A systematic approach to road safety impact assessment

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Outline of lecture

- The concept of road safety impact assessment
- A model of the activities/steps involved in road safety impact assessment
- The contribution of research to road safety impact assessment
- Levels of road safety impact assessment
- The importance of adopting a broad perspective regarding potentially effective measures
- Sources of uncertainty in road safety impact assessment and the prospects of reducing uncertainty

The concept of road safety impact assessment

- European directive:
  - A strategic comparative analysis of the impact of a new road or a substantial modification to the existing network on the safety performance of the network
- A more general definition:
  - A numerical estimate of the expected effects on safety (number of accidents and/or injured road users) of a single road safety measure or a set of road safety measures forming a programme
  - Expected effects on safety refer to changes in the expected number of accidents or the expected number of injured road users as a result of the introduction of a road safety measure or a set of measures (i.e. compared to a baseline alternative)

Stages of road safety impact assessment

Stage 1	Describe current road safety problems and assess their relative importance in contributing to fatalities and injuries
Stage 2	Develop road safety targets and decide on quantification of these as well as other policy objectives
Stage 3	Survey potentially effective road safety measures and decide which measures still have a potential for improving safety
Stage 4	Describe the current road transport system and establish a framework for analysis of alternative policy options
Stage 5	Develop alternative road safety policy options, showing the main directions for road safety policy
Stage 6	Estimate the effects of each policy option on the number of killed or injured road users, as well as effects with respect to other policy objectives
Stage 7	Assess sources of uncertainty in estimated effects and discuss the treatment of uncertainty in road safety policy making
Stage 8	Determine considerations relevant to the choice of road safety policy and choose preferred policy
Stage 9	Implement preferred road safety policy and evaluate effects of that policy

Levels of road safety impact assessment

- Several levels of government may be involved:
  - International (e.g. EU-level)
  - National (as part of developing a national road safety programme)
  - Regional (state or county level)
  - Local (municipal level; single community)
- The level of detail depends on the level of goverment:
  - The lower the level of government, the more detailed becomes the assessment
  - A basic distinction is between the assessment of projects with a known location and known accident history and more general assessments
  - I will concentrate on the latter (more general assessments)

Stage 1: Assess road safety problems

- Road safety problems = anything that contributes to accidents or injuries
- Assess problems in terms of:
  - Magnitude
  - Severity
  - Externality
  - Inequity
  - Complexity
  - Spatial dispersion
  - Changes over time
  - Perceived urgency
  - Amenability to treatment
- Determine which problems should be targeted in a road safety programme

Important road safety problems

- Speeding
- Driving under the influence of alcohol and/or drugs
- Not wearing protective devices
- Vulnerability of unprotected road users in mixed traffic
- Increasing incompatibility between motor vehicles
- Hazardous road locations (”black spots”)
- Road user distraction and fatigue
  - Mobile phones
  - Fatigue

Stage 2: Setting road safety targets

- Targets may be qualitative or quantitative
- Quantified targets have been found to be associated with better road safety performance
- Quantified targets are particularly effective if:
  - They are supported by the highest level of government
  - They are ambitious, yet in principle achievable
  - They are long term (10-15 years)
- Pitfalls to be avoided in setting targets:
  - Setting too many sub-targets
  - Setting targets one does not know how to realise

Stage 3: Survey road safety measures

- Conduct a broad survey including all potentially effective road safety measures
- A road safety measure is potentially effective if:
  - There is reason to believe it may reduce the number of accidents and/or the severity of injuries
  - The measure has not already been fully implemented
- Reasons for believing are of two kinds:
  - Evaluation studies have found that the measure improves road safety
  - The measure favourably influences risk factors that are known to contribute to accidents or injuries

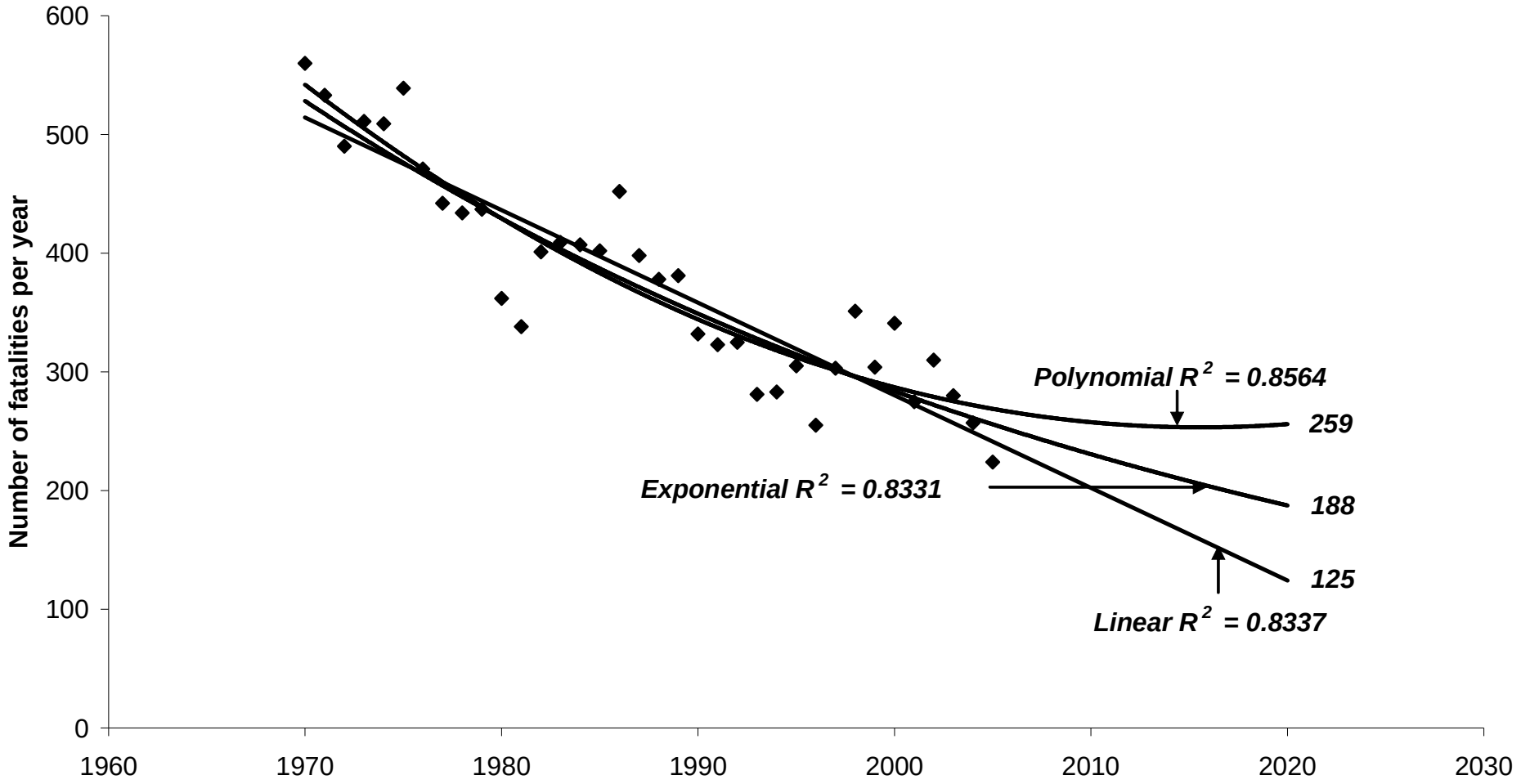
Stage 4: Define framework for analysis

- Define a baseline scenario and forecast number of accidents or injured road users
- Decide on the time horizon for the analysis, i.e. the length of the period for implementing road safety measures and the length of the period for which impacts are estimated
- Determine main parameters for analysis (discount rate, etc)
- Determine other constraints on analysis

Baseline scenario for Norway 2007-2020

- Traffic is expected to grow by 17%
- Modal split will remain unchanged
- No modes of travel will be banned
- No new road safety measures will be introduced, but road maintenance and police enforcement continue at present levels
- Vehicle safety features already on the market will continue to spread

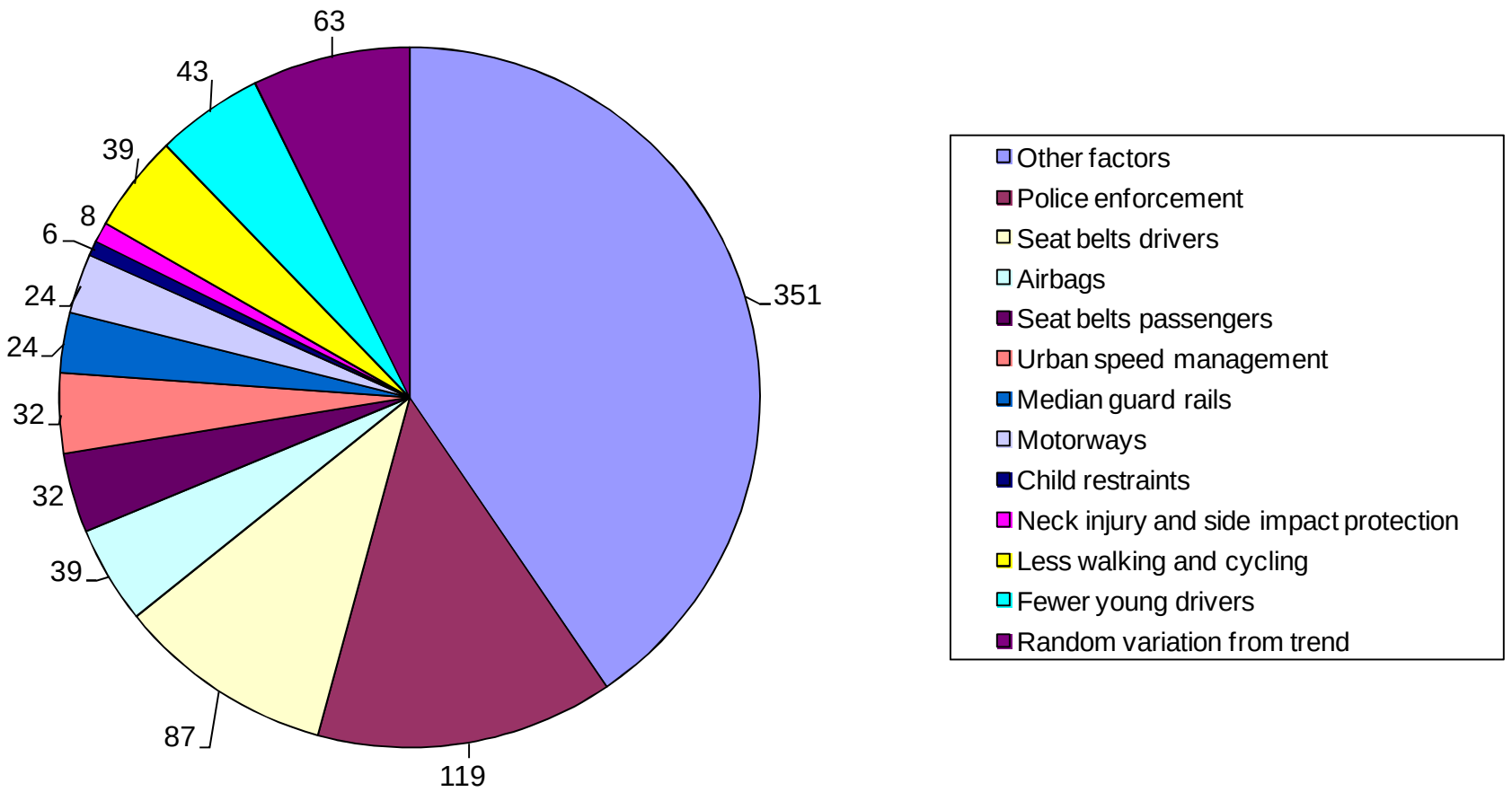
Number of road accident fatalities in Norway and projections based on past trends



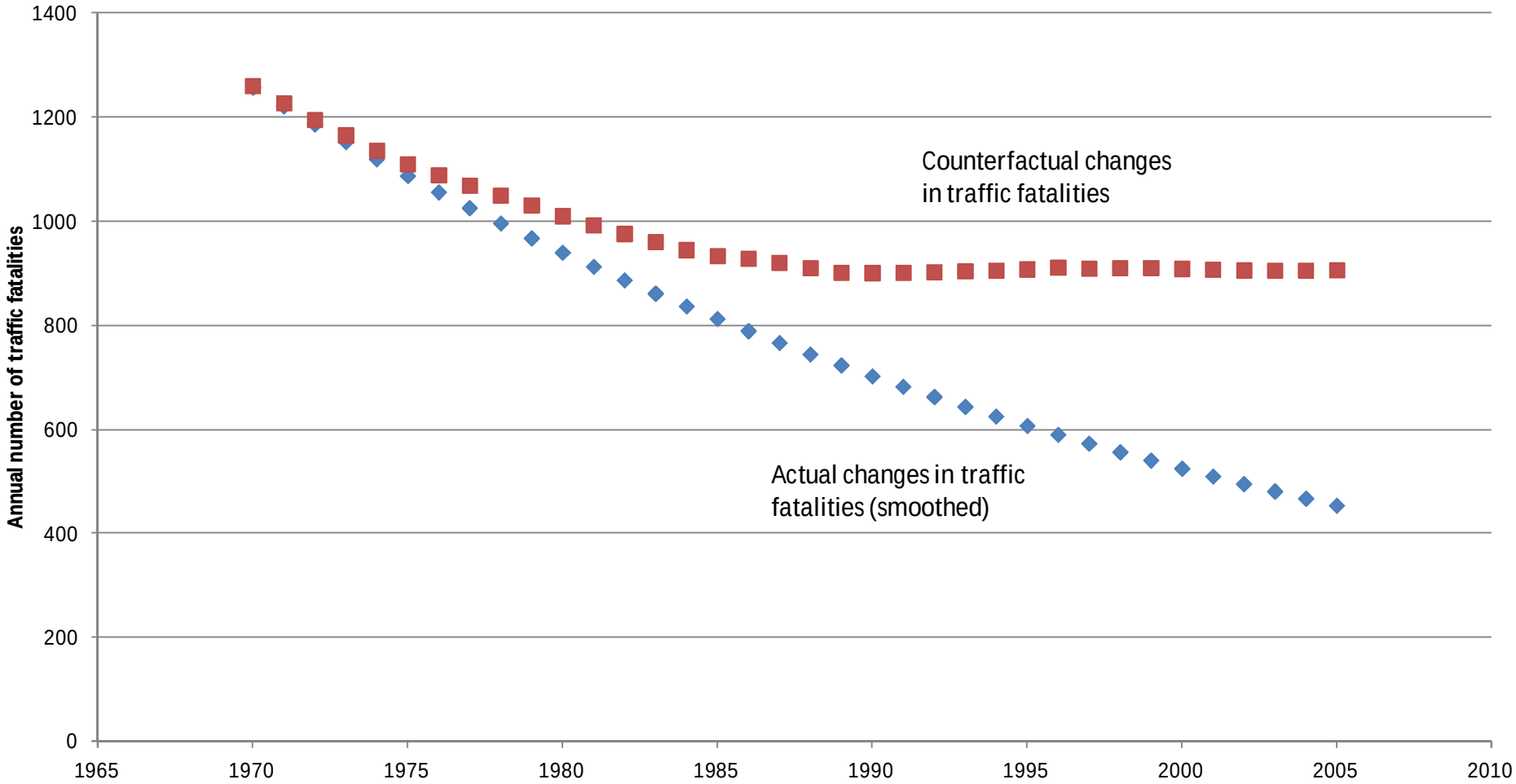
Difficulties of developing a baseline prediction

- The baseline should ideally speaking show what is likely to happen if no new road safety measures are introduced
- What do we mean by a ”new” measure?
  - A measure not used before, e.g. building a new road or introducing any new safety feature (guard rails, road lighting, etc) on a road
  - New safety features on motor vehicles
  - A higher level of police enforcement or more effective deployment of police manpower
- Past trends show the effects of all measures that were introduced earlier
- These effects need to be estimated and controlled for

Factors that may have contributed to fewer fatalities in Sweden 1970-2005



Smoothed description of actual changes in traffic fatalities in Sweden 1970-2005 compared to counterfactual development if safety measures had not been introduced



Stage 5: Main options for use of road safety measures

- Options may refer both to the use of a single measures and to the combined use of several measures
- Some generic options for a single measure:
  - Not use it at all
  - Use it at the same level as now (e.g. 50 junctions converted to roundabouts each year)
  - Stepping up the use of the measure
- Some generic options for national road safety programmes:
  - Continue present policies
  - Optimal use of safety measures
  - Maximum conceivable use of safety measures

Implementation modelling

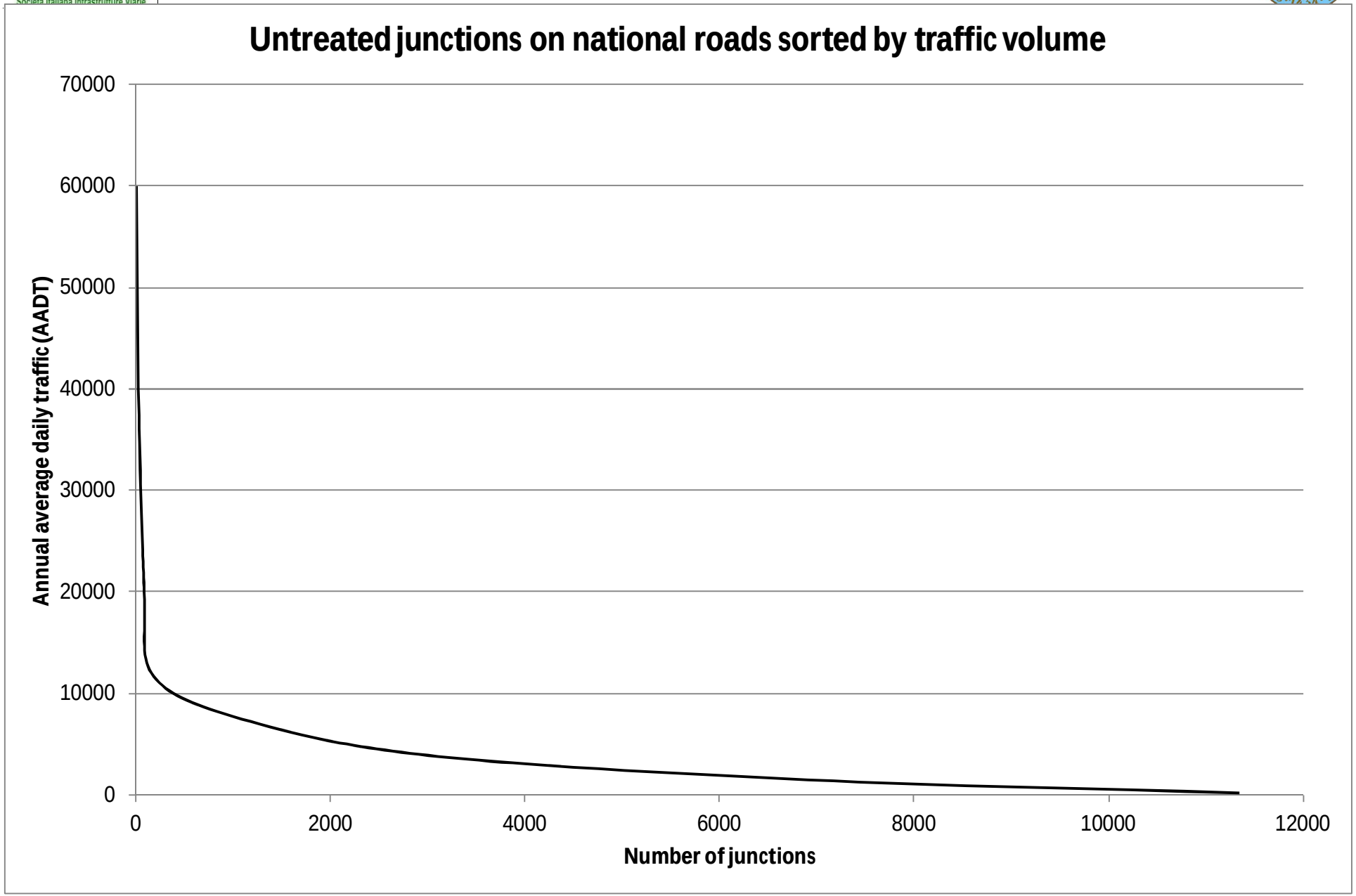
- Rules for the introduction of a safety measure intended to maximise benefits and permit a marginal analysis
- Marginal analysis = analysis of the benefits and cost added by introducing an additional unit of a safety measure
- Optimal use of a safety measure = marginal benefits equal marginal costs
- Elements of implementation modelling:
  - Define units for the use of a measure
  - Estimate current degree of implementation
  - Estimate potential for future implementation

Selection for treatment

- Define ”units” of implementation:
  - 1 junction
  - 1 kilometre of road
  - 1 motor vehicle
  - 1 road user
  - Multiple of current enforcement
- Determine the current rate of implementation:
  - Example: crash helmets worn by 99-100% of moped and motor cycle riders = fully implemented
- Determine the number of ”candidates” for implementation:
  - Units for which a measure has not been introduced

Example: junctions that can be treated

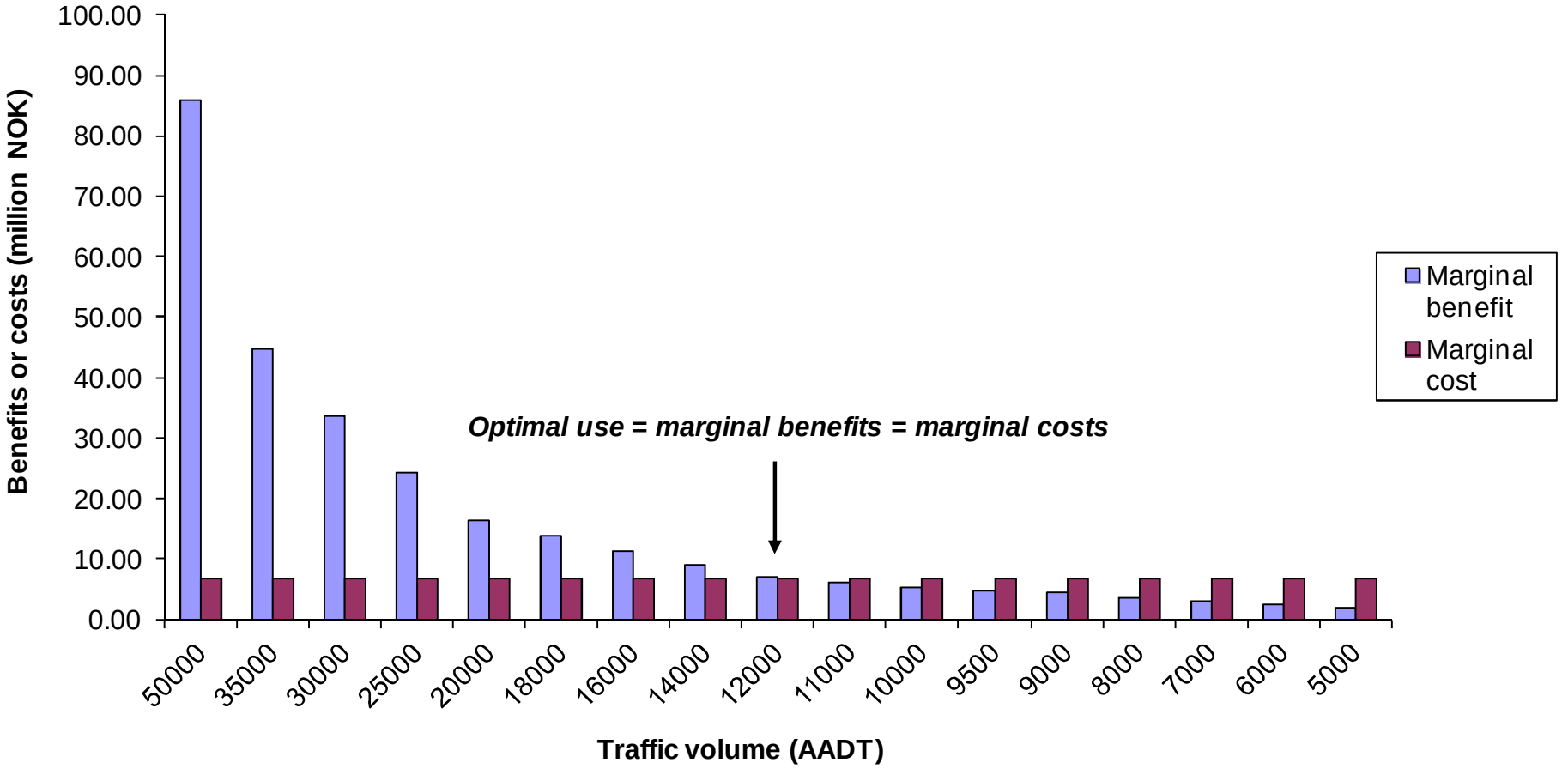
	Traffic volume (AADT)						
Junctions by measure	**0-1499**	**1500-3999**	**4000-7999**	**8000-11999**	**12000-19999**	**20000-39999**	**40000-**
All junctions on national roads	5824	5499	3082	1626	1213	339	70
Channelised junctions (islands)	142	185	293	231	272	93	1
Channelised junctions (paint)	72	183	138	69	120	17	0
Roundabouts	57	80	144	132	174	53	2
Signalised junctions	0	0	60	250	550	100	40
No measure in junction	5553	5051	2447	944	97	76	27
Candidates (for any measure)	4440	4000	2000	750	75	60	20


Untreated junctions on national roads sorted by traffic volume
Annual average daily traffic (AADT)
70000
60000
50000
40000
30000
20000
10000
0
0
2000
4000
6000
8000
10000
12000
Number of junctions

Main elements of marginal analysis of road safety measures

- Measures are introduced according to declining marginal benefits
- Account is taken of non-linearity in the relationship between traffic volume and the number of accidents
- Account is taken of the fact that injury severity varies between different types of accident
- Account is taken of the relationship between traffic volume and the cost of introducing a measure

Illustration of how optimal use of a road safety measure is determined - conversion to roundabouts



Stage 6: Estimate impacts of main policy options

- Basic model for estimating first order impacts:
  - Number of units x traffic per unit x injury risk x effect of measure
  - $120 \times 12{,}000 \times 365 \times 0.091 \times 10^{-6} \times 0.018 \times 0.49 = 0.42$
- Basic model for estimating combined effects:
  - E = effect of a measure = proportion of target accidents it prevents
  - R = residual of a measure = proportion of target accidents it does not prevent = 1 – E
  - Method of common residuals:
  - $1 - [(1 - E_1) \times (1 - E_2) \times (1 - E_3) \times \ldots (1 - E_n)$

Example of effects assumed in impact assessment

		Percentage change in the number of road users injured by injury severity		
Measure	**Target accidents**	**Killed**	**Seriously injured**	**Slightly injured**
Road safety inspections	All accidents	-15	-10	-5
Pedestrian bridge or tunnel	Pedestrians crossing road	-80	-80	-80
Motorways	All accidents	-57	-60	-49
Bypasses	Accidents in towns bypassed	-25	-25	-25
Roundabouts (T-junctions)	Accidents in junctions	-49	-33	-31
Roundabouts (X-junctions)	Accidents in junctions	-64	-53	-51
Roadside safety treatment	Running-off-the-road	-22	-22	-22
Rehabilitation of roads	Non-junctions accidents	-20	-20	-20
Guardrails along roadside	Running-off-the-road	-45	-45	-40
Median guard rails	Head-on accidents	-80	-45	+10
Median rumble strips (wide)	Head-on accidents	-23	-16	-8

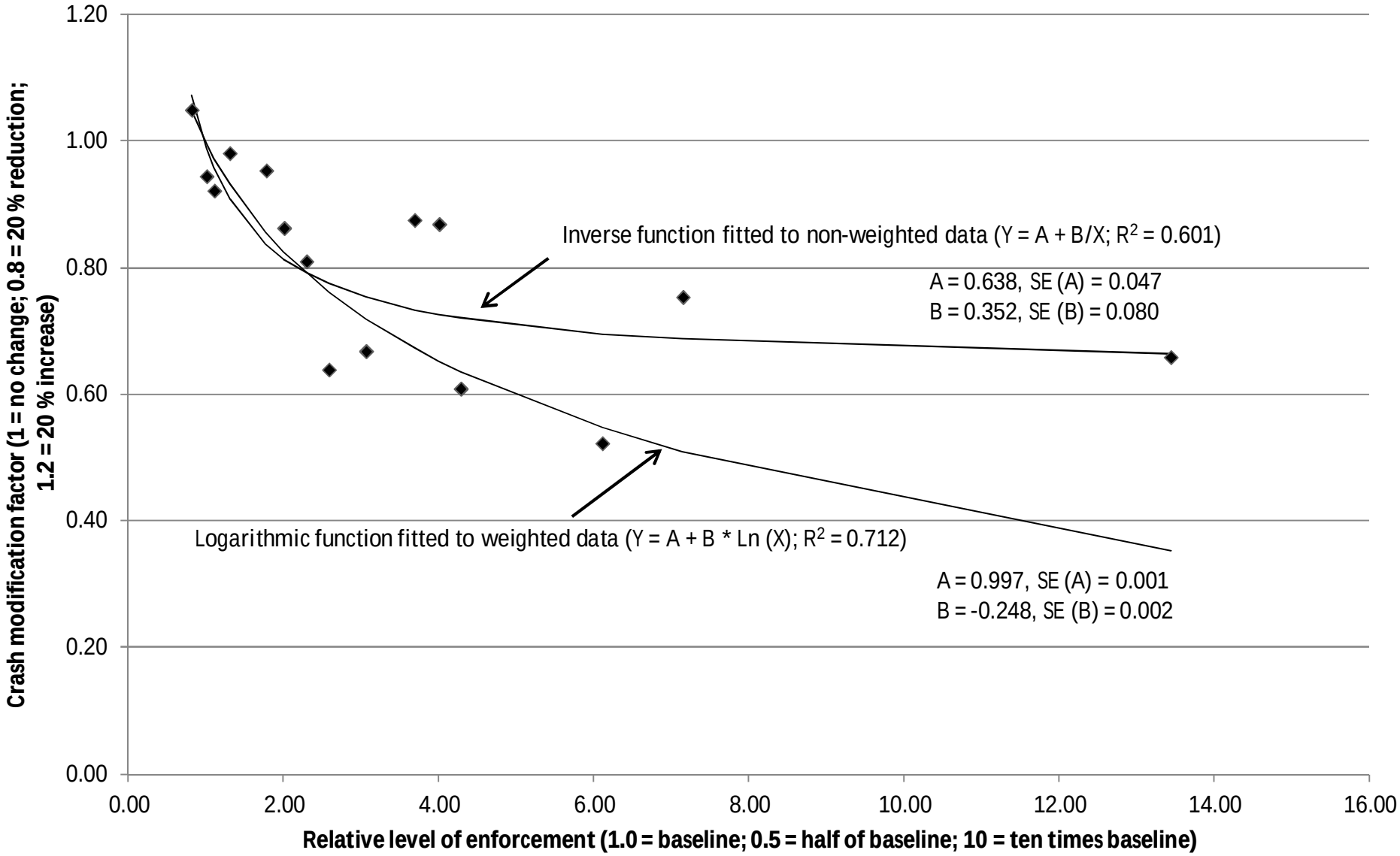
Example of results of cost-benefit analysis

		Estimated reduction of the number of road users killed or seriously injured (first order effects)	
Road safety measure	**Benefit-cost ratio**	**Killed**	**Seriously injured**
Road-related safety measures			
Bypass roads	1.38	0.2	1.3
Pedestrian bridge or tunnel	1.47	3.3	10.6
Converting T-junction to roundabout	1.86	1.9	6.1
Converting X-junction to roundabout	2.62	3.0	12.0
Roadside safety treatment	2.77	0.5	2.1
Reconstruction and rehabilitation of roads	1.57	1.0	3.2
Guardrails (along roadside)	2.53	1.3	5.3
Median guard rails on undivided roads	1.40	1.7	2.5
Median rumble strips (1 metre wide)	2.41	1.0	1.7

How best to represent the effects of safety measures

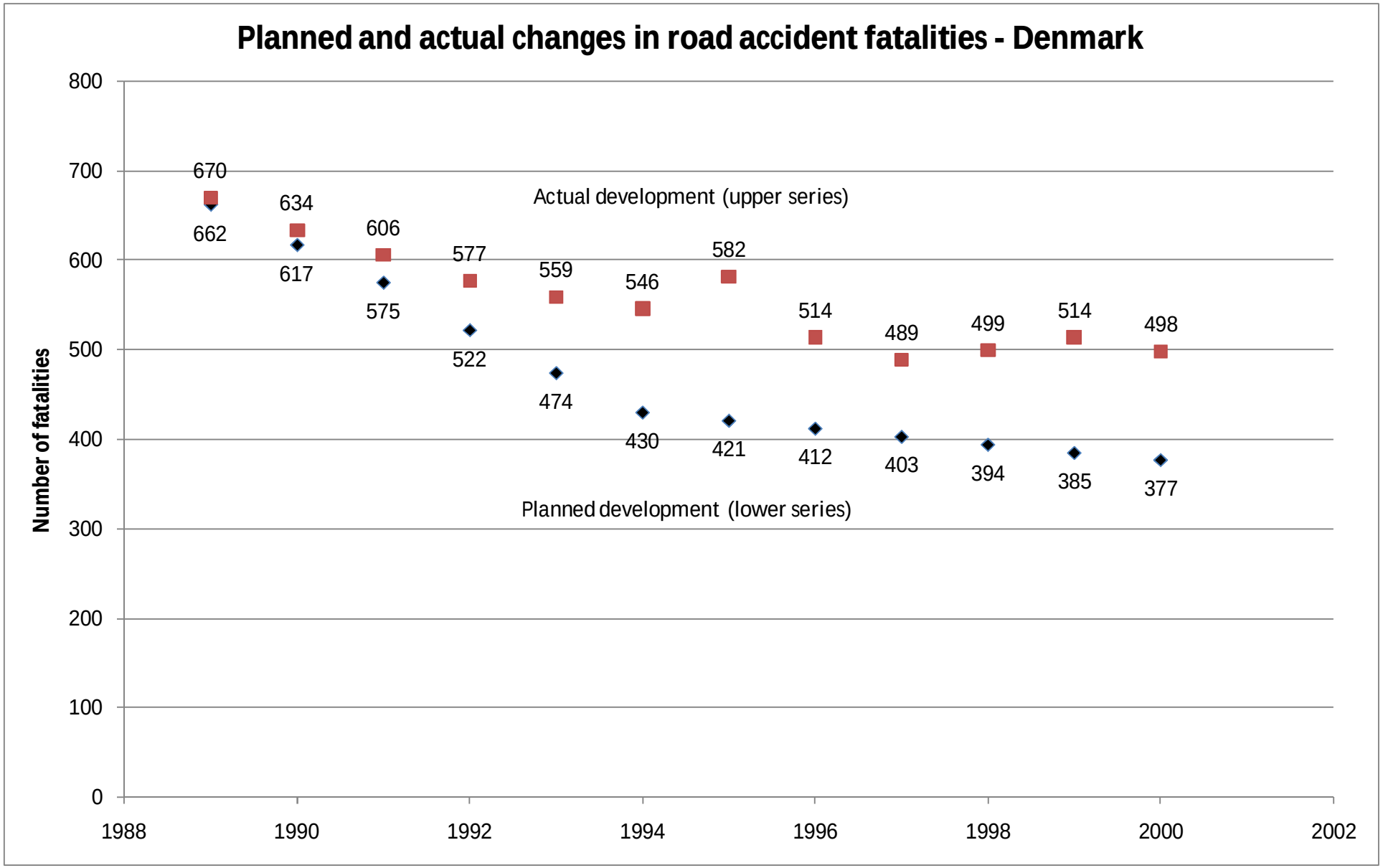
- It is increasingly realised that the effects of a road safety measure varies systematically, depending on, for example:
  - Characteristics of the measure (the higher the level of road lighting, the larger the effect on accidents at night)
  - Characteristics of the traffic environment (converting four leg junctions to roundabouts is more effective than converting three leg junctions)
  - How measures are combined into a programme
- Systematic variation in the effects of a measure ought to be modelled in terms of an accident modification function
- However, few such functions have been developed

Crash modification function for speed enforcement fitted to grouped data



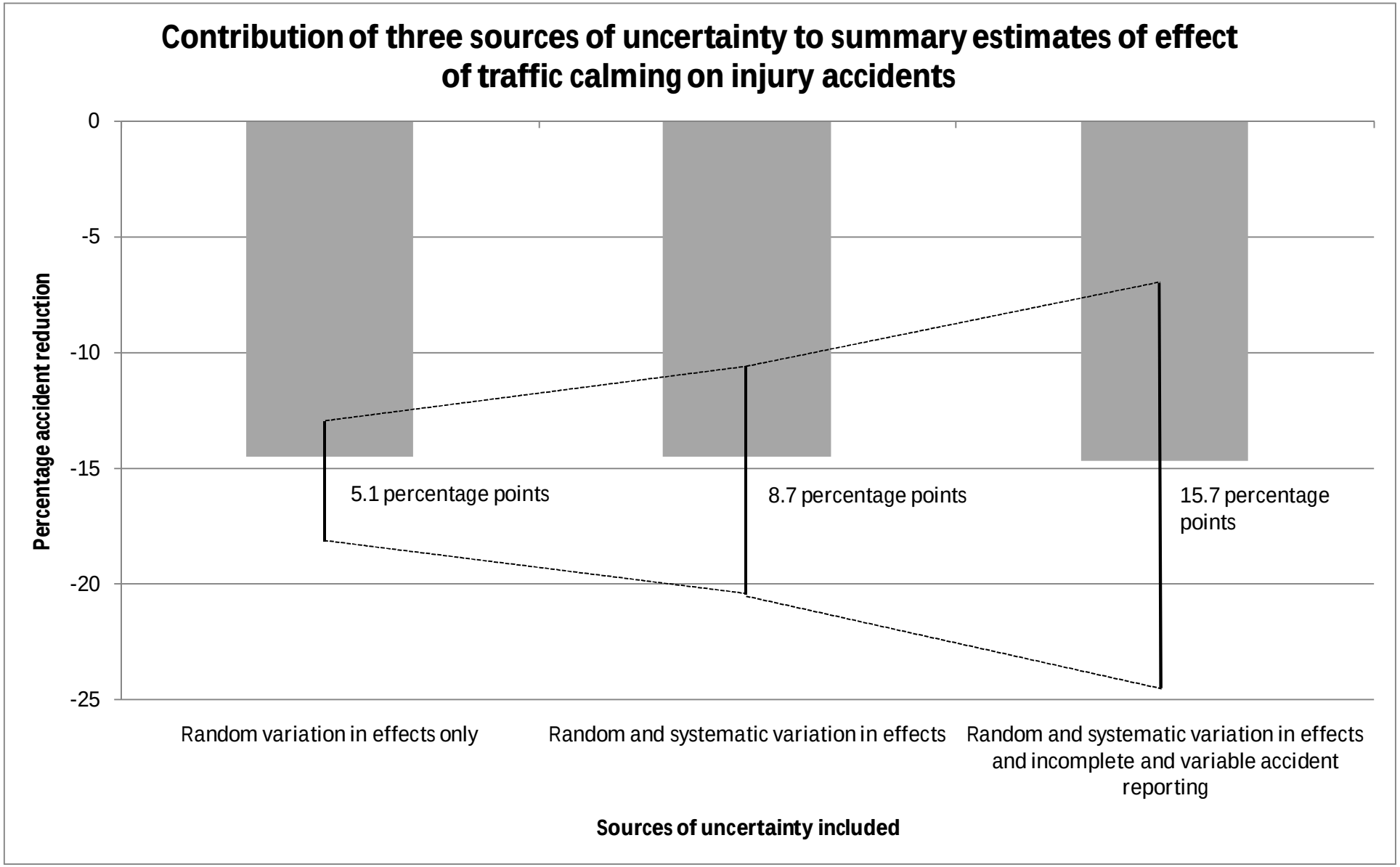
Stage 7: Assess uncertainty

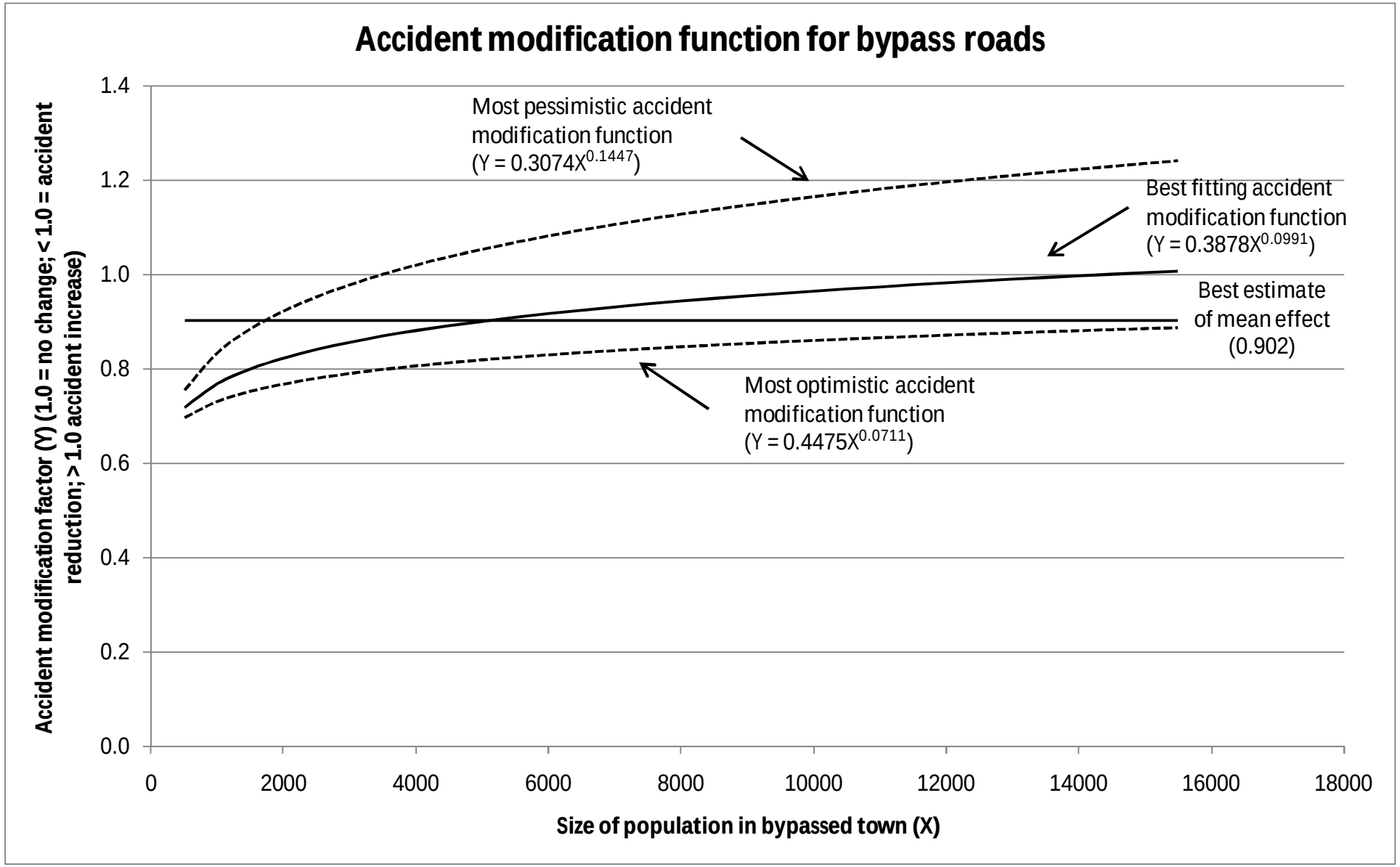
- Determine sources of uncertainty
- Estimate the variance attributable to each source of uncertainty
- Estimate total uncertainty attributable to all sources
- Assess the sensitivity of policy priorities to uncertainty
- Develop a strategy (research programme) for reducing uncertainty


Planned and actual changes in road accident fatalities - Denmark
Number of fatalities
800
700
600
500
400
300
200
100
0
1988
1990
1992
1994
1996
1998
2000
2002
Actual development (upper series)
Planned development (lower series)
670
662
634
617
606
575
577
522
559
474
546
430
582
421
514
412
489
403
499
394
514
385
498
377

Sources of uncertainty

1. Random variation in target accidents
2. Incomplete accident reporting
3. Uncertain definition of target accidents
4. Random variation in effects of safety measures
5. Unknown sources of systematic variation in effects
6. Unknown duration or stability of effects of measures
7. Modification of effect when combined with other measures
8. Uncertain effects of exogenous factors
9. Uncertain degree of implementation of programme
10. Uncertain monetary valuation of benefits


Contribution of three sources of uncertainty to summary estimates of effect of traffic calming on injury accidents
Percentage accident reduction
0
-5
-10
-15
-20
-25
5.1 percentage points
8.7 percentage points
15.7 percentage points
Random variation in effects only
Random and systematic variation in effects
Random and systematic variation in effects and incomplete and variable accident reporting
Sources of uncertainty included


Accident modification function for bypass roads
Accident modification factor (Y) (1.0 = no change; < 1.0 = accident reduction; > 1.0 accident increase)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Size of population in bypassed town (X)
Most pessimistic accident modification function (Y = 0.3074X^0.1447)
Best fitting accident modification function (Y = 0.3878X^0.0991)
Best estimate of mean effect (0.902)
Most optimistic accident modification function (Y = 0.4475X^0.0711)

Possibility of quantification

Source of uncertainty	Possibility for quantification
1 Random variation in target accidents	Yes
2 Incomplete accident reporting	Yes
3 Uncertain definition of target accidents	No
4 Random variation in effects of measures	Yes
5 Systematic variation in effects of measures	Yes
6 Uncertain duration of effects	No
7 Uncertainty in combined effects	No
8 Uncertain effects of exogenous factors	No
9 Uncertain degree of implementation	No
10 Uncertain monetary valuation of safety	Yes

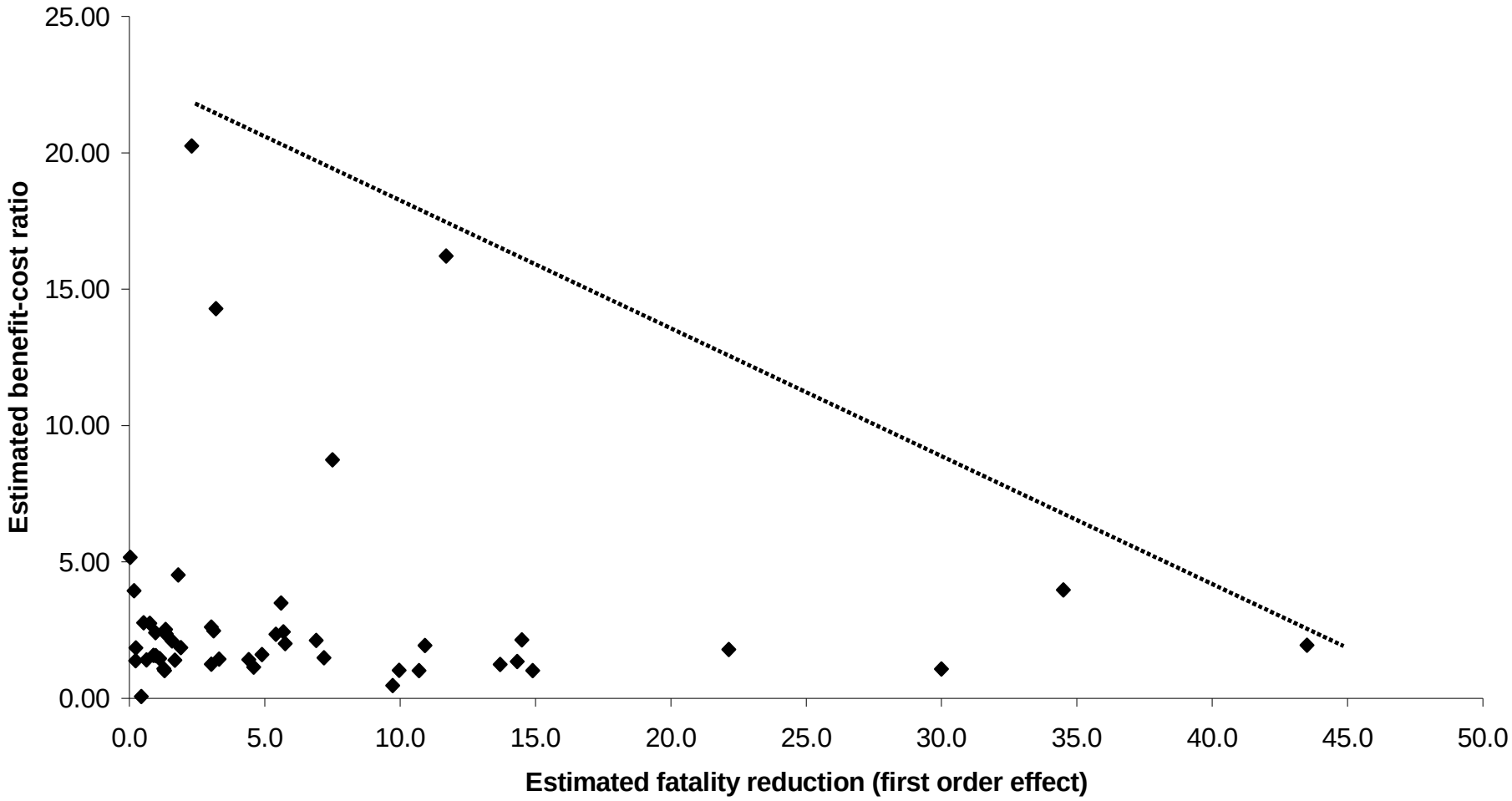
Conclusions regarding uncertainty

- There are many sources of uncertainty in the estimated effects and benefits of national road safety programmes
- These sources of uncertainty are not always recognised and are almost never discussed explicitly in road safety programmes
- Ten sources of uncertainty have been discussed – not all of them can be quantified
- It should not come as a surprise that estimated effects of road safety programmes are almost never realised in practice
- Uncertainty cannot be greatly reduced

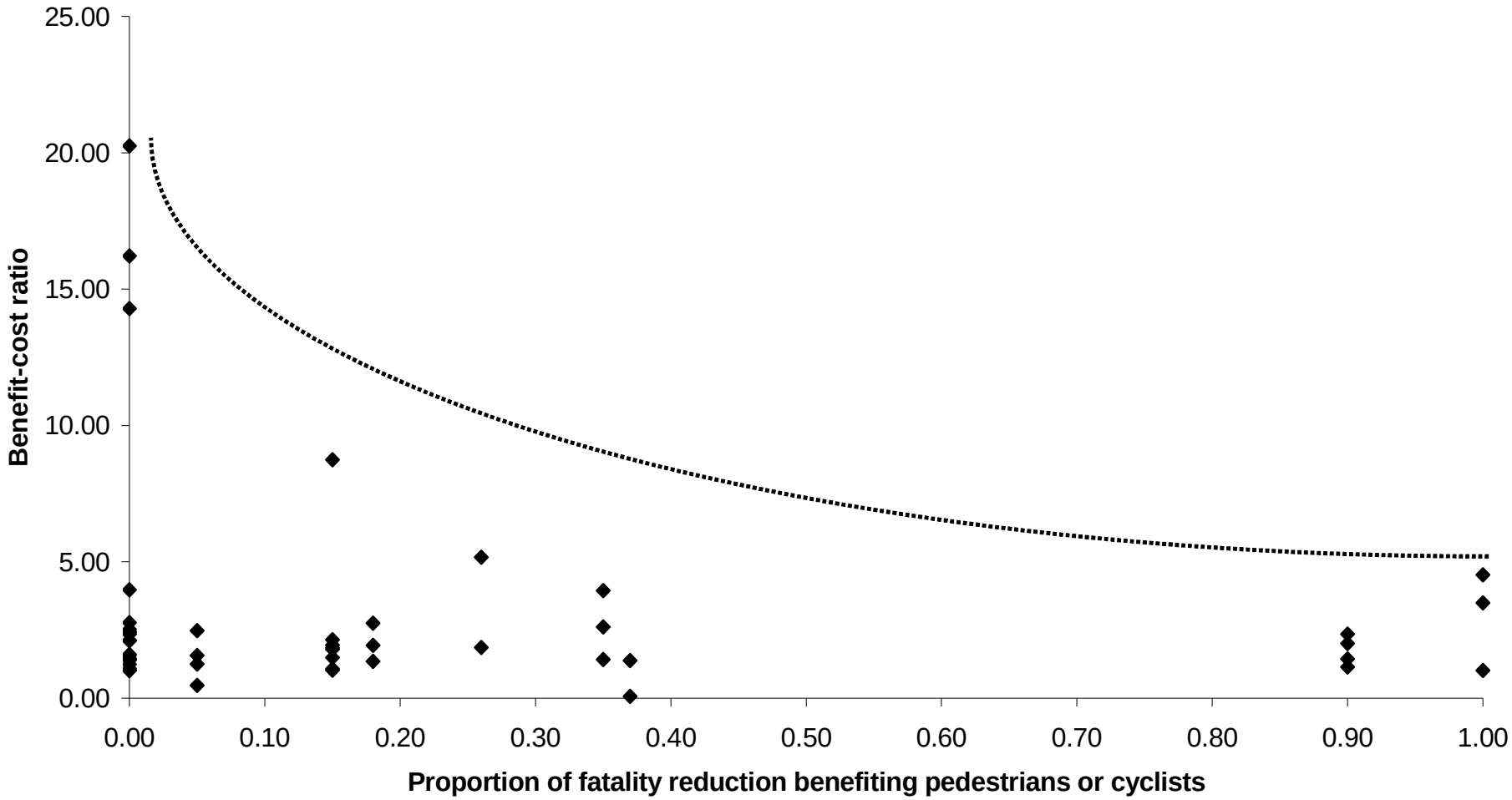
Stage 8: Considerations relevant for policy choice

- Additional or competing criteria for priority setting
- Resource allocation mechanisms influencing selection for treatment
- Presence of competing incentives
- Presence of social dilemmas
- Public acceptance
- Power and path dependence

Relationship between estimated fatality reduction (first order effect) and benefit-cost-ratio



Relationship between proportion of benefits for pedestrians and cyclists and benefit-cost-ratio



A case of a social dilemma

Table 10: Societal versus user perspective on studded tyres.

	Amounts in million NOK (1 NOK ? 0.12 EURO)	
Item	**Gains (favourable impacts)**	**Losses (adverse impacts)**
	Gains and losses to road users	
Accidents	132.5	
Travel time	53.1	
Additional trips made	5.0	
Costs of studded tyres		95.2
Fuel consumption		44.0
Total impacts	190.6	139.2
	Gains and losses external to road users	
Accidents	61.4	
Road wear		46.4
Air pollution		180.0
Total impacts	61.4	226.4
	Gains and losses for society as a whole	
Total impacts	252.0	365.6

Stage 9: Implement programme

- Assign clearly defined responsibilities to all agencies involved
- Ensure that all agencies are committed to implementing the programme
- Develop a set of safety performance indicators that are monitored regularly
- Conduct a mid-term assessment
- Stick to the target; revise the programme of action

Areas where more knowledge is needed

- How best to estimate the combined effects of several measures
- How to overcome social dilemmas
- How to adjust targets optimally to the feasible set of measures
- Public acceptance of various road safety measures

Suggested reading

- Report 897/2007: Prospects for improving road safety in Norway (can be downloaded at: www.toi.no)
- Elvik, Rune. The trade-off between efficiency and equity in road safety policy. *Safety Science*, 47, 2009, 817-825
- Elvik, Rune. Dimensions of road safety problems and their measurement. *Accident Analysis and Prevention*, 2008, 40, 1200-1210
- Elvik, Rune. Road safety management by objectives: a critical analysis of the Norwegian approach. *Accident Analysis and Prevention*, 2008, 40, 1115-1122