Trans-Hudson Corporation	789	391	0
Port Authority Transit Corporation	209	196	3
San Francisco Bay Area Rapid Transit District	3,928	3,836	25
Southeastern Pennsylvania Transportation Authority	2,142	1,647	11
Washington Metropolitan Area Transit Authority	2,346	2,057	28
<b>Total</b>	<b>44,839</b>	<b>34,081</b>	<b>337</b>
<b>Annual Average</b>	<b>6,406</b>	<b>4,869</b>	<b>48</b>



# Light Rail Safety Summary

<b>TABLE 2. Light Rail Accidents 2002-2008</b>	<b>Incidents</b>	<b>Injuries</b>	<b>Fatalities</b>
Bi-State Development Agency	244	239	1
Dallas Area Rapid Transit	134	124	9
Denver Regional Transportation District	43	42	2
Greater Cleveland Regional Transit Authority	92	55	2
Los Angeles County Metropolitan Transportation Authority	592	474	34
Maryland Transit Administration	54	67	3
Massachusetts Bay Transportation Authority	1,044	751	2
New Jersey Transit Corporation	8	7	1
Niagara Frontier Transportation Authority	162	159	1
Port Authority of Allegheny County	96	51	1
Sacramento Regional Transit District	136	93	9
San Diego Metropolitan Transit System	75	70	13
San Francisco Municipal Railway	600	536	10
Santa Clara Valley Transportation Authority	48	32	8
Southeastern Pennsylvania Transportation Authority	3,483	1,453	10
Tri-County Metropolitan Transportation District	202	188	5
Utah Transit Authority	158	109	8
<b>Total</b>	<b>7,171</b>	<b>4,450</b>	<b>119</b>
<b>Annual Average</b>	<b>1,024</b>	<b>636</b>	<b>17</b>



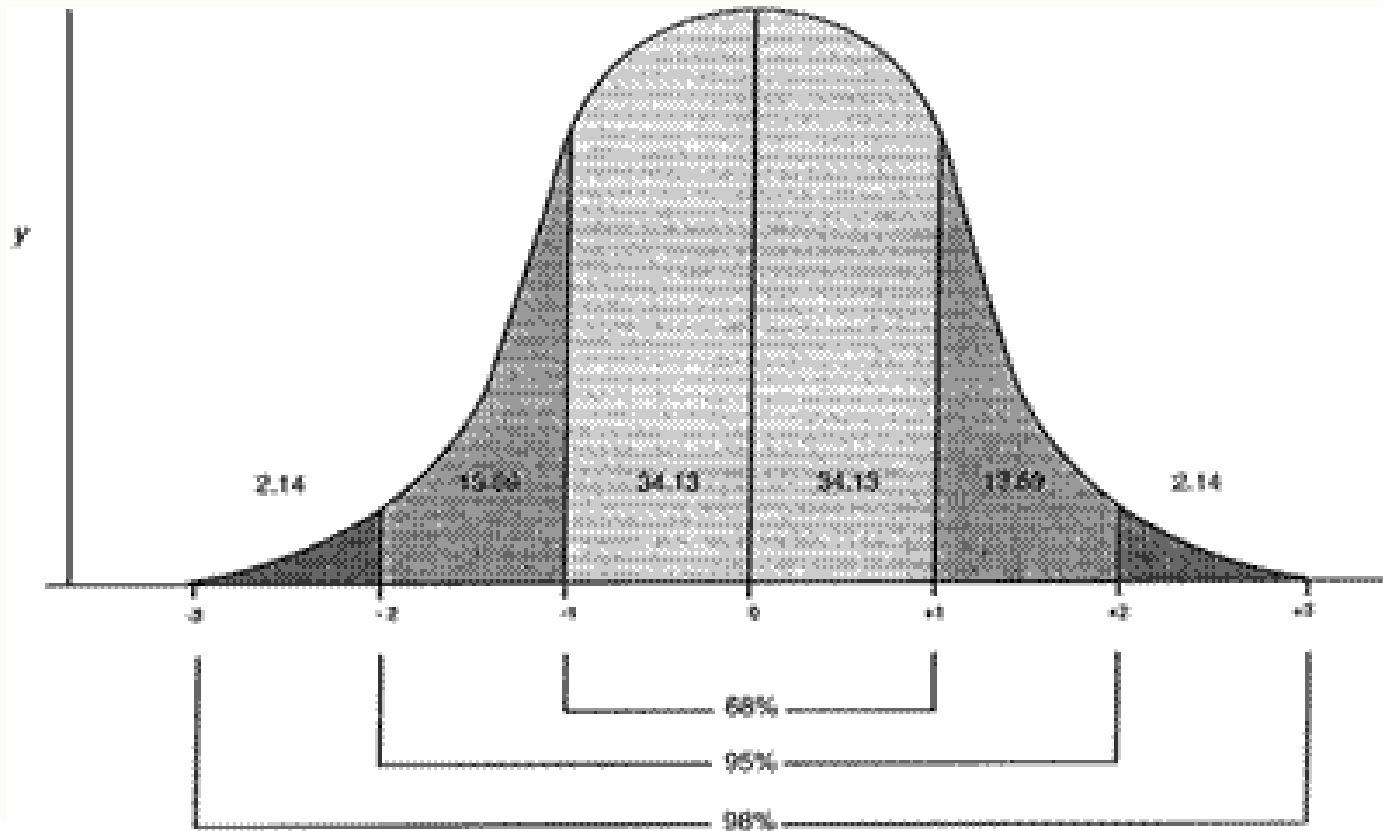
# Methodology

- Safety Indicators
  - Incidents
  - Injuries
  - Fatalities
- Normalization
  - Controls for size of system
  - Larger agencies have more accidents
- Normalization factors
  - Unlinked Passenger Trips (UPT)
  - Passenger Miles Traveled (PMT)

*Considered normalizing on vehicle miles and route miles but found inconsistencies in the data*



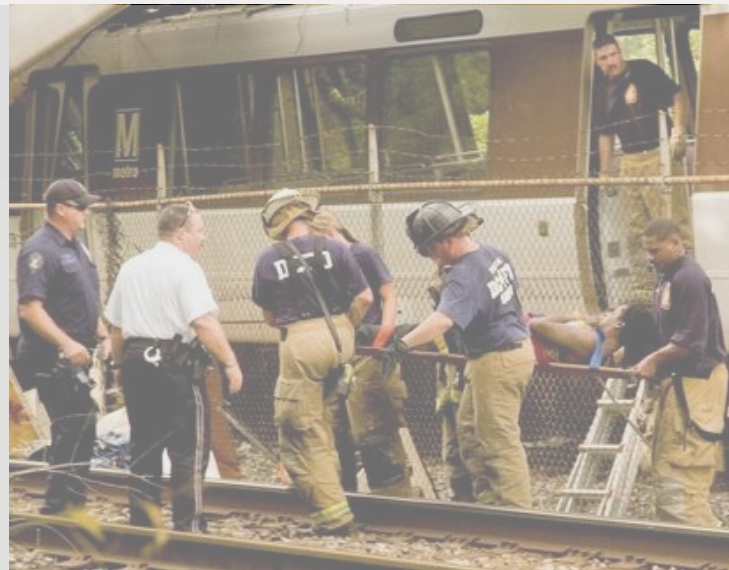
# Law of Large Numbers & Normal Distribution



Inferential statistics rely on the *Law of Large Numbers* and the known properties of the *Normal Distribution* to test whether variability in sample data reflects random processes or systematic differences

# Statistical Assumptions

- Incident rates are normally distributed across all transit agencies
- A two-sided Student t-distribution used to determine the statistical significance of the six metrics
- For heavy rail with 13 degrees of freedom the 99% confidence interval has a threshold of  $\alpha = 3.0123$ .
- For light rail with 16 degrees of freedom the 99% confidence interval has a threshold of  $\alpha = 2.9208$ .
- When  $t\text{-stat} \leq \alpha$  or  $t\text{-stat} \geq \alpha$ , the t-statistic is considered to be statistically significant.
- **The null hypothesis supposes there is no significant difference in accident rates among US heavy rail and light rail properties.**



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# Heavy Rail

14 Properties

6,406 Incidents

4,869 Injuries

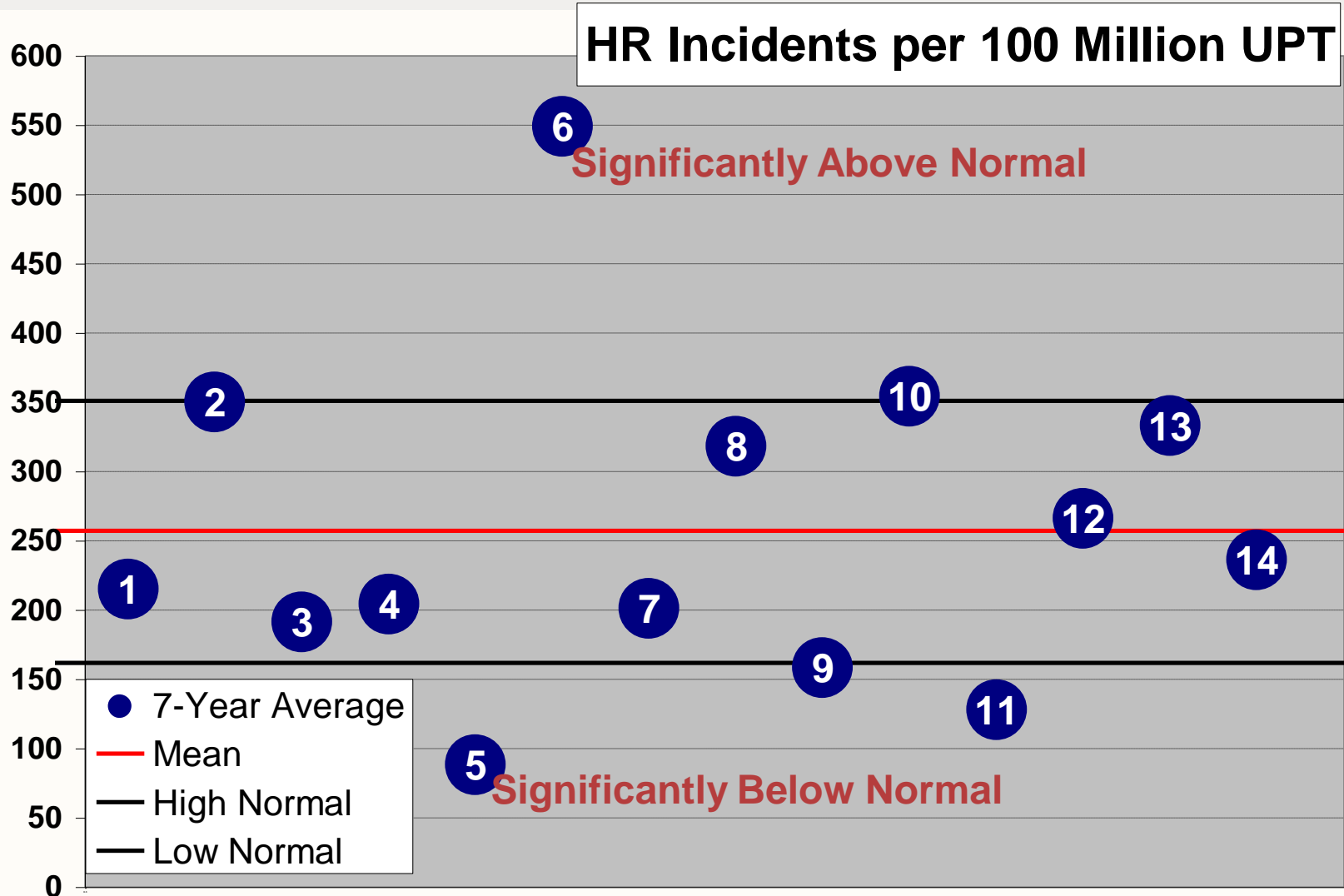
48 Fatalities





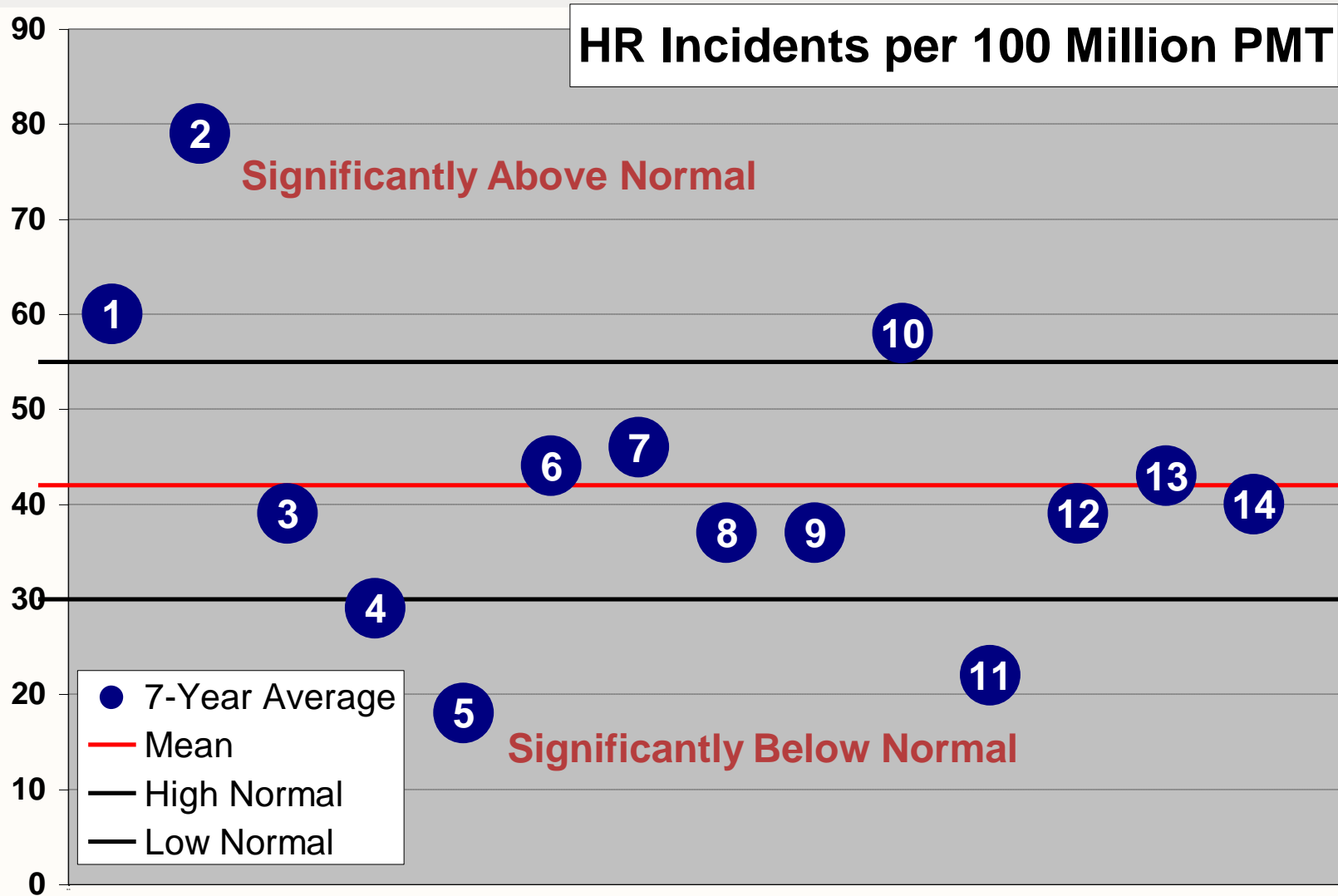
# Heavy Rail: Incidents per Passenger Trip

36% Outside Normal Range



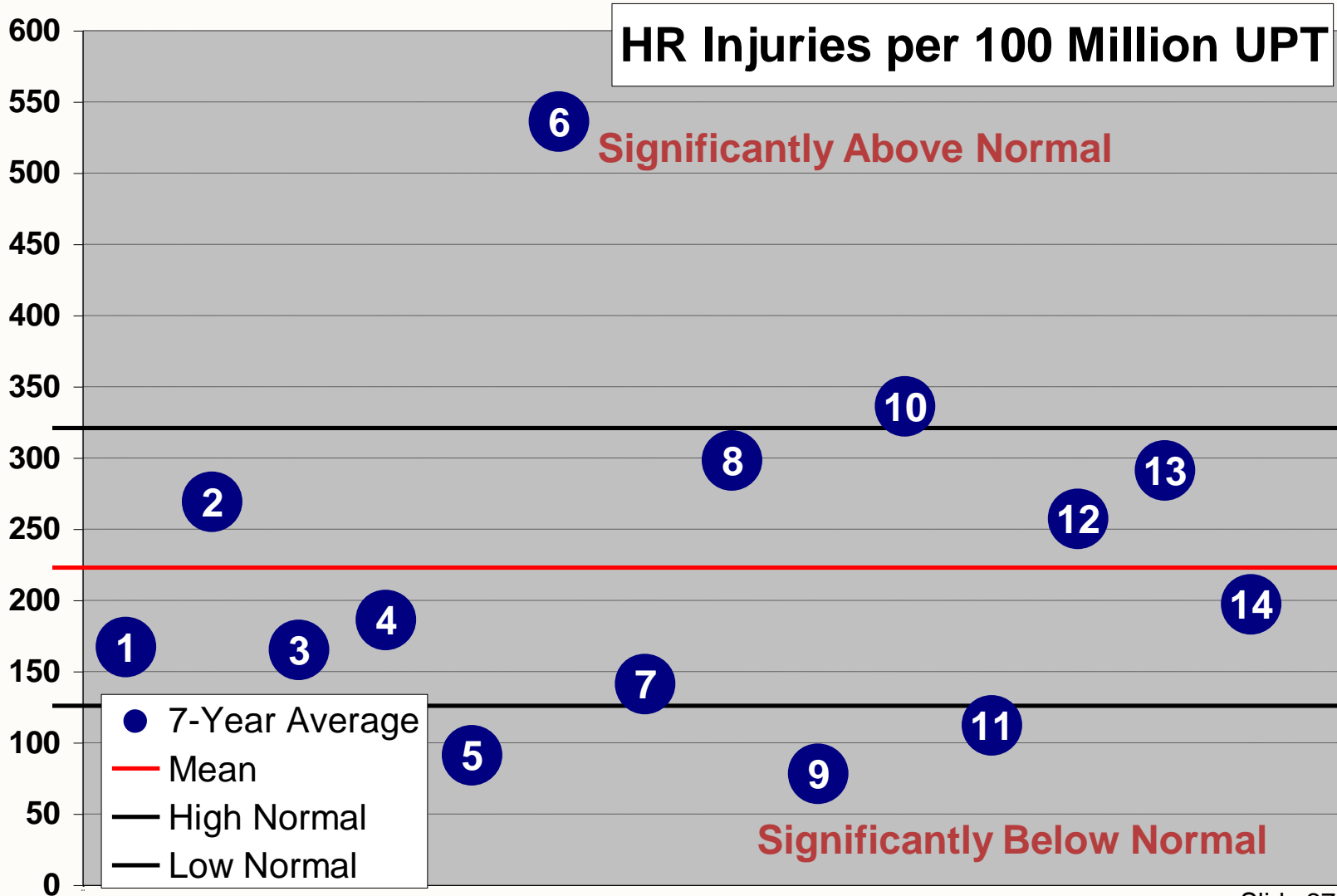
# Heavy Rail: Incidents per Passenger Mile

43% Outside Normal Range



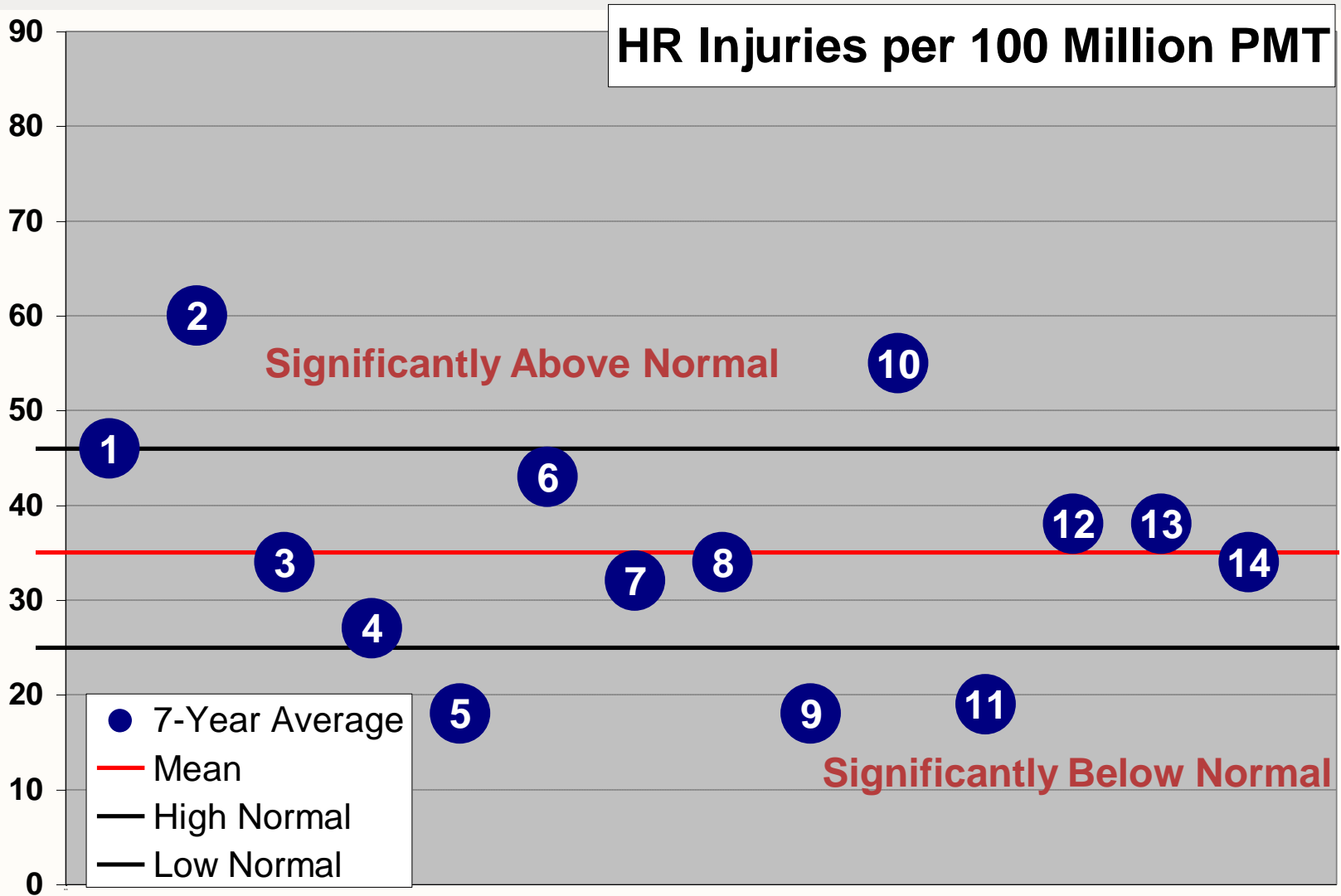
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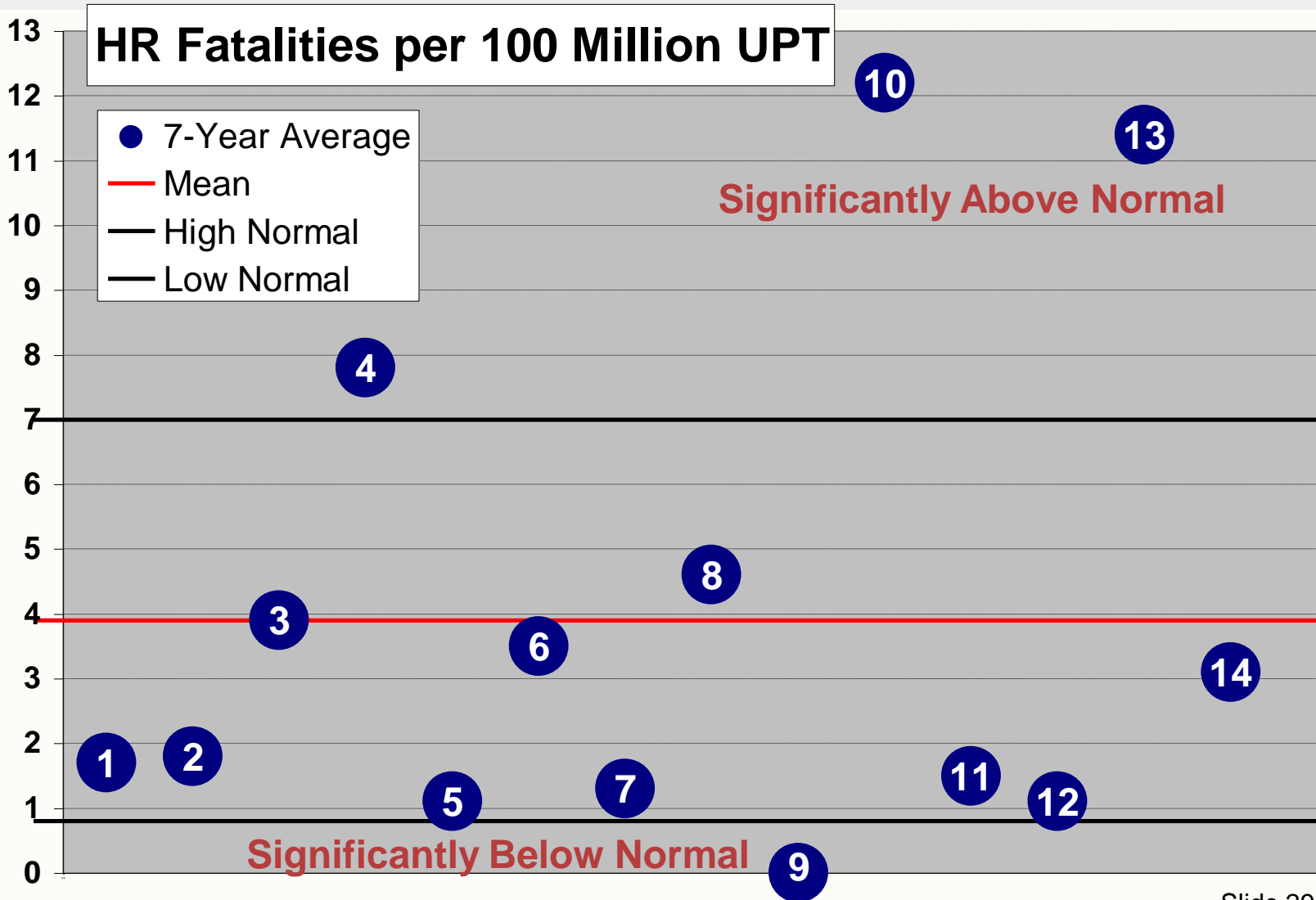
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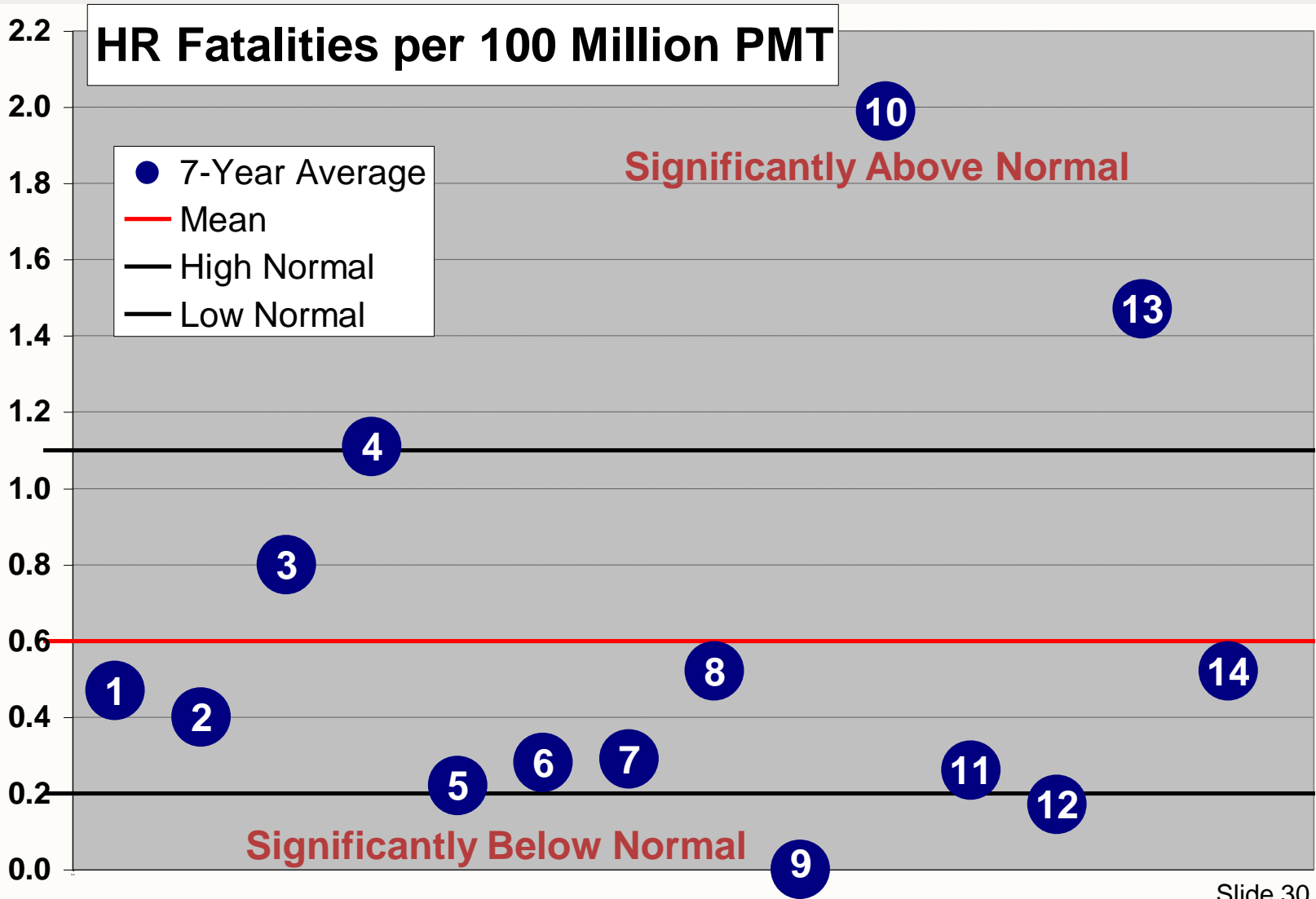
# Heavy Rail: Fatalities per Passenger Trip

29% Outside Normal Range



# Heavy Rail: Fatalities per Passenger Mile

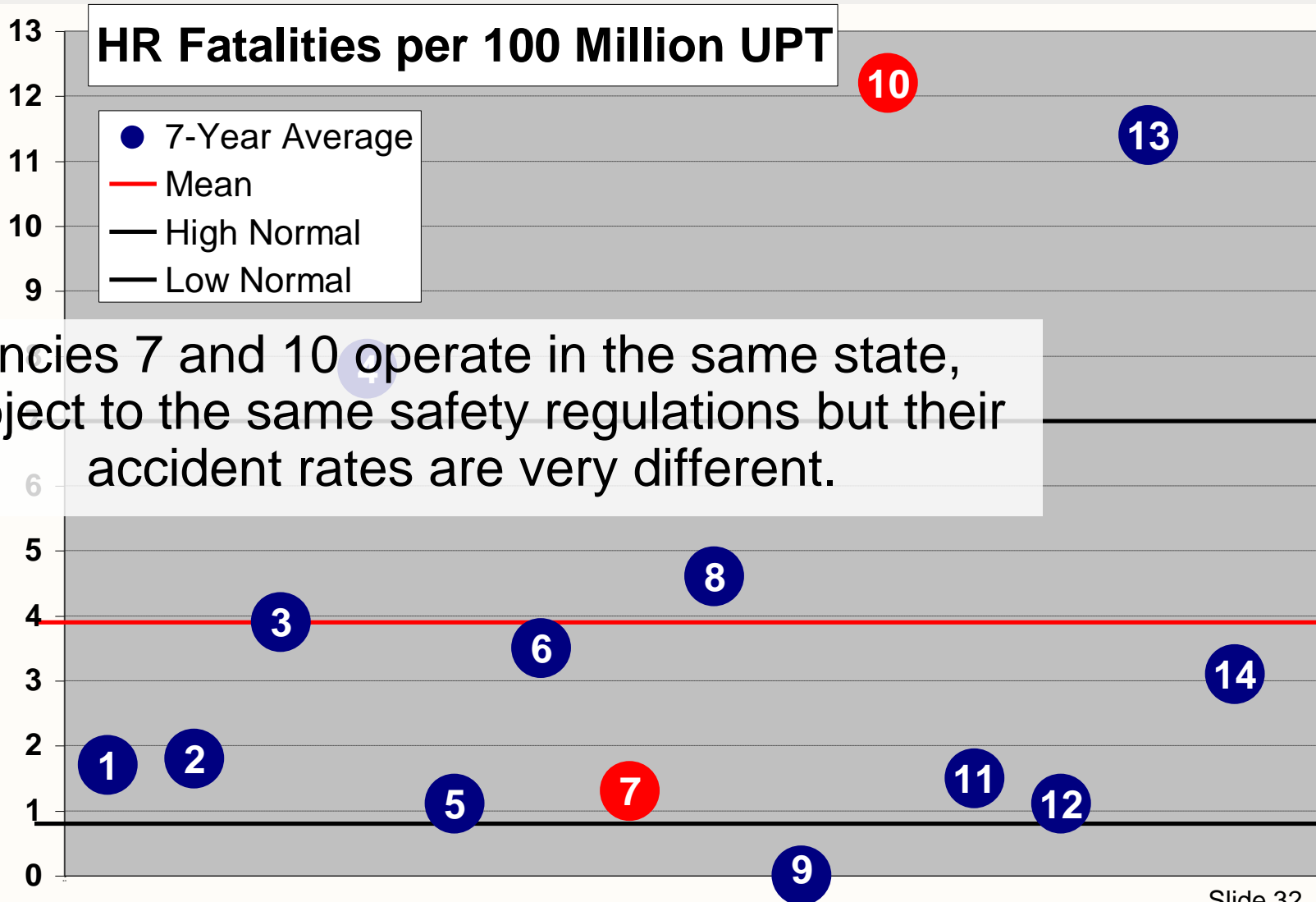
29% Outside Normal Range



# Heavy Rail: Discussion

- The findings support the assertion that safety is **NOT** equivalent across all US heavy rail operations
- More than a third of the reported accident rates are statistically too low or too high to be considered normal assuming all heavy rail transit agencies are equally safe
- It is not clear why there are significant disparities
  - Differences in safety culture?
  - Differences in management precautions?
  - Differences in operating environment?

# Heavy Rail: Anomalies



Agencies 7 and 10 operate in the same state, subject to the same safety regulations but their accident rates are very different.

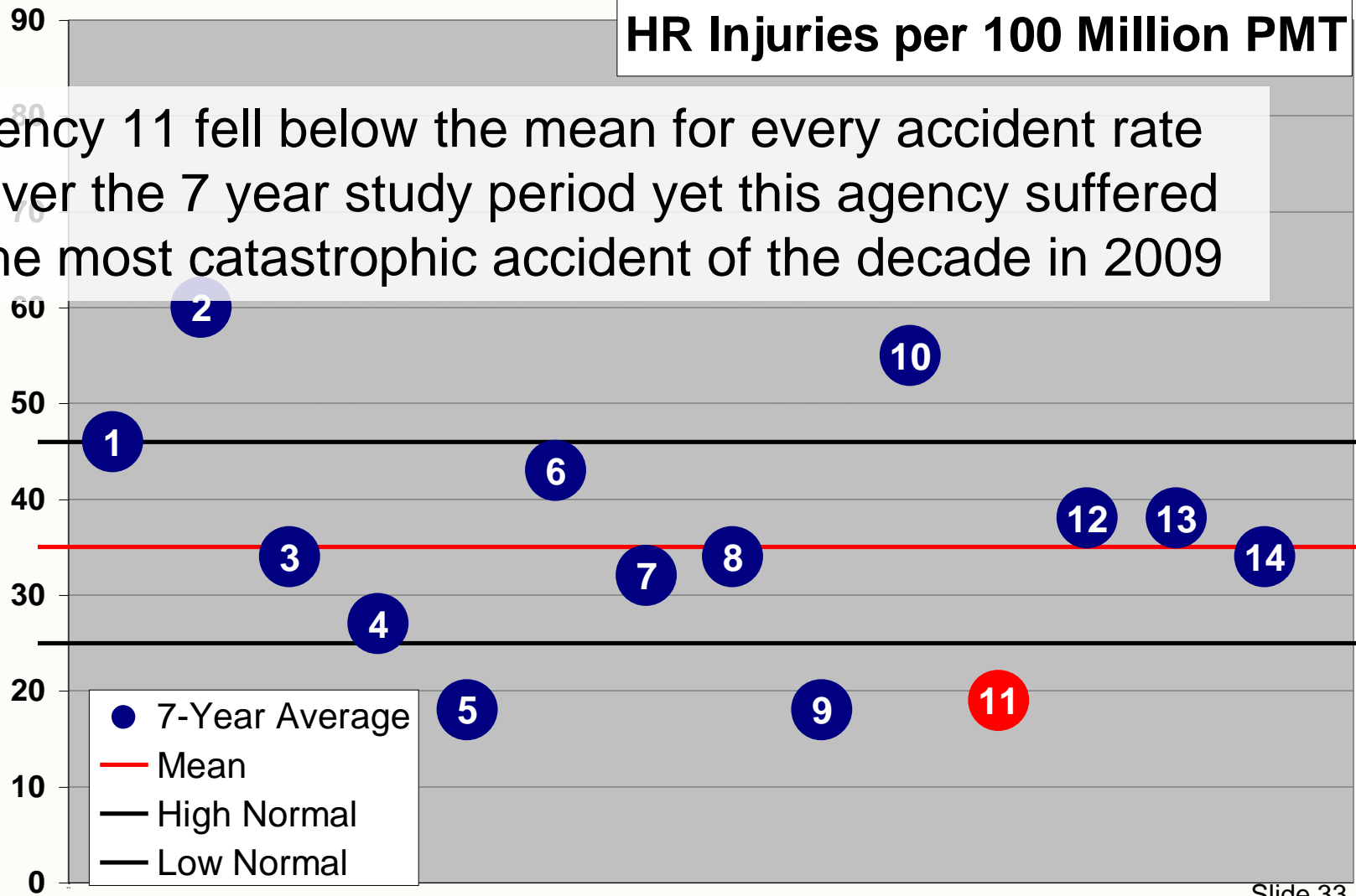




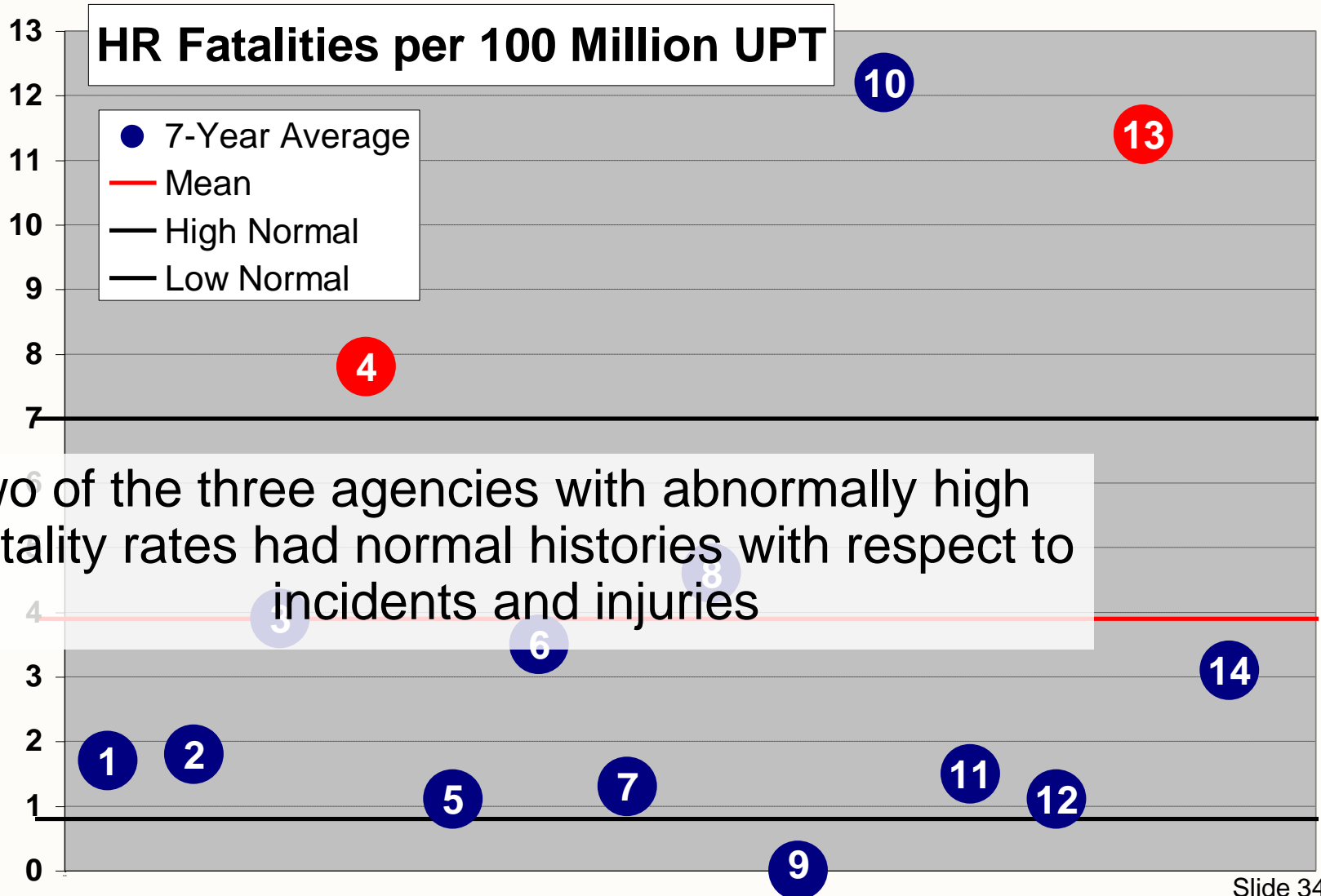
# Heavy Rail: Anomalies

HR Injuries per 100 Million PMT

Agency 11 fell below the mean for every accident rate over the 7 year study period yet this agency suffered the most catastrophic accident of the decade in 2009



# Heavy Rail: Anomalies



Two of the three agencies with abnormally high fatality rates had normal histories with respect to incidents and injuries



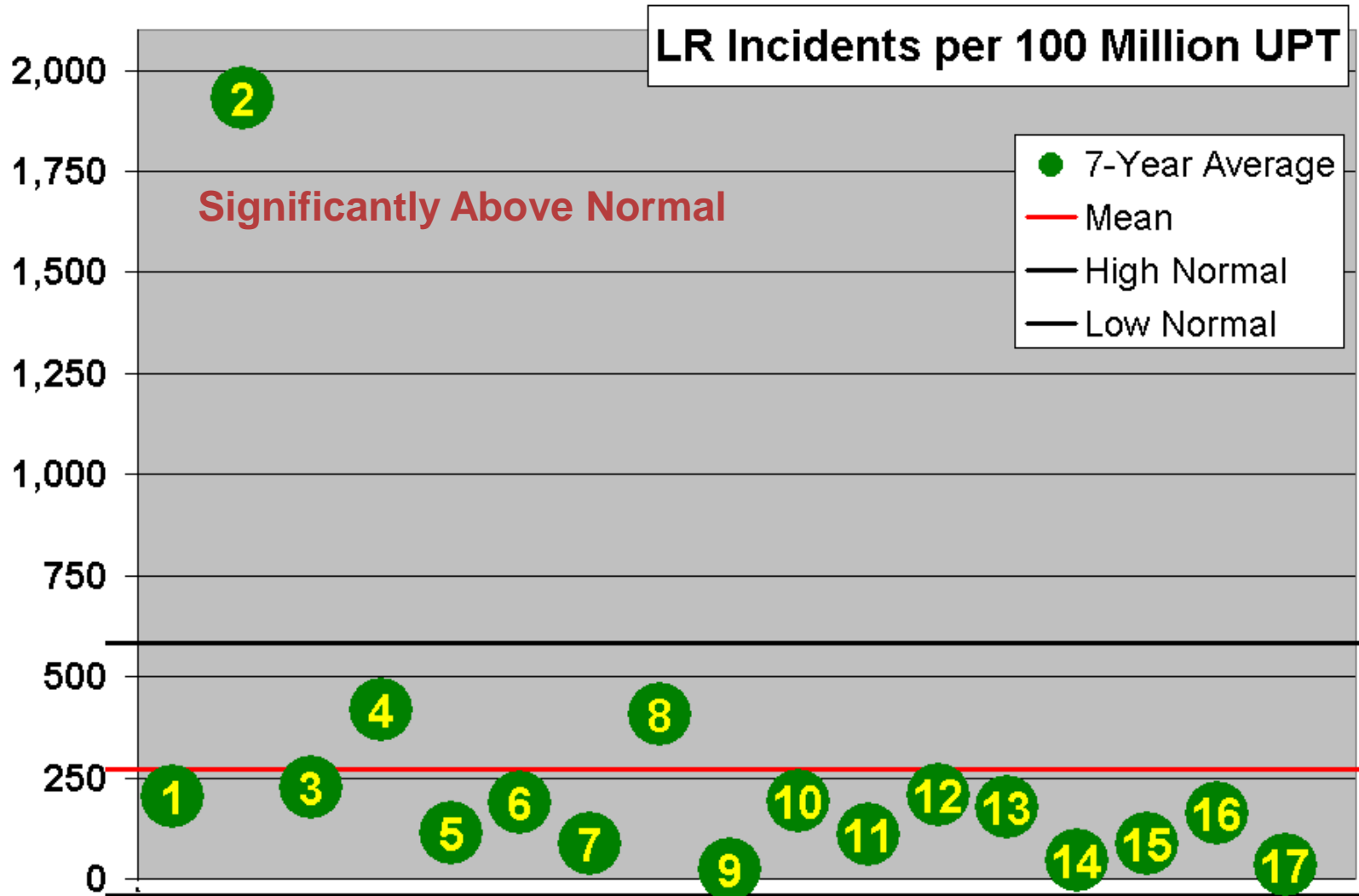
# Light Rail

17 Properties  
7,171 Incidents  
4,450 Injuries  
119 Fatalities



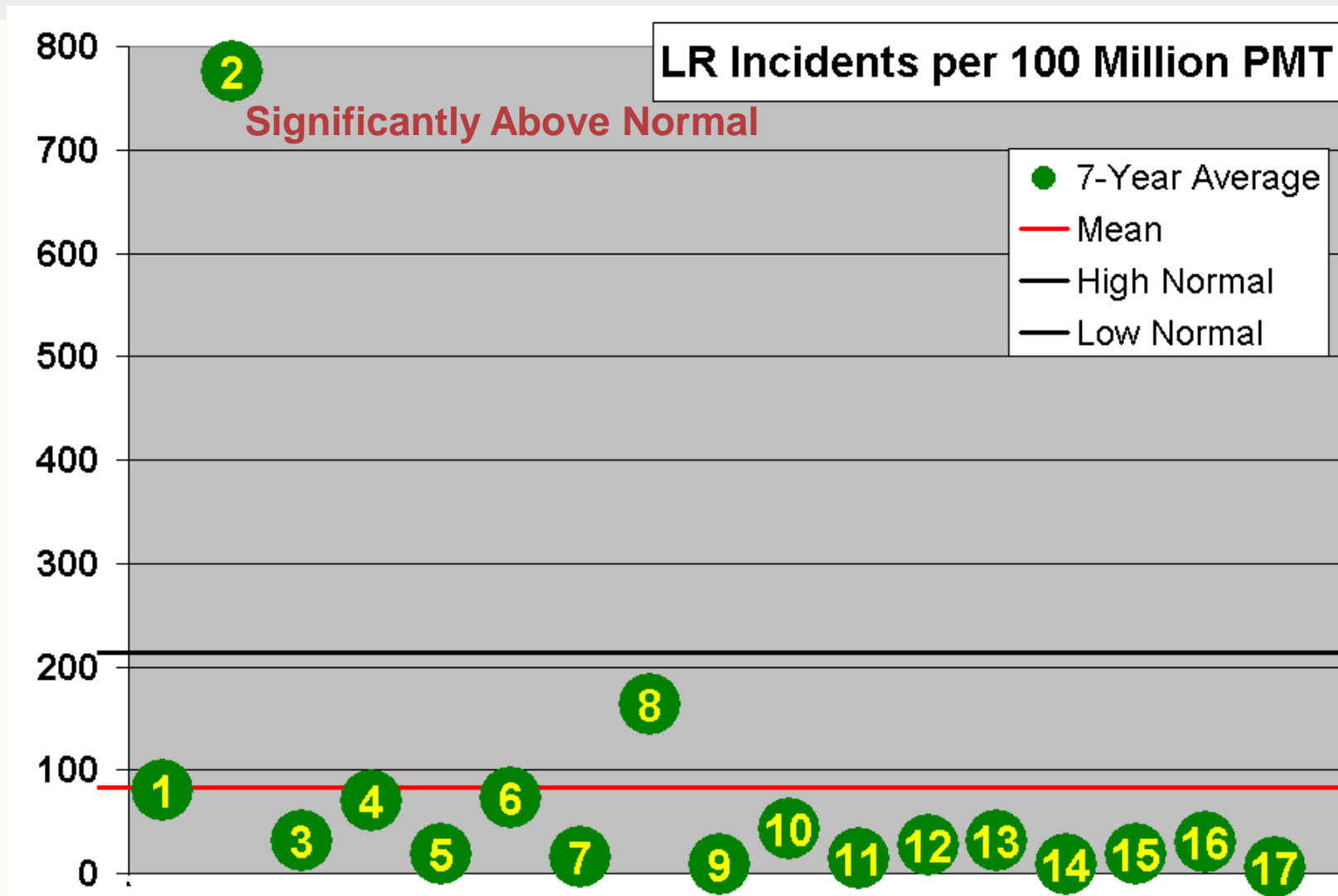
# Light Rail: Incidents per Passenger Trip

Only 6% Outside Normal Range



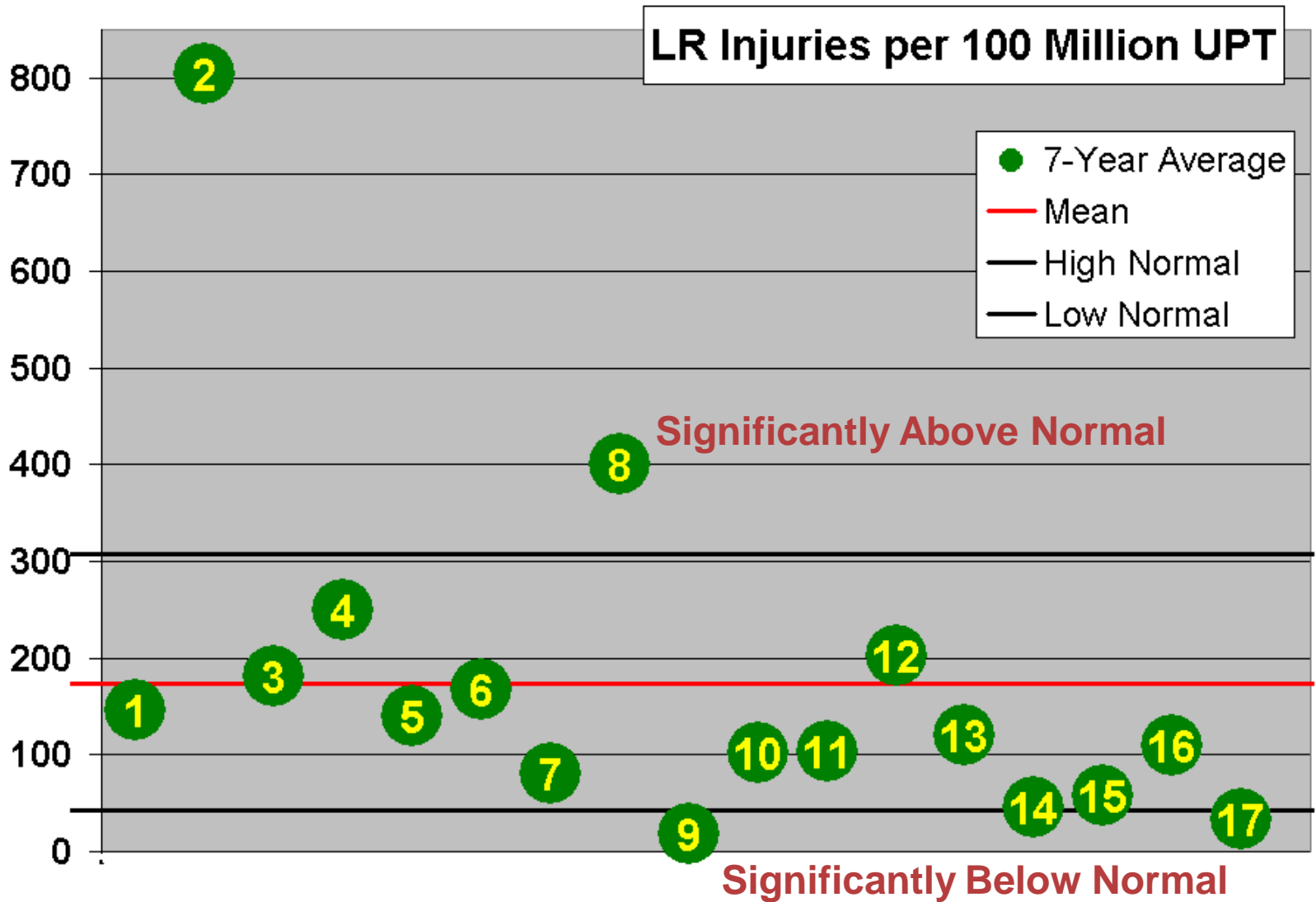
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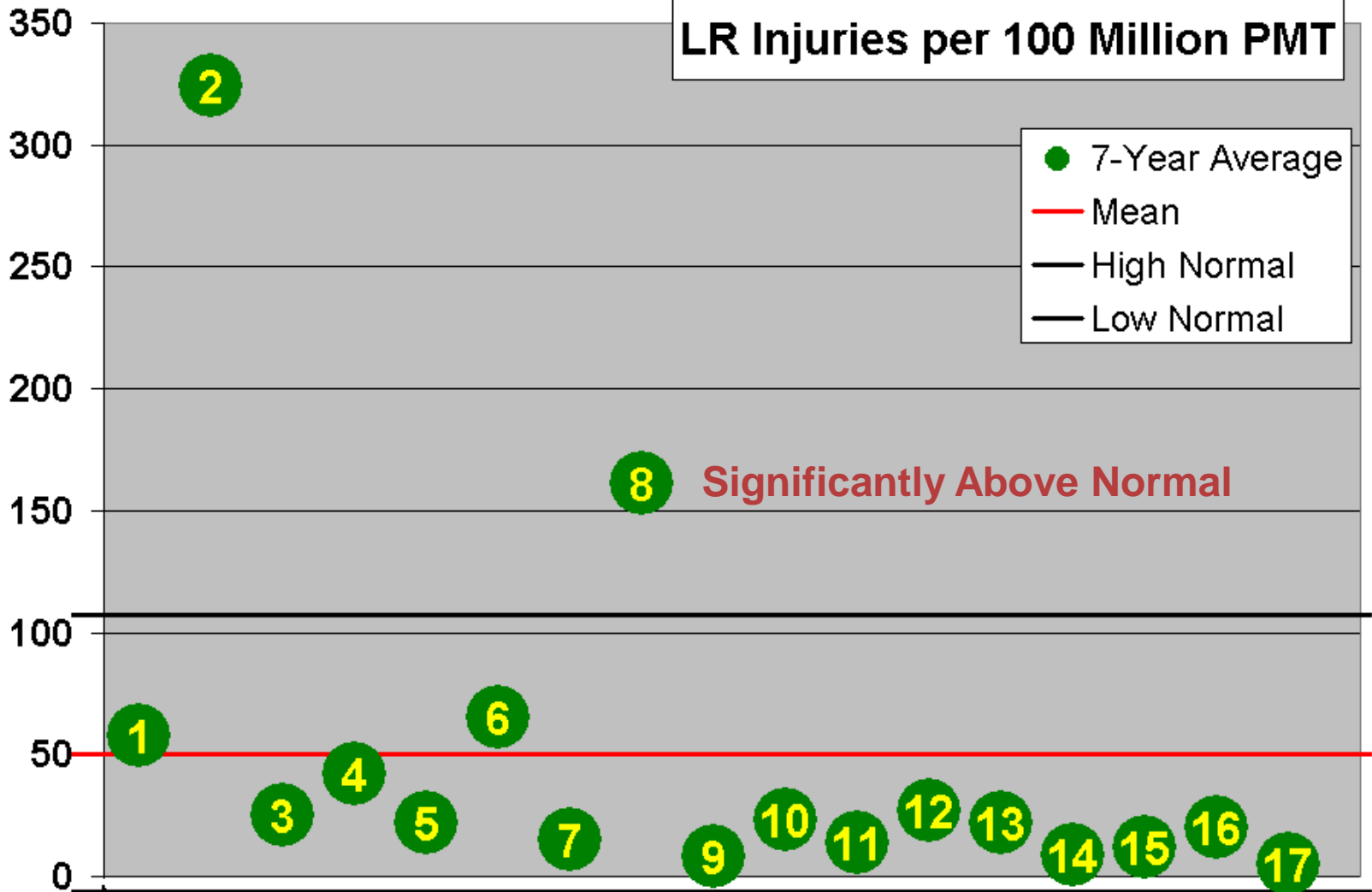
# Light Rail: Injuries per Passenger Trip

24% Outside Normal Range



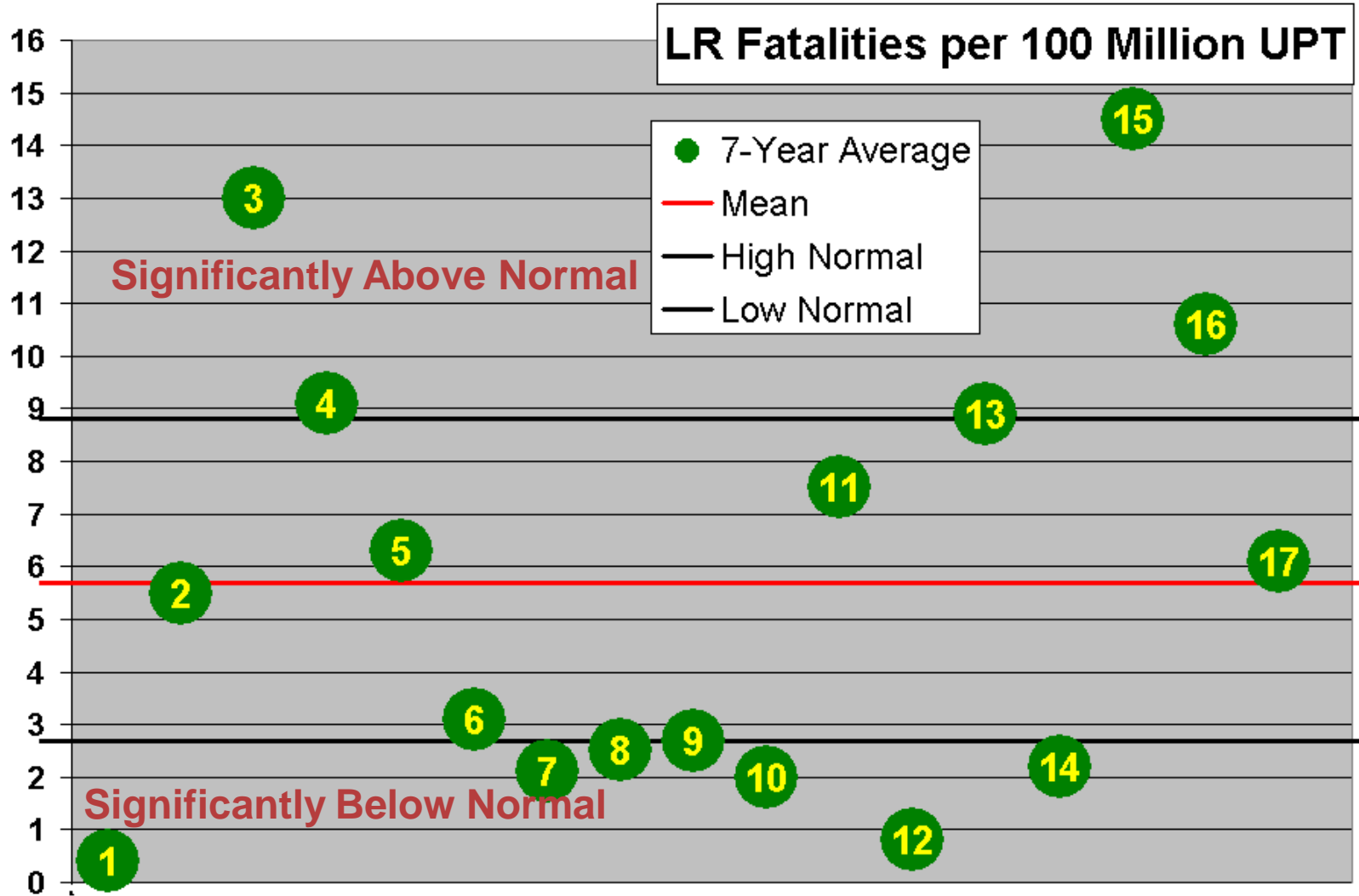
# Light Rail: Injuries per Passenger Mile

12% Outside Normal Range



# Light Rail: Fatalities per Passenger Trip

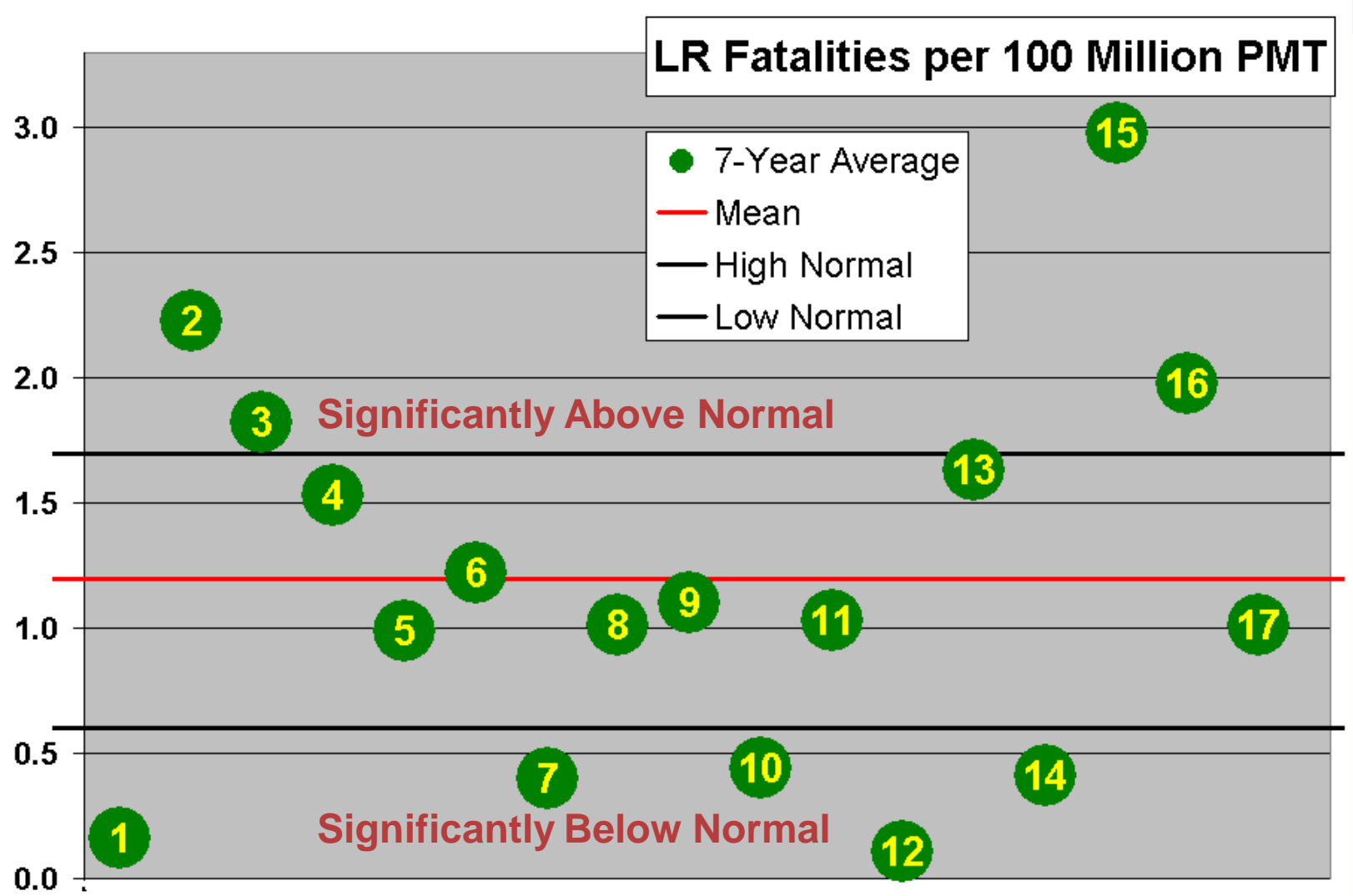
71% Outside Normal Range





# Light Rail: Fatalities per Passenger Mile

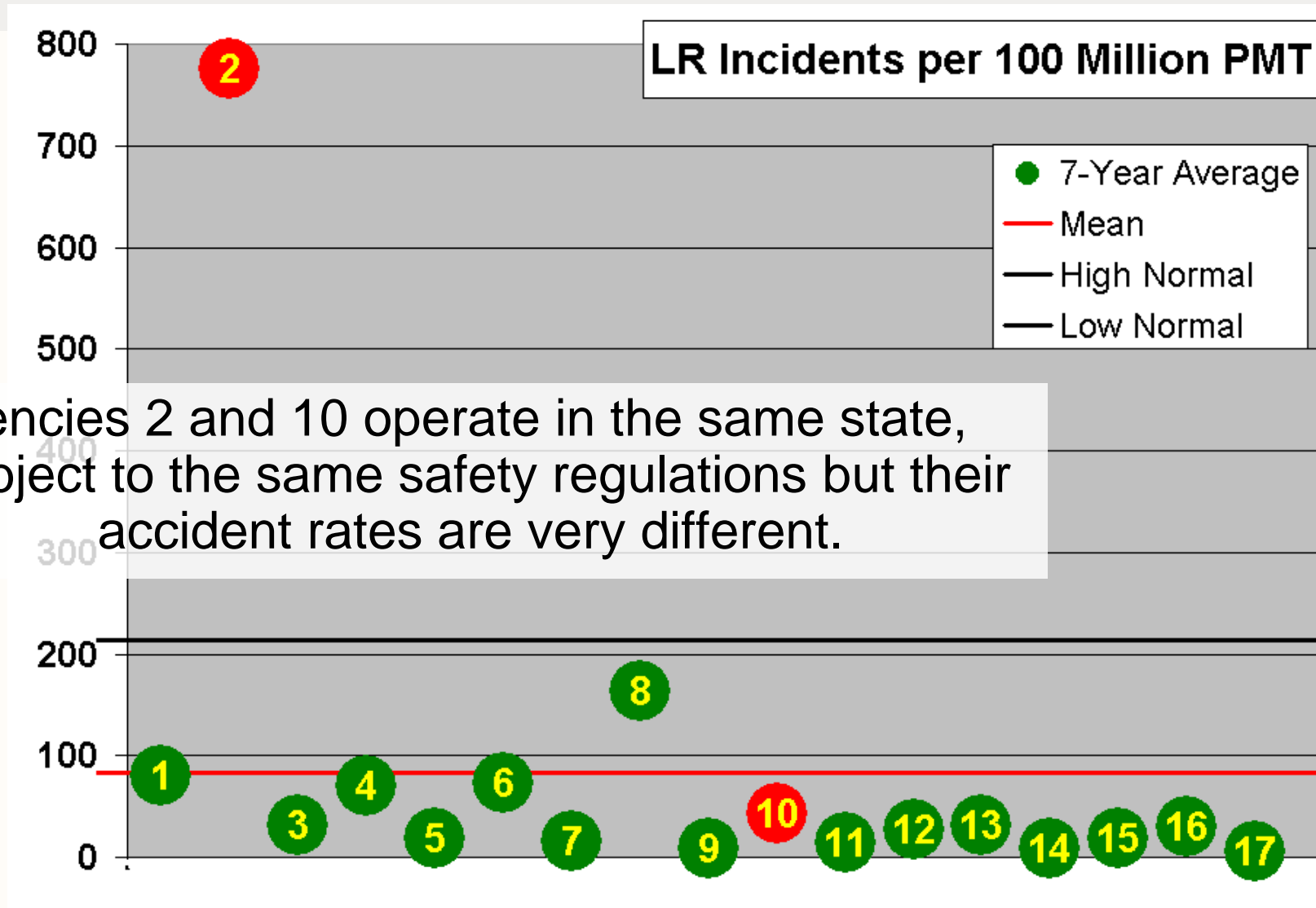
53% Outside Normal Range



# Light Rail: Discussion

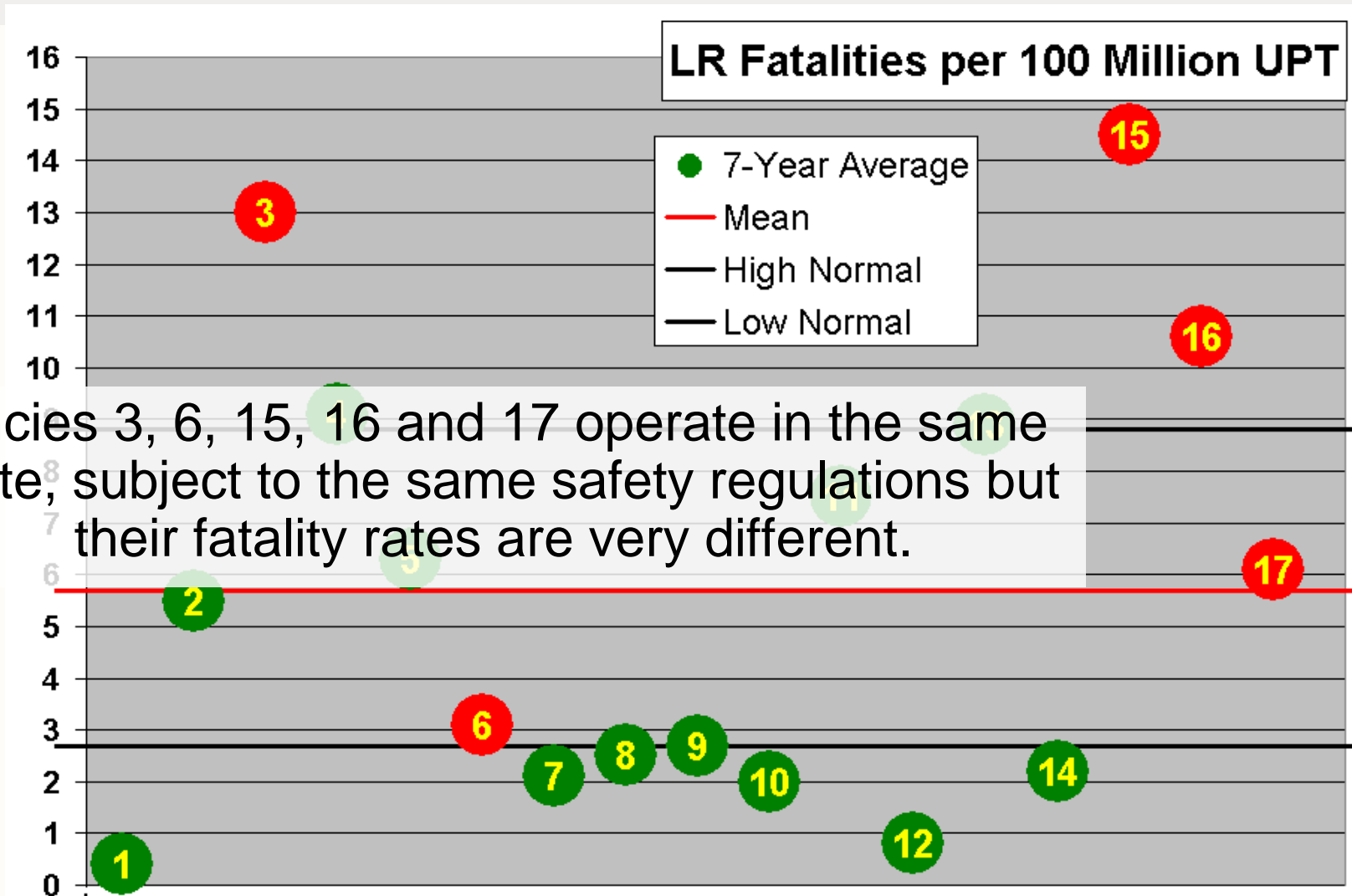
- The findings support the assertion that safety is **NOT** equivalent across all US light rail operations
- Almost one-third of the reported rates are too low or too high to be considered “normal”
- Unlike heavy rail, the array has some very obvious outliers
- Negative lower bound brings assumption of normal distribution into question
- It is not clear why there are significant disparities
  - Differences in safety culture?
  - Differences in management precautions?
  - Differences in operating environment?

# Light Rail: Anomalies



Agencies 2 and 10 operate in the same state, subject to the same safety regulations but their accident rates are very different.

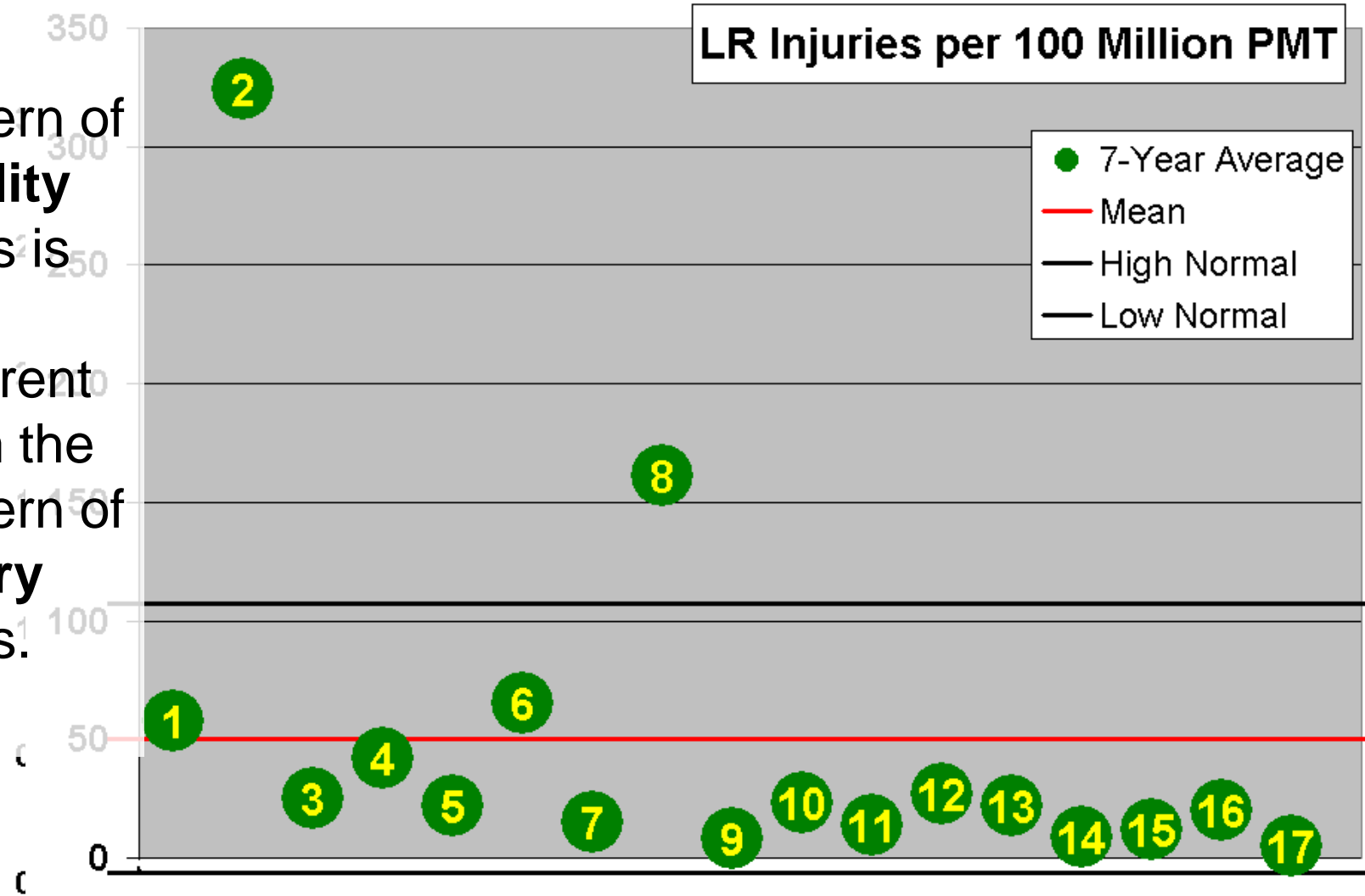
# Light Rail: Anomalies

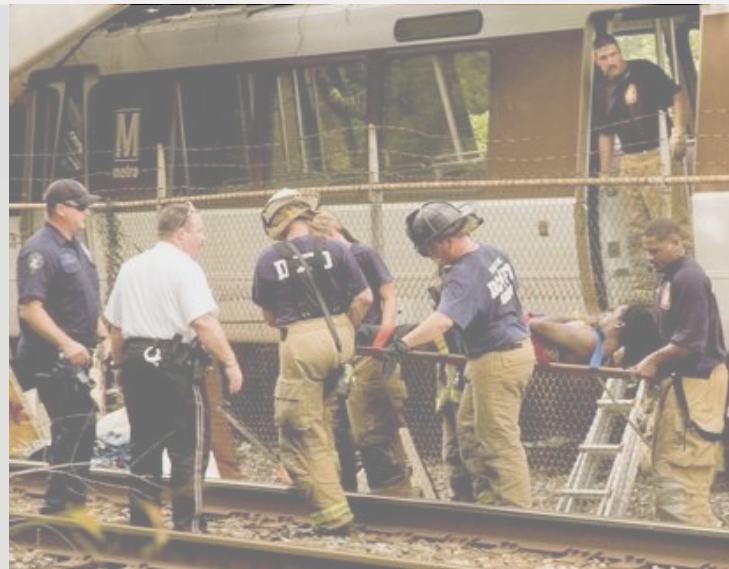


Agencies 3, 6, 15, 16 and 17 operate in the same state, subject to the same safety regulations but their fatality rates are very different.

# Light Rail: Anomalies

- The pattern of fatality rates is very different from the pattern of injury rates.





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# Concerning Fatality Rates

Incident and injury rates are poor predictors of fatalities

Heavy Rail Correlation Matrix	Per Unlinked Passenger Trip		
	Incidents	Injuries	Fatalities
Incidents per Unlinked Passenger Trip	1.00		
Injuries per Unlinked Passenger Trip	<b>0.98</b>	1.00	
Fatalities per Unlinked Passenger Trip	<b>0.39</b>	<b>0.43</b>	1.00
	Per Passenger Mile		
	Incidents	Injuries	Fatalities
Incidents per Passenger Mile	1.00		
Injuries per Passenger Mile	<b>0.91</b>	1.00	
Fatalities per Passenger Mile	<b>0.22</b>	<b>0.40</b>	1.00



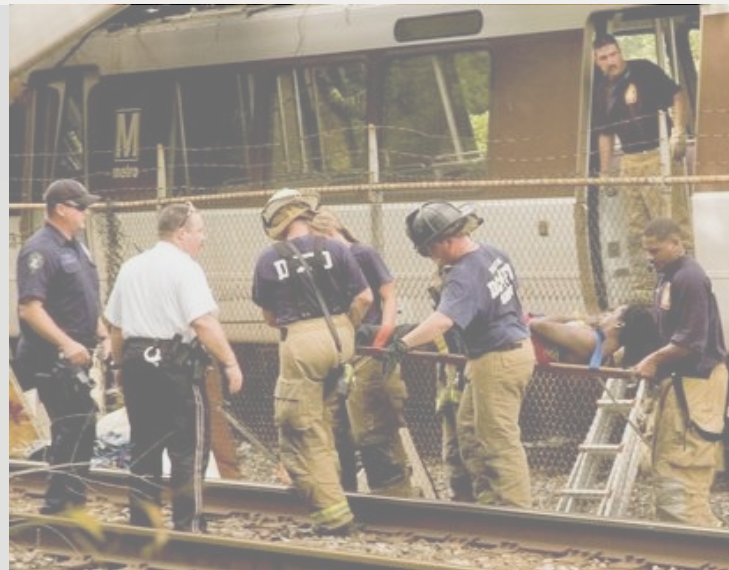
# Concerning Fatality Rates

No statistical relationship was found between fatality rates and other measures of safety

Light Rail Correlation Matrix	Per Unlinked Passenger Trip		
	Incidents	Injuries	Fatalities
Incidents per Unlinked Passenger Trip	1.00		
Injuries per Unlinked Passenger Trip	<b>0.96</b>	1.00	
Fatalities per Unlinked Passenger Trip	<b>0.00</b>	<b>0.05</b>	1.00
	Per Passenger Mile		
	Incidents	Injuries	Fatalities
Incidents per Passenger Mile	1.00		
Injuries per Passenger Mile	<b>0.93</b>	1.00	
Fatalities per Passenger Mile	<b>0.10</b>	<b>0.07</b>	1.00







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# Conclusions

1. Travel on US rail transit systems, especially heavy rail is generally very safe.
2. The analysis found a statistically significant record of inconsistent safety among US rail transit agencies.
3. It is not clear why there are significant disparities among transit agencies
4. However, the data **do not** appear to support that disparities reflect a *“patchwork of state agencies with inconsistent standards, inadequate powers and insufficient staffing.”*
5. Incident and injury rates are statistically poor predictors of fatality rates. Rail transit fatalities seem so infrequent that existing data on incidents and injuries doesn't help predict fatalities.



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