USING SPEED-CRASH MODELS APPROPRIATELY

Bill Frith and Fergus Tate
WSP New Zealand

YYYY/MM/DD

Excessive speed is a prime contributor to road trauma

In 2022 there were 104 fatal crashes, 459 serious injury crashes, and 1405 minor injury crashes where travelling too fast for the conditions was a contributing factor.

- We need assess the crash impact of speed changes
- These changes may be upward or downward and may result from road safety measures, changes in speed limits, other unrelated factors, or a combination
- In many cases such analysis requires models which link speed changes to crash changes (speed-crash models)
- ***Increasingly important with Governments focus on those changes that are economically viable***

Road Controlling Authorities to determine speed limits using consistent benefit-cost analysis criteria (Draft Land Transport GPS)

Simple guidance for practitioners on which model is appropriate in what context is hard to find

- Different models may apply:

  - to different road types
  - when the speed distribution changes in different ways

- The speed distribution may be truncated, as in mandatory intelligent speed adaptation

- Police enforcement, may cause an overall downward move and some truncation accompanied by a reduction in the width of the distribution

- These impacts may happen in reverse where speeds are allowed to increase by increasing speed limits or reducing enforcement

- When choosing a model in a particular situation the principles on which the model is based are important

Main types of models linking speed to crashes/ injuries

- **Models linking vehicle speeds to injury or crash risk in the event of a collision**

- **Models to estimate the safety benefits or disbenefits of speed changes**

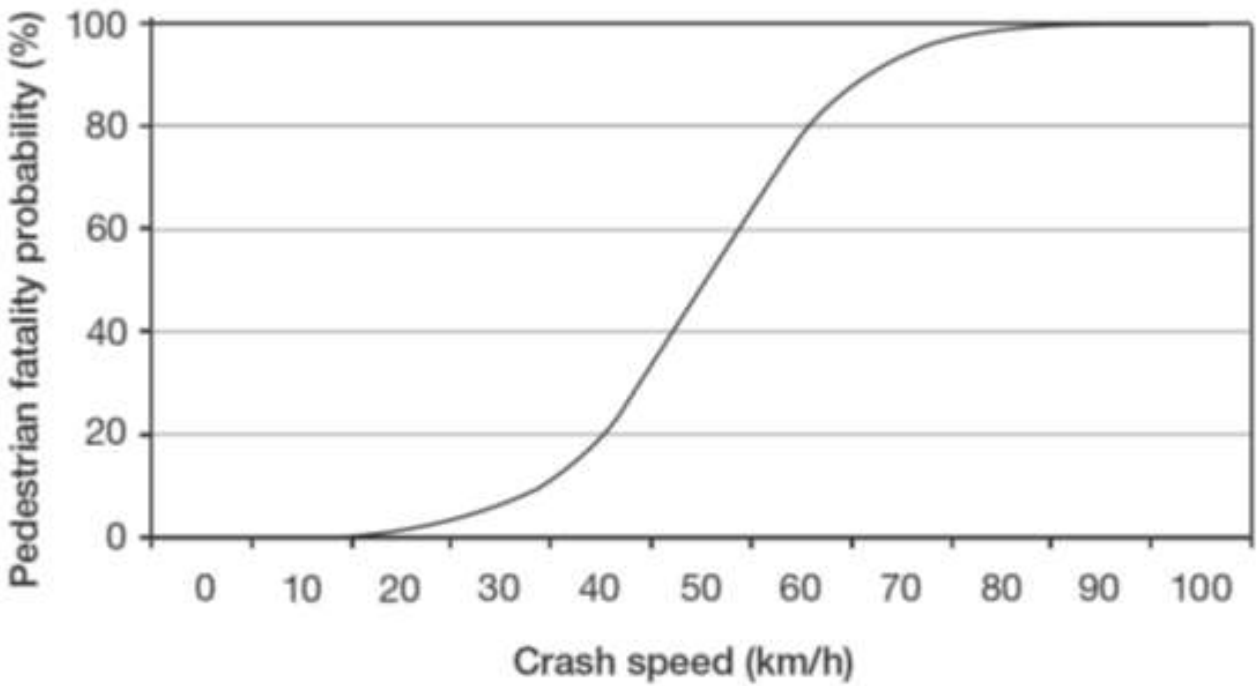
  - **Mean Speed Crash Risk Models**

    - Power models
    - Exponential models

  - **Individual Speed Crash Risk Models**

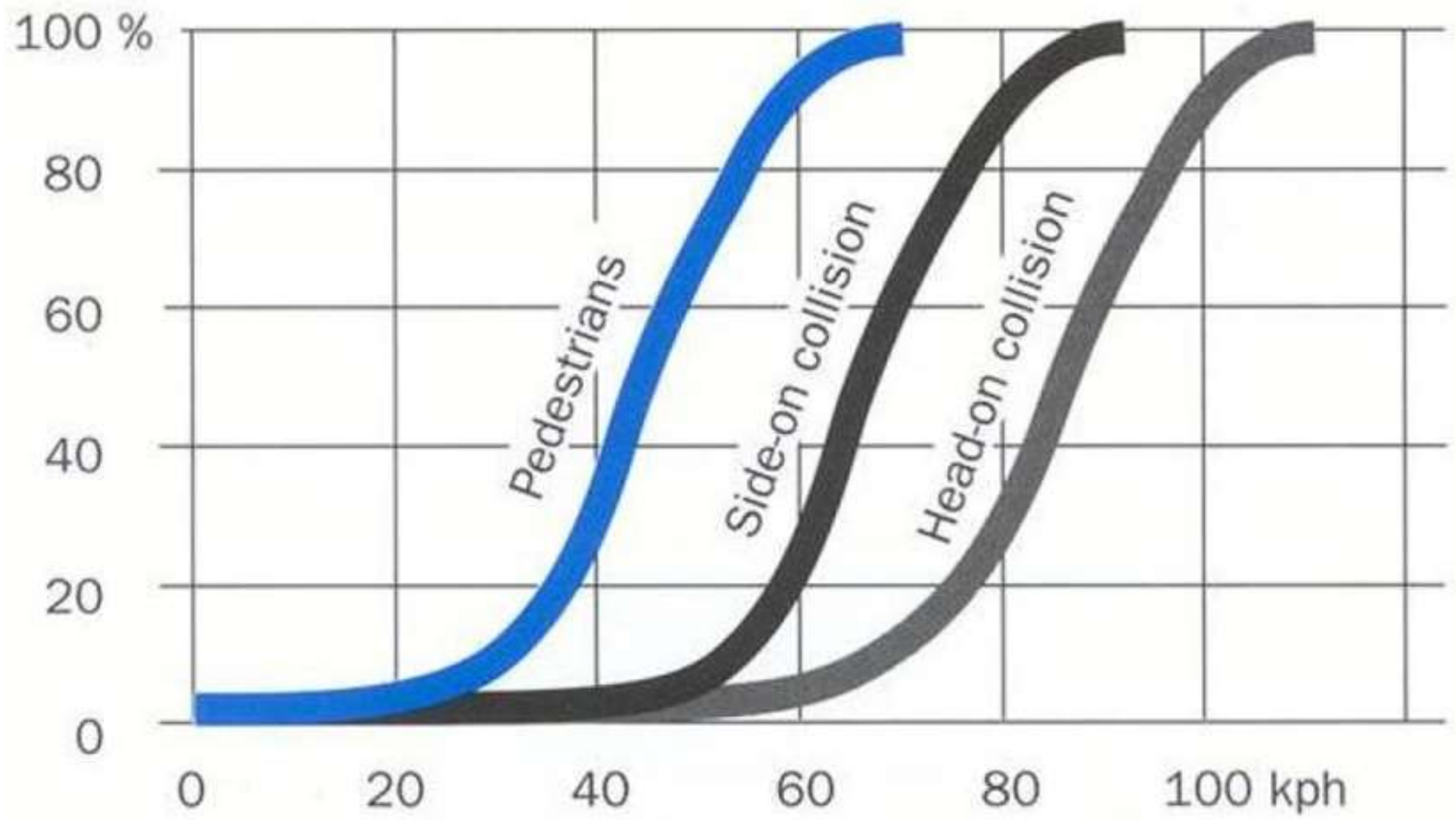
- **Models linking vehicle speeds to injury or crash risk in the event of a collision**

These are used to illustrate the impact of vehicle crash speeds on the severity of vulnerable road user collisions.



Wegman and Aarts 2006, p36

Risk of death for collisions with pedestrians vs side-on collisions and head-on collisions Corben (2011)



Power models linking mean speed to crash risk

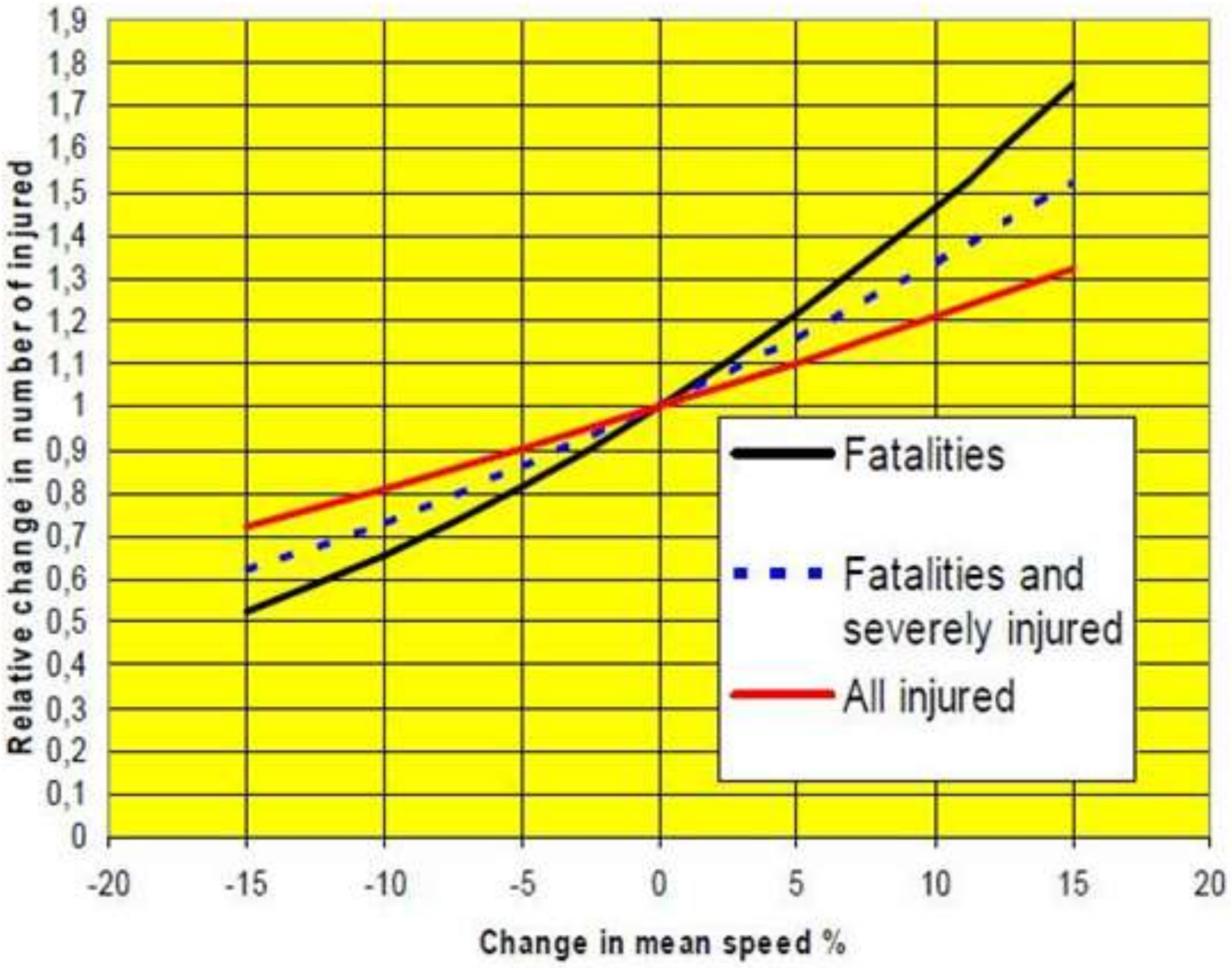
Nilsson (1981) studied speed changes following highway speed limit changes in Sweden and validated a simple model linking speed change with change in crashes and casualties.

$$\mathbf{Crashes_{after} = Crashes_{before} \cdot (Speed_{after} / Speed_{before})^{Power}}$$

Powers:
2 for injury crashes,
3 for DSI (Death and serious injury) crashes
4 for fatal crashes

The model is also valid for injury data. (The powers may differ slightly.)

Relationship between speed changes and changes in casualty rates (Nilsson 2004, p90)



These have been refined by Elvik and Cameron using later information

Power estimates (with standard error (SE) estimates below	Traffic Environment			
	Urban arterial	Rural highway	Freeway	All studies
Fatalities	4.3	4.7.	4.9	4.9.
SE	0.92	0.49	0.15	0.14
DSIs	1.6	2.5	4.9	3.7.
SE	0.23	0.26	0.14	0.11
All levels of injury severity	1.7	2.5	2.8	2.8
SE	0.17	0.16	0.03	0.03

Exponential Models

Derived from the Nilsson's power models.

- Elvik (2013) looked at Nilsson's power models with respect to vehicle speed before the speed change.
- Possible with data sets over wider speed ranges than those available to Nilsson at the time of his work.
- Elvik transforming the models into related, but **speed environment specific**, exponential models.
- Achieved by fitting power models to different speed ranges covering the speed distribution and fitting an exponential distribution to the resultant "sub-powers".

$$Y_1 = Y_0\, e^{\beta\,(v_1 - v_0)}$$

Where Y_1 and Y_0 denote crash numbers after and before a change in speed from v_0 to v_1
These fitted the data as well as the Power model

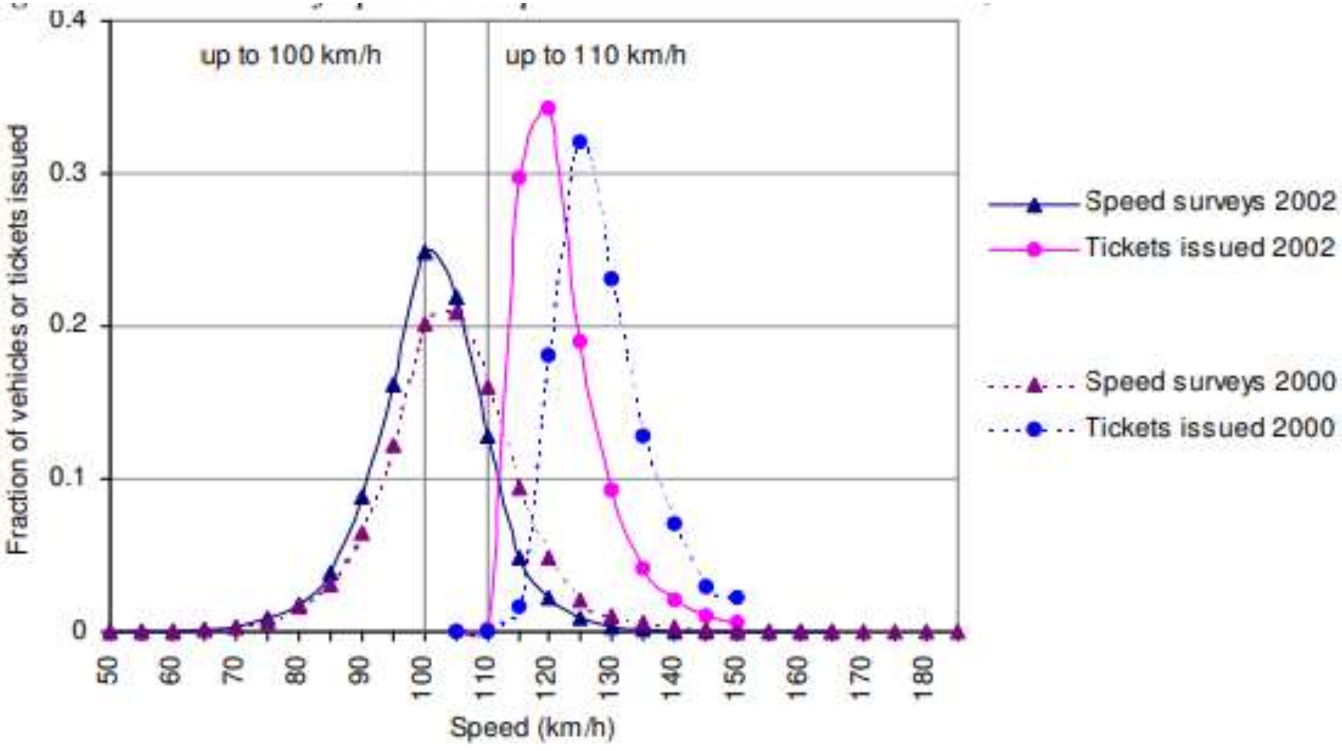
Exponential Models

. Summary of estimates of exponents by traffic environment						
	Rural roads/freeways		Urban/residential roads		All roads	
Crash/injury seventy	Best estimate	95% conf interval	Best estimate	95 % conf interval	Best estimate	95% conf interval
Fatal crash	4.1	2.9 to 5.3	2.6	0.3 to 4.9	3.5	2.4 to 4,6
Deaths	4.6	4.0 to 5.2	3.0	-0.5 to 6.5	4.3	3.7 to 4.9
Serious injury crash	2.6	-2.7 to 7.9	1.5	0.9 to 2.1	2.0	1.4 to 2.6
Serious injuries	3.5	0.5 to 5.5	2.0	0.8 to 3.2	3.0	2.0 to 4.0
Minor injury crashes	1.1	0.0 to 2,2	1.0	0.6 to 1.4	1.0	0.7 to 1.3
Minor injuries	1.4	0,5 to 2.3	1.1	0.9 to .3	1.3	1.1 to 1.5
All injury crashes	1.6	0.9 to 2.3	1,2	0.7 to 1.7	1.5	1.2 to 1.8
All injuries	2,2	1.8 to 2.6	1.4	0.4 to 2.4	2.0	1.6 to 2.4

A drawback for NZ users is the lack of exponent estimates for DSI crashes and DSI injuries.

Should power /exponential models be used when the speed distribution shape changes?

- Nilsson’s original work involved changes in the shape of speed distributions
- These changes meant the distributions became slimmer. Example from Povey et al , 2002



Indicates that these models may be used where the shape of the speed distribution typically slims and movesrather than truncates.
These situations could include

- patrol car enforcement
- camera enforcement with uncertainty whether the camera will issue a ticket
- some forms of ISA (Intelligent Speed Adaptation

Individual Risk Models

- These models attempt to compare the risks of crash involved individual drivers traveling at their chosen speeds with the speeds of drivers not involved in a crash

- Studies by Kloeden et al, 1997, 2001 and 2002 compared the speeds of crash involved drivers with the average of the speed distribution of non-crash involved drivers

Findings

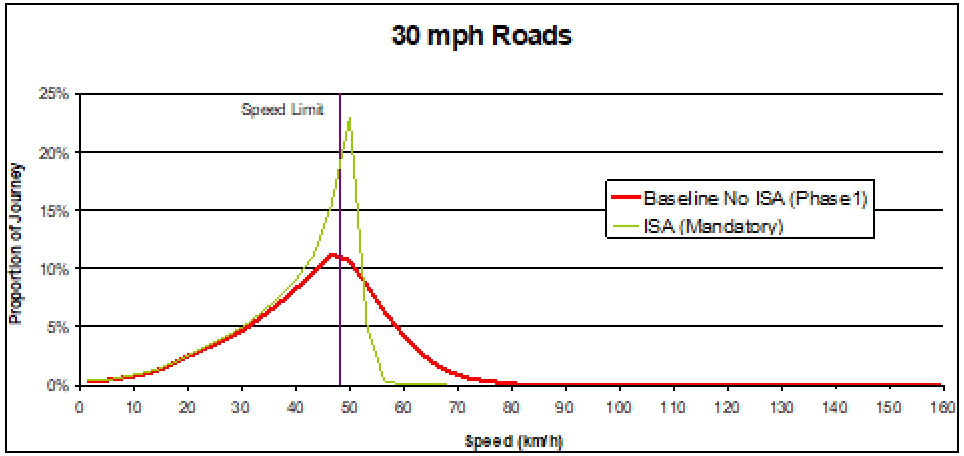
- Urban areas: the risk of casualty crash involvement doubled with each 5km/h increase in free-travel speed above the 60km/hr urban speed limit of the time
- Rural areas: the risk of casualty crash involvement doubled for vehicles travelling 10 km/h above the mean control speed and became nearly six times higher at 20 km/h above the mean control speed

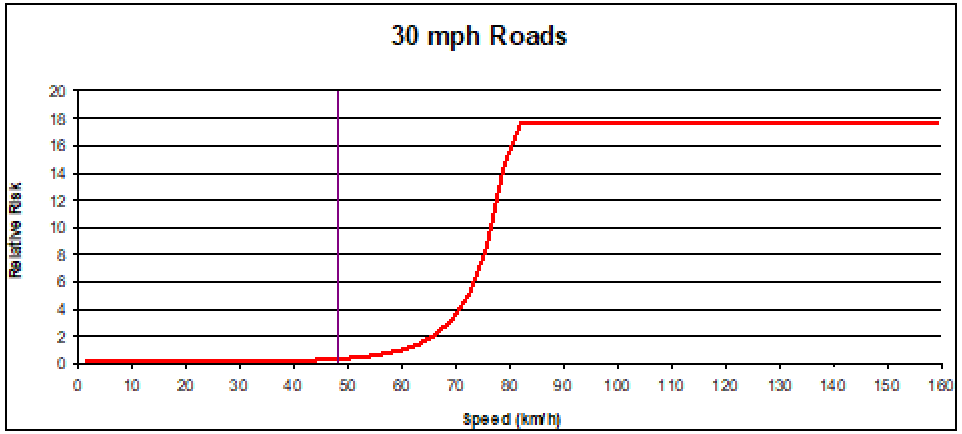
Comment

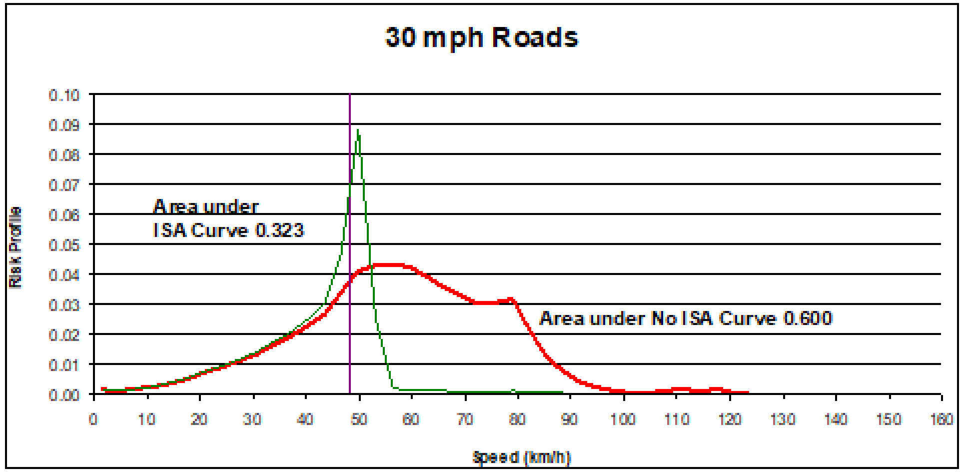
- Individual risk models tend to produce higher crash change estimates than the power model and the exponential model

- This occurs where the shape of the speed distribution changes radically. Eg where the major speed change approaches a truncation of the distribution as with mandatory ISA

Individual Risk Model –Truncated Speed Distribution-Mandatory ISA







Calculate percent difference in crashes by comparing area under the risk /speed curves for the before and after situation

Before ISA Area =0.600
After ISA area =0.323

Difference in risk is 0.323/0.600 or 54%

Speed variance plays no part in the models

- The impact of speed variance on crashes is heavily weighted towards damage only crashes, which are not a road safety concern Elvik (2014)

- Vehicles need to be close enough to each other to interact for speed variance to meaningful impact on safety. Frith and Patterson (2001) indicating that of the total vehicle kilometres of travel on New Zealand roads only about 10% are by vehicles at headways of less than 20 metres

- Often speed means and variances are calculated over long time periods including many vehicles which are separated in time and thus unable to interact. Speed variances calculated in this way have scant safety relevance

- Both Kloeden et al (2001) and Elvik (2009) found no evidence that getting slower drivers to increase their speed (thereby reducing speed variance) was advantageous to safety

Conclusions

Power And Exponential Models

- Higher travel speeds are associated with reduced safety, measured by crash and injury increases
- The extent of this reduction depends on crash/injury severity, road type and the initial speeds
- The rate of increase is greater for more severe injuries and higher speeds
- These characteristics are embodied in the power and exponential models
- Both methods estimate the percentage change in crashes after a change in mean speed and are simple to use
- The power and exponential models are best suited to situations where the speed distribution moves with an unchanged, slimmed down or widened shape. Where changes are heavily weighted to slowing the fastest drivers, the results may be conservative
- The exponential model makes some allowance for changes in the speed distribution shape by being based on disaggregated 10km/hr wide speed tranches
- The exponential model's weakness is that it has been produced only for fatal crashes, injury crashes and property-damage-only crashes and is not fully disaggregated by road type

Conclusions

Individual Risk Models

- Like the power and exponential models, they imply that safety decreases exponentially with speed
- They embody more underlying assumptions than the power and exponential models and are based on a small number of studies, sometimes only one
- They have overestimated crash changes where their estimates have been compared to actual crash changes from speed limit changes, speed camera deployment and hot gas-pedal ISA
- Their usefulness is in highly bespoke situations such as the ISA analyses of Waibi et al (2013) rather than more routine jurisdictional evaluations

Speed Changes to Reduce Vulnerable Road User Trauma.

- The power, exponential and individual risk models mentioned above are unlikely to provide good estimates of the impact of such measures
- It is best to rely on modelling the consequences of collision to justify such measures

Recommendations

- Make sure you are using the right power/exponent for the road type and crash/injury severity being considered
- Unless there is evidence that a measure will produce speed distribution changes more than a simple shifting and/or widening or slimming, the power or the exponential model should be used
- The exponential model is preferred when considering network/ crash/ injury combinations for which exponents are available
- The powers and exponents used in the models have confidence limits
- Only use the models where these confidence limits are of reasonable size
- Rely on modelling the consequences of collision to justify measures to protect vulnerable road users
- In cases where the speed distribution is expected to change in an unusual way a bespoke method may need to be used
- Always check your results afterwards against the real change