Quantifying safety effects of infrastructure countermeasures

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Safety in numbers -- challenges in quantifying the effects of infrastructure countermeasures

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Quantifying safety effects and transport equity – the connection

- Equity requires that road user safety well-being be explicitly considered in transport decision making in the first place

Is it better to be ……..

- **DEAD?**

- **OR ALIVE AND STUCK IN TRAFFIC??**

Hauer, E., 1994. *Can one estimate the value of life or is it better dead than stuck in traffic?* Transportation Research 28, 109–118.

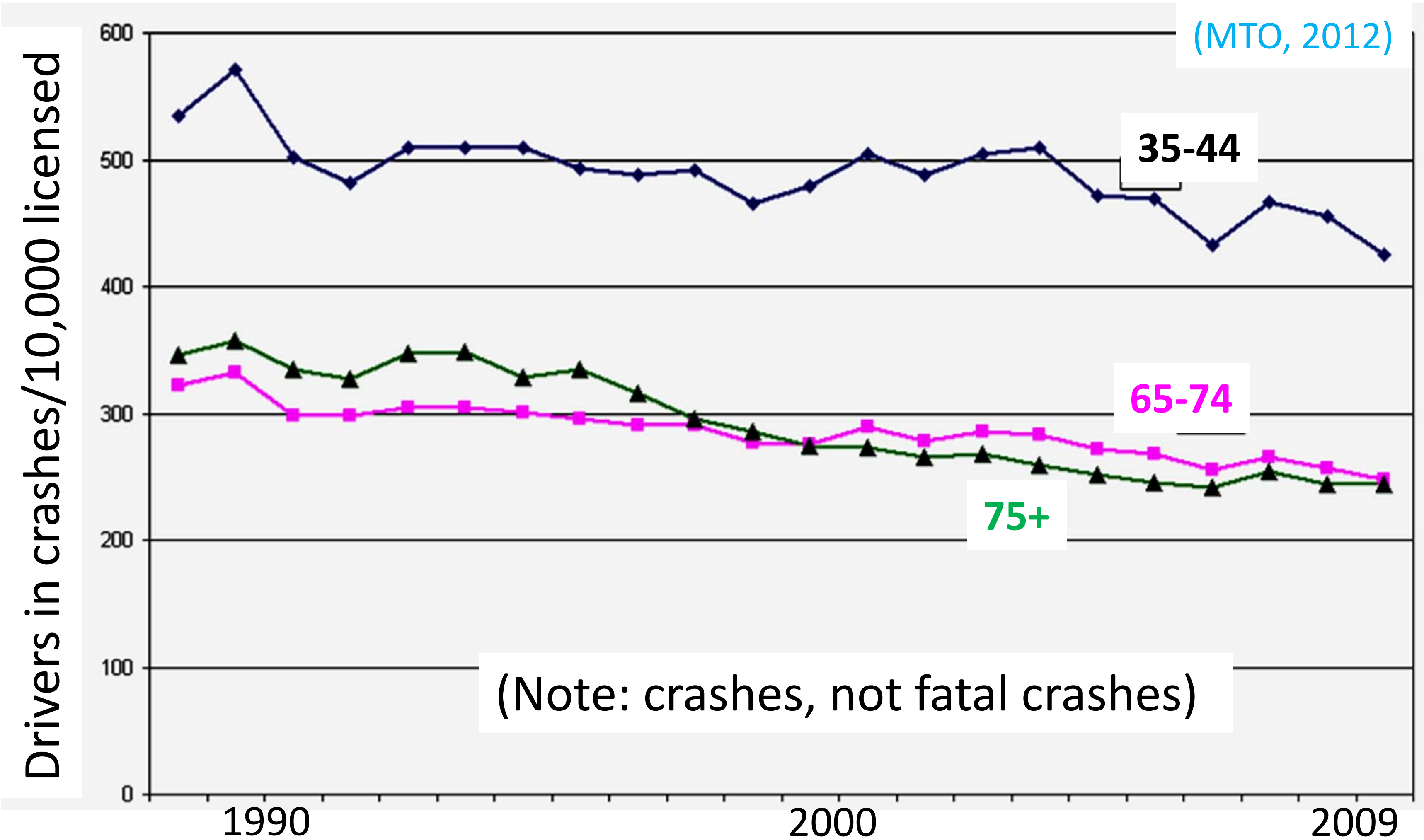
Quantifying safety effects and transport equity – the connection

- Equity requires that road user safety well-being be explicitly considered in transport decision making in the first place.
- The consideration and maximization of safety of all road users.
  - Young and not so young
  - Walkers, cyclists and transit users
  - Abled and disabled

The rap against elderly drivers

- *Older drivers are overrepresented in fatal crashes, mainly owing to their frailty, not their ability to drive safely.*
- *When seniors are compared with nonseniors who drive the same amount, the overrepresentation disappears completely, except among people who drive fewer than 3000 kilometres per year.*
- *Unlike younger drivers, older drivers are a danger mainly to themselves.*

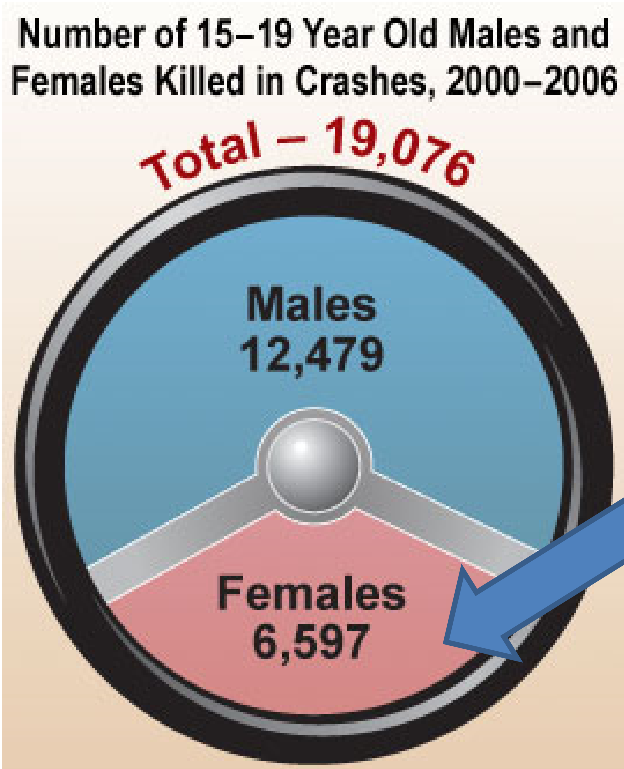
Ezra Hauer. In defence of older drivers
Canadian Medical Association Journal. 2012 Apr 3; 184(6): E305–E306. doi: 10.1503/cmaj.110814



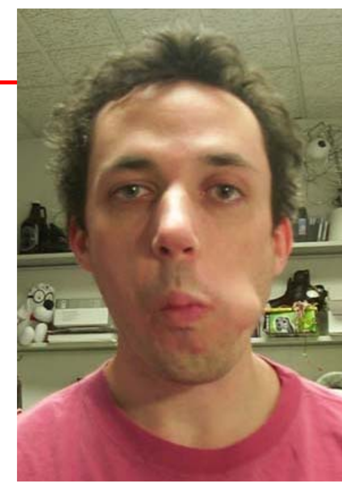
Per licensed driver the elderly are better!

... *so why do younger administrators pick on them?*

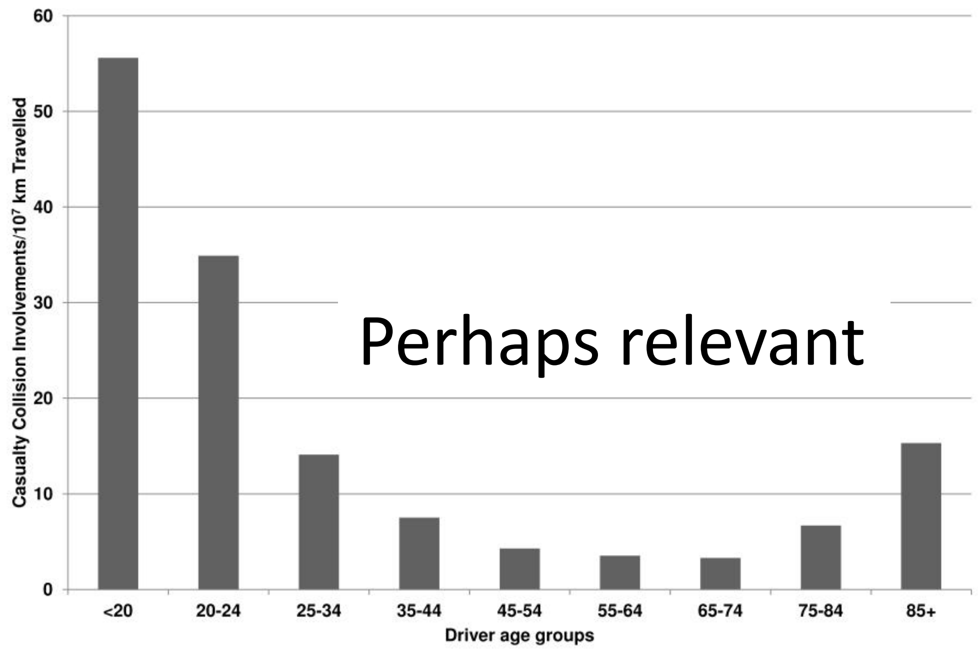
… is it akin to?

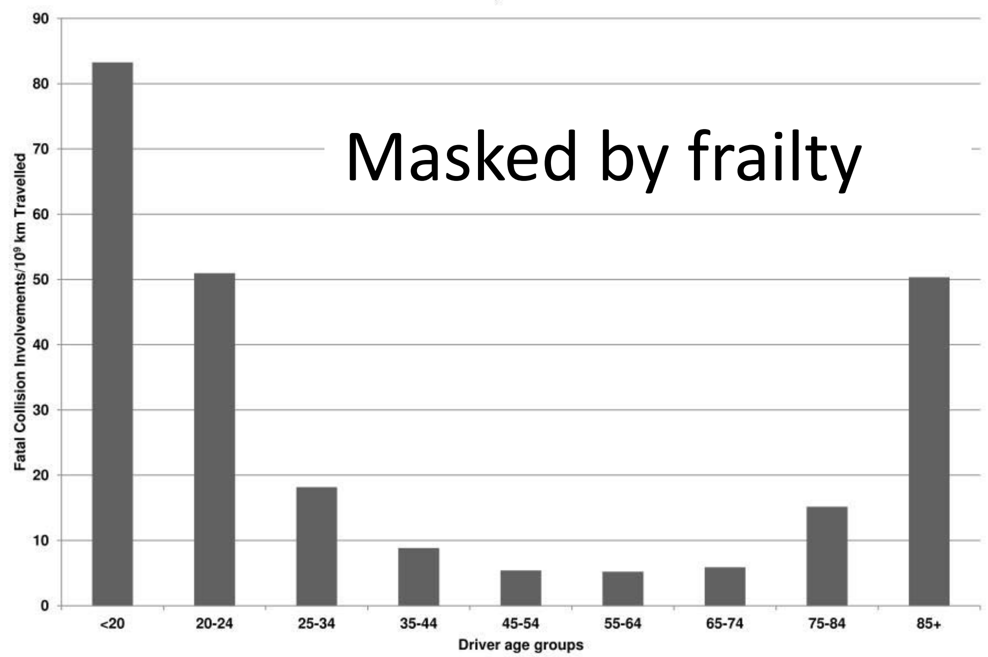


So what are we to do about those 'women drivers'?



(The Safety Network, Editorial Board, 2012)





Canada data – similar to US

Quantifying safety effects and transport equity – the connection

- Equity requires that road user safety well-being be explicitly be considered in transport decision making in the first place.
- The consideration and maximization of safety of all road users.
  - Young and not so young
  - Walkers, cyclists and transit users
  - Abled and disabled
- That these considerations be based in credible knowledge on safety effects of interventions
  - i.e., Crash Modification Factors (CMFs)

    CMF= 0.9 → 10% reduction

Consideration of safety of all road users

Some examples of credible knowledge on crash modification factors (CMFs)

ROAD DIETS

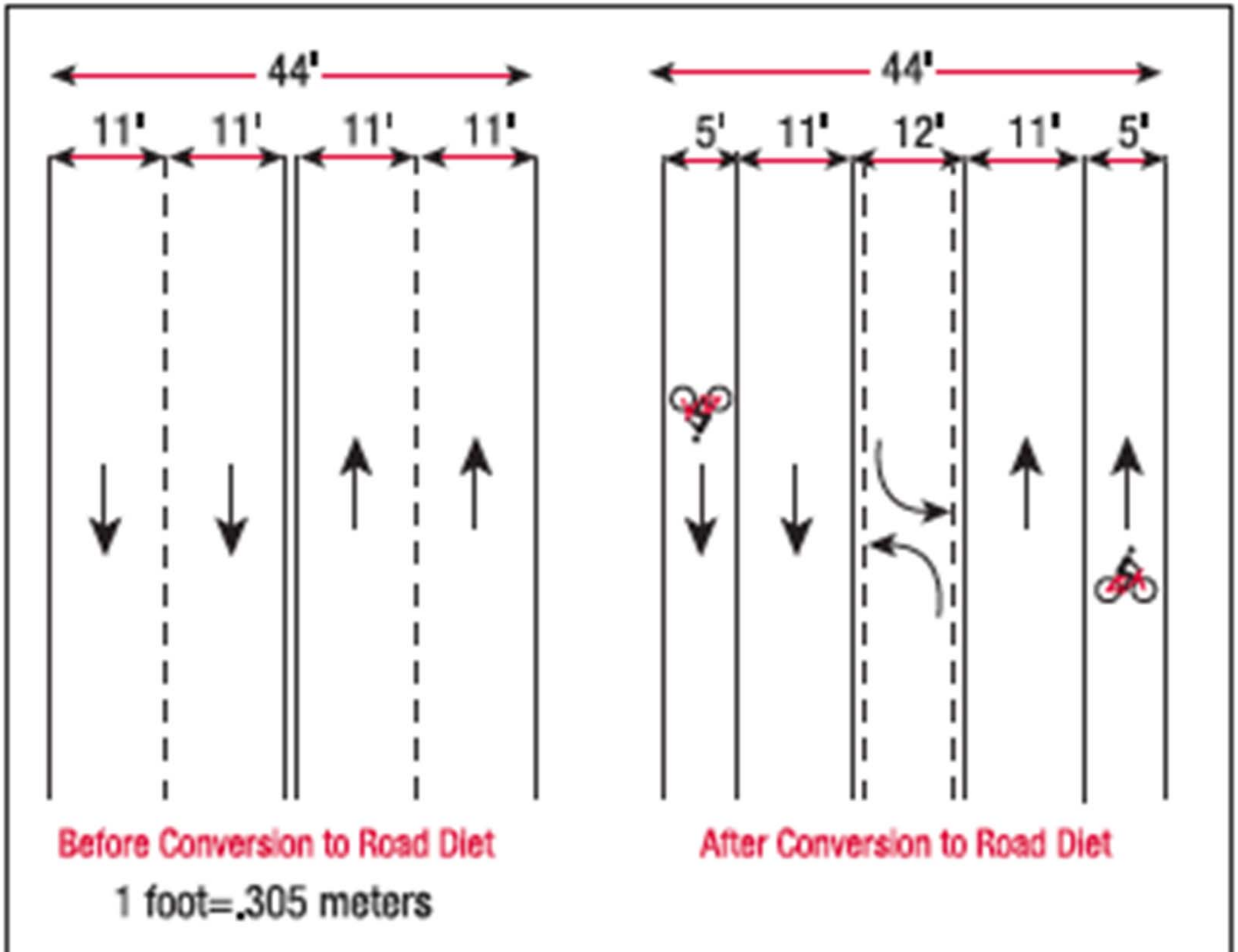


Figure 1. A representative road diet.

Figure 1. Photo. Four-lane configuration before road diet.

Source: Pedestrian Bike Information Center, "Road Diets" training module, 2009.

Figure 2. Photo. Three-lane configuration after road diet.

Source: Pedestrian Bike Information Center, "Road Diets" training module, 2009.

HSIS

WAY SAFETY INFORMATION SYSTEM

SUMMARY REPORT

Evaluation of Lane Reduction "Road Diet" Measures on Crashes

This Highway Safety Information System (HSIS) summary replaces an earlier one, Evaluation of Lane Reduction "Road Diet" Measures and Their Effects on Crashes and Injuries *(FHWA-HRT-04-082), describing an evaluation of "road diet" treatments in Washington and California cities. This summary reexamines those data using more advanced study techniques and adds an analysis of road diet sites in smaller urban communities in Iowa.*

A *road diet* involves narrowing or eliminating travel lanes on a roadway to make more room for pedestrians and bicyclists.(1) While there can be more than four travel lanes before treatment, road diets are often conversions of four-lane, undivided roads into three lanes—two through lanes plus a center turn lane (see figure 1 and figure 2). The fourth lane may be converted to a bicycle lane, sidewalk, and/or on-street parking. In other words, the existing cross section is reallocated. This was the case with the two sets of treatments in the current study. Both involved conversions of four lanes to three at almost all sites.

Table 2. Results of the EB analysis for the Iowa and HSIS data concerning 4-lane to 3-lane road diets.[5,6,7]

CRASH TYPE STUDIED AND ESTIMATED EFFECTS

STATE/ SITE CHARACTERISTICS	ACCIDENT TYPE	NUMBER OF TREATED SITES	CMF (STANDARD DEVIATION)
Iowa: Predominately U.S. and State routes within small urban areas (average population of 17,000)	Total crashes	15 (15 mi)	0.53 (0.02)
California/Washington: Predominately corridors within suburban areas surrounding larger cities (average population of 269,000)	Total crashes	30 (25 mi)	0.81 (0.03)
All sites	Total crashes	45 (40 mi)	0.71 (0.02)

Goughnour E., Carter D., Lyon C., Persaud B. et al. Safety Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals on Pedestrian Safety. FHWA-HRT-18-044, 2018. https://rosap.ntl.bts.gov/view/dot/37580

EB studies

Estimated CMFs for Protected Left-Turn Phasing Evaluation

City	Treatment Sites	CMF for Vehicle–Vehicle Crashes (SE)	CMF for Vehicle–Vehicle Injury Crashes (SE)	CMF for Pedestrian–Vehicle Crashes (SE)
Chicago	70 sites (68 protected/permissive, 2 protected only)	1.031 (0.040)	0.890 (0.079)	1.136 (0.146)
New York City	9 sites (1 protected/permissive, 8 protected only)	**0.672*** (0.110)	0.788 (0.153)	0.718 (0.196)
Toronto	136 sites (134 protected/permissive, 2 protected only)	1.025 (0.011)	**0.951*** (0.020)	1.106 (0.061)
All cities combined	215 sites (203 protected/permissive, 12 protected only)	1.023 (0.016)	**0.942*** (0.028)	1.091 (0.066)

* A CMF that is statistically significant at a 95-percent confidence level.

Note: New York City has a city-wide prohibition on RTOR.

CMF for ped-vehicle crashes is less than 1.0 for values of 24-hour crossing volumes of 5,500 and above

Estimated CMFs for Leading Pedestrian Interval (LPI)

City	Treatment Sites	CMF for Total Crashes (SE)	CMF for Total Injury Crashes (SE)	CMF for Vehicle–Pedestrian Crashes (SE)
Chicago	56	**0.90*** (0.027)	**0.83*** (0.046)	**0.81*** (0.070)
New York City	42	**0.84*** (0.031)	**0.86*** (0.037)	0.91 (0.062)
Charlotte	7	0.90 (0.09)	1.09 (0.18)	0.54 (0.38)
All cities combined	105	**0.87*** (0.02)	**0.86*** (0.03)	**0.87*** (0.05)

* A CMF that is statistically significant at a 95-percent confidence level.

Treatments for Uncontrolled Pedestrian Crossings

Before-after and Cross-sectional

RRFB

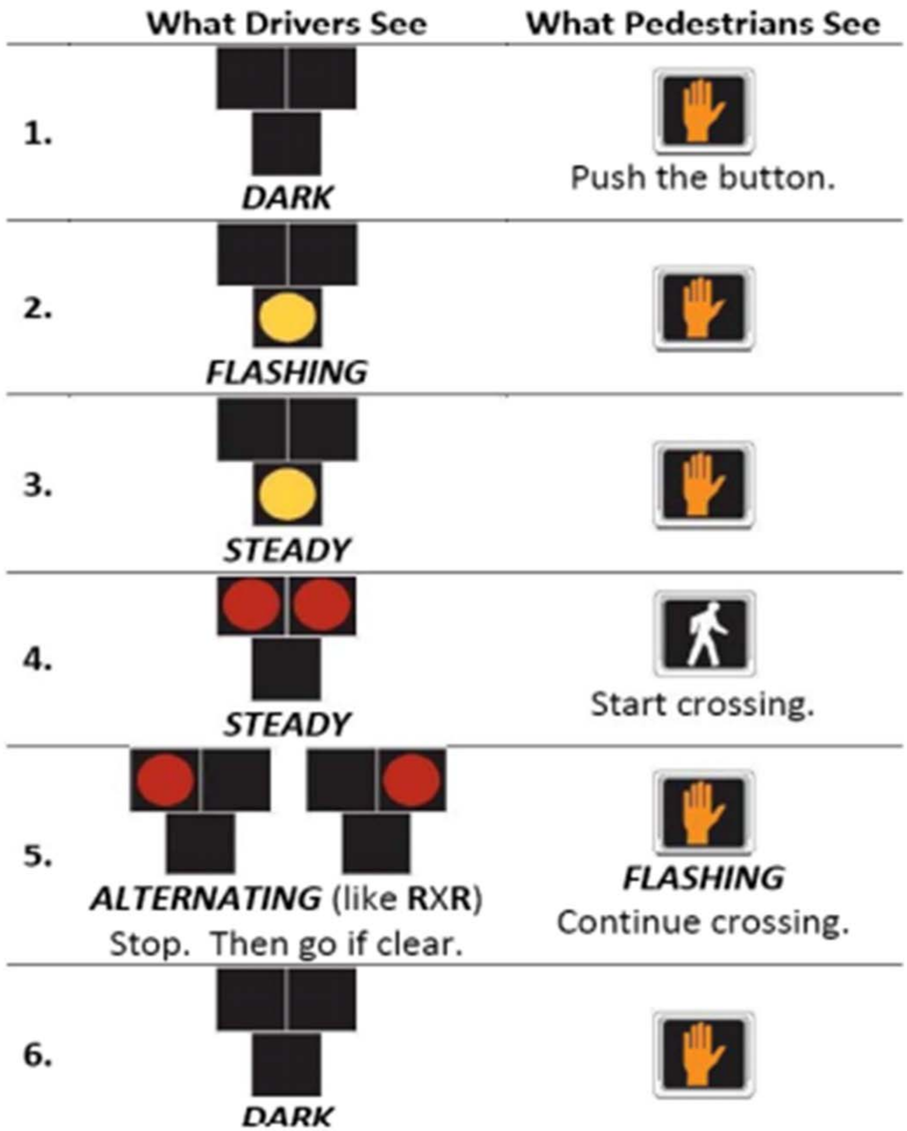
Refuge Island

PHB (HAWK)

Advance stop

Advance Yield

PHB (HAWK)


What Drivers See
What Pedestrians See
1.
DARK
Push the button.
2.
FLASHING
3.
STEADY
4.
STEADY
Start crossing.
5.
ALTERNATING (like RXR)
Stop. Then go if clear.
FLASHING
Continue crossing.
6.
DARK

Treatment	Crash Type	Recommended CMF		Study Basis
		Estimate	SE	
RI	Pedestrian	0.685	0.183	Median from two studies
	Total	0.742	0.071	Cross section
	All injury	0.714	0.082	Cross section
	Rear-end–sideswipe total	0.741	0.093	Cross section
	Rear-end–sideswipe injury	0.722	0.106	Cross section
AS	Pedestrian	0.750	0.230	Median from two studies
	Total	0.886	0.065	Before–after
	Rear-end–sideswipe total	0.800	0.076	Before–after
PHB	Pedestrian	0.453	0.167	Median from two studies
PHB and AS	Pedestrian	0.432	0.134	Median from two studies
	Total	0.820	0.078	Before–after
	Rear-end–sideswipe total	0.876	0.111	Before–after
RRFB	Pedestrian	0.526	0.377	Cross section

Zegeer C., Lyon C., Srinivasan R., Persauud B. and 8 others. Development of Crash Modification Factors for Uncontrolled Pedestrian Crossing Treatments. Transportation Research Record 2636, 1–8, 2017.

KEY CHALLENGES IN DEVELOPING AND APPLYING KNOWLEDGE ON SAFETY EFFECTS

-- BIAS BY SELECTION– REGRESSION TO THE MEAN

… safety benefits overstated in evaluations

… treatments that are not cost-effective may be justified

-- ROAD USER BEHAVIORAL ADAPTATION

ANTHROPOLOGICAL MISCELLANEA.

1890

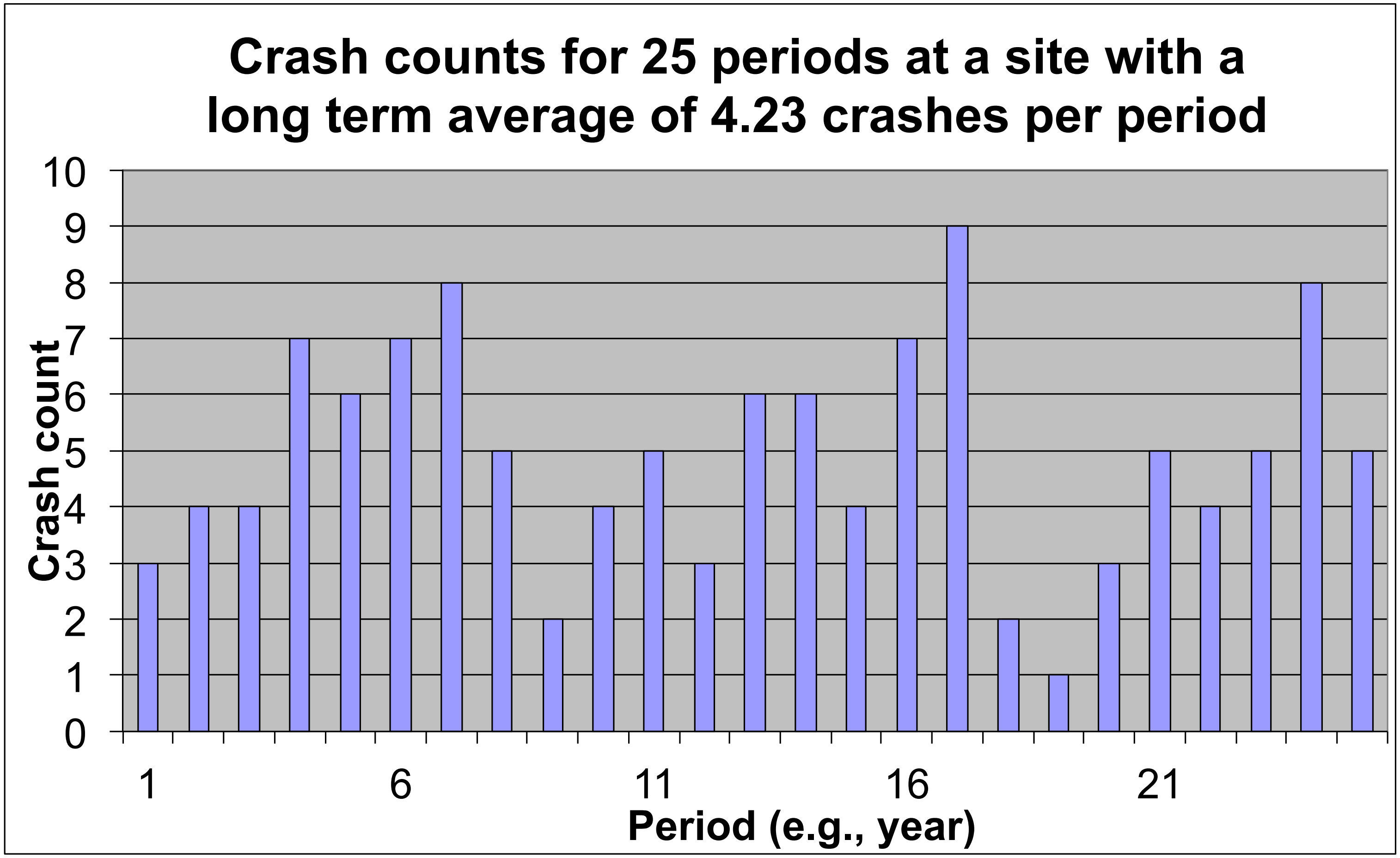
REGRESSION *towards* MEDIOCRITY *in* HEREDITARY STATURE.

By FRANCIS GALTON, F.R.S., &c.

"When mid-parents are taller than mediocrity, their children tend to be shorter than they"

... Almost 100 years after Galton's work

THE REGRESSION TO THE MEAN PROBLEM IN ESTIMATING CMFs FROM SIMPLE BEFORE-AFTER STUDIES

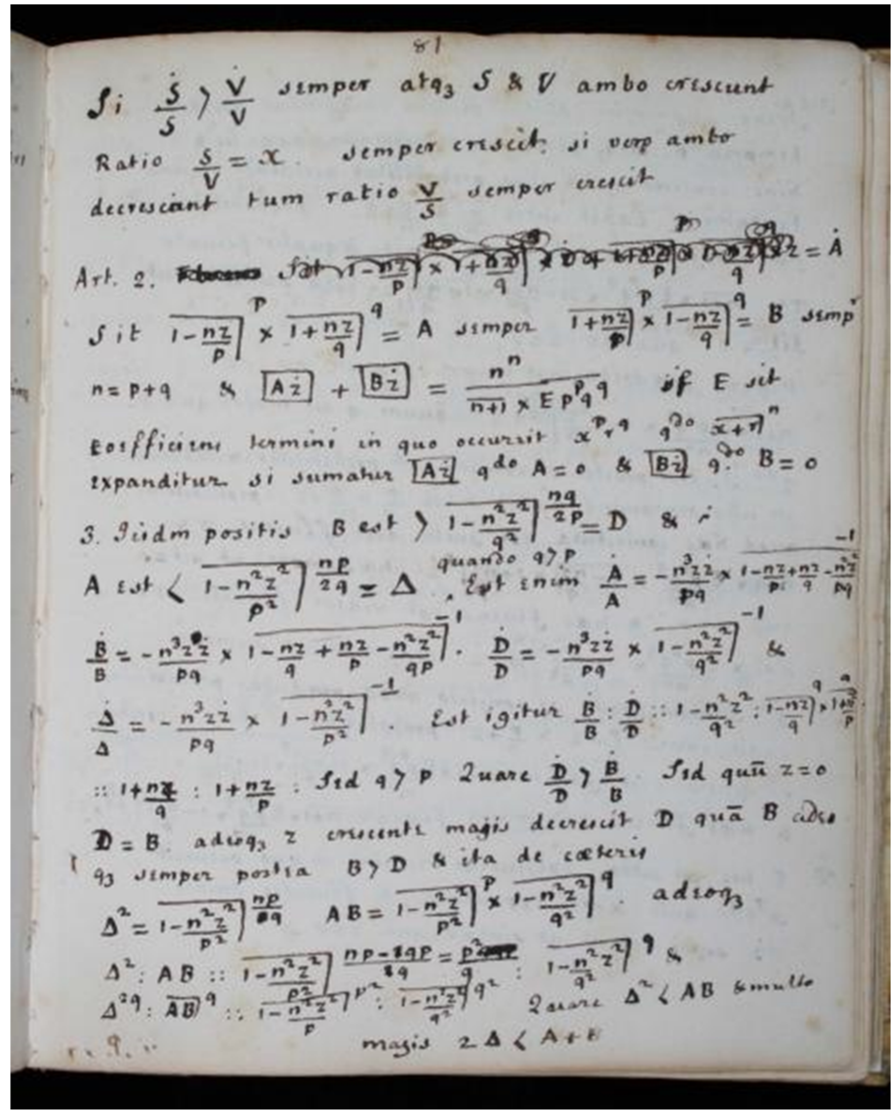


Other issues related to the development of CMFs –before-after design

- Observed change in crashes after a treatment may be due not only to the treatment, but to other factors:
  - Changes in traffic volume, crash reporting or weather,
  - Regression-to-the-mean (RTM)
    - Treatment effects are overestimated
- State or the art empirical Bayes methodology resolves the RTM problem and in the process can account for the other factors, but ...

..... it's complicated!

$$P(H|DX) = \frac{P(H|X) \times P(D|HX)}{P(D|X)}$$



REGRESSION TO THE MEAN IN INSTALLING GATES AT RAIL CROSSINGS WITH FLASHERS

Crashes before = 286
Crashes after = 114

Apparent savings = 172
(60% reduction)

The Reality:
(EB) Crashes expected=208
RTM=286-208=78 (27%)

Actual savings
(208 - 114) = 94
(45% reduction)

Pedestrian countdown signals – are they effective?

Breaking News from Toronto!

WEDNESDAY, APRIL 17, 2013

WILL PEDESTRIAN COUNTDOWN SIGNALS SUFFER THE SAME FATE AS MARKED CROSSWALKS?

A recent study from University of Toronto PhD student Sacha Kapoor and Arvind Magesan evaluated the impact of installing pedestrian countdown timers at various intersections throughout Toronto over a four-year period. After much parsing of data, the study concluded that installing countdown signals resulted in a five-percent increase in crashes versus intersections without the special signals. But there are nuances to that conclusion:

> *"The data reveals starkly different effects for collisions involving pedestrians and those involving automobiles only. Although they reduce the number of pedestrians struck by automobiles, countdowns increased the number of collisions between automobiles. We show that countdowns cause fewer minor injuries among pedestrians for every pedestrian on the road and more rear ends among cars for every car on the road."*

Further, while the the countdown signals increase crashes overall, at the most dangerous intersections the installation of countdown signals reduced crashes and made the intersections safer.

"...cities might benefit from installing countdowns at dangerous intersections and not at safe ones."

It's easy to jump to conclusions about studies based on headlines, but decisions about infrastructure should be based on a more thorough evaluation of the evidence--particularly when pedestrian safety is at stake.

As more cities embrace countdown signals at intersections, Toronto study casts doubt on their safety

Tom Blackwell | 03/10/13 | Last Updated: 03/10/13 8:49 PM ET
More from Tom Blackwell | @tomblackwellNP

They are the latest in crosswalk safety and have been installed across Canada and the U.S. at a cost of thousands of dollars each. But the pedestrian-countdown signals in this country's biggest city seem to have actually increased crashes between people and cars, a detailed new study suggests.

The Toronto researchers looked at pedestrian accident statistics from 2000 to 2009, with the signals implemented in the last three years of that period. Their original study concluded that the countdowns had no impact, up or down, on the collision numbers. Then they performed a more sophisticated statistical analysis of the data, factoring in trends in accident rates over time, including an overall drop in pedestrian collisions, as well as the effect different seasons have on the statistics, said Dr. H.

It is an "observational" study and not the same as doing a strictly controlled experiment, but the result seems accurate, he said.

After a second analysis of data that they had studied and reported on earlier, researchers at the Hospital for Sick Children concluded that the signals at almost 2,000 Toronto intersections were linked to a 26% increase in the rate of collisions. The rate of serious or fatal pedestrian-automobile crashes jumped even more — by 50%, they reported in the journal *Injury Prevention*.

Separating fiction from fact

2018 Study: CMFs for PCS
115 intersections in Charlotte NC and 218 in Philadelphia

Crash Type	CMF	S.E. of CMF
Total	0.921*	0.017
Injury & Fatal	0.988	0.026
Rear end	0.875*	0.027
Angle	1.027	0.042
Pedestrian	0.912#	0.055

Note: * indicates CMF is statistically significant at the 95% confidence level;
# indicates CMF is statistically significant at 90% confidence level.

ROAD USER BEHAVIOURAL ADAPTATION TO INFRASTRUCTURE SAFETY TREATMENTS – EVIDENCE, IMPLICATIONS AND MITIGATION

Premise

- Accumulation of evidence suggests that road users respond and adapt to safety treatments
  - Drivers in particular
  - Adaptation may occur over time and/or space
  - Consequences can be positive (e.g., red light cameras)
  - Consequences mostly negative
    - Some believe net effect of treatment is zero (risk homeostasis)
- Influence of adaptation on treatment effects needs to be considered in applying crash modification factors in making cost-effective infrastructure investment decisions.
- At the moment this is generally not done
- Other aspects of driver adaptation
  - Vehicle automation
  - Adaptation to physical limitations, e.g., aging

(Selected) Empirical evidence for infrastructure safety treatments

- Curve delineation
- (Permanent) raised pavement markers (PRPM)
- Red light cameras
- Other

Curve Delineation (2 lane roads)

Srinivasan et al. (2012)

Crash Type	AADT Range	CMF[*] (standard error)
Lane departure crashes	< 3,800	1.206 (0.136)
	> 3800	**0.731 (0.067)**
Crashes during dark	< 3,800	1.192 (0.136)
	> 3800	**0.678 (0.085)**
Lane departure crashes during dark	< 3,800	1.200 (0.138)
	> 3800	**0.712 (0.093)**

Treatment should be targeted where it is likely to be effective;
Otherwise speed mitigation measures could be implemented

So… should NZ rethink curve delineation policy?
…. perhaps knowledge is not transferable?

CMFs for PRPM

Persaud et al. (2004)

(Significant at 5% level)

	All	Day	Night	Dry	Wet
New Jersey Non-Selective 174 miles	**1.03**	**1.05**	**0.99**	**1.05**	**0.97**
New York Selective 82 miles	**0.90**	**1.0**	**0.87**	**1.05**	**0.80**

… *Drilling down on effects of RPMs*

Two lane roads

AADT	CMF for Flatter curves	CMF for Sharper curves
<5000	1.16	1.43
5001-15000	No change	1.26
15001-20000	0.76	1.03

- ***"Enhanced visibility could encourage drivers to increase speed, especially where traffic volumes were low – can be dangerous on sharper curves"***
- ***Consider speed reduction measures for mitigation***
- ***Treatment should be targeted where it is likely to be effective, e.g., at sites with a high number of wet weather night crashes***

Despite compelling evidence of driver adaptation to PRPM..

NCHRP

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

REPORT 600

2012

Human Factors Guidelines for Road Systems

Second Edition

page 6-11 notes: "*Raised reflective pavement markers are highly effective at improving curve visibility and reducing crashes, especially when used in combination with centerlines and edge lines.*" Statement is referenced to "Nemeth, Z.A., Rockwell, T.H., and Smith. G.L. (1986) "Recommended Delineation Treatments at Selected Situations on Rural State Highways

Red Light Cameras

Persaud et al. (2005)

	Right-angle		Rear-end	
	Total	Injury	Total	Injury
Estimate of CMF	0.754	0.843	1.149	1.240
(standard error)	(0.029)	(0.059)	(0.030)	(0.116)

- Driver adaptation evidenced in rear-end crash increase -- **undesired**
- Evidence of a **desired** spillover effect – decrease in angle crashes and a negligible increase in rear-end crashes at sites without cameras.
- Spillover benefit must be considered in planning and evaluating RLCs
- Spillover sites cannot be used as "control" in treatment evaluation

To counteract the unintended consequences of increases in rear-end crashes, adjustments to the intergreen period could be considered, as well as improving the friction on intersection approaches.

A sample of other treatments with driver adaptation effects

- Zegeer et al. (2002): Pedestrian crash risk greater at marked crosswalks at AADT > 10,000
  - **Attributed to the false sense of security**

- (Angelastro, 2010) … more sight distance at a roundabout allows drivers to approach a conflict point at higher speeds with a negative impact on safety.
  - **FHWA Roundabout Guide …. “traffic engineers should provide no more than the minimum required intersection sight distance on each approach. Excessive intersection sight distance can lead to higher vehicle speeds that reduce the safety of the intersection for all road users (vehicles, bicycles, pedestrians).”**

- Bahar et al. (2006): Hypothesized that any effect of the level of brightness of pavement markings may be minimized by driver adaptation to road conditions.
  - **”the best estimate of the joint effect of retroreflectivity and driver adaptation is approximately zero for road segments in non-daylight hours.”**

- Assum et al. (1999): Drivers compensate for road lighting in terms of increased speed and reduced concentration.
  - **Example of studies that are not crash- based so cannot be used in assessing driver adaptation in planning infrastructure safety measures.**

- Lyon et al.'s 2017 EB study found that pavement friction improvements can increase crashes, especially on dry roads.
  - **Negative consequences could potentially be minimized with the application of mitigation measures such as increased enforcement and/or more prominent advisory and speed limit signing.**
  - **Also by better targeting friction improvement projects.**

Summing up this presentation

- Transport equity requires that road user safety well-being be explicitly be considered in transport decision making in the first place.
- The consideration and maximization of safety benefits of all road users.
- That these considerations be based in credible knowledge on safety effects of interventions.