Negative transport externalities

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EPFL - 2 hour lecture (main concepts presented)

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Outline

1. Types of external costs and why they are ubiquitous in transportation

2. Evaluation methods: theory and empirical estimates

   a). Value of travel time and congestion

   b). Environmental externalities

   c). Safety and the value of human *life* [is monetarization possible?]

1. Types of externalities and why they occur?

Nature of externalities

Definition: A *technological externality* exists when the actions of an agent affect the utility or production possibilities of other agents without a market in which the effects are priced. *Example, firm polluting a river. Raising flowers provides a positive externality to the neighbors*

Example: Emissions from driving a gasoline or diesel-fueled vehicle. [*Effect on health, erosion of structure, etc*.]

Discussion : agglomeration forces (technological spillover), silicon valley and EV car in Europe: positive externalities.

Cause of externality: The perpetrator does not care (fully) about the utility of other agents (or s/he is not aware of these externalities)

Externalities can be positive and negative. Mains attention is limited here to negative externalities.

Technological & pecuniary externalities

Technological externalities differ from pecuniary externalities.

Definition: A *pecuniary externality* exists when the actions of an agent affect other agents through **prices**.

Example: Assume an airline boosts its output. This raises unit labor (*demand increases, so wages increase*) and other input costs increase for competing airlines.

→Other airlines are made worse off, but the input suppliers are made better off (possibly cost decreases). The two effects offset (in the absence of other economic distortions). [*No market failure when, e.g. the wages increase*; *normal operation of markets*].

Degree of internalization

Costs can be wholly external or partly external.

Wholly external

1. **Pollution** Also greenhouse gas emissions, noise

Partly internalized

2. **Congestion**

Atomistic users (e.g., road vehicles). No internalization.
Non-atomistic users (e.g., airlines with market power) Partial internalization. [e.g. Air France imposes congestion to other users, but also suffers from congestion]. Crowding in Public transport; other example: fleet of vehicles.

Degree of internalization

Partly internalized (continue)

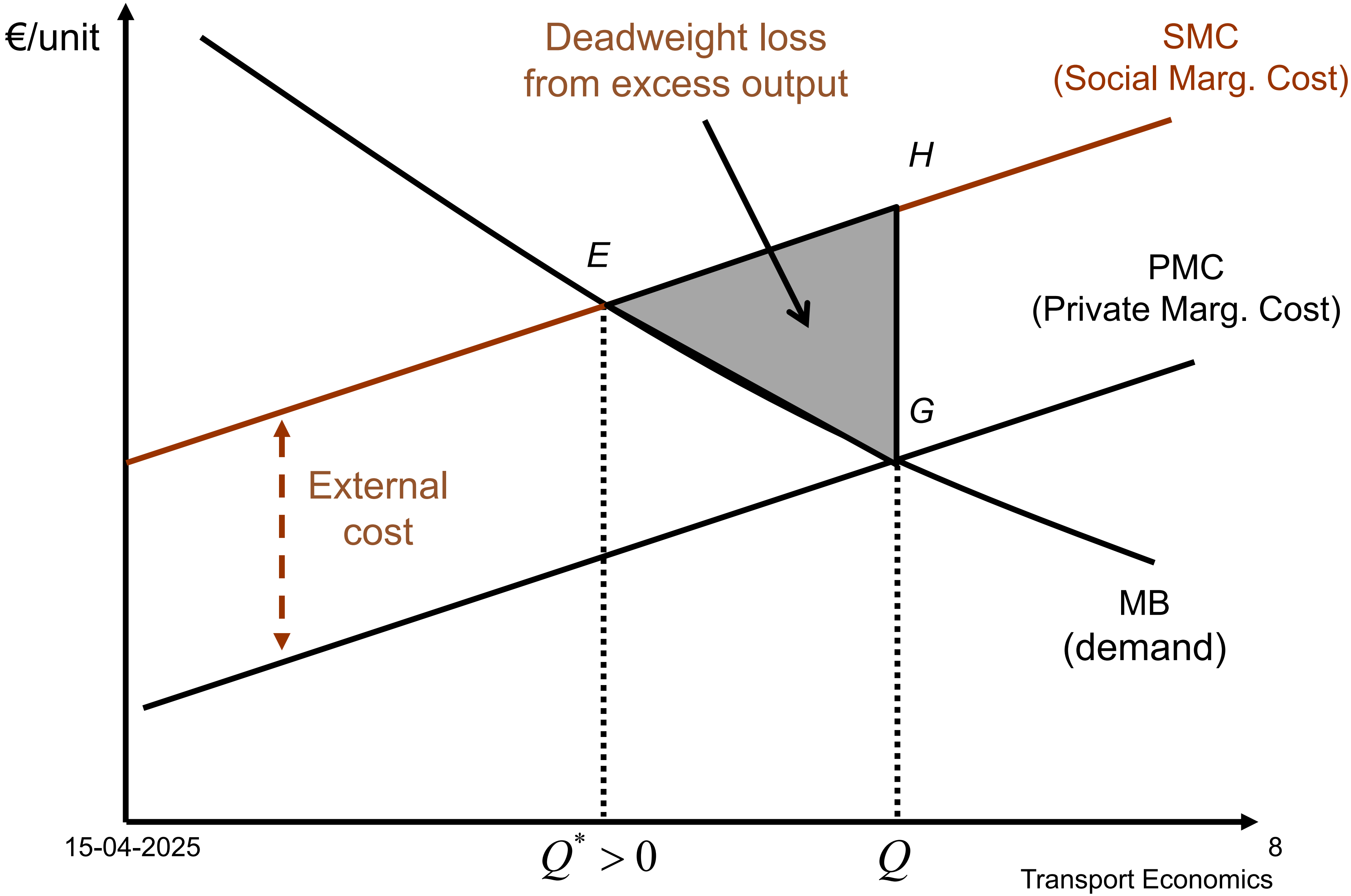
3. **Damage** to roads and other transport infrastructures [e.g. **Trucks**] may destroy the road but also their own vehicles;

4. **Crashes**

Partial internalization provides agents with an incentive (negative feedback) to limit their activity and therefore externalities (e.g., congestion-based tolls).

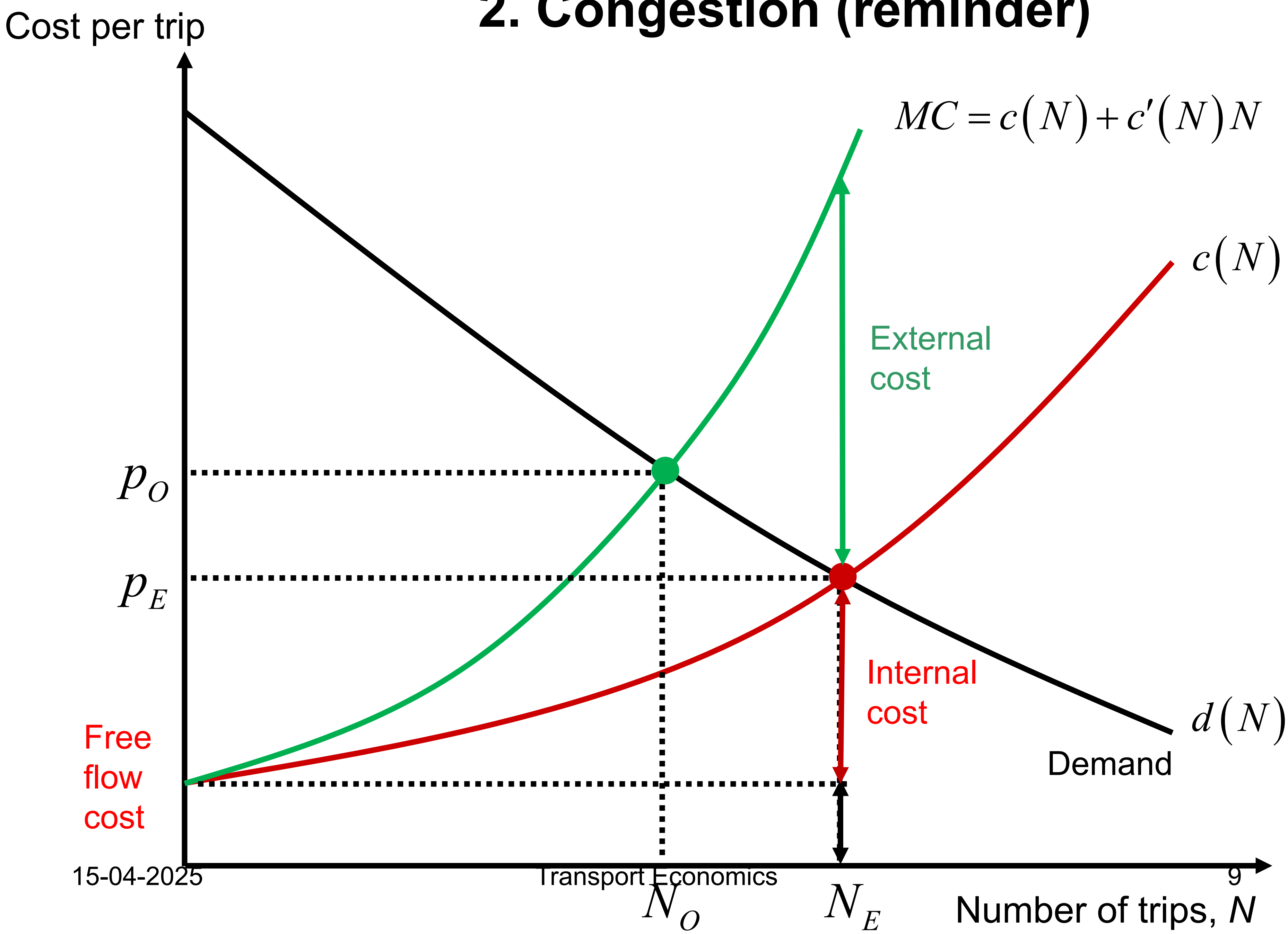
Medium/long run partial internalization: Dangerous roads may induce people to use transit.

1. Pollution



€/unit
Deadweight loss
from excess output
SMC
(Social Marg. Cost)
H
E
PMC
(Private Marg. Cost)
G
External
cost
MB
(demand)
$Q^* > 0$
Q

2. Congestion (reminder)



Marginal travel by→ **External effect on ↓**	**Road**	**Rail**	**Air**	**Water**	*Remarks*
Travel time underway (opportunity cost of time)	++	0	0	0?	Additional drivers and vehicles slow down other vehicles on the road, but additional passengers, trains, or planes do not slow down other trains or planes while underway, because for safety reasons rail and air lanes en route are not permitted to become congested. It might be possible for some short-haul shipping lanes to become crowded.
Crowding, comfort of passenger travel	+	+	+	0?	Highway congestion can make drivers anxious. Crowding on trains can make people stand, which can be uncomfortable. While passengers on plane have a reserved seat, crowded flights are less comfortable because there is less room to "stretch out," less overhead luggage space, etc.
Reliability of arrival time (passenger, freight)	++	0	+	0	The greater the variation in delay times the greater the uncertainty about arrival times (Small *et al.*, 1999). Congestion can occur at airports due to too many incoming and outgoing flights (Poole and Dachis, 2007).
Boarding or disembarking time	n.a.	+	+	0	Large crowds can cause minor delays in boarding trains and planes, increase dwell time at stations, and slow disembarkation.
Time spent at garage/station/terminal / port (opportunity costs, comfort costs, reliability costs)	+?	0	++	+?	Road congestion can result in extra search time for parking spaces. Passenger rail lines have one train per station per track on fixed schedules, and although freight trains can experience crowding at rail yards, the costs are faced by the operator. At airports with different carriers and limited terminal capacity, additional flights can cause significant airport delays for all other flights (Brueckner, 2002).
Cars and trucks waiting at rail or **raised-bridge crossings.**	n.a.	+	0	+	Additional train cars increase the time that cars and trucks must wait at rail crossings. Additional ships can increase the time that cars and trucks wait at raised-bridge crossings.

ALONE

Delucchi and McCubbin (2011, Table 15.2)

Why congestion occurs?

de Palma and Lindsey (2001/2015)

1. Temporal Peaking of demand

Systematic daily, weekly and seasonal fluctuations.
→ Due to: work hours, school schedules, business operating hours, holidays. (True in transportation, telecommunications, recreational facilities, …).

2. Rigidity of Transportation Supply

[Demand fluctuates but supply is more or less fixed, so rationing will take place.]

3. Output is Not Storable

4. Flawed usage incentives

Costs are partly external (too many users at equilibrium)

3. Road damage

de Palma, Kilani and Lindsey (2007)

U : Utility from a trip
N : aggregate usage level
C : cost of a trip
s : road capacity [lanes]
Q : pavement quality (inverse of roughness) [with 15 cm, road is not strong]
m : maintenance intensity
α : rate of quality depreciation
β : measure of usage-related depreciation

Utility function of a traveler assumed to be: ($\gamma > 0$)

$$U = \gamma Q - C(N).$$

Steady-state quality level is assumed to be: $Q^s = \frac{1}{\alpha}\left(m - \beta \frac{N}{s}\right).$

Why maintenance is often so poor, worldwide?

4. Crashes

Focus here: road transportation

Two types of costs.

1. Cold-blooded costs

- Vehicular damage, loss of work output, hospital treatment.

→ These costs can be estimated fairly **accurately** using standard statistical and accounting data.

2. Warm-blooded costs

- Injury, death, suffering, immobility, grief of relatives.

→ **More difficult to monetarize.**

4. Crashes

Types of costs (cont.). Internal versus external costs

1. Internal costs (not covered)

- Vehicular damage that is not covered by insurance [deductible, incentive]
- Loss of work output for self-employed
- Out-of-pocket hospital treatment costs
- Suffering, immobility (internal and external)

2. External costs (covered)

- Vehicular damage that is covered by insurance
- Loss of work output for employed workers (covered by social insurance)
- Hospital treatment covered by public sector or insurance
- Suffering, immobility (internal and external)
- Grief of relatives

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4. Crashes

What proportion of costs are external?

Depends on……

- Whether people take into account crash costs borne by others
- Whether people have systematically biased perceptions of accident risks (behavioral economics plays a role)
- How responsibility for crashes is allocated between the parties involved, type of insurance (Peirson and Vickerman, 2001).

Estimates of the fraction of costs that are external: there are different estimates:

Gómez-Ibáñez (1997) : a minority.
Parry and Bento (2000) : 10%-40%.
Parry et al. (2007) : 13%-44%

Diapositive 15

a6 Decsion prise en fonction des probability estimées, très fausse (exple Probabilité d'accident).
adepalma; 13/04/2016

See alone

4. Crashes

TABLE 1
SOCIAL COSTS OF TRAFFIC ACCIDENTS IN THE UNITED STATES, 2000

	Property damage only	Minor injury	Serious injury	Fatalities	All injuries
Number of injuries	23,631,696	7,208,043	607,882	41,821	31,489,442
Total cost per injury, $	2,532	10,401	259,718	3,366,387	13,766
quality adjusted life years	0	2,880	135,275	2,389,179	6,444
property damage	1,484	2,845	4,982	10,273	1,875
travel delay	803	776	1,004	9,148	812
medical & emergency services	31	1,539	33,899	22,928	1,106
market and household productivity	98	70	291	795,601	3,058
insurance & legal	116	1,131	45,965	139,258	617
Total injury costs, $billion	60	75	158	141	433

Note: Minor injuries are those with quality-adjusted life years below $4,500.
Source: U.S. National Highway Traffic Safety Administration (2002).

Parry, Walls and Harrington (2007).

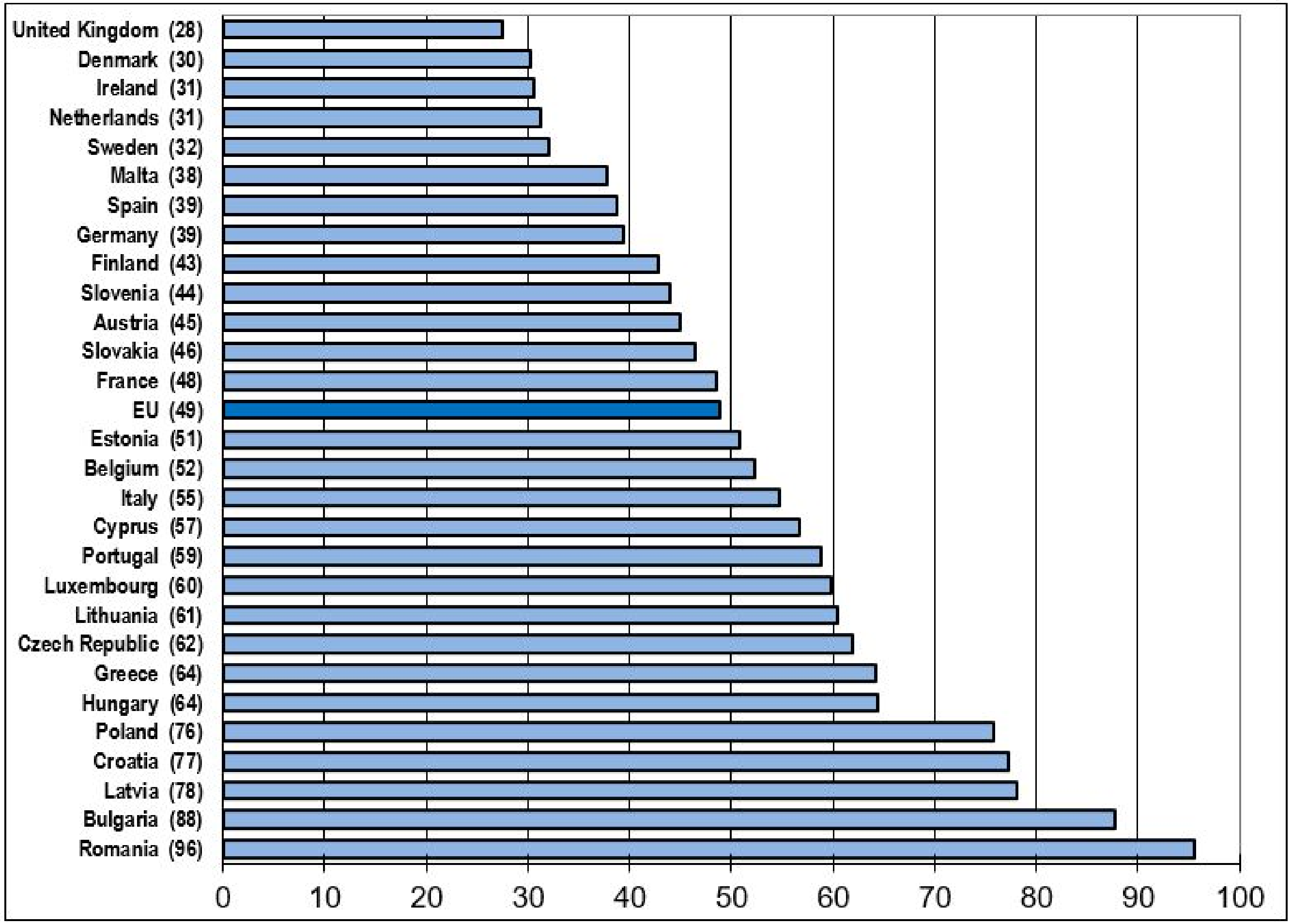
Cost of crashes [$€_{2002}$]

Country	Fatality	Severe injury	Slight injury
Belgium	1,603,000	243,200	15,700
Czech Republic	932,000	125,200	9,100
France	1,548,000	216,300	16,200
Germany	1,493,000	206,500	16,700
Greece	1,069,000	139,700	10,700
Italy	1,493,000	191,900	14,700
Latvia	534,000	72,300	5,200
Netherlands	1,672,000	221,500	17,900
Norway	2,055,000	288,300	20,700
Poland	630,000	84,500	6,100
Spain	1,302,000	161,800	12,200
Sweden	1,576,000	231,300	16,600
United Kingdom	1,617,000	208,900	16,600

HEATCO (2006) as reported by Friedrich and Quinet (2011, Table 16.5)

Fatalities per million inhabitants by country (2018)

2018 *Road safety statistics: what is behind the figures*?



Economic impact of accident (order of magnitude)

Rapport : "Conseil national de la Sécurité routière" (France)

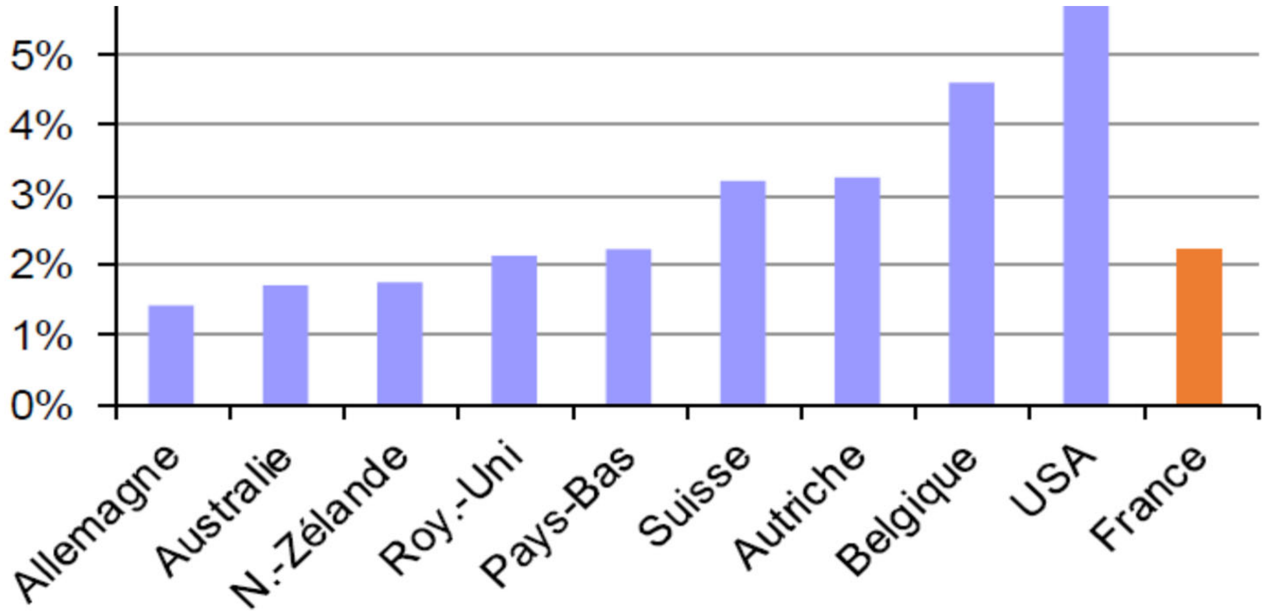
- In 2016: 38,3 Billions € (2,2 % of GNP) for major injuries (F)
- + 10.4 Billions € for property damages

with 3.1 Millions € = statistical value of human life.

13% of accidents occur during commuting

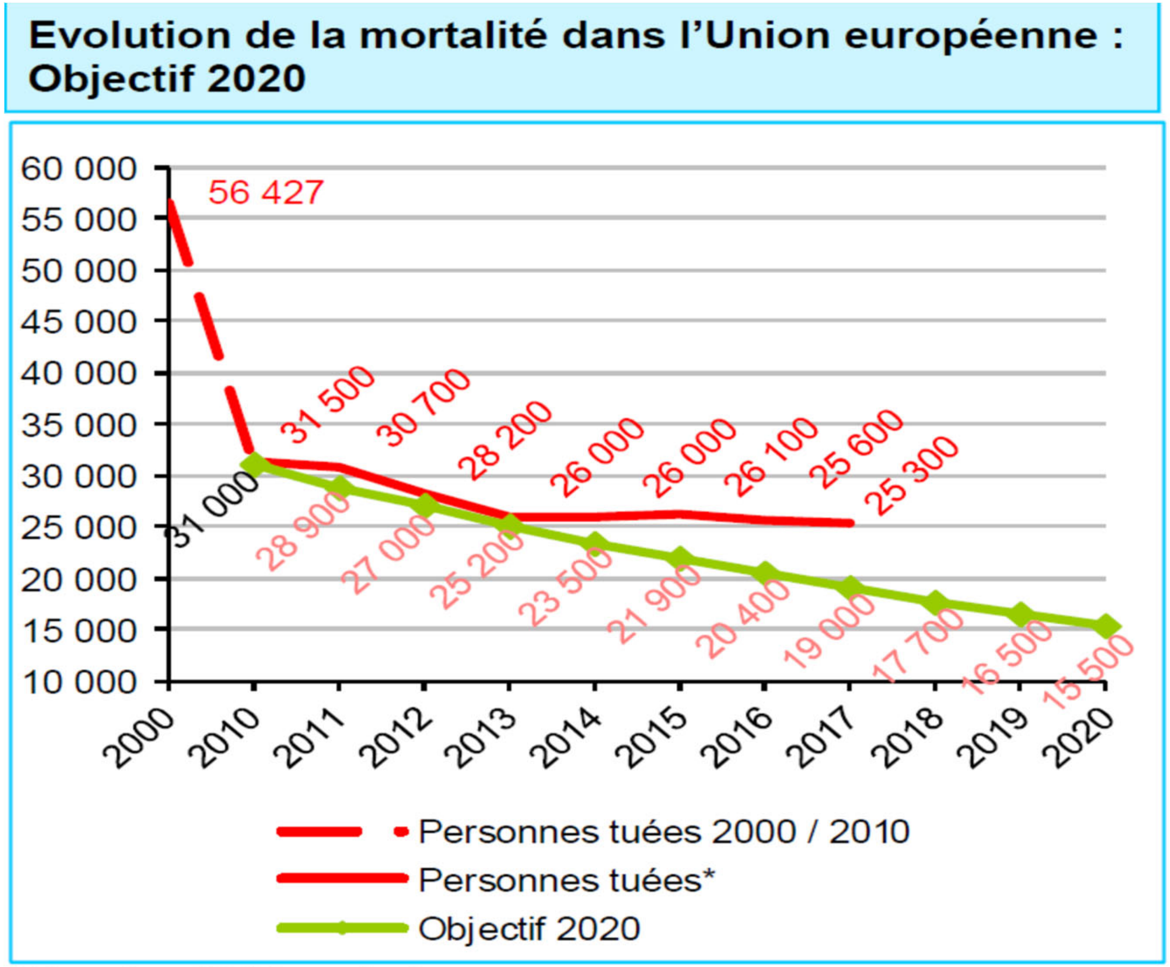
6 Millions days lost for the firms

Accident cost (road) as a %National product, in high income countries



Source : Wijnen et Stipdonk, 2016 ; France: estimation DSR sur 2017.

Evolution of casualties in the EU



* Données 2017 provisoires
Source : Commission européenne, DG-Move, mai 2018.

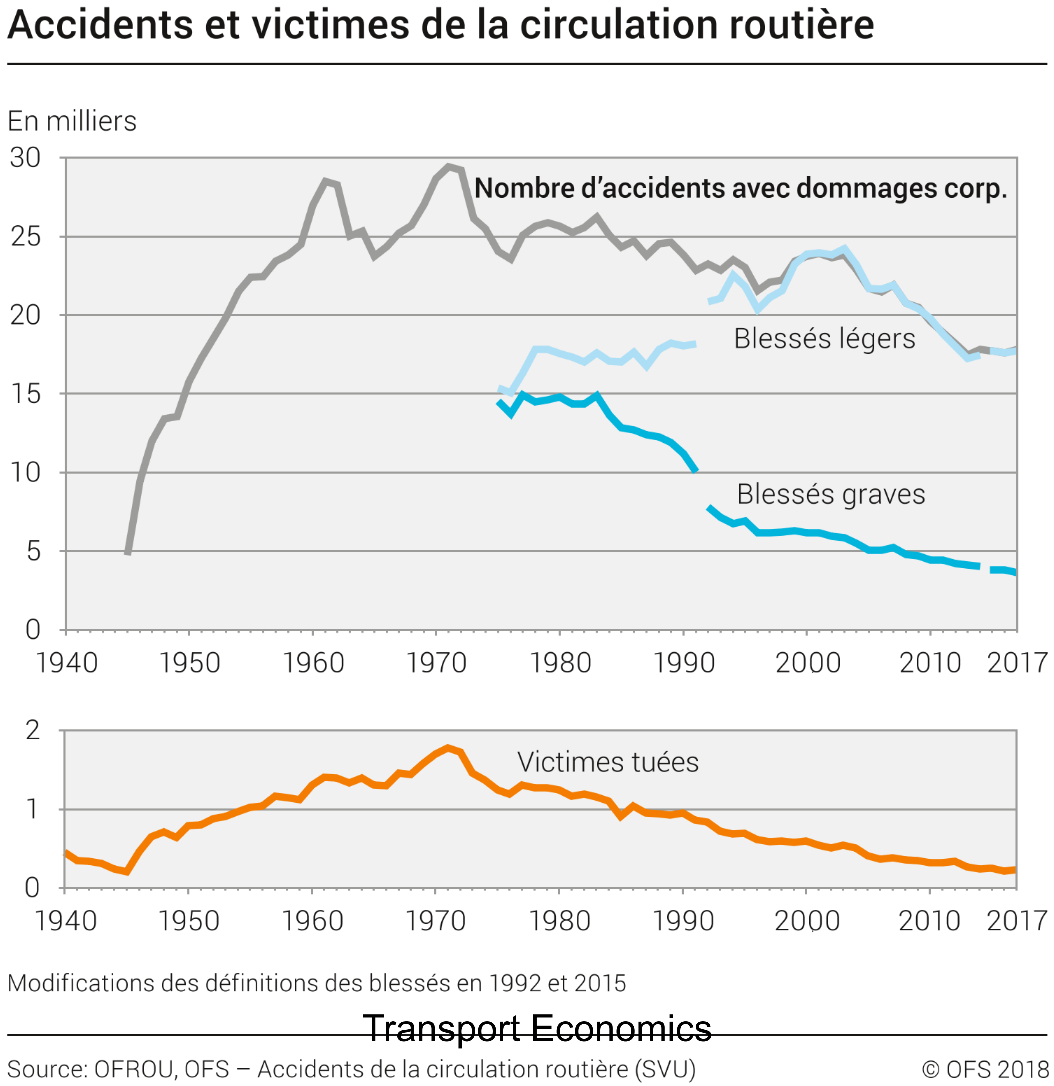
CBA of speed limitation

- Max speed on secondary roads (*Départementale*) 90km/h → 80km/h.
- Discussion: What are the components of CBA analysis?

[Reply: more accidents and more saved time]

Along those lines: should we decrease max speed on highways, reduce temperature at home given the Ukraine war?

Switzerland: accidents and fatalities on roads



4. Crashes

Determinants of crash costs

1. Infrastructure

(a) Road design

(b) Number of entrances, exits and intersections per kilometre of roadway [Lighting, traffic signs,…]

(c) Pavement conditions

2. Usage

(a) Traffic volumes and speeds [and acceleration]

(b) Mix of vehicle types

(c) Presence of pedestrians and bicyclists (threshold effects)

3. Travel conditions

(a) Time of day [light, ..]

(b) Weather conditions [Rains, fog, snow,…]

4. Crashes

2. (a) Traffic volumes and speeds

Drivers trade off travel time, crash risk and safety effort.

An additional driver affects crash rates in two opposing directions:

(+) More opportunity for multi-vehicle collisions $n(n\text{-}1)$ [opportunities for crash];

(-) Slows other drivers down ⇒ more time to react, less severe collisions

- Traffic congestion has little or no impact on the frequency of road accidents on the M25 motorway around London, England (Wang et al., 2009).
- Speed variance matters (Lave, 1985) Raising speed limit could make road more safe!
- **Two-way causality**: Congestion affects crash rates and crashes themselves contribute to congestion

4. Crashes

2. (a) Traffic volumes and speeds

Theory of risk compensation or homeostasis: [Gerard Wilde] : Agent adjust their behaviour to maintain a low, nonzero, level of risk.

Note: « Windfall Effects » = « effets d’aubaine »

Windfall Effects refer to situations where individuals or organizations receive unexpected benefits or advantages, often without changing their behavior or making any new effort.

A company gets a tax break for hiring a worker, but they would have hired that person anyway. The tax break is then considered a **windfall effect** — it didn’t change the company’s decision, just rewarded them

4. Crashes

2. (b) Mix of vehicle types

Light and heavy vehicles (cars, trucks & buses)

Empirical evidence not clear cut. Crash rates may be higher in mixed traffic than in homogeneous traffic (Forkenbrock and March, 2005; Middleton and Lord, 2005). No evidence that mix of trucks and cars increase accidents. Truck driver are professional and security distance may be too high.

Light vehicles

Light vehicles include cars and light trucks (vans, pickup trucks, sport utility vehicles (SUVs). These vehicles differ considerably in weight, height, and rigidity.

Light trucks may offer better protection to occupants than light vehicles, but they pose a greater danger to other road users.

4. Crashes

2. (b) Mix of vehicle types

Summary of White (2004)

→ Light trucks pose a greater danger to car occupants, pedestrians, bicyclists and motorcyclists than cars because light trucks are taller, heavier and more rigid.

Consequences of driving an SUV [compare with the cars]:

- \+ **lower damage** in the case of a single-vehicle crash
- \- **higher probability of being in a single-vehicle crash** (than for a car) [impression of being slow since higher elevation]
- \- **higher probability of being in a two-vehicle crash**
- \- **cause more damage to other vehicle** in a two-vehicle crash

  Traveling in a car : 61% [more likely to die that if accident with a car]
  Pedestrian : 82% [more likely to die that if hit by a car]
  Motorcycle : 125% [higher probability to dies than is hit by a car]

Anderson and Auffhammer (2011) obtain similar results: the probability of dying in a vehicle-to-vehicle crash increases appreciably with the weight of the other vehicle [Prisoner dilemma].

4. Crashes

Trend in crash rates

Crash rates per kilometer have been declining over time due to:

- Improved vehicle technology, safer road designs
- Seatbelt laws (But could increase crash frequency due to risk compensation.)
- Tighter speed limits & enforcement
- Increases in minimum driving age, graduate licensing rules
- Driving bans or jail for severe infractions (alcohol, drugs, excessive speed,..)
- Fewer people walk

Crash rates still high in some developing countries:

Annual fatalities per 100,000 vehicles:
(The Economist, 2013)

See also work of the World Bank:

Nigeria	1,042
United States	15
Britain	7

2. Evaluation methods: theory and empirical estimates

Overview: Relative costs of externalities

U.S. roads (Small and Verhoef, 2007, Table 3.3): externality costs

#1 Congestion : 64% of total

#2 Crashes : 24%

#3 Environmental : 6% [depends on: value of $C0_2$/t, discount rate]

#4 Other (noise, etc.): 6%

U.S. all major modes (Delucchi and McCubbin, 2011)

Roads : #1. Crashes #2. Congestion.

Air : #1. Noise #2. Congestion.

Europe all major modes (Friedrich and Quinet, 2011)

Similar to U.S. in magnitudes and rankings

2a). Value of travel time and congestion

Congestion

To determine the costs of congestion delay one needs to estimate:

1. How travel time decreases with traffic volume
2. The *Value of Travel Time* (*VOT*): The disutility or opportunity cost of travel time

Consider just 2. here.

The wage theory of VOT

Applicable only for trips conducted during work.

The idea: Savings in travel time can be used two ways:

1. To reduce the time spent doing a given amount of work.

   The wage reflects payment necessary to **compensate workers for loss of leisure time.**

2. To **do more work** in the same amount of time

   The wage reflects the marginal value product of work.

Value of travel time

Limitations of the wage theory of VOT

- Employers incur overhead costs in addition to the wage
- Employers pay labor taxes, and employees pay income taxes
- Employees may be able to use travel time productively
- Work hours are often fixed. Employees cannot balance the benefits and costs of additional work at the margin
- Employees may incur disutility from work

[Becker, de Sarpa, Small's studies on VOT].

Value of travel time

Methods of estimating the VOT
(and preferences generally)

Revealed preference : Uses data on observed behaviour

Stated preference : Uses data collected from questionnaires

Value of travel time

Revealed preference

Example: Mode choice with a tradeoff between time and money

	Money cost	Travel time
Plane	\$50	2 hours
Train	\$25	3 hours
Bus	\$20	3.5 hours

If individual is observed to choose the train [Hypothetical numbers].

$\Rightarrow$ VOT more than $\dfrac{\$25-\$20}{(3.5-3)\ \text{hours}} = \$10/\text{hr}$

$\Rightarrow$ VOT less than $\dfrac{\$50-\$25}{(3-2)\ \text{hours}} = \$25/\text{hr}$

Value of travel time

Revealed preference (cont.)

Assessment

Need to control for attributes of modes (or other choices) besides travel time and monetary cost. Data may be lacking.

\+ RP corresponds to actual behavior

\- SP "choices" may reflect faulty information or miscalculation:

- underestimation of variable car costs
- overestimation of travel time
- overestimation of time saved on new roads
- small stops are systematically forgotten, recorded travel times are rounded (FMS or **F**ast **M**obility **S**urvey, Moshe Ben-Akiva; de Palma and Dantan, 2017, Economica book.)

Value of travel time

Stated preference

Uses data collected from questionnaires

Example of a question:

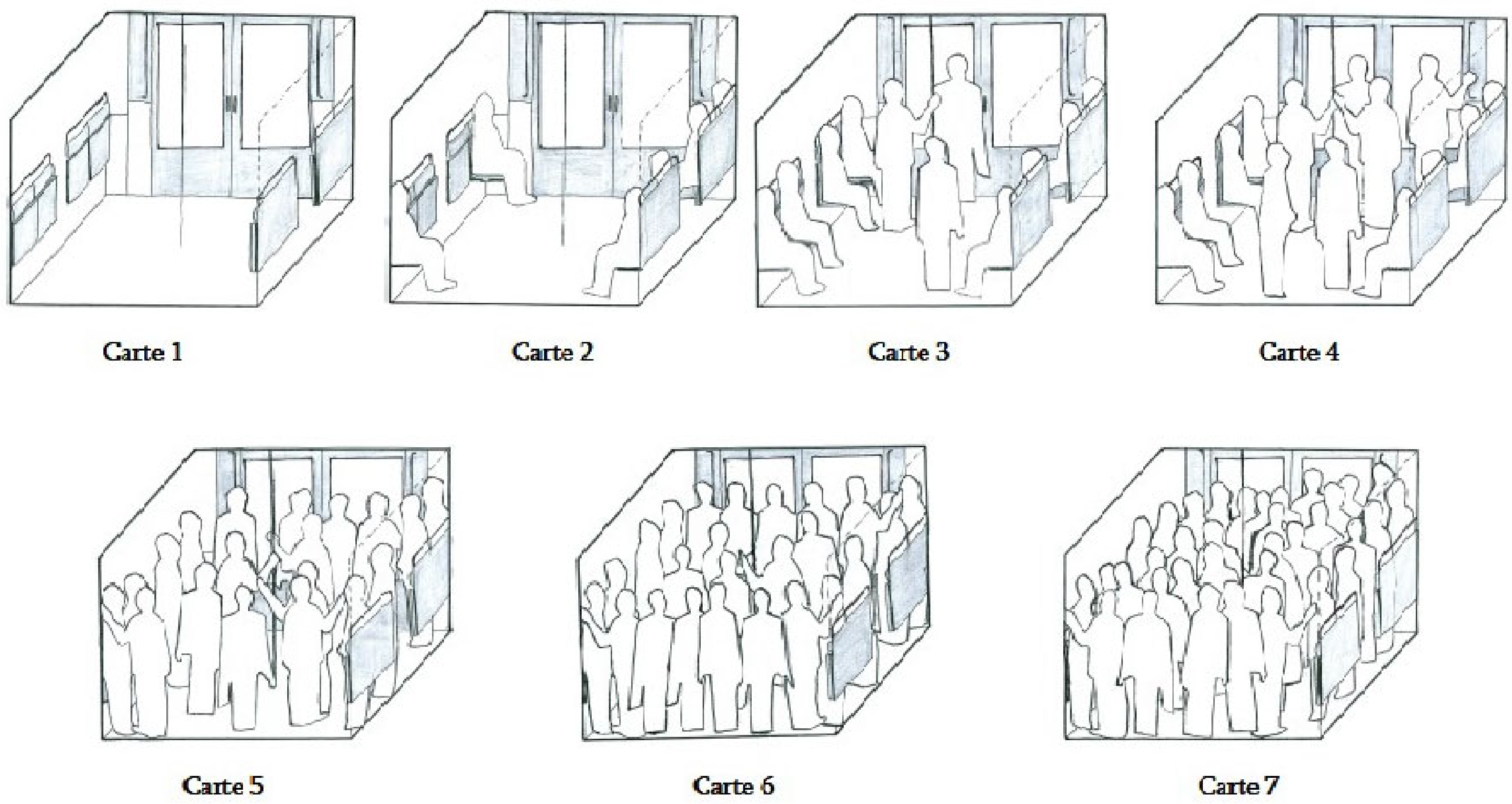
- How much would the <u>cost</u> of your preferred mode have to increase to make you indifferent between it and your next best alternative? [→e.g. $1.00]
- How much would the <u>travel time</u> of your preferred mode have to increase to make you indifferent between it and your next best alternative? [→e.g. 6 minutes]

Estimated VOT = cost increase / time increase.

e.g. $1.00/6 minutes = $10/hr.

Value of travel time

VOT depends on the degree of crowding in public transport



Monchambert, Haywood and Koning (2015)

Value of travel time

Stated preference (cont.)

Advantages & disadvantages relative to revealed preference:

+ RP data may not exist
+ Respondents need not be familiar with alternative modes
+ No need to control for attributes that are not of interest
- No incentive to be accurate.
- Rounding of answers [e.g. 5 mins., 10 mins.]
- Rationalization may be a problem [lying because embarrassment]
- Respondents may protest by distorting their answers. e.g. willingness to pay tolls [lying as for a protest].

Value of travel time estimates

For journey to work

Rough average: 50% of gross wage rate.

Range: 20-100% of gross wage rate

Trip purpose

Higher for business than recreation

Income

Elasticity about 0.9 (Abrantes and Wardman, 2011)

Trip duration

Elasticity of 0.16 (Abrantes and Wardman, 2011)

Distance [miles]	VOT [UK pence/min.]
2	6.0
10	9.4
50	11.6
100	13.4
200	15.4

Size of time savings

Controversial

Value of travel time variability VOR comparable to VOT in urban area.

Value of travel time estimates

Time valuations relative to in-vehicle time

Travel time component	Mean value [Multiple of in-vehicle time]
Walk time	1.66
Access time	1.81
Walk and wait time	1.46
Adjustment time (= frequency delay)	0.72
Headway	0.80
Search time (for parking)	1.38
Late time (= frequency delay)	7.40
Delay time (congestion)	1.48

Wardman (2001, Table 2)

External congestion costs for roads

ALONE

COST DRIVERS		COST ESTIMATION BY ROAD TYPE		
Vehicle Type	Traffic situation	Motorway	Rural road	Urban road
Passenger car	Uncongested	0.012	0.039	0.028 0.004[2)]
	Dense	2.102	1.333	2.879
	Congested	2.161	2.074	3.292 1.315
Motorcycle	Uncongested	0.005	0.020	0.014
	Dense	1.052	0.667	1.440
	Congested	1.080	1.037	1.646
Bus	Uncongested	0.022	0.080	0.055 0.007
	Dense	4.205	2.666	5.759
	Congested	4.321	4.149	6.584 2.461
LGV Large Good Vehicles	Uncongested	0.017	0.060	0.041
	Dense	3.154	1.999	4.319
	Congested	3.241	3.111	4.938
HGV Heavy Good Vehicles	Uncongested	0.029 0.010-0.260	0.009	0.069 0.007
	Dense	5.257	3.332	7.198
	Congested	5.401	5.186	8.230 2.461

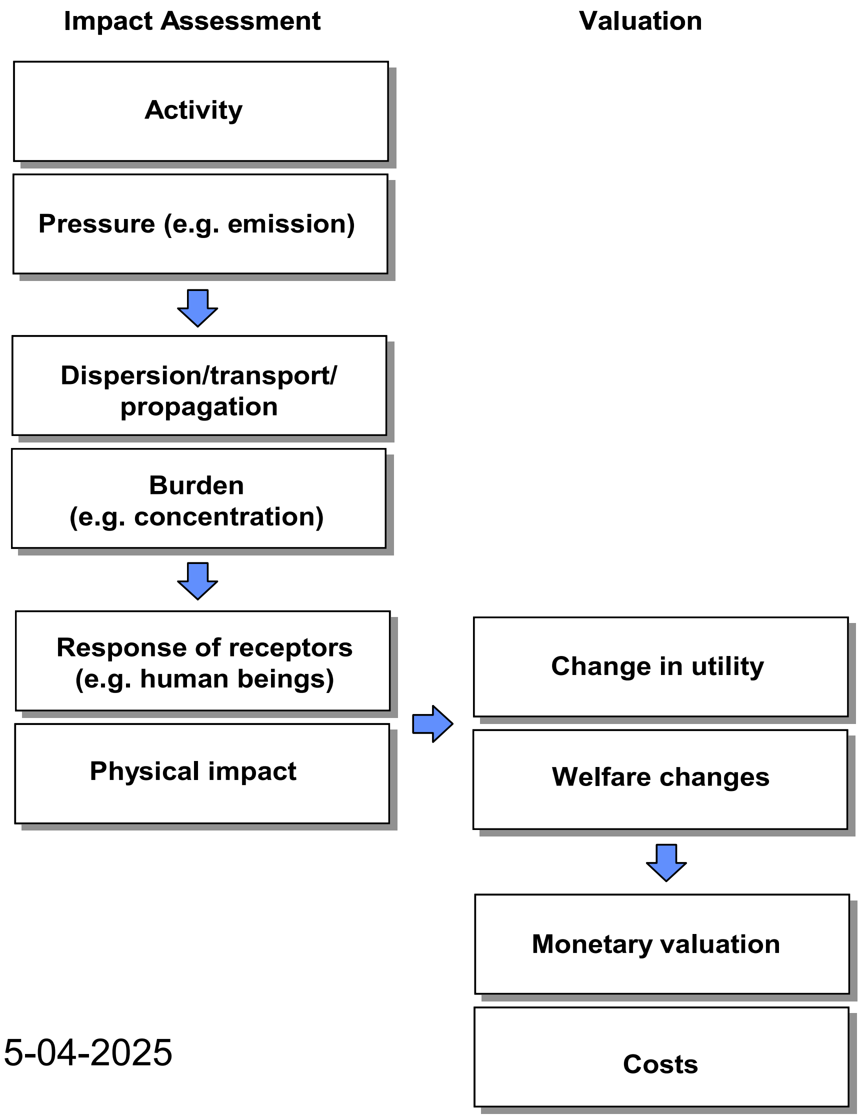
Friedrich and Quinet (2011, Table 16.3)

2b). Environmental Externalities (discussed last lecture)

Environmental externalities

The Impact Pathway approach

Friedrich and Quinet (2011, Figure 16.1)



Diapositive 45

a9 heavy vehicle, type of convertesn hogh widely the pollution is disperse, in what direction,cncentration, physical impact, valuation welfare change, monetary valuation...

adepalma; 13/04/2016

Emissions

Road transport , €$_{2002}$ per tonne

Pollutant emitted	NO_x	NMVOC	SO_2	$PM_{2.5}$	
Effective pollutant	Nitrogen oxides	Secondary O_3	Sulphates, Acid deposition	Particles: Primary $PM_{2.5}$	
Local environment				urban	outside built-up areas
Austria	4,300	600	3,900	430,000	72,000
Belgium	2,700	1,100	5,400	440,000	95,000
Czech Republic	3,200	1,100	4,100	270,000	67,000
Denmark	1,800	800	1,900	400,000	47,000
Estonia	1,400	500	1,200	160,000	27,000
Finland	900	200	600	360,000	30,000
France	4,600	800	4,300	410,000	82,000
Germany	3,100	1,100	4,500	400,000	78,000
Greece	2,200	600	1,400	270,000	38,000
Hungary	5,000	800	4,100	230,000	59,000
Ireland	2,000	400	1,600	440,000	46,000
Italy	3,200	1,600	3,500	390,000	71,000
Latvia	1,800	500	1,400	140,000	26,000
Lithuania	2,600	500	1,800	160,000	32,000
Luxemburg	4,800	1,400	4,900	730,000	104,000
Netherlands	2,600	1,000	5,000	440,000	86,000
Poland	3,000	800	3,500	190,000	57,000
Portugal	2,800	1,000	1,900	270,000	40,000
Slovakia	4,600	1,100	3,800	200,000	54,000
Slovenia	4,400	700	4,000	280,000	58,000
Spain	2,700	500	2,100	320,000	44,000
Sweden	1,300	300	1,000	370,000	36,000
Switzerland	4,500	600	3,900	460,000	76,000
United Kingdom	1,600	700	2,900	410,000	64,000

Non-Methane Volatile Organic Compounds

Friedrich and Quinet (2011, Table 16.7)

Emissions

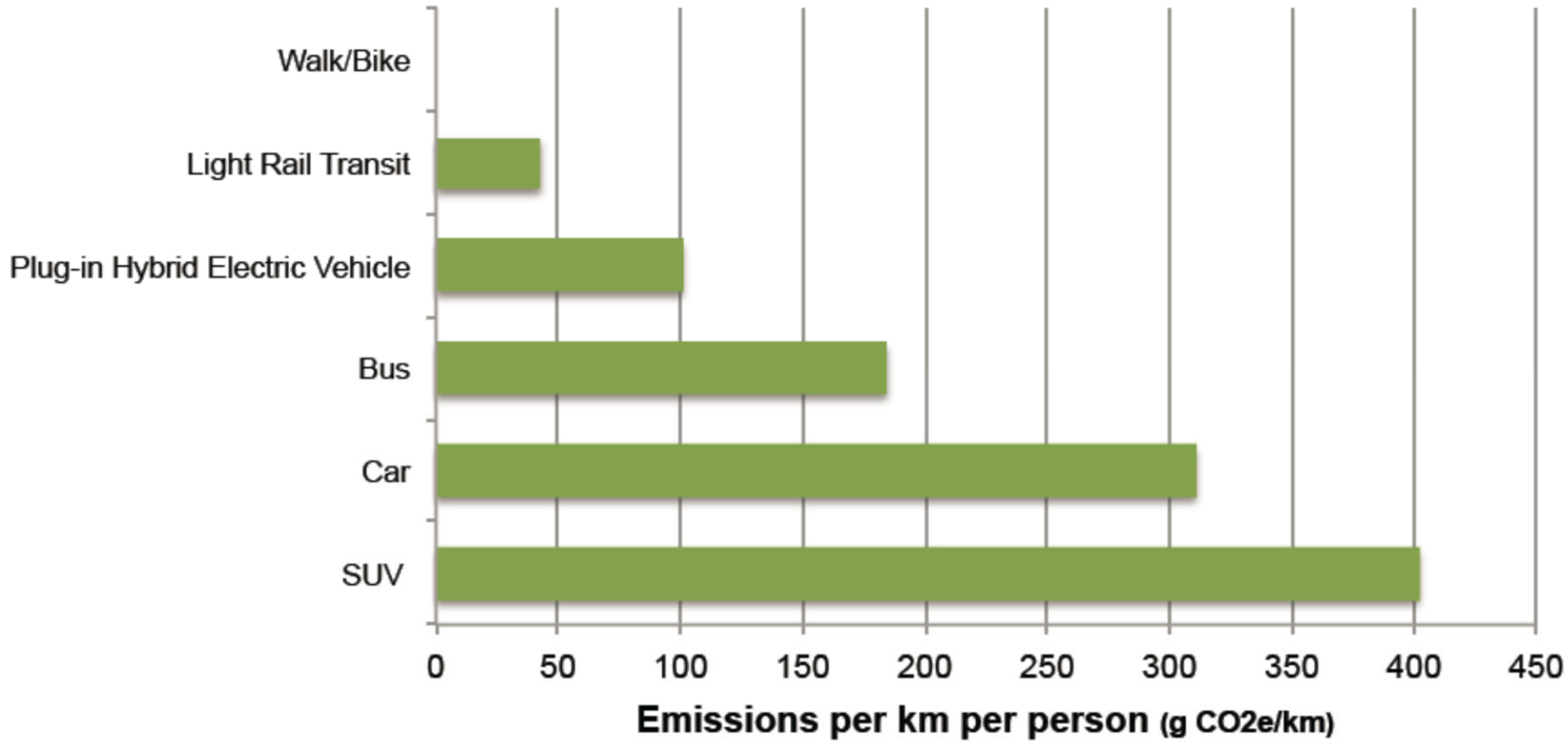


Figure 3: Emissions per kilometre by transportation mode

Burda et al. (2012). Read : Vosough; S , A. de Palma & R. Lindsey (2022).

2c). Safety and the value of human life

Value of human life: estimation methods

Traditional approach: Value of life = lost earnings + legal expenses. Example: Ford's decision not to reinforce fuel tanks of the Pinto [→ 15 year of forgone wages, PV]…now, much better approach….

Modern approach: Calculate the *Value of a Statistical Life*: **VSL**.

Definition: The monetary value of a small mortality risk reduction that would prevent one *statistical* death.

VSL is estimated from settings by considering a tradeoffs between risk and money (e.g., hazardous jobs).

VSL used by the US Federal <u>Aviation</u> Admin.: $9.2 million.

[Combination of SP & RP].

Value of human life: estimation methods

Defensive expenditures method

According to a cost-benefit approach, expenditures on safety should be increased to the point where:

Marginal cost of saving a statistical life = VSL

The VSL can be estimated by observing the marginal costs incurred

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Value of human life

Dependence of VSL on age

Does VSL decrease monotonically with age?

Dependence of VSL on health

Use value of Quality-**A**djusted **L**ife **Y**ears (**QALY**): A QALY is a measure of the usefulness perceived by patients of a medical action, which corresponds to one year of life gained:

$129,000 per QALY.

For patient on kidney dialysis: One year of life provides half a QALY.

a11 A 90 year old guy with Kedney problem should have lower value of Life? No, equity and lobby groups of retreated people will complain (contrversial case).

adepalma; 13/04/2016

Value of human life

Dependence of VSL on income

VSL increases with income according to both the traditional and the modern calculation approaches.

The income elasticity is controversial (Hammitt & Robinson, 2011), i.e. how VSL increases with individual income.

- U.S. regulatory agencies: Use an elasticity of 0.4 to 0.6.
- Cross-country & longitudinal studies find an elasticity of 1.0 or larger

Some unpalatable implications (controversial)

- More money should be spent on improving the safety of facilities and services used by rich people [but do not forget equity issues!]
- "Polluting industries should be exported to developing countries" (Lawrence Summers, 1992) [President of Harvard, 2001-2006]!

Compensation from General Motors for faulty ignition switches will depend on age and income (Keenan, 2014)

25-year-old, married with 2 children, income $75,000/yr: $5.1 million

17-year-old student, living with parents: $2.2 million

a12

VSL used in policy analysis

US$1,000 (2005)

Country	Source	Official value based on...	VSL
New Zealand	Trawén *et al.* (2002)	SP study (Miller and Guria, 1991).	1,790
Norway	Trawén *et al.* (2002)	meta-analysis (Elvik, 1993).	2,051
Sweden	SIKA (2005)	SP study (Persson and Cedervall, 1991).	1,996
Unit. Kingdom	UK DoT (2007)	multi-stage approach (Carthy *et al.*, 2000).	2,308
United States	US DoT (2002)	meta-analysis (Miller, 1990).	3,309

Andersson and Treich (2011, Table 17.2)

a12 Mata ananlysis combining many studies.
adepalma; 13/04/2016

Catastrophic events

- Martin Weitzman (formerly at Harvard) has worked for decades on environmental economics, global warming and environmental disasters.
- "Catastrophic events" (natural / human) have large consequences, but occur with small probabilities: see Drazen Prelec, MIT, on probability weighting functions and biased perceptions. Twin tower example.
- Is the COVID-19 a *Black Swan?* (*S*ee Nicholas Taleb)
- Paul Krugman New York Times opinion:
- https://www.nytimes.com/2020/04/02/opinion/coronavirus-economy-stimulus.html

Ambiguity

- Standard: probabilities are unknown and inferred by the DM
- Strong: some new process may occur, unexpectedly, such as a war, a pandemic, or a disease, ….

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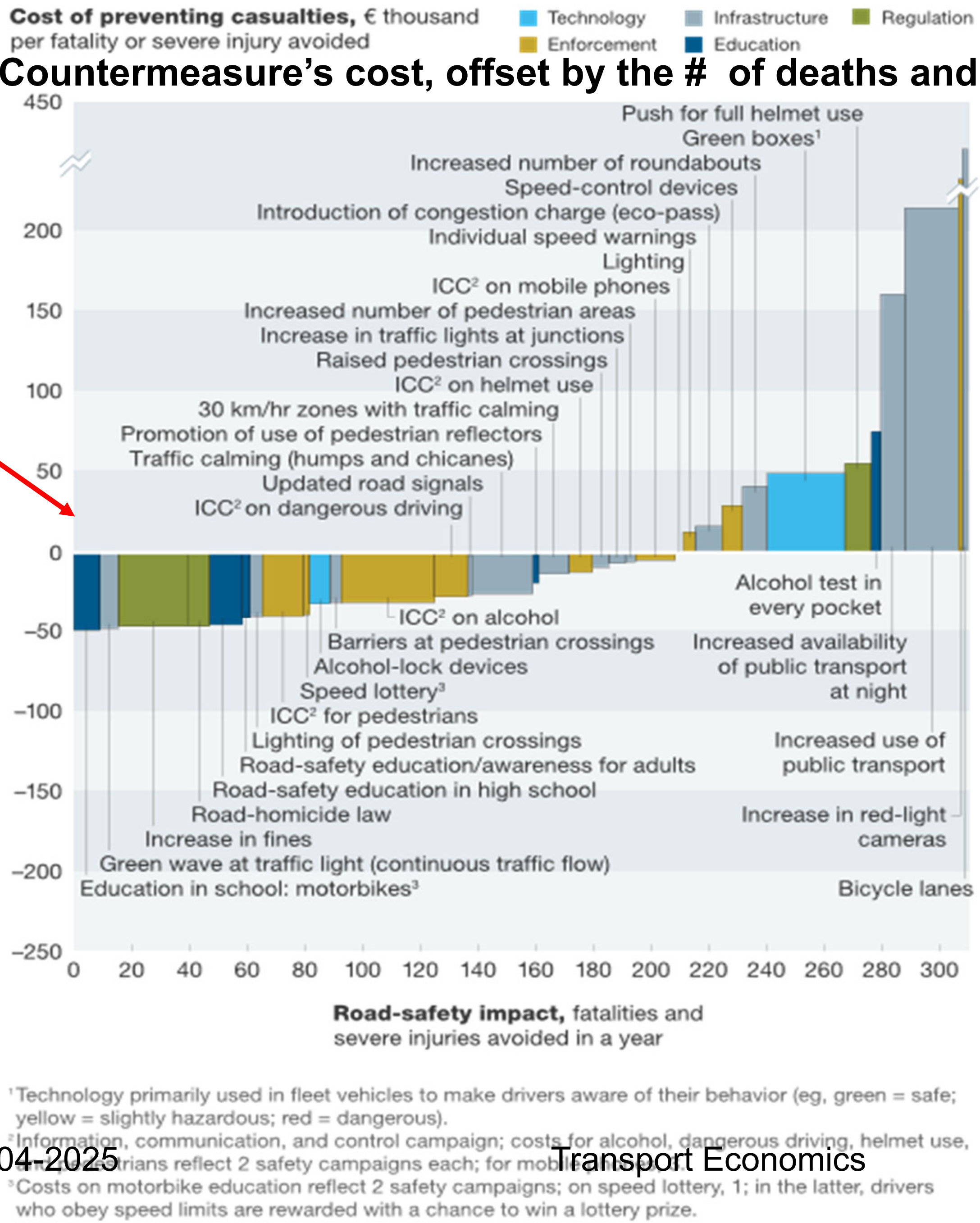
EXTRA MATERIAL

ALONE

y-axis : Countermeasure's cost, offset by the # of deaths and injuries it can prevent

Ghislanzoni et al.(2013). McKinsey: A cost curve to improve road safety



Those that save the most lives per euro are on the left of the curve

→x-axis : Road-safety impact: # of fatalities & severe injuries avoided in a year