The Economics of Transportation Safety

Ian Savage
<table>
<thead>
<tr>
<th>Decade</th>
<th>Events</th>
</tr>
</thead>
</table>
| 1950s   | PhD Harvard, 1952<br>Harvard Economic Research project
          | Northwestern University, 1959<br>Input-Output Analysis<br>Transportation and industrial location |
| 1960s   |                                                                       |
| 1970s   |                                                                       |
| 1980s   |                                                                       |
| 1990s   |                                                                       |
| 2000s   |                                                                       |
# Leon N. Moses 1924-2013

<table>
<thead>
<tr>
<th>Decade</th>
<th>Events</th>
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| 1950s      | PhD Harvard, 1952  
Harvard Economic Research project  
Northwestern University, 1959  
Input-Output Analysis  
Transportation and industrial location |
| 1960s      | NUTC Director of Research 1960-64  
Urban and regional economics  
Inland waterways study 65-70 |
<p>| 1970s      |                                                                                         |
| 1980s      |                                                                                         |
| 1990s      |                                                                                         |
| 2000s      |                                                                                         |</p>
<table>
<thead>
<tr>
<th>Decade</th>
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<tbody>
<tr>
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<td>Inland waterways study 65-70</td>
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<td>1970s</td>
<td>Chair, Dept of Economics 1970-72</td>
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<td></td>
<td>President, Regional Science Assoc, 1972</td>
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<tr>
<td></td>
<td>NUTC Director 1974-79</td>
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<tr>
<td></td>
<td>Urban area structure</td>
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<tr>
<td></td>
<td>Production in time and space</td>
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<tr>
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<td>5 deregulation conferences</td>
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<tr>
<td>1980s</td>
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<td>1990s</td>
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<td>Activity</td>
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<tr>
<td>1980s</td>
<td>Deregulation and safety</td>
</tr>
<tr>
<td>1990s</td>
<td>HazMat transportation, Truck safety</td>
</tr>
<tr>
<td>2000s</td>
<td>Retires, 2005</td>
</tr>
</tbody>
</table>
"The risks of bodily harm are not unreasonable when consumers understand that risks exist, can appraise their probability and severity, know how to cope with them and voluntarily accept them to get benefits that could not be obtained in less risky ways“

Corwin D. Edwards
National Commission on Product Safety
Part 1

What are the risks?
Clean up your language

Accidents  Crashes

Incidents
Magnitude of the risk

- Transportation related fatalities are 1 in every 56 deaths in the United States (average over period 2000-2009)
- But are 38% of all “unintentional injury deaths”
- Equivalent to the sum of the 2nd and 3rd most prevalent causes (falls and poisonings)
- Over the 2000-09 decade annual average fatalities were 43,239
43,239
Average Annual Total
2000-2009
43,239
Average Annual Total
2000-2009

36,927 (85.4%)
Private transportation only

6,312 (14.6%)
Commercial transportation
## Passenger fatalities per billion passenger miles 2000-09

<table>
<thead>
<tr>
<th>Mode of Travel</th>
<th>Fatalities per Billion Passenger Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riding a motorcycle</td>
<td>212.57</td>
</tr>
<tr>
<td>Driving or passenger in car and light truck</td>
<td>7.28</td>
</tr>
<tr>
<td>Passenger on a local ferry boat</td>
<td>3.17</td>
</tr>
<tr>
<td>Passenger on commuter rail and Amtrak</td>
<td>0.43</td>
</tr>
<tr>
<td>Passenger on urban mass transit rail</td>
<td>0.24</td>
</tr>
<tr>
<td>Passenger on a bus (holding more than 10 passengers – transit, intercity, school, charter)</td>
<td>0.11</td>
</tr>
<tr>
<td>Passenger on commercial aviation</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Highway fatalities per vehicle mile (index with 1975=100)
Railroad collisions and derailments per train mile (index with 1975=100)
Commercial aviation passenger fatalities per million enplanements (with 5yr m.a.)
Economists have limited comparative advantage in analyzing these crashes.
1. 55% of occupant-fatalities in single-vehicle crashes
2. 30% of occupant-fatalities are passengers
3. 10% of fatalities are motorcyclists
4. Third of fatal crashes involve alcohol
5. Elevated risk for men in general (3 X), and those under the age of 24 (2 X)
6. Human frailties such as inattention, cognitive overload and poor judgment abound
43,239
Average Annual Total 2000-2009

36,927 (85.4%)
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43,239 Average Annual Total 2000-2009

36,927 (85.4%) Private transportation only

6,312 (14.6%) Commercial transportation

5,244 (12.1%) Private transportation users

“Externalities” and “Bilateral crashes” dominate
43,239
Average Annual Total 2000-2009

36,927 (85.4%)
Private transportation only

6,312 (14.6%)
Commercial transportation

5,244 (12.1%)
Private transportation users

874 (2%)
Employees
## Rates per 1,000 Employees 2009

<table>
<thead>
<tr>
<th>Industry</th>
<th>Fatality</th>
<th>Non-fatal Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing</td>
<td>8.81</td>
<td>15</td>
</tr>
<tr>
<td>Agriculture</td>
<td>0.76</td>
<td>53</td>
</tr>
<tr>
<td>Taxi and limousine</td>
<td>0.62</td>
<td>37</td>
</tr>
<tr>
<td>Truck transportation</td>
<td>0.29</td>
<td>57</td>
</tr>
<tr>
<td>Water transportation</td>
<td>0.24</td>
<td>33</td>
</tr>
<tr>
<td>Construction</td>
<td>0.12</td>
<td>47</td>
</tr>
<tr>
<td>Pipeline transportation</td>
<td>0.10</td>
<td>15</td>
</tr>
<tr>
<td>Rail transportation</td>
<td>0.06</td>
<td>23</td>
</tr>
<tr>
<td>Air transportation</td>
<td>0.06</td>
<td>71</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.03</td>
<td>31</td>
</tr>
<tr>
<td>Bus transportation</td>
<td>0.03</td>
<td>33-48</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.03</td>
<td>50</td>
</tr>
</tbody>
</table>
43,239
Average Annual Total 2000-2009

36,927 (85.4%)
Private transportation only

6,312 (14.6%)
Commercial transportation

5,244 (12.1%)
Private transportation users

874 (2%)
Employees

175 (0.4%)
Passengers
Part 2

How much safety?, or
How safe is “safe enough”?
Perfect safety  
"crash will never occur"

No safety  
"crash certain to occur"

$ per trip
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Prevention cost: $ per trip
Air New Zealand Flight 901, November 28, 1979
Chief Inspector of air accidents blamed the pilots
Chief Inspector of air accidents blamed the pilots

Royal Commission of Inquiry by Justice Peter Mahon accusing Air NZ management of a cover-up and conspiracy and "an orchestrated litany of lies"
James T. Reason

- Professor of Psychology, University of Manchester
“Swiss cheese theory”
Perfect safety
"crash will never occur"

No safety
"crash certain to occur"

Prevention cost

Suggests to me that the nature of this relationship is far from clear
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

Prevention cost

$ per trip

Crash costs & legal payments

Perfect safety
“crash will never occur”
Perfect safety

"crash will never occur"

No safety

"crash certain to occur"

Prevention cost

Crash costs & legal payments

$ per trip
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

Expected cost

Prevention cost

Crash costs & legal payments

$ per trip
Perfect safety: “crash will never occur”

No safety: “crash certain to occur”

Crash costs & legal payments

Expected cost

Prevention cost

$ per trip

$^{\text{min}}$
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Prevention cost

Crash costs & legal payments

$ per trip

Expected cost

Range of feasible production

$^{min}$

Perfect safety: "crash will never occur"

"crash certain to occur"
Benchmark model of consumers

- Many consumers
- Each buys at most one unit of travel per period of time
- Net value of non-safety attributes of transportation relative to next best consumption option varies across consumers (gives a downward sloping demand curve and a buy / don’t buy decision)
Consumers’ valuation of safety

- \( S = \) safety probability where \( 0 \leq S \leq 1 \)
  - \( 0 = \) crash certain to occur
  - \( 1 = \) crash will never occur
Consumers’ valuation of safety

• $S =$ safety probability where $0 \leq S \leq 1$
  ▪ $0 =$ crash certain to occur
  ▪ $1 =$ crash will never occur

• $\theta_i S =$ value of safety attribute by consumer $i$
Consumers’ valuation of safety

- $S =$ safety probability where $0 \leq S \leq 1$
  - $0 =$ crash certain to occur
  - $1 =$ crash will never occur
- $\theta_i S =$ value of safety attribute by consumer $i$
- $\theta_i > 0$ – everyone agrees more safety is better than less safety
- But some consumers value it more than others
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$
Valuation ($\theta_i$)

We don’t know the range or distribution of $\theta_i$

- For passengers (excepting some measure of central tendency – Value of a Statistical Life)
- Or for freight
Benchmark model

- Obtain a marginal cost of safety
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Crash costs & legal payments $ per trip

Range of feasible production

Expected cost

Prevention cost $^{\text{min}}$

Perfect safety: "crash will never occur"
$S_{\min}$

Perfect safety

“crash will never occur”
Safety Smin

Perfect safety
“crash will never occur”
Benchmark model

- Obtain a marginal cost of safety
- Benchmark model has price competed downward to marginal cost
Benchmark model

- Obtain a marginal cost of safety
- Benchmark model has price competed downward to marginal cost
- Consumers will purchase more safety until their $\theta_i$ just equals the “marginal price” of the increment of safety
$\theta_a$

$S_{\min}$

Perfect safety
“crash will never occur”

MC(S)
mc(S) - Safety

$S_{\text{min}}$

$\theta_a$

Perfect safety: "crash will never occur"
Perfect safety
"crash will never occur"
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$

Safety ($S$)

$1$ – perfect safety

$S_{\text{min}}$

$0$ – no safety
Valuation ($\theta_i$)

$\theta^H$

assuming $P=MC$

Safety ($S$)

$S^H$

$S^L$

$S_{\text{min}}$

Range of demand

$1$ – perfect safety

$0$ – no safety
Distribution of consumers

Frequency

Safety

$S^L$  $S^H$
In a functioning competitive market carriers position themselves to satisfy consumer tastes
In a functioning competitive market carriers position themselves to satisfy consumer tastes.

**Graph**: 
- **Horizontal Axis**: Safety 
- **Vertical Axis**: Frequency 
- **Points**:
  - $S^L$ 
  - $S^H$ 

**Truckload trucking**: “Shippers get what they want at the price they want”
Imperfect competition

• In many modes “economies of density” limit the number of competitors
Imperfect competition

• In many modes “economies of density” limit the number of competitors
• “Lumpy” supply means that many passengers and also shippers with varied tastes have to share the same vehicle/train/plane/ship
Imperfect competition

• In many modes “economies of density” limit the number of competitors
• “Lumpy” supply means that many passengers and also shippers with varied tastes have to share the same vehicle/train/plane/ship
• Implies limited safety choices – “one size fits all”
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$

safety differentiation to blunt price competition

Carrier 1 (higher safety & higher price)

Carrier 2
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$

Carrier 1

Carrier 2
Valuation ($\theta_i$)

$\theta^H$

Carrier 1

Carrier 2

Not consume

perhaps
Implications

• Consumers may rationally choose less than perfect safety
Implications

• Consumers may rationally choose less than perfect safety

• Higher-safety and lower-safety options may optimally co-exist
Implications

• Consumers may rationally choose less than perfect safety
• Higher-safety and lower-safety options may optimally co-exist
• Diversity of safety offerings may be a sign that the market works not a sign of market failure
Implications

• Consumers may rationally choose less than perfect safety
• Higher-safety and lower-safety options may optimally co-exist
• Diversity of safety offerings may be a sign that the market works not a sign of market failure
• Lower safety offerings reflect lower taste for safety by some shippers and passengers
How much safety?
How much safety? - who knows!

Limited knowledge on “production function” of safety

Know of only one paper to estimate this – for a monopoly railroad

Price = marginal cost not realistic for firms with large fixed costs

Limited knowledge on distribution of tastes for safety
Part 3

“Intolerable risk”
Valuation ($\theta_i$)

$\theta^H$  

assuming $P=MC$

$\theta^L$

Safety ($S$)

$1$ – perfect safety

$0$ – no safety

$S_{\min}$

Range of demand
Valuation ($\theta_i$)

$\theta^H$

assuming $P=MC$

Range of demand

Safety ($S$)

$S^{H}$

$S^{L}$

$S_{\text{min}}$

$1$ – perfect safety

$0$ – no safety
Valuation ($\theta_i$) assuming $P=MC$

Safety ($S$)

$1$ – perfect safety

$0$ – no safety

Range of demand

$\Theta^H$

$S^H$

$S^L$

$S_{\text{min}}$

$\Theta^L$
Valuation ($\theta_i$)

$\theta^H$

assuming $P=MC$

Range of demand

Safety $(S)$

$1$ – perfect safety

$0$ – no safety

$S^H$

$S^L$

$S_{min}$
Safety \( (S) \)

\[ S_{\min} \]

Valuation \( (\theta_i) \)

\[ \theta^H \]

\[ \theta^L \]

Range of demand

1 – perfect safety

0 – no safety

assumining \( P=MC \)

Low taste for safety

and/or

Low ability-to-pay for safety
Part 4

Deviations from the (unknown) optimal level(s)
Assumptions for ideal marketplace

- Many carriers and P=MC
Assumptions for ideal marketplace

- Many carriers and \( P=MC \)
- Consumers are fully informed
- Consumers can make rational choices
Valuation ($\theta_i$)

Not consume

Presumes consumers can identify each firm’s safety offerings and act on it

Carrier 1

Carrier 2

perhaps
What if consumers were totally uninformed?
What if consumers were totally uninformed?

Valuation ($\theta_i$)

$\theta^H$

$\theta^L$

Carrier 1

Carrier 2

low price
What if consumers were totally uninformed?

Constrained if consumers can identify “notorious” carriers

But how and what do consumers learn?

How do carriers signal “high safety”?

Valuation ($\theta_i$)

Carrier 1

Carrier 2

low price
Much dispersion

- many carriers
- consumers have varied tastes
- consumers are not bundled together
- consumers are well informed
- “vertical differentiation”
<table>
<thead>
<tr>
<th>Much dispersion</th>
<th>Little dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>• many carriers</td>
<td>• few carriers</td>
</tr>
<tr>
<td>• consumers have varied tastes</td>
<td>• consumers have similar tastes</td>
</tr>
<tr>
<td>• consumers are not bundled together</td>
<td>• consumers bundled together – “one size fits all”</td>
</tr>
<tr>
<td>• consumers are well informed</td>
<td>• difficult to determine carriers’ safety or differentiate between them</td>
</tr>
<tr>
<td>• “vertical differentiation”</td>
<td></td>
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</tbody>
</table>
Assumptions for ideal marketplace

- Many carriers and P=MC
- Consumers are fully informed
- Consumers can make rational choices
- All third party effects internalized by carrier
  - Externalities
  - Bilateral crashes
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

Crash costs & legal payments

$ per trip

Expected cost

Range of feasible production

S_{\text{min}}

Prevention cost

Perfect safety
“crash will never occur”
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Prevention cost

Crash costs & legal payments

Expected cost

Range of feasible production

$ per trip

$^{\text{min}}$

Perfect safety: "crash will never occur"

"crash certain to occur"
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Prevention cost: Crash costs & legal payments

Expected cost

Range of feasible production

$ per trip

S\text{\textsubscript{min}}

No safety: "crash certain to occur"  Perfect safety: "crash will never occur"
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

Crash costs & legal payments

Expected cost

Range of feasible production

$ per trip

Prevention cost

Plus price of transportation falls, so more exposure

S_{\text{min}}

S_{\text{min}}
Assumptions for ideal marketplace

• Many carriers and P=MC
• Consumers are fully informed
• Consumers can make rational choices
• All third party effects internalized by carrier
  – Externalities
  – Bilateral crashes
• Carriers make rational choices
Assumptions for ideal marketplace

- Many carriers and P=MC
- Consumers are fully informed
- Consumers can make rational choices
- All third party effects internalized by carrier
  - Externalities
  - Bilateral crashes
- Carriers make rational choices

Interact for prevalent market failure
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

$ per trip

Crash costs & legal payments

Prevention cost
Perfect safety: "crash will never occur"

No safety: "crash certain to occur"

Prevention cost

Crash costs & legal payments

Incurred "for sure" now

$ per trip

No safety

Perfect safety

"crash will never occur"
Perfect safety
“crash will never occur”

No safety
“crash certain to occur”

Incurred “for sure” now

“Possibly” incurred now or later

Prevention cost

Crash costs & legal payments

$ per trip
Perfect safety  
“crash will never occur”

No safety  
“crash certain to occur”

$ per trip

Crash costs & legal payments

Unintentional or Avaricious Myopia

In incurred now or later

“Possibly” incurred now or later

Incur "for sure" now

Prevention cost

Perfect safety  
“crash will never occur”
“What is the harm in removing a few slices of cheese”
“What is the harm in removing a few slices of cheese”
“What is the harm in removing a few slices of cheese”

Unintentional or Avaricious Myopia requires consumers “not to notice”
Unintentional myopia

• Primarily associated with inexperienced new entrants
• Basis of most safety regulation
• Initial certification of:
  – Carriers
  – Equipment
  – Employees
• Presumably consistent with $S^{\min}$
Avaricious myopia – “cheating”

• Incumbent firm deviating from past performance
• We all can think of firms in all modes that we believe have engaged in this
• “Milking” or “burning” a reputation
• Generally associated with firms close to bankruptcy, or needing to “get through” a difficult period
Valuation ($\theta_i$)

$\theta^H$

$\theta^L$

Carrier 1 ($p_1, S_1$)

Carrier 3 ($p_3, S_3$)

Carrier 2 ($p_2, S_2$)
Valuation ($\theta_i$)

“Cheats”
Maintains price
Lowers safety
Lowers costs

Carrier 3 ($p_3, S_3$)

Carrier 1 ($p_1, S_1$)

Carrier 2 ($p_2, S_2$)
Avaricious myopia – “cheating”

• Economists are perplexed by the existence of “cheating” in stable markets

• Why is this?
Economics of reputation

1. New “high quality” firm cannot initially charge a high price
Economics of reputation

1. New “high quality” firm cannot initially charge a high price
2. Charges low price (loses money) until consumers learn quality is high
Economics of reputation

1. New “high quality” firm cannot initially charge a high price
2. Charges low price (loses money) until consumers learn quality is high
3. Can now price consistent with high quality
4. Price at high quality covers cost plus just compensates over time for initial loses
5. If you “burn your reputation” get one time gain but lose stream of future price premiums
6. No incentive to cheat in equilibrium
Economics of reputation

1. New “high quality” firm cannot initially charge a high price
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Equilibrium competitive prices are such that there is no incentive to cheat
Part 5

How (relatively) important are these deviations?
## Magnitude of failures varies by mode

<table>
<thead>
<tr>
<th>Mode</th>
<th>Few Carriers (limited choice)</th>
<th>Consumers Poorly Informed</th>
<th>Consumer Cognitive Failures</th>
<th>External Costs not Covered</th>
<th>Bilateral Crashes</th>
<th>Carrier Myopia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Driving</td>
<td>*</td>
<td>*</td>
<td>***</td>
<td>*</td>
<td>***</td>
<td>n/a</td>
</tr>
<tr>
<td>Private Aviation &amp; Boating</td>
<td></td>
<td></td>
<td>Few failures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Passenger</td>
<td>**</td>
<td>***</td>
<td>***</td>
<td>*</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Road Freight</td>
<td>*</td>
<td>*</td>
<td>none</td>
<td>***</td>
<td>***</td>
<td>***</td>
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<tr>
<td>Maritime Freight</td>
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<td>*</td>
<td>none</td>
<td>**</td>
<td>*</td>
<td>***</td>
</tr>
<tr>
<td>Rail Freight</td>
<td>***</td>
<td>*</td>
<td>none</td>
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<td>***</td>
<td>**</td>
</tr>
<tr>
<td>Pipelines</td>
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<td>***</td>
<td>none</td>
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</tr>
</tbody>
</table>
Part 6

What (more) can we do about it?
<table>
<thead>
<tr>
<th>Liability / legal reforms?</th>
<th>Few Carriers (limited choice)</th>
<th>Consumers Poorly Informed</th>
<th>Consumer Cognitive Failures</th>
<th>External Costs not Covered</th>
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<th>Carrier Myopia</th>
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More extensive insurance holding?

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More information collection and dissemination in the Internet age?

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The old standby - regulatory action to enforce some minimum standard

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Few failures
The safety regulation problem

- What is the minimum acceptable performance?
- What is the optimal inspection strategy?
- How to express the standard in terms of something you can measure?
- What should be the penalties?
- What is the effect on prices for those above the minimum?
Final Thoughts

What can we conclude?
Take aways

• Difficult to quantify “optimal safety”
• It will likely involve higher and lower safety carriers coexisting
Take aways

• Difficult to quantify “optimal safety”
• It will likely involve higher and lower safety carriers coexisting
• Market failures are rife, but their nature and magnitude varies by mode
Take aways

• Difficult to quantify “optimal safety”
• It will likely involve higher and lower safety carriers coexisting
• Market failures are rife, but their nature and magnitude varies by mode
• Policy responses are numerous
  – Each have their pluses and minuses
  – Non-trivial to implement
  – Should be deployed in combination
Plenty of opportunity for research

Unsure about optimal level(s) of safety

Unsure about nature and magnitude of market failures

Unsure about policy effects
“Transportation econ. courses with Leon and his cigar were epic! . . . many of us had careers in transportation because of him.” Vicki Whamond Bretthauer

"When I arrived from Italy at NU I was a 25 year old young kid who did not know anything about the realities of American Life. It was [Prof.] Moses who helped me to adjust at NU's life, and motivate me when I was down, or when I could have done better on an exam. Yet these human qualities where coupled by a great professional rigor and vigor that were for me the ultimate example to imitate in action." Corrado Letta
“Leon was one of my favorites and I often tried to sit at the same table with him during Transportation Center BAC meetings.” Chuck Lounsbery

"There is no doubt in my mind that he was one of the few persons who had a very significant impact on me and my spirit. He was great as a scientist and very kind as a human being. I have not seen him for a long time but I always thought about him, now I will carry his memory in my heart."

Yossi Prashker
October 24, 1924 – October 12, 2013

• Friend

• Leader

• Scholar