Sekretariat for supercykelstierne

Social cost-benefit analysis of bicycle infrastructure projects

Victor Mayland Nielsen & Britt Wolterman

Social Cost-Benefit Analyses (SCBA)

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- Cost benefit analyses
  - Translates costs and benefits to monetary terms
  - Weighs these monetary costs and benefits to create one number
  - Number judges the profitability of an investment

“How much does society benefit from this investment?”

What can you use a SCBA for?

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- Evaluating decisions and/or helping future decisions about improving society
- Making sure tax money is spent well
- Choosing the best alternative (even if alternative is investment in different mode)
- Getting support for a project
- Optimising the investment for the project
- Making it clear who benefits from the project
- Getting a sense of the uncertainties of the project

Ex Post

Ex Ante

Result from a SCBA

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Net present value (NPV): How much does society gain from making this decision today?

How?
Ps and Qs

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- Two main ingredients in a cost/benefit analysis
  - The Q's: the changes in traffic (travelled kilometres) of all modalities
  - The P's: the costs and benefits per kilometre of all modalities

How?
Ps and Qs

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Compared to the reference case:

- How much does number of cyclists change?
- How much does number of cars change?
- How much does number of public transit users change?

Compared to the reference case:

- How much does society benefit per kilometre of cycling?
- How much does it cost society per kilometre of car driving?
- How much does it cost per kilometre of using public transit?

How?
Reference case

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- Even if the alternative to the investment is no investment, the “no investement”-reference case also includes changes
  - Background trend in increase in bicyclists
  - Cars get used to the bikes (=less accidents)
- The project might not just make changes in Qs, but also in Ps
  - Roads might be safer, faster or more comfortable
  - Cars may be inconvenienced

How?
Differences

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- Everyone is affected differently
  - Bicyclists, cars and public transit users all have different costs and benefits for society
  - People commuting are willing to pay more to save time than people travelling for leisure
  - Already active bicyclists get less health benefits than less active people
  - Any more?
- We end up with a lot of different groups of people – each group with their own Q and P
  - The more differences are accounted for, the more accurate the results

General differences between Dutch and Danish SCBA methods for bike projects

Judging the differences between DK and NL bike SCBA methods

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Criteria	Example
Were all the Ps and Qs accounted for in this project?	Did we forget the effects from public transit?
Were all the Ps and Qs accounted for correctly?	Did we take into account that the competing road for cars was more congested than others in Denmark?
Were changes in the reference case accounted for?	Did we assume there were no maintenance costs without the project?
Were all the Ps and Qs measured/estimated correctly for this project?	Did we assume that the increase in bicyclists is the same as everywhere else? / Did we measure the increase on the first sunny day of the year?
Were differences in Ps and Qs between groups accounted for?	Did we consider that electric bikes gets less health benefits and more accidents?

Comparing social cost benefit analyses for Danish and Dutch cycle highways

- Ex—post (on a lot of the projects)
  - More precise estimates
  - Only possible after a project
  - Evaluation can help improve ex-ante methods
- Standard model for all routes
- Few distinctions between types of routes

- Ex-ante (only)
  - More assumptions
  - Possible before a project
  - Brings more of the SCBA benefits
- Starting from scratch every time
- Differentiating based on the situation

One size fits all vs situational

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- One size fits all more or less
- 55 projects
- 1 method for all projects using the same parameters with slight variations based on type of route

- Situational
- 80+ projects
- Limburg had more health problems, so the health benefit of biking was higher there
- Cuijk-Nijmegen had a competing bus route

One size fits all vs situational

- Lower work time cost per project
- Works as a tool for gathering accumulated knowledge
- Low chance of mistakes

- More precise
- More flexible
- Lower impact if there is a mistake
- Accounts for the big differences in Ps and Qs between projects

- Blindness for changes over time
- Lack of consideration of situational differences
- Big impact if there is a mistake

- Time consuming
- Less accumulated knowledge sharing
- Higher chance of mistakes

Danish and Dutch costs and benefits on projects

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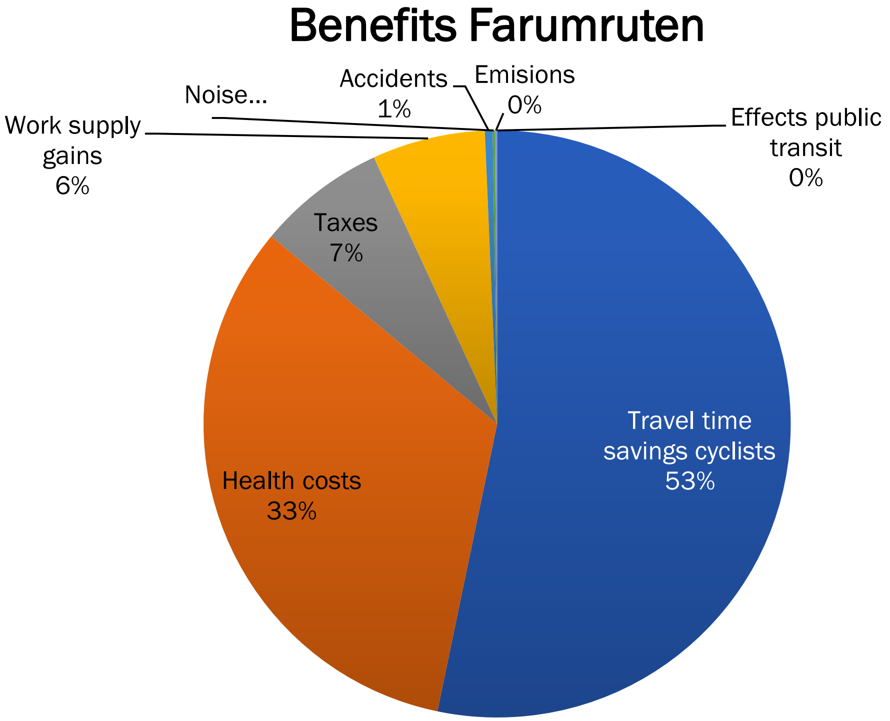

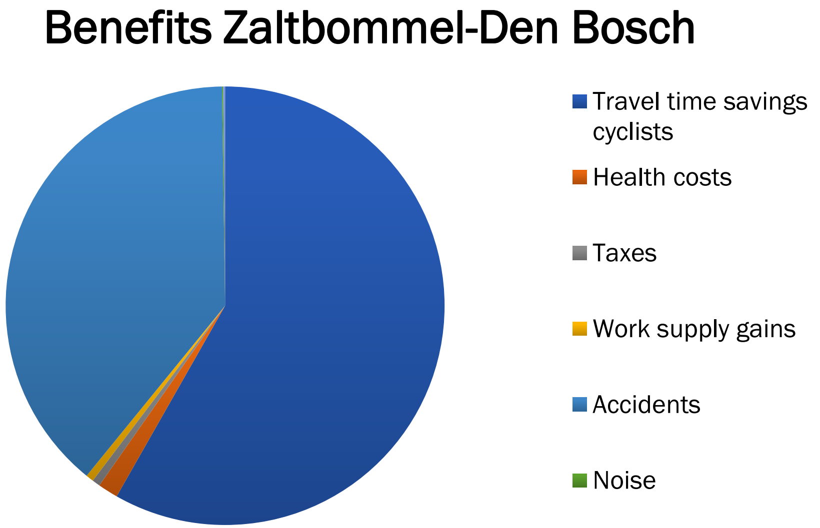

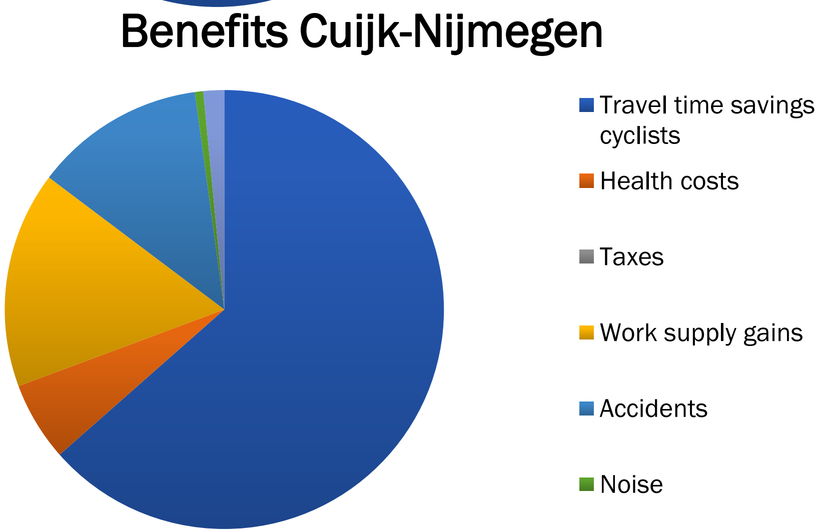

Differences in Qs between Dutch and Danish SCBA methods for bike projects

The Qs: Traffic changes: Bicyclist increases and modal shift

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- Estimated traffic jump in bicyclists from traffic counts and background growth trend
- Survey where those new bicyclists come from
  - Use previous modal split of new bicyclists and DTU survey to calculate reduction in car drivers
- Assumed same modal shift from Albertslund and Farum for the rest
- Ignores people moving from public transit to biking (assumed that scale economies and subsidies cancel eachother out)
- Assumed average kilometers travelled the same after switching to biking

- Made an assumption about modal shift and where new cyclists come from based on other cases
- Based on network traffic modeling: Estimation of origins and destinations of trips
- Estimation assuming rational behavior
- Situational differences
  - Cuijk – Nijmegen: Passengers had to wait another 10 minutes and less occupied bus route needed more subsidy to function

Differences in Ps between Dutch and Danish SCBA methods for bike projects

The Ps:
The investment

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- Construction costs
  - 0-alternative is normal bike paths on (parts of) the route
- Maintenance costs
  - New bike paths (including increases in size)
  - Improved bike paths (increased maintenance priorities on these routes)
  - Based on actual budget for maintenance per kilometre of path for the City of Copenhagen
- Residual value

- Construction costs
  - 0-alternative is normal bike paths on the route
- Maintenance costs
  - Often based on percentage of construction costs
  - Details depends on situation
    - New or existing bike paths
    - Type of path
    - Etc.

The Ps: Marginal external costs (benefits)

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Table 1
Comparison of parameters considered in CBA transport contexts.
Source: COWI and City of Copenhagen, 2009 (‘CPH’ in this table); EC, 2014a, b (EC); ECF, 2016 (ECF); Litman and Doherty, 2011 (VTPI).

Parameter	Definition	EC	CPH	ECF	VTPI
Environment					
1. Climate change	Cost of climate change effects linked to greenhouse gas emissions (CO_2, other long-lived GHG)	X	X	X	X
2. Air pollution	Cost of air pollution, including economic and health effects of CO, NO_x, $PM_{2.5}$, PM_{10}, SO_x, VOC, and O_3.	X	X	X	X
3. Noise pollution	Cost of noise, including amenity costs (property values, productivity or health costs)	X	X	X	X
4. Soil and water quality	Pollution of ground water and soils related to contaminants from traffic (heavy metals, hydrocarbons, road salt, etc.)			X	X
5. Land use and infrastructure	Space requirements for infrastructure construction, including parking; roadway land and parking value; loss of ecosystem service values			X	X
6. Traffic infrastructure maintenance	Cost of infrastructure maintenance, administration and traffic police		X		X
7. Resource requirements	Resources needed to build cars/bicycles, as well as the cost to recycle resources, or to deposit wastes (lifecycle based)			X	X
Travel time and vehicle operation					
8. Vehicle operation	Cost of owning and operating a particular transport mode, including duties and taxes, insurance, fuel and vehicle depreciation	X	X	X	X
9. Travel time	The cost of travel time associated with the use of a specific transport mode	X	X		X
10. Congestion	Cost of roadway congestion imparted on other road users, including additional travel time, operating costs, fuel costs, reliability costs, pollution, climate change, accidents, noise		X		X
Health, accidents and perceived comfort					
11. Health benefits (better health, productivity gains and prolonged life)	Savings to the healthcare system as a result of partaking in active transportation; reduction in sick leave days; longer lives.		X	X	X
12. Accidents (collisions)	The costs of minor and major injuries, and fatalities, attributed to medical expenses, pain and suffering, loss of life. Material damage associated with car accidents	X	X	X	X
13. Perceived safety & discomfort	Perceived accident risks in traffic as a result of exposure to motorized traffic; discomfort because of exposure to exhaust fumes			X	
Quality of life, tourism and infrastructure					
14. Quality of life, branding and tourism	Value derived from being considered a progressive city with a high quality of life; value of open spaces for tourism		X		

X: considered in respective study.

Gössling et al (2019)

Table 2
The external and private cost of car, bicycle and walking.

Parameter	Car, €$_{2017}$/pkm		Bicycle, €$_{2017}$/pkm		Walking, €$_{2017}$/pkm	
	External	Private	External	Private	External	Private
1. Climate change						
Climate change	0.011	0	0	0	0	0
Subsidies	0.003	0	0	0	0	0
2. Air pollution						
Air pollution	0.007	0	0	0	0	0
3. Noise pollution						
Noise pollution	0.007	0	0	0	0	0
4. Soil and water quality						
Soil and water quality	0.005	0	< 0.001	0	< 0.001	0
5. Land use and infrastructure						
Infrastructure construction	0.030	0	0.002	0	0.002	0
Roadway land use	0.011	0	< 0.001	0	< 0.001	0
Parking land use	0.021	0.022	< 0.001	< 0.001	–	–
Ecosystem services	?	0	?	0	?	0
6. Traffic infrastructure maintenance						
Traffic infrastructure maintenance	0.004	0	< 0.001	0	< 0.001	0
7. Resource requirements						
Resource requirements	0.007	0	< 0.001	0	< 0.001	0
8. Vehicle operation						
Vehicle operation	0	0.250	0	0.047	0	0.041
9. Travel time						
Travel time	0	0.253	0	0.474	0	1.264
10. Congestion						
Congestion	0	0.355	0	< 0.001	0	< 0.001
Barrier effects	0	0.005	0	< 0.001	0	< 0.001
11. Health benefits						
Health benefits	0	0	−0.193	−0.134	−0.386	−0.268
Prolonged life	0	0	0.007	−0.320	0.014	−0.640
12. Accidents (collisions)						
Accidents	0.002	?	< 0.001	0.066	< 0.001	0.066
13. Perceived safety & discomfort						
Perceived safety & discomfort	?	?	–	0.014	–	0.036
14. Quality of life, branding and tourism						
Quality of life, branding and tourism	0	0	?	?	?	?
Total	0.108	0.885	−0.184	0.147	−0.370	0.499

Gössling et al 2019

The Ps:
Marginal external costs (benefits)

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- Climate change
- Travel time
- Air pollution
- Congestion
- Noise pollution
- Accidents
- Transport infrastructure
- Health benefits

- Water & soil pollution
- Resource use
- Land use
- Perceived safety and discomfort
- Tourism, branding and quality of life

Gössling et al (2019)

The Ps:
Marginal external costs (benefits)

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Scientific work

- Cowi & Ministry of Transport 2010
- Incentive & Municipality of Copenhagen 2014
- Energy Authority 2018

Updating and compiling

TERESA by DTU (2018)

Yearly updated excel file

Scientific work

- CE Delft & VU 2010
- Ecorys 2017
- CE Delft & VU 2014

Updating and compiling

Decisio MKBA

Occasional compiled report

The Ps:
Marginal external costs (benefits)

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MEC in EUR/1000km in 2018 euros	European Commission 2014	Cowi & CPH 2010 (vkm)	CE Delft & VU 2014 (pkm)	MKBA Decisio 2017 (pkm)
Air pollution	1-32 (dep on vehicle)	2.9	3.9	10.5 (pollution and climate change together)
Climate change	14-39 (dep on vehicle)	1.4	12.9	
Noise (city)	8.8-21.4 (dep on traffic density)	21.2	12.8	10.4
Accidents (car / biking)	1-19 (dep on vehicle and type of road)	43.5 / 150.9	41.9 / 88.3	33.2 / 88.1
Congestion	0-2426 (dep on time and type of road)	53.3	67.9	(case based)
Infrastructure	5	1.5	2.5	(uses CE Delft & VU)
Health biking	(not included)	- 475.9	- 181.1 (average)	- 134.8-165.9

The Ps: Marginal external costs (benefits)

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MEC in EUR/1000pkm in 2018 euros	Cowi & CPH 2010	CE Delft & VU 2014	MKBA Decisio 2017
Air pollution	2.1	3.9	10.5 (pollution and climate change together)
Climate change	1	12.9	
Noise (city)	15.1	12.8	10.4
Accidents (car)	31.1	41.9	33.2
Congestion	38,1	67.9	(case based)
Infrastructure	1.1	2.5	(uses CE Delft & VU)
Health biking (including accidents)	- 325.1	- 92.8	- 46.7 – 77.8

The Ps:
Marginal external costs (benefits)

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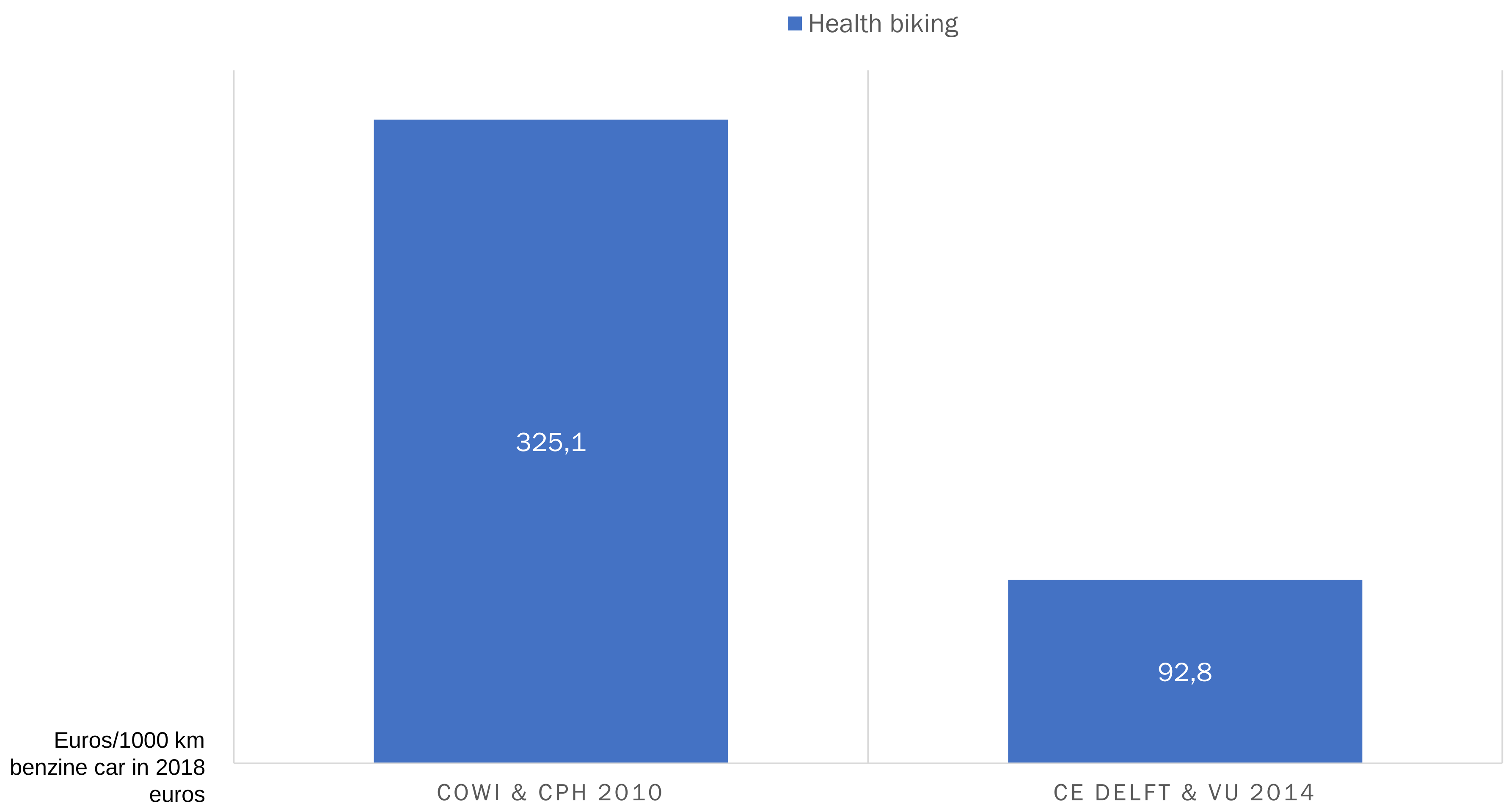
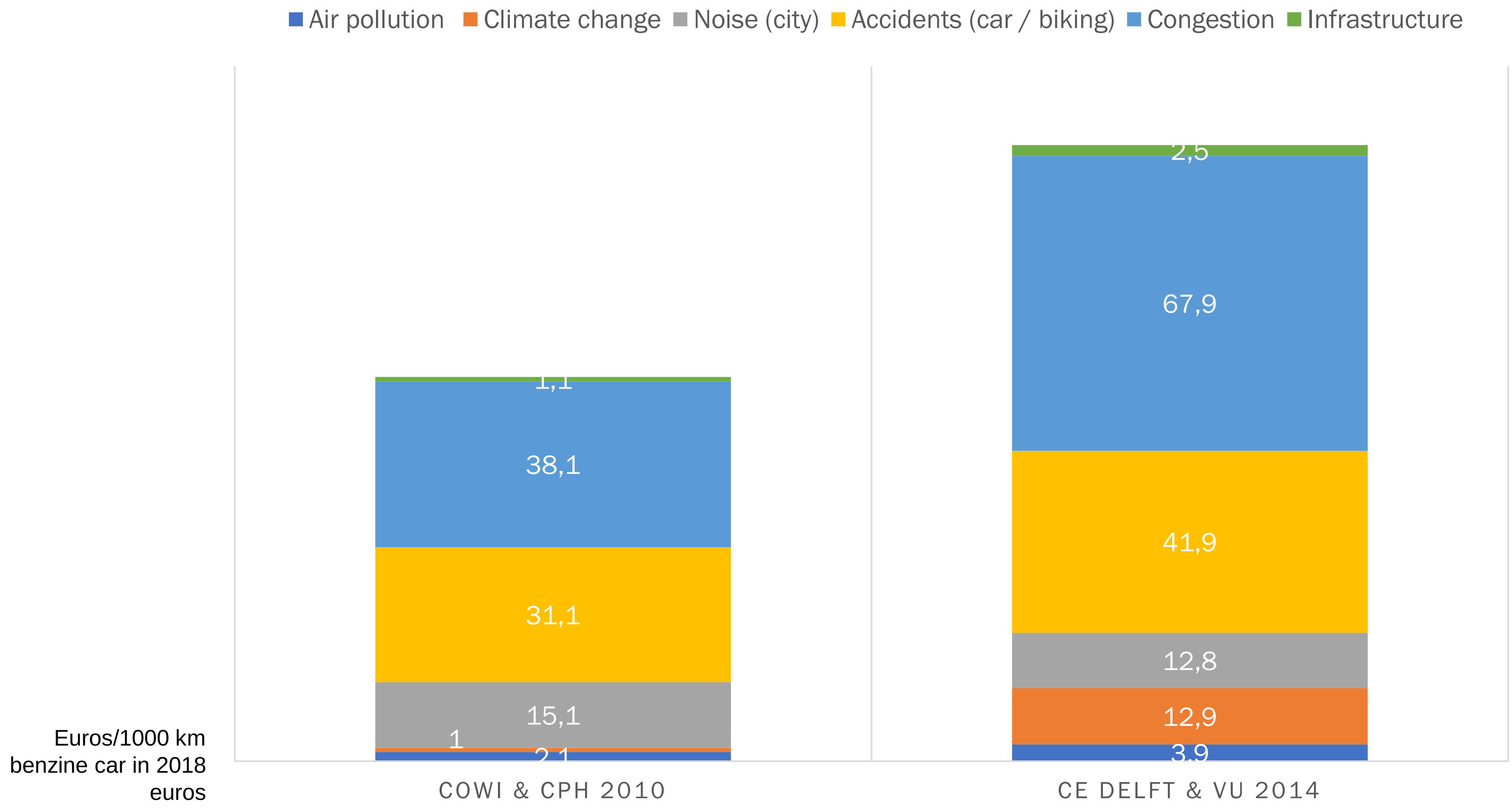


The Ps:
Marginal external costs (benefits)

DECISIO ECONOMIC RESEARCH



The Ps: Congestion

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- Uses the average MEC for a private car non-differentiated by urban/rural or time of day
  - Multiplied by the reduction in kilometres
- Source: Trængselskommissionen 2010
  - Estimations based on international studies and a study on one street in Copenhagen
  - "More thorough update of the external congestion costs should await new studies"

- Included as time travel savings and reliabilty of travel time for cars
- Effects on the rest of the network are calculated using a traffic model
- If traffic model not possible, a congestion MEC is used based on a case study of a comparable situation

The Ps: Time savings for bicyclists

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- Calculated from average speed changes on two routes
- Assumed the same for all other routes
- For routes that did not measure speed before and after
  - What time changes must have caused the corresponding traffic jump using a time travel elasticity?

- Travel time savings, multiplied by a reliability factor
- Based on case-based educated guesses
  - Are intersections getting faster/removed?
  - Is the pavement improved?
  - How much does this affect the speed?

The Ps:
Health benefits

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- Source: Cowi 2009
  - Direct costs: treatment, early death, saved future expenses due to early death
  - Production losses: Sickness leave, early pension early death
  - Assumed that half of the people get the benefit from biking (mostly benefits people who don't do physical activity more than 30 minutes)

- Source: Decisios own study
  - Direct costs: Health costs relating to accidents and health care
  - Productivity losses: less sick days, life expectancy
  - Burden of disease (value of more healthy years)
  - Corrected for personal characteristics, additionality, internalisation of choice, effects from e-bikes
- Some situational differences
  - Limburg: City had more health problems

The Ps:
Health benefits

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Tabel 9.1 Årlige omkostninger ved fysisk inaktivitet, mio. DKK

Prisniveau	2005-priser	2008-priser
Direkte omkostninger*	2.883	3.141
- heraf behandling	*3.109*	*3.387*
- heraf tidlig død	*140*	*153*
- sparede fremtidige omkostninger som følge af tidlig død	*-366*	*-399*
Produktionstab**	7.540	8.726
- heraf sygefravær	*2.912*	*3.370*
- heraf førtidspensionering	*3.072*	*3.555*
- heraf tidlig død	*1.555*	*1.800*

Tabel 9.5 Samfundsøkonomiske gevinster ved cykling som følge af undgået sygdom, DKK pr. km

2008-priser	Fysisk aktive/ moderat aktive (50%)	Fysisk inaktive (50%)	Vægtet gennemsnit	Effekttype
Direkte omk. til behandling	0	1,76	0,88	Eksternalitet
Produktionstab (ekskl. for tidlig død)	0	3,69	1,84	Delvist internaliseret[1]
- heraf fremtidigt forbrug	0	1,84	0,92	Internaliseret
- heraf nettoproduktionstab	0	1,84	0,92	Eksternalitet
I alt	0	5,45	2,72	

1) Bemærk at den del af produktionstabet der er eget forbrug i teorien er internalise-

Tabel 9.9 Samfundsøkonomiske gevinster ved cykling som følge af forlænget levetid, DKK pr. km

2008-priser	Fysisk aktive/moderat aktive (50%)	Fysisk inaktive (50%)	Vægtet gennemsnit	Effekttype
Personrelaterede velfærdsgevinster	0	5,31	2,66	Internaliseret
Direkte omkostninger	0	-0,13	-0,06	Eksternalitet
Netto produktionstab	-	-	-	Eksternalitet
I alt	0	5,19	2,59	

Note: Direkte omkostninger omfatter sundhedsvæsenets årlige ressourceforbrug for-

Tabel 4-4 Jaarlijkse zorgkosten en reductiekansen

	Jaarlijkse zorgkosten (in mrd €)*	% reductie min.*	% reductie max.*
Beroerte	2,2	3%	27%
Borstkanker (Vrouw)	0,7	4%	10%
Coronaire hartziekten	2.1		
Dementie (inclusief alzheimer)	4,8		
Diabetes	1,7		
Dikke darmkanker	0,5		
Osteoporose	0,3		

Bron: Ecorys (2017).

Tabel 4-5 Toepassing gezondheidseffecten per fietsafstand

Afstand	Aandeel van totaal gefietste km's*	Aandeel gezondheidswinst**
0 tot 1 km	2%	75%
1 tot 3,7 km	30%	75%
3,7 tot 7,5 km	28%	50%
	20%	50%
	12%	25%
	7%	25%

egde fietsafstanden per persoon per jaar (CBS).

Tabel 4-6 Ziektelast en reductiekansen

	Ziektejaar-equivalenten (YLD)*	% reductie min.**	% reductie max.**
Beroerte	170.700	3%	27%
Borstkanker (Vrouw)	30.000	4%	10%
Coronaire hartziekten	190.900	4%	10%
Dementie (inclusief alzheimer)	60.800		
Diabetes	178.100		
Dikke darmkanker	21.100		
Osteoporose	2.500		

*bron: volkgezondheidenzorg.info **bron: Ecorys (2017)

Tabel 4-8 Toe te passen waarden voor gezondheidseffecten (in eurocent per fietskilometer) per type ingreep

Intern/ Extern effect	Type effect	Algemene fietsstimulering/infra	Gezondheidsstimulering
Extern	Arbeidsproductiviteit	4	8
	Ziektekosten	3	5
Intern	Ziektelast	2-4	8-12
	Levensduur	4-5	7-10

The Ps:
Accidents

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- Source: Cowi 2010
  - Uses risks and costs for (based on reductions in driving)
    - Light personal damage (treatment costs)
    - Heavy personal damage (treatment costs)
    - Deaths (value of statistical life)
    - Material damage
    - Net production loss
    - Police and ambulances
- Bike accidents not included as it is assumed that the safety improvements on the route will equalise with the otherwise increased amount of accident risk

- Source: CE Delft & VU 2010
  - Uses risks and costs for
    - Medicinal costs
    - Treatment costs
    - Material costs
    - Net production loss
    - Immaterial costs
- Sometimes situational differences
  - Some routes are/become more safe than others
    - Limburg – Trambaan: Number and type of intersections
    - Zaltbommel – Bosch: Decreases in accidents

The Ps:
Inconvenience for cars / comfort for bikes

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- Inconvenience for cars
  - Includes measures differentiated by <u>type</u> of route (finger, ring etc.).
  - Takes into account
    - Losses of parking space
    - Car time losses from prioritizing bikes in intersections
    - Speed reducing measures
  - Calculated the average inconvenience per kilometre of bike path
    - Not taking into differences in traffic levels, number of parking spots, intersections and speed reducing measures

- Comfort for bikes
  - Comfort and experience has been added in some studies using questionaires

The Ps: Noise

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- Source: Cowi 2010
  - Includes Nuissance and health costs
    - Nuissance: Hedonic pricing model using decibels -> yearly saving per dB
    - Health costs: Ischemic heart disease/hypertension -> treatments costs, sickness leave, death

- Source: CE Delft & VU 2010
  - Includes nuissance and health costs
    - Nuissance: Social or economic costs of disturbance in leisure activities, physical disturbance like pain or suffering, hinder (probably hedonic pricing)
    - Health costs: Stress reactions (cardiac arrhythmias, high blood pressure, hormonal changes).

The Ps:
Pollution / climate change

- Source: Cowi 2010
  - Pollution
    - Includes emissions of PM2.5, NOx, SO2, HC, CO and their costs on
      - Health
      - Harm on buildings
      - Harm on agriculture and foresting
  - Climate change
    - EU quota trade prices

- Source: CE Delft & VU 2010
  - Pollution
    - Includes emissions of PM2.5, NOx, SO2, PM10 and their costs on
      - Health
      - Harm on buildings and materials
      - Harm on agriculture
      - Impacts on eco systems
  - Climate change
    - Looks more into detail for different pollutants, but recently uses the price for maintaining current goal

The Ps:
Fiscal changes

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- Taxes
  - Reduction in gas tax revenues
  - Reflux of those taxes
  - Reflux of reductions in externalities
- Work supply changes
  - Distortion is 10% of construction costs (only sometimes does the project affect this)
  - Work supply gains is assumed to be 10% of time gain (not in value of time?) (could be argued agglomeration benefits from density)

- Taxes
  - Reduction in gas tax revenues
  - Reduction in subsidies (for public transit)
- Work supply changes (sometimes)
  - Labor market effects if structurally unemployed people are affected or if bad economy
  - Assumed that money would have been spent on something else leading to productiveness

Improvements for both countries

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- The MECs that were not included
  - Water & soil pollution
  - Resource use
  - Land use
  - Perceived safety and discomfort
  - Tourism/branding
- Other effects
  - Synergies between pedestrians and cyclists (if c saves time in intersection, so does p)
  - Urban benefits of cycling
  - Option value
  - Public transit levels of complexities of inclusion
- Differences
  - Differences between inner city and suburb (accidents, congestion, noise)
  - Pollution higher for bicyclists
  - E-bikes lower health benefits, more accidents
  - For long rides less health benefits (no gym tomorrow)
  - Electric cars pollute less + increase in these
  - Leisure bicyclists – what would they have done if not biking?
  - Value of time different for bicyclists
  - On rainy days, more benefits for cycling

General improvements for Denmark SCBA

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- Better estimations of increases in bike traffic
- Including public transit
  - Taking into account the complex consequences of people moving from PT to biking
    - Mohring economics
    - Subsidies and revenues: Frequency, occupancy, and future increases in ridership
- Including improvements in comfort for bicyclists
- Congestion: MECs by Cowi might not be the best way → switch to traffic modeling / case-based MEC
- Differentiate more between routes
  - Congestion levels
  - Inconvenience for cars
  - Ridership increases
- Clear differences in MEC – opportunity to compare and improve methods on a deeper level
  - Health: Value is higher for people not exercising and people already biking are a more active demographic
  - Climate change
- **Didn't include benefit for riders in the inner city**
- **Doing more ex-ante analyses (next slide)**
- **Accounting for differences in traffic between weekdays and weekends**

Ex-ante vs ex-post

DECISIO
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- Evaluating decisions and/or helping future decisions about improving society
- Making sure tax money is spent well
- Choosing the best alternative (even if alternative is investment in different mode)
- Getting support for a project
- Optimising the investment for the project
- Making it clear who benefits from the project
- Getting a sense of the uncertainties of the project

Ex Post

Ex Ante = more insightful

General improvements for Netherlands SCBA

DECISIO ECONOMIC RESEARCH

- Better modelling tools
  - With a standard excel template that allows changes, we can both be on top of situational differences and improve efficiency
  - With an expanded list of elements in all costs, we can keep track of our knowledge and add as we learn
    - In that way we can always be sure that we considered everything
- Clear differences in MEC – opportunity to compare and improve methods on a deeper level
  - Health: Value is higher for people not exercising and people already biking are a more active demographic
  - Noise
  - Climate change
- Do more ex-post for evaluation – in order to make better ex-ante studies
- Filling in the “holes” (the elements included in the Danish but not the Dutch methods)
  - Inconveniences for car drivers due to biking (less parking, slowed down traffic, longer red lights)
  - Hedonic pricing model for noise

Moving further

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- A Europe wide TERESA model with updated numbers every year including new studies
- Continuous knowledge compiling database about methods when new research has been done
- Through the Handshake project, communicate with cities whenever new studies are done with different methods
- Let the Handshake project continue as a growing network