Lecture 3: Risk Factors

Introduction

- The number of people killed or injured in road crashes depends basically on the three factors (Nilsson 2002):
  - Exposure
  - Crash rate
  - Injury severity

Introduction

- **Exposure**: the amount of activity in which crashes may occur.
  - In road traffic, the amount of activity refers to the amount of travel, that is the number of person kilometres of travel performed.
  - There are various ways to travel by road: as a pedestrian, by cycling, by driving a car, by taking the bus, etc. Not all of these ways involve the same level of crash risk.
  - The risk to which one is exposed as a road user is not independent of the combination of various means of transport in traffic.

Introduction

- **Crash rate:** the risk of crash per unit of exposure.

$$\text{Crash Rate} = \frac{\text{Average Crash Frequency in a Period}}{\text{Exposure in Same Period}}$$

- A useful indicator of the probability of crash occurrence.
  - The higher the crash rate, the higher the probability of a crash on a given trip of a given length.
  - Sometimes also called crash risk, risk of crash, level of risk.

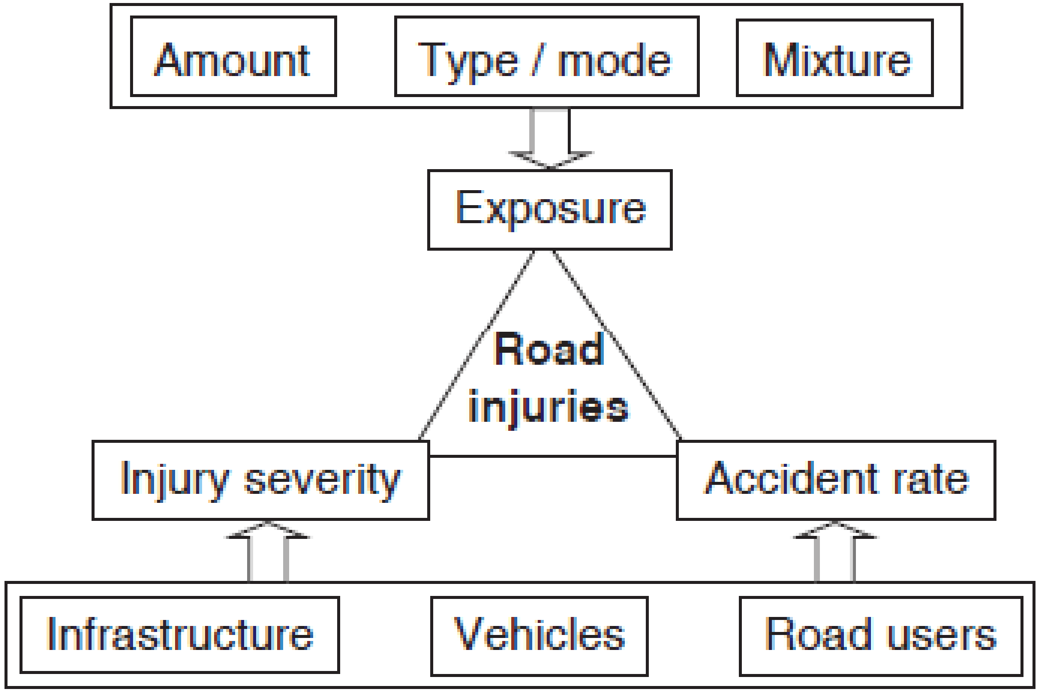
Introduction

- The probability of crash occurrence is affected by a very large number of risk factors related to the elements of the traffic system:
  - Road users,
  - Vehicles,
  - Infrastructure.
- **A risk factor for crashes** is any factor that increases the probability of crash occurrence.
- Risk factors are statistically related to the probability of crashes, but not all risk factors can be regarded as causes of crashes.

Introduction

- **Injury severity**: refers to the outcome of crashes in terms of injuries to people or damage to property.
  - In theory, the severity of the consequences of a crash is a continuous variable.
  - In practice, simple scales that take on just a few discrete values are often used to indicate crash or injury severity, such as the KABCO scale.
- The outcome of a crash in terms of injury to people or damage to property is also affected by a very large number of factors.

Introduction



A taxonomy of factors affecting road safety

Introduction

- In principle, there are four ways of reducing the number of persons killed or injured in road crashes:
  - By reducing exposure to the risk of crashes, that is, by reducing the amount of travel;
  - By shifting travel to means of transport that have a lower level of risk;
  - By reducing the crash rate for a given amount of travel;
  - By reducing crash severity, that is, by protecting people better from injury.

Exposure

- When travelling by road, the main means of transport available are walking, cycling, riding a moped or motorcycle, driving a car, being a passenger in a car and going by bus.
- Studies of the relationship between exposure and crashes usually refer to traffic volume:
  - defined as the number of motor vehicles using a road per unit of time.
  - The volume of travel includes passengers in addition to drivers.
  - Pedestrians and cyclists tend not to be included, usually because there are no reliable counts of their numbers.

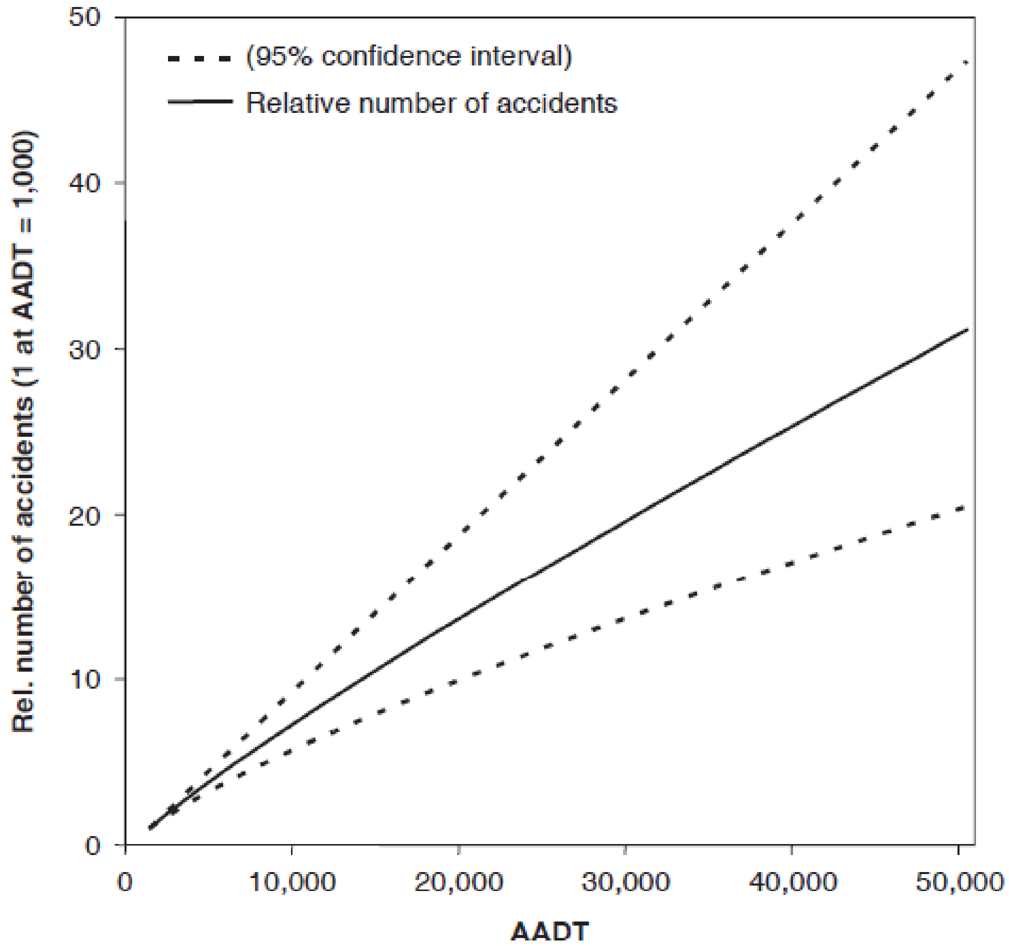
Exposure

- The effects of the amount of travel on the number of crashes can be expressed in many ways. Two of the most informative are to
  - describe, by means of a mathematical function, the shape of the relationship between traffic volume and crashes
  - indicate the contribution that traffic volume makes to explaining systematic variation of the number of crashes

Exposure

- The relationship between traffic volume and crashes
  - Increasing traffic volumes are usually related to increasing numbers of crashes;
  - The number of crashes is <u>not linearly</u> related to traffic volume.
  - Usually, the percentage increase of the number of crashes is <u>less than</u> the percentage increase of traffic volume
    - increasing traffic volumes are often related to better road standards
    - drivers may pay more attention at high volumes than at low volumes

Exposure



$$N = \text{AADT}^{\beta}$$

When traffic volume increases by 10%, the estimated increase of the number of crashes is 8.8%, with a 95% confidence interval from 7.7% to 9.9%.

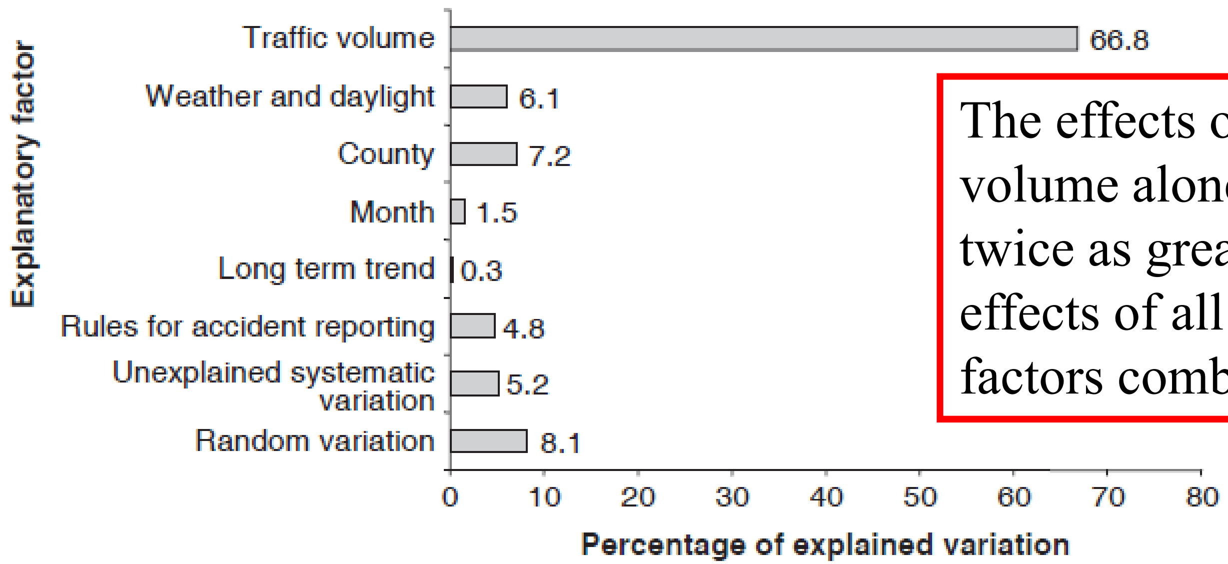
Estimated relationship between traffic volume (AADT) and the number of crashes, based on 28 studies

Exposure

- The effects of the amount of travel on the number of crashes can be expressed in many ways. Two of the most informative are to
  - describe, by means of a mathematical function, the shape of the relationship between traffic volume and crashes
  - indicate the contribution that traffic volume makes to explaining systematic variation of the number of crashes

Exposure

- The contribution of traffic volume to explaining systematic variation of the number of crashes.

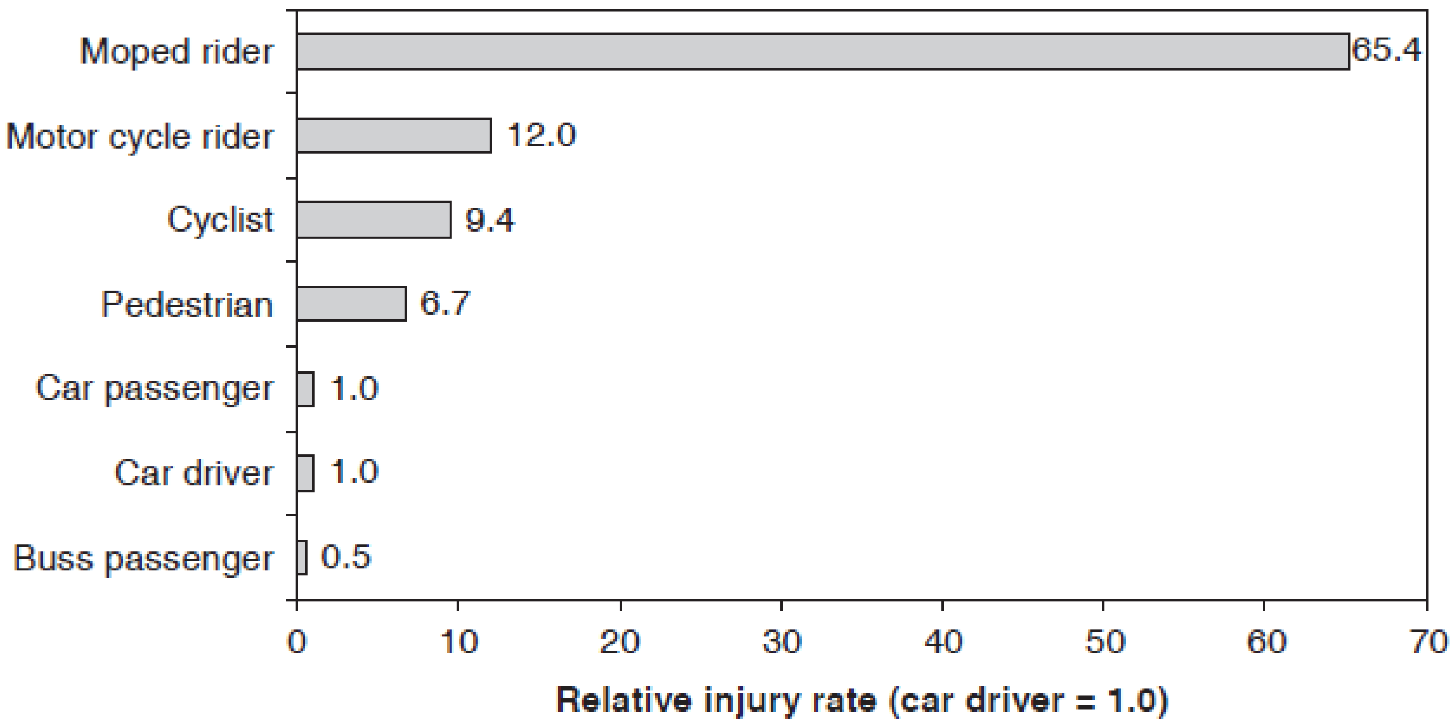


The effects of traffic volume alone is about twice as great as the effects of all other factors combined.

Contribution of various factors to explaining the variation in injury crashes by county and month in Norway

Exposure

- Crash rates for different types of exposure



Relative injury rates for different means of transport – mean for five countries: SE, DK, UK, NL, and NO

Exposure

- Crash rates for different types of exposure
  - Travelling by moped or motorcycle involves a risk of injury, which is over 10 times higher than that of a car driver.
  - Pedestrians and cyclists also run a high risk of being injured per kilometre of travel.
  - Car passengers have the same risk of injury as car drivers.
  - Travelling by bus is the safest.

Exposure

- Why are pedestrians, cyclists and riders of mopeds and motorcycles at such a high risk of getting injured in road traffic?
  - Factors affecting crash involvement rate
    - Pedestrians and cyclists tend to do most of their travel in urban areas, where the overall crash risk is higher than in rural areas.
    - Moped riders are often young and inexperienced.
    - Although motorcycle riders may be more experienced, a motorcycle is capable of going at a higher speed than a moped.
  - Factors affecting the probability of injury, given that a road user is involved in a crash
    - Much of the difference in injury rate is attributable to differences in the protection from injury offered in a crash.

Exposure

- The mixture of road users
  - Most of the road system carries mixed traffic, that is, all or most categories of road users use the same area for travel.
  - Do the relative proportions of different road users in traffic affect the number of crashes?
    - A study by Brude & Larsson (1993)

Number of accidents involving groups 1 and 2 $= \alpha Q_1^b Q_2^c$

In this formula, Q_1 is the number of road users of type 1, Q_2 is the number of road users of type 2, b and c are coefficients to be estimated and α is a scaling constant.

Number of pedestrian accidents $= 0.0000734 \times \text{MV}^{0.50} \times \text{PED}^{0.72}$

Number of bicycle accidents $= 0.0000180 \times \text{MV}^{0.52} \times \text{CYC}^{0.65}$

where MV is the number of motor vehicles (AADT = annual average daily traffic), PED is pedestrian volume and CYC is cyclist volume.

Exposure

- The mixture of road users (cont.)

$$\text{Number of pedestrian accidents} = 0.0000734 \times MV^{0.50} \times PED^{0.72}$$

  - A highly non-linear relationship between exposure and the number of crashes.
    - e.g., PED 500 ->1000, MV 5000 ->10000, N_{PED}: 2.33↑
  - The risk run by each pedestrian, at a given amount of motor traffic, declines strongly.
    - e.g., PED 100 ->1000, the number of pedestrian crashes per pedestrian exposed: 50%↓

Each pedestrian is safer if more pedestrians there are.

Risk Factors for Crash Involvement

- Type of road

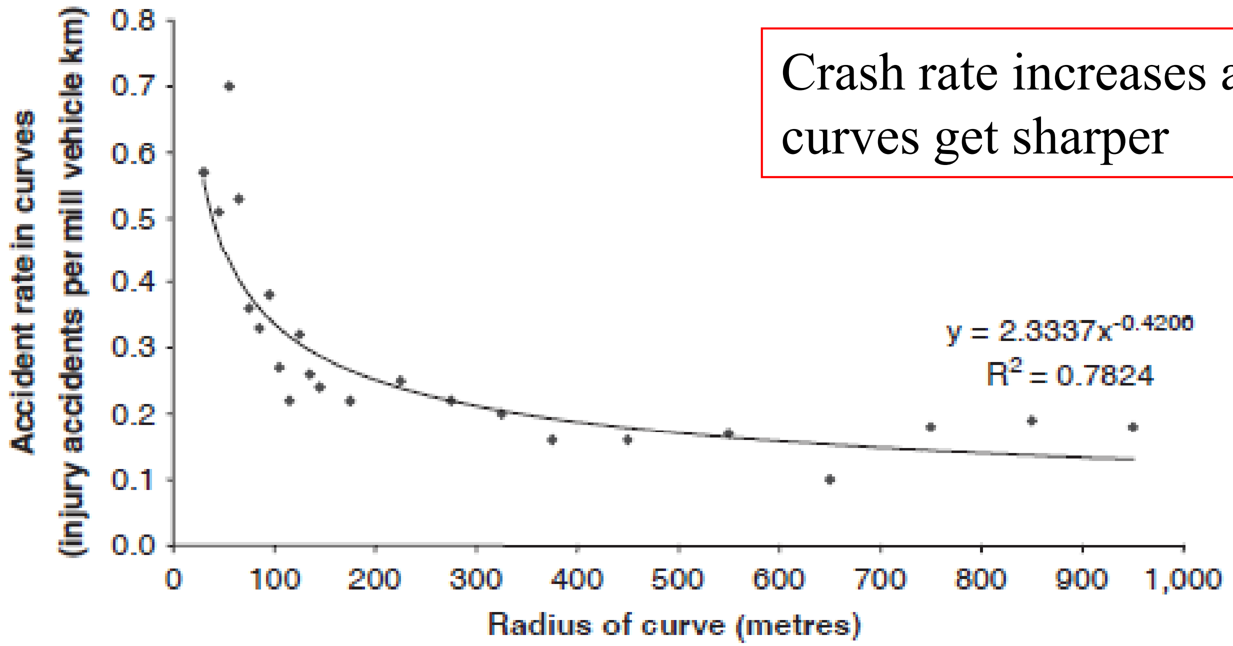
Relative risk of injury crashes on different types of roads in different countries (risk on motorways = 1.00)

	Relative risk of injury accidents in different countries							
Type of road	Denmark	Finland	Germany	UK	Norway	The Netherlands	Sweden	USA
				Rural areas				
Motorway	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Main road	3.97	2.91	3.00	2.82	2.28	1.33	1.29	2.72
Collector road	4.67	3.27			3.46	3.67	2.34	4.56
Access road	5.67	6.11		5.11	5.53	7.17	1.34	8.66
				Urban areas				
Main road	11.00	7.86		7.17	5.22		2.15	5.68
Collector	9.11	6.82			6.46	18.33	3.96	5.61
Access road	9.98	7.35		7.06	12.13	9.50	3.09	8.81
All	4.61	3.75	5.33	4.42	4.04		2.22	4.64

Risk Factors for Crash Involvement

- Design of road
  - Road width: number of lanes, lane width
    - In rural areas, crash rate <u>declines</u> as road width increases,
      - Speed is relatively high, and a wider road may provide an added margin of safety.
    - In urban areas, crash rate <u>increases</u> as road width increases,
      - More traffic will cross the road, so the wider the road is, the longer the time to cross a road.
  - Design of junctions: number of junctions, access points
    - The crash rate increases if a junction has more legs
    - The crash rate increases if a higher proportion of traffic enters the junction from the minor road
  - Horizontal and vertical alignment

Risk Factors for Crash Involvement



Crash rate increases as curves get sharper

Effect of radius of curve on crash rate, based on Norwegian data

Risk Factors for Crash Involvement

- Environmental risk factors

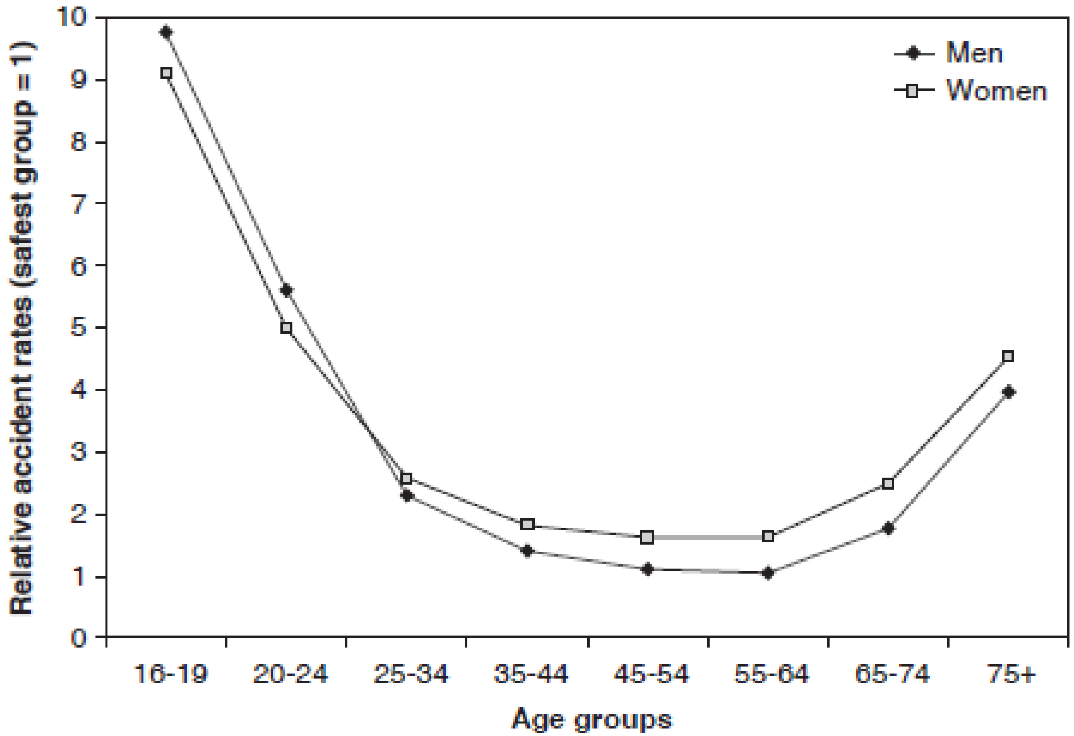
Relative risk of injury crashes in different environmental conditions: estimate for Norway

Factor	Value of factor	Relative accident rate	Confidence interval
Light conditions	Daylight	1.0	
	Darkness – vehicle accidents	1.0	(0.9; 1.1)
	Darkness – pedestrian accidents	2.1	(1.7; 2.5)
	Darkness – bicycle accidents	1.6	(1.2; 2.0)
Road surface conditions	Dry bare road	1.0	
	Wet bare road	1.3	(1.1–1.8)
	Wet snow	1.5	(1.1–2.0)
	Snow or ice covered road	2.5	(1.5–4.0)

The risk of crashes increases in the dark, on the wet roads and when the roads are covered with snow or ice.

Risk Factors for Crash Involvement

- Age and gender of road user



Relative rates of involvement in injury crashes by driver age and gender, based on nine studies

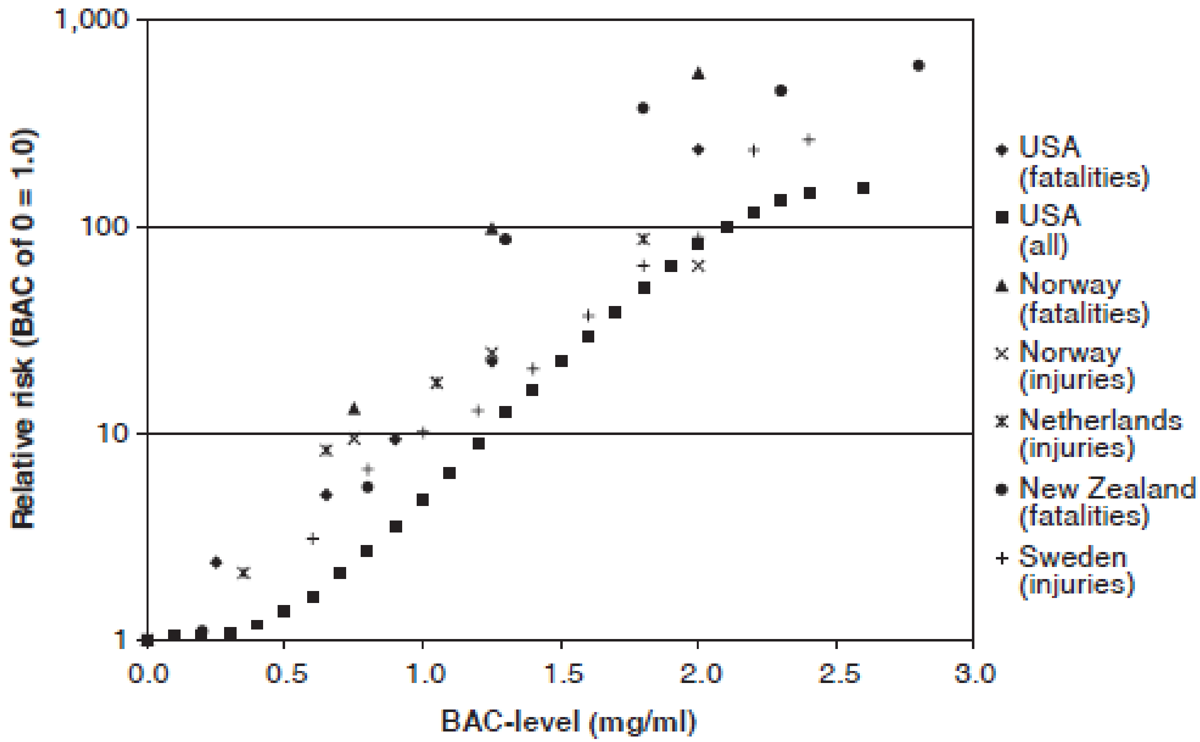
1, A U-shaped function of driver age, both for men and women;
2, The lowest crash rate: men at the age of 45-54 or 55-64;
3, In young drivers, men tend to have a higher crash rate;
4, From about 30, the mean crash rate is higher for women.

Risk Factors for Crash Involvement

- The mean crash involvement rate, all ages taken together, is higher for women than for men in these studies.
  - women drive less than men
    - Crash involvement rate per kilometre of driving is not independent of the distance driven, but decreases as driving distances increase.
  - women tend to drive smaller cars than men
    - Small cars do not give as good protection against injury in a crash as large cars.
  - women tend to drive more in towns and cities
    - risk of crashes is higher in urban areas than in rural areas.

Risk Factors for Crash Involvement

- Impairment through the use of alcohol

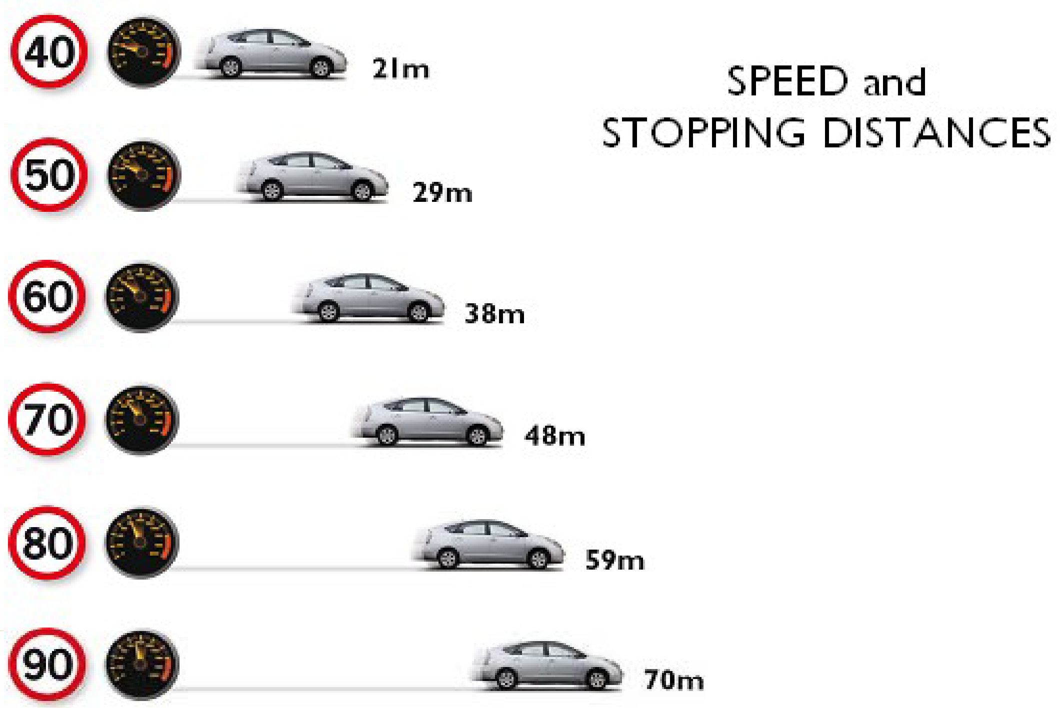


There are few other risk factors that have been found to increase crash rate by a factor of more than 100.

Association between blood alcohol level and relative crash involvement rate

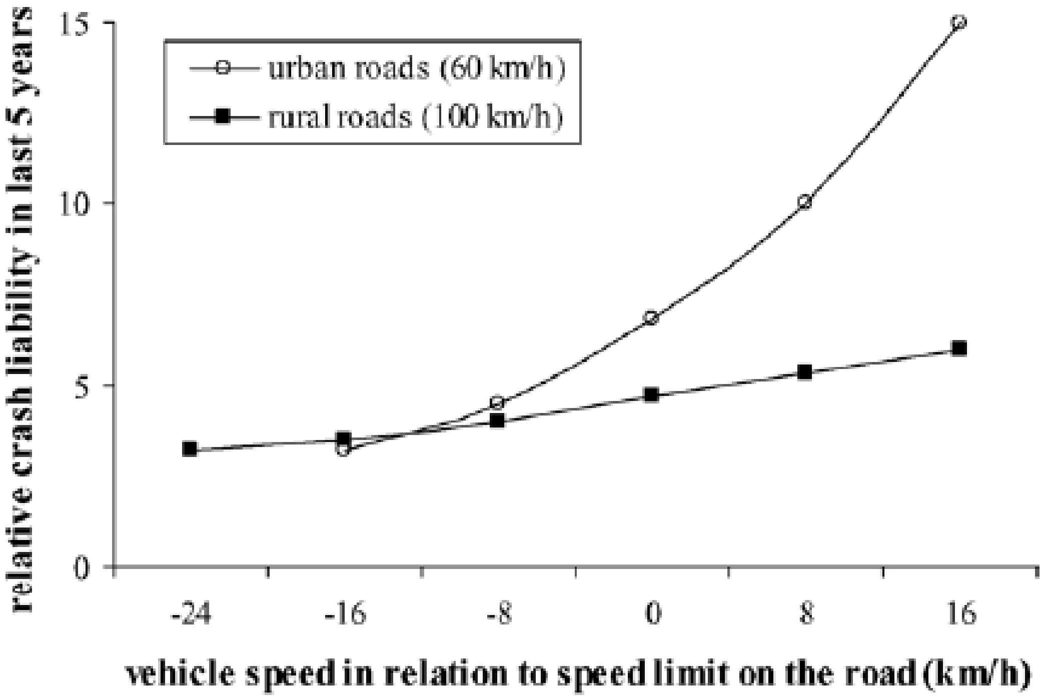
Risk Factors for Crash Involvement

- Speed of travel
  - Driving speed influences both the number of road crashes and the severity of injuries.



Risk Factors for Crash Involvement

- Speed of travel

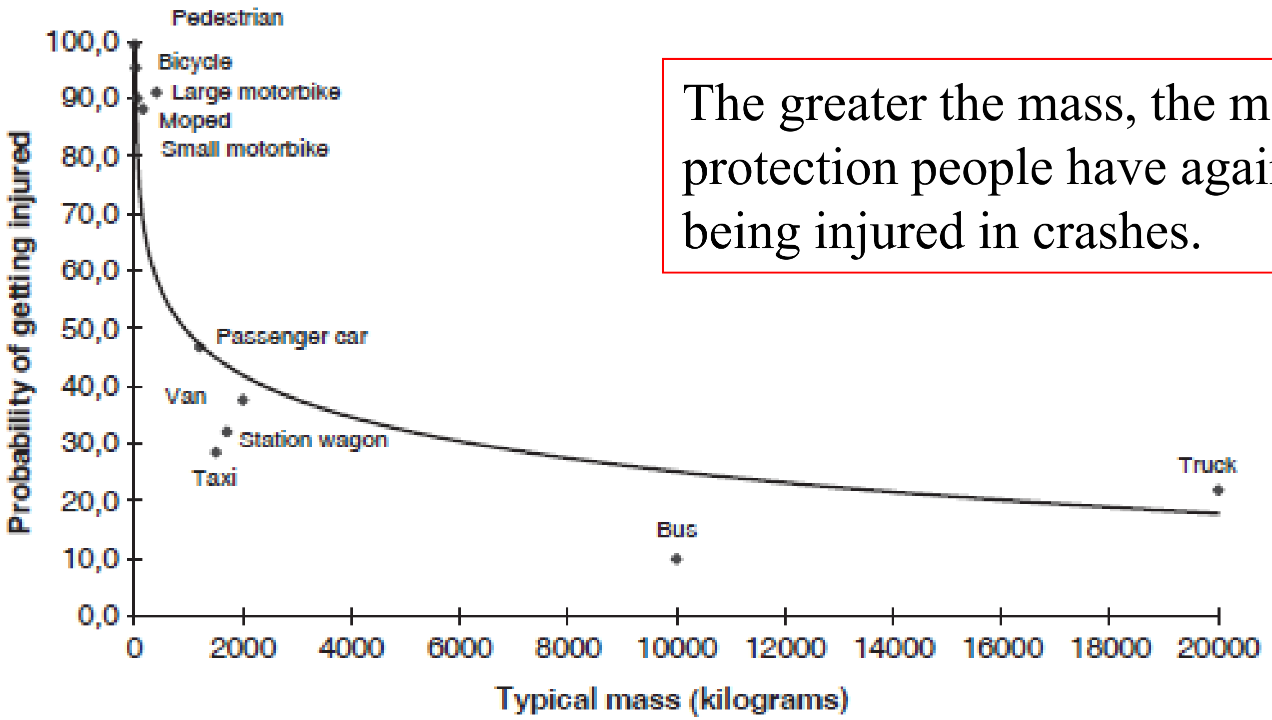


1, The relationship has the shape of an exponential function;
2, It is much steeper for urban roads than for rural roads.

The relation between speed and crash rate on urban 60 km/h and rural 100 km/h roads (Fildes et al., 1991)

Risk Factors for Injury Severity

- Type of motor vehicle – vehicle mass



The greater the mass, the more protection people have against being injured in crashes.

Relationship between mass of vehicle (or road user) and probability of getting injured when involved in an injury crash, based on Norwegian crash statistics

Risk Factors for Injury Severity

- Speed
  - The probability that a crash will result in injury is proportional to the *square* of the speed; for serious injury proportional to the *cube* of the speed; and for fatal injury proportional to the *fourth power* of the speed.
  - On average, a 1% reduction in the mean speed of traffic leads to a 2% reduction in crashes resulting in injuries, a 3% reduction in crashes resulting in severe injuries, and a 4% reduction in fatal crashes.

Risk Factors for Injury Severity

- Protective systems
  - Seat belts
    - e.g., Elvik & Vaa (2004) indicated that the use of seat belts reduces the probability of being killed by 40-50% for drivers and front-seat passengers and by 25% for passengers in the rear seats.
  - The use of safety seats for children and infants
    - e.g., WHO indicated that infant deaths in cars are reduced by 70% and for small children by 50% due to the use of safety seats.
  - Helmet use
    - Motorcycle helmets have been shown to have a clear impact on reducing fatal and serious head injuries by between 20% and 45%;
    - Bicycle helmets diminish the risk of head and brain injuries by 63% to 88%.

Dimensions of Road Safety Problems

- **Magnitude**
- **Severity**
- **Externality**
- Inequity
- Complexitiy
- Spatial dispersion
- Temporal stability
- Perceived urgency
- Amenability to treatment

(Elvik, 2008)

Dimensions of Road Safety Problems

- Magnitude
  - The magnitude of a road safety problem is the size of the contribution a certain risk factor makes to crashes.
  - Attributable risk is a good indicator
    - The fraction of crashes or injuries that is attributable to a certain risk factor, that is, the size of the reduction in the number of crashes or injuries that could be achieved by removing the risk factor.
    - <u>The target attributable risk</u>: the reduction in risk that must be achieved within the target group in order to get the same risk level as the reference group.
    - <u>The population attributable risk (PAR)</u>: the contribution that the enhanced risk level makes to the total number of people killed or injured.

Dimensions of Road Safety Problems

- Magnitude

$$\text{Population attributable risk} = \frac{\text{PE(RR} - 1)}{(\text{PE(RR} - 1)) + 1}$$

where
PE is the proportion of exposure in the presence of the risk factor,
RR is the relative risk associated with it.

Dimensions of Road Safety Problems

- Magnitude

Number of fatalities, injuries, amount of travel and relative risks of fatality and injury for unprotected and protected road users in Sweden (Thulin and Nilsson, 1994)

Injuries, travel and risk	Unprotected road users	Protected road users	All road users
Killed road users	259	466	725
Injured road users	6,454	14,633	21,087
Mill person km of travel	6,661	114,861	121,522
Relative fatality rate	9.58	1.00	1.47
Relative injury rate	7.61	1.00	1.36
Attributable fatality risk	0.896	Reference	0.320
Attributable injury risk	0.869	Reference	0.266

If the risk factor is eliminated, the amount of travel remaining unchanged, the number of crashes could be reduced by 32%

Dimensions of Road Safety Problems

- An example

  Suppose that 10% of travel is exposed to a risk factor A that involves a relative risk of crash involvement of 3, what will be the population attributable risk to this risk factor?

Dimensions of Road Safety Problems

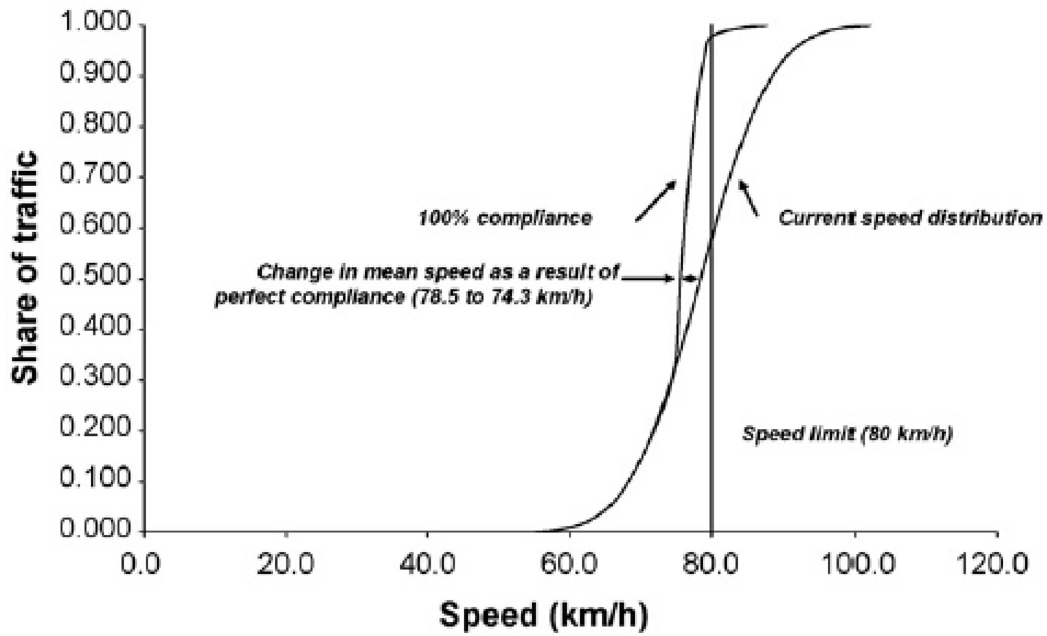
- The PAR above is estimated when the risk factor is categorical. When the risk factor is continuous, like speed, how to estimate PAR?
- A functional relationship is needed to express RR
  - e.g. a power model can be used for the relationship bewteen speed and road safety

$$\frac{y_1}{y_0} = \left(\frac{v_1}{v_0}\right)^x$$

    - v_0, v_1: median speed before/after change
    - y_0, y_1: number of crashes before/after change
    - x = 1.5 (all injury crashes), x = 3 (crashes ≥1 serious injury), x = 4.5 (fatal crashes)

Dimensions of Road Safety Problems

- An example: To estimate the risk attributable to speeding



$$\text{Fatality risk attributable to speeding} = 1 - \left(\frac{74.3}{78.5}\right)^{4.5}$$

$$= 1 - 0.781 = 0.219$$

Dimensions of Road Safety Problems

- Severity
  - A road safety problem or a risk factor is more severe if it contributes more to severe crashes (e.g., fatalities and serious injuries) than to less severe crashes (e.g., slight injuries or property damage).
- How to measure?
  - Define PAR for crashes for each severity level (e.g., fatal-serious-slight)
  - If PAR for more severe crashes is higher => a more severe road safety problem

Dimensions of Road Safety Problems

- An example:
  - Fatalities attributable to speeding: 0.239
  - Serious injuries attributable to speeding: 0.173
  - Slight injuries attributable to speeding: 0.093
  - => For fatalities, 61% of the risk attributable to speeding [(0.239-0.093)/0.239] can be assigned to the contribution of the severity gradient.

Dimensions of Road Safety Problems

- Externality
  - Defined as an activity performed by one actor that has impacts on the welfare of another actor and where the actor producing the impact does not consider it in decisions about the activity.
  - In road traffic context, an externality exists when travel performed by one group of road users imposes an additional risk on another group of road users.

Dimensions of Road Safety Problems

- Externality

Injured road users in police reported crashes in Norway 1998-2005 by combination of groups involved

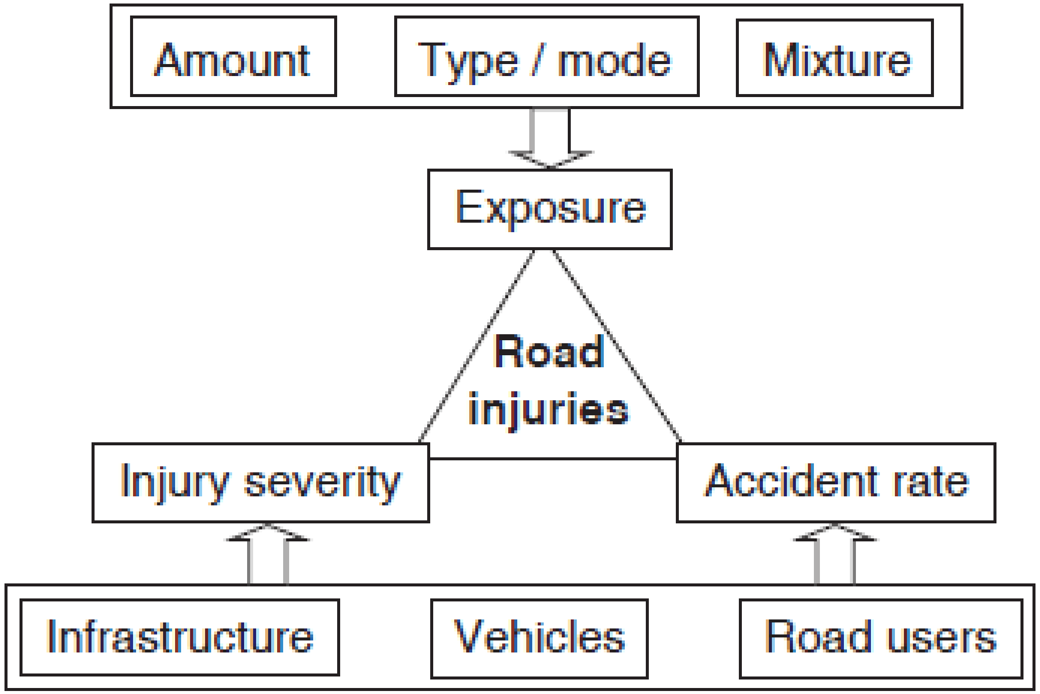
Injured as occupant of	Counterpart in accident												
	Truck-trailer	Truck	Bus	Van	Car	Large MC	Small MC	Moped	Cycle	Pedestrian	Other	None	Total
Truck-trailer	73	32	10	5	96	0	1	0	2	0	3	533	755
Truck	80	102	37	40	197	3	0	2	2	1	22	481	967
Bus	120	103	63	43	290	1	0	7	3	8	36	627	1,301
Van	115	214	80	271	1,038	3	0	4	3	8	35	954	2,725
Car	1789	2736	1210	2815	31,355	203	31	59	59	78	543	19,859	60,737
Large MC	41	84	46	128	1,926	107	5	26	25	25	43	2,216	4,672
Small MC	10	14	9	47	474	4	14	21	6	5	10	340	954
Moped	23	68	47	150	2,350	17	26	139	36	51	46	1,036	3,989
Cycle	42	144	105	286	4,388	42	12	82	254	58	83	644	6,140
Pedestrian	54	220	318	409	5,635	61	13	147	167	37	188	185	7,434
Other	17	54	14	20	158	5	0	2	4	2	31	414	721
Total	2364	3771	1939	4214	47,907	446	102	489	561	273	1040	27,289	90,395

1789 car occupants were injured in crashes in which the other party was a truck-trailer

Dimensions of Road Safety Problems

- Externality
  - In total, 2364 road users were injured in crashes in which truck-trailers were involved, of which 2291 (=2364-73) were not occupants of the truck-trailer.
  - On the other hand, the risk other road users impose on occupants of truck-trailers accounts for only 149 (=755-533-73) injured occupants.
  - The ratio between these two numbers may serve as a numerical index of the external risk created by truck-trailers, which is 2291/149=15.38
  - The number of injuries to other groups of road users in crashes involving truck-trailers is 15 times greater than the number of injuries to truck-trailer occupants – a large net external risk of truck-trailer.

Summary



Amount
Type / mode
Mixture
Exposure
Road injuries
Injury severity
Accident rate
Infrastructure
Vehicles
Road users