Keynote Topic Area C
“Traffic Management, Operations, and Safety”

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WCTR 2019 Mumbai

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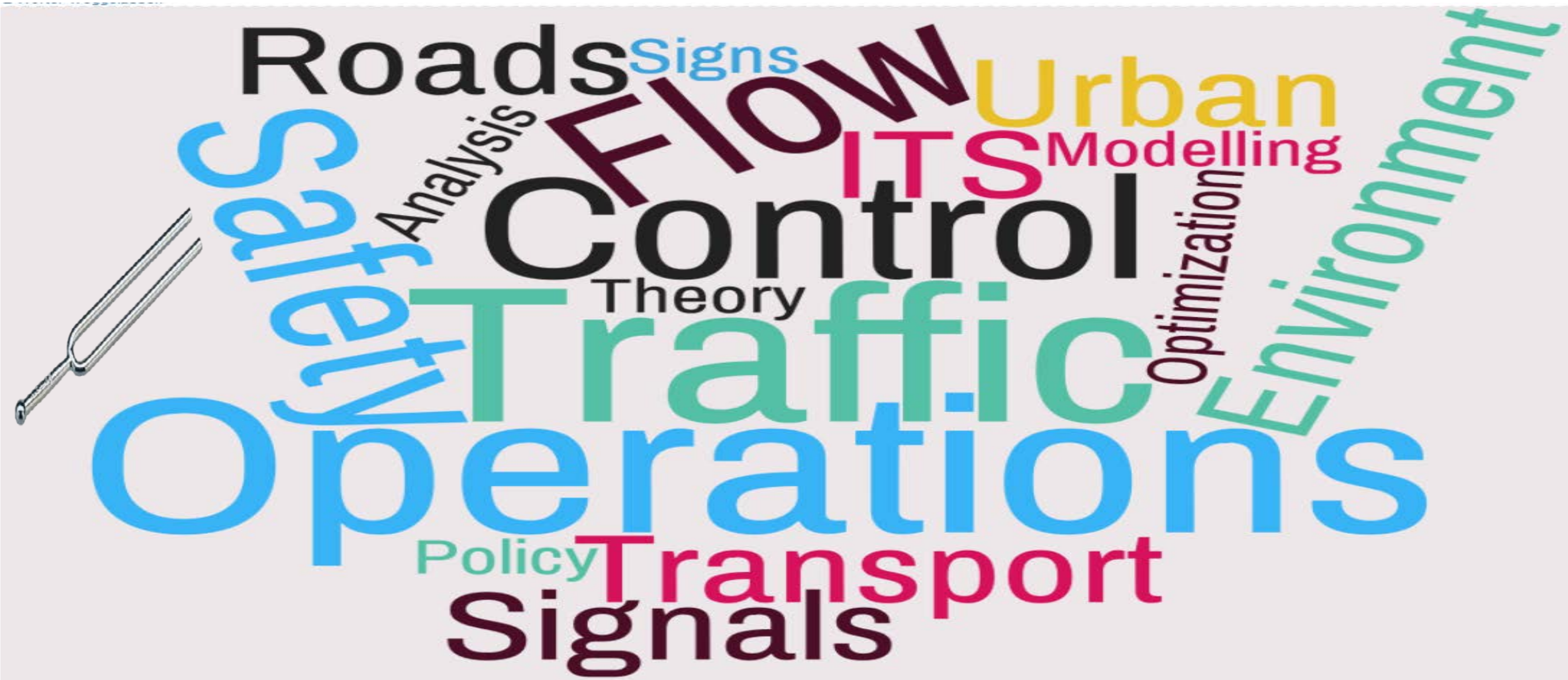

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Multi-criteria Assessment of Traffic Signal Control

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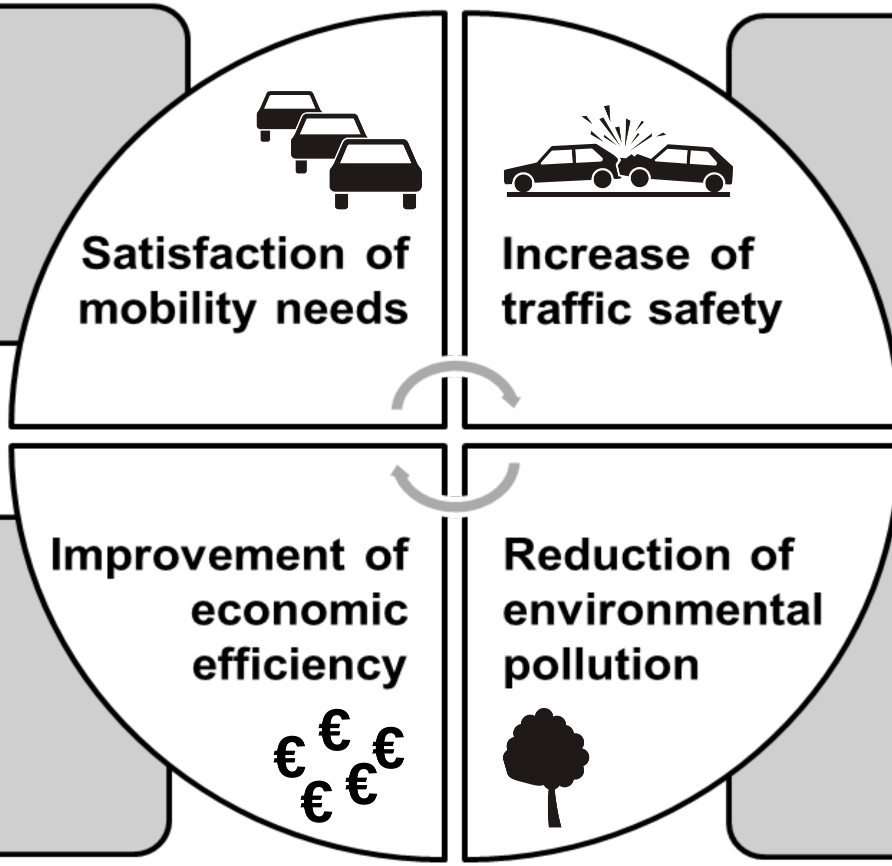
Challenge 1

Considering All Relevant Impacts

- delay for vehicles (motorized and not motorized)
- delay for individuals
- number of stops
- queue lengths
- comfort



- number of traffic accidents
- number of slight injuries
- number of severe injuries
- number of fatalities

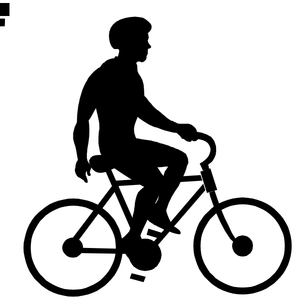
- average travel speed
- saturation degree of green times

- emission of air pollutants
- ambient air quality
- noise level
- energy consumption, CO_2 emission

➔ The impacts must be measured!

Challenge 2

Considering All Relevant Road Users



In addition, the needs of residents must be considered.

➔ The number of people in each road user group must be known (or estimated).

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Challenge 3

Identifying Goal Conflicts

Goal conflicts cannot be avoided.

Example:

Measures to promote pedestrians or cyclists at traffic signals are having impacts on other road users:

- Delay, number of stops, and queue lengths in motorized individual traffic
- Delay in public transport
- Emissions of noise and air pollutants in motorized individual traffic and heavy vehicle traffic (where applicable also roadside noise and air pollution levels)
- Fuel consumption and CO_2-Emissions in motorized individual traffic and heavy vehicle traffic


Hamburg, Germany Photo: © Boltze 1989


Hamburg, Germany Photo: © Boltze 1989

→ Measures to promote one mode must always consider the impacts on other modes.

→ Need for quantification of multiple impacts.

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Challenge 4

Achieving a Fair Balance

How to value the delay for pedestrians in comparison to those for cyclists, public transport passengers as well as car drivers and passengers?

How many litres additional fuel consumption and how many grams of exhaust emissions can be accepted, in order to accelerate a bus and reduce the delay for each passenger by about 10 s?

Promoting pedestrian traffic, by which criteria can we decide to interrupt a green wave due to a pedestrian request at roadside, although it may lead to disruption of traffic flow as well as increased energy consumption and emissions?

How do we consider the side-effect of a green wave for cyclists that more stops and accelerations of motorized vehicles lead to a significantly higher air pollution concentration?

- ➔ A fair balance is required to deal with goal conflicts.
- ➔ Transparent and comprehensible consideration of negative and positive impacts.

Challenge 5

Weighting and Aggregation of Impacts

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Aggregation of same indicators for different modes:

- Simple accumulation (e.g. air pollution)
- Person-based aggregation (e.g. delay)

Consolidation of impacts on different goals and indicators:

- Scaling the indicators based on a command variable (cost, delay, …).
- Derivation of quantitative conversion factors from literature.

Basically, the resulting values can be aggregated with the same weight.

A particular weight can be applied (but must be justified!)

- to consider otherwise intangible effects or
- due to political or planning reasons.

➔ Rules to value and to weight the different impacts must be established.

Challenge 6

Prioritizing Specific Modes

General **promotion of walking, cycling and public transport** due to less environmental impacts.

Absolute priority for one single traffic mode is not appropriate. Instead, overall impacts of measures must be considered to avoid inadequate negative impacts on other modes and parameters.

As we already consider all impacts on the different road user groups, **a further prioritization is simply not necessary**.

Example:

Priority for a fully occupied bus is self-evident due to the potential delay for a high number of passengers, to low fuel consumption and low emissions.

➔ Under comprehensive consideration of all impacts there is usually **no need for any further prioritization**.

➔ We need to apply **conditional priority instead of absolute priority**.

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Challenge 7

Considering Impacts on Mode Choice

Mode Choice is very important for the sustainability of the transport system.

In principle, measures at traffic signals must consider the **indirect impacts** by medium-term or long-term changes in mode choice.

However, changes in mode choice caused by specific measures at traffic signals are **hard to prove** with available methods. Need for research!


Tokyo, Japan   Photo: © Boltze 2005

- ➔ To deteriorate traffic flow for individual car traffic with intent is no suitable means of influencing mode choice! There are too many negative impacts (congestion, delay, noise and air pollution, negative health impacts, …).
- ➔ Preference for measures to influence mode choice without negative environmental impacts.


Darmstadt, Photo: © IVV

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Challenge 8
Considering Specific Situations

Examples for considering the specific situation in traffic signal control:

Traffic volume
Consideration already widely applied.
The above mentioned comments on impact estimation and fair balance should be considered.

Number of passengers in public transport vehicles, position of public transport vehicles before/behind schedule
From absolute priority to conditional priority!

Air pollution levels
Higher weight for emissions in situations with critical air quality.

Road-side land-use and facilities
Using signal programs which reduce the number of stops and accelerations at places and in times with higher need for noise protection.

→ Promotion of situation-responsive, adaptive traffic signal control.

Photos: © IVV

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Wrap-up – Summary of Challenges

Challenge 1	**Considering all Relevant Impacts**
Challenge 2	**Considering all Road Users**
Challenge 3	**Identifying Goal Conflicts**
Challenge 4	**Achieving a Fair Balance**
Challenge 5	**Weighting and Aggregation of Impacts**
Challenge 6	**Prioritizing Specific Modes**
Challenge 7	**Considering Impacts on Mode Choice**
Challenge 8	**Considering Specific Situations**

➔ Which methods could be used to cope with these challenges?

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Potential Methods for Impact Assessment

Satisfaction of Mobility Needs

- Calculations, e.g. based on Highway Capacity Manual
- Traffic Flow Simulation (macroscopic/microscopic)
- Qualitative Estimation of Comfort Levels
- Questionnaire surveys

Increase of Traffic Safety

- Accident Analysis based on Accident Data from comparable Situations
- Using Auxiliary Quantities (such as number of stops)

Reduction of Environmental Pollution

- Emission Modelling (Noise and Air Pollution)
- Modelling of Ambient Air Quality

Improvement of Economic Efficiency

- Traffic Engineering Calculation
- Traffic Flow Simulation (macroscopic/microscopic)


Photo: © Boltze 2018

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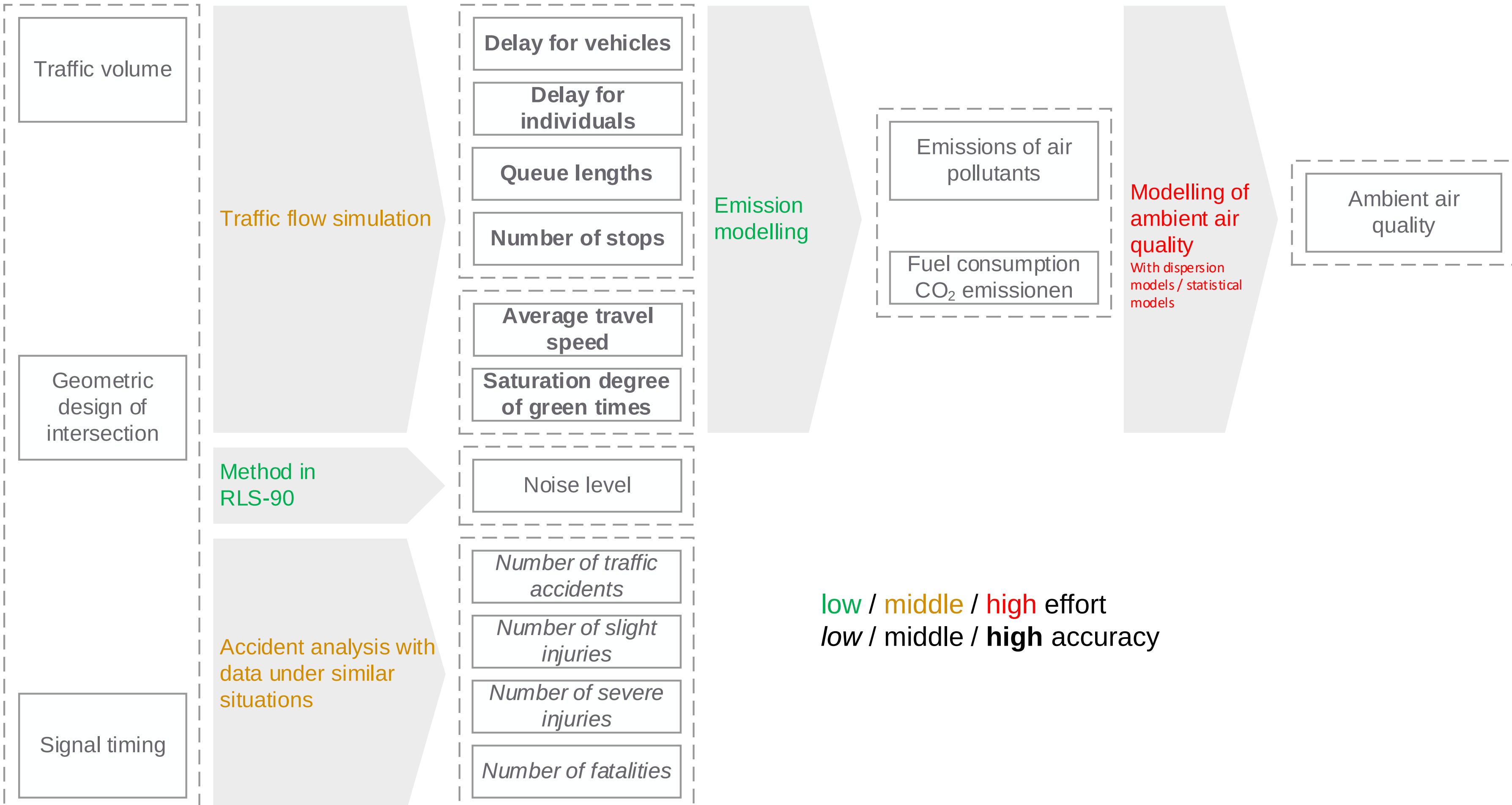
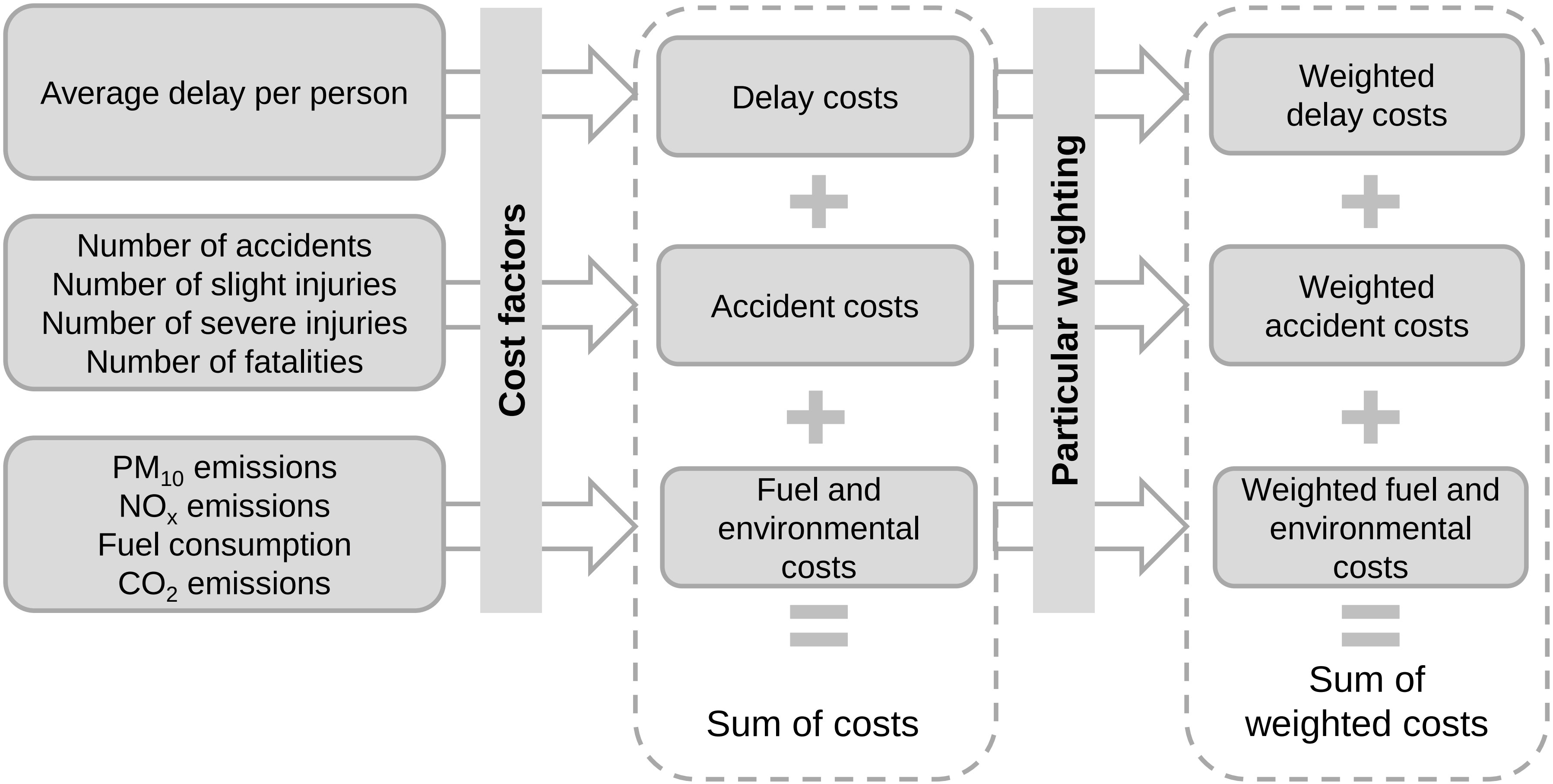
Methods to Estimate/Measure Impacts During Planning



Source: own illustration

Overview – Costs as the Leading Criteria



Cost Factors for Delay

Two cost components are considered:

- value of time in private transport,
- time-dependent operation cost.

Peak hours		Walking	Cycling	Public transport	Motorised private transport		Heavy transport	Source
				Bus, tram	Car	LCV	HDV	
Value of time in private transport	Average occupancy rate [p/veh]	-	-	40 (bus) 80 (tram)	1.3			Own calculation based on BVWP 2030 (Dahl et al. 2016)
	Value of travel time saving [€/p-h]	4.21	4.40	4.42	4.93			
Time-dependent operation cost	Personnel cost [€/p-h]			20.14		17.64	20.14	

If possible, the **average occupancy rate of public transport vehicles** should be estimated site- and time-specific.

In case of dynamic control strategies, the **occupancy rate** can be measured in real-time and considered in the online optimisation.

Impending **increase in costs due to extra vehicle demand** can be taken into consideration through particular weighting.

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Cost Factors for Traffic Accidents

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The German Federal Highway Research Institute (BASt) annually calculates and publishes the **economic costs of traffic accidents** in Germany.

		Cost factor (at 2012 price)
Personal injury	Fatality	1,161.892 €/person
	Severe injury	116,151 €/person
	Slight injury	4,829 €/person
Property damage	Accident with personal injury	15,606 €/accident
	Accident with fatality	43,096 €/accident
	Accident with severe injury	20,782 €/accident
	Accident with slight injury	13,959 €/accident
	Serious accident just with property damage	20,808 €/accident
	Other accident (including achohol accident)	5,951 €/accident

Source: Baum et al. 2011 and Bundesanstalt für Straßenwesen 2016, own illustration

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Cost Factors for Emissions and Energy Consumption

Cost factors for emissions based on the evaluation method for the Greman Federal Transport Infrastructure Plan (BVWP 2030) and another study from the Federal Environmental Agency

Air pollutant	Specific damage costs (for CO_2 damage and avoidance costs) [€/t] at 2010 price	
	urban	rural
PM exhaust	364,100[1)]	122,800[1)]
PM_{10} resuspension und abrasion	33,700[2)]	11,000[2)]
NO_x	15,400[1)]	15,400[1)]
CO_2	80[2)3)]	80[2)3)]

1) Source: BVWP 2030 (Dahl et al. 2016, S. 111)

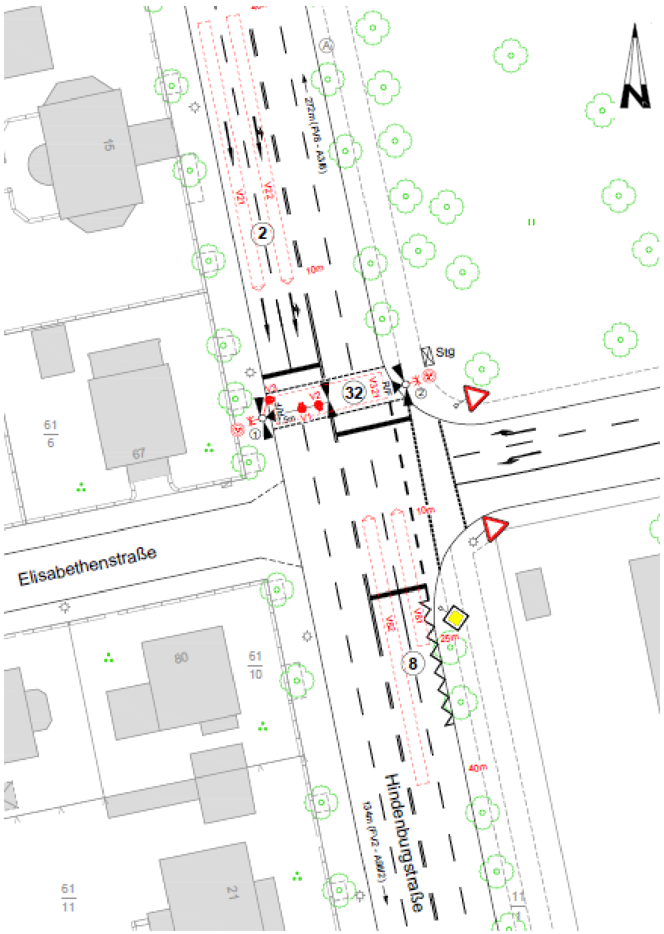
2) Source: Methodenkonvention 2.0 zur Schätzung von Umweltkosten (Schwermer 2012a, p 5)

3) This value corresponds to the middle value given in the literature.

Cost factors for energy consumption according to BVWP 2030 (at 2012 price):

- Petrol and diesel 0.71 €/l (without taxes)
- Electricity rate for private households 17.84 Cent/kWh (without taxes und fees)

Introduction to Case Study 1: Pedestrian Crossing



Source: Straßenverkehrs- und Tiefbauamt Stadt Darmstadt

- Pedestrian crossing on coordinated corridor
- Originally not integrated in the coordination (status: November 2016)
- Medium number of passing vehicles and low number of crossing pedestrians
- Long queues in the morning peak hours
- Features to generate alternative signal programs:
  - cycle time
  - pedestrian request (activated/deactivated)
  - coordination

Implementation of the Assessment Method: Pedestrian Crossing (1)

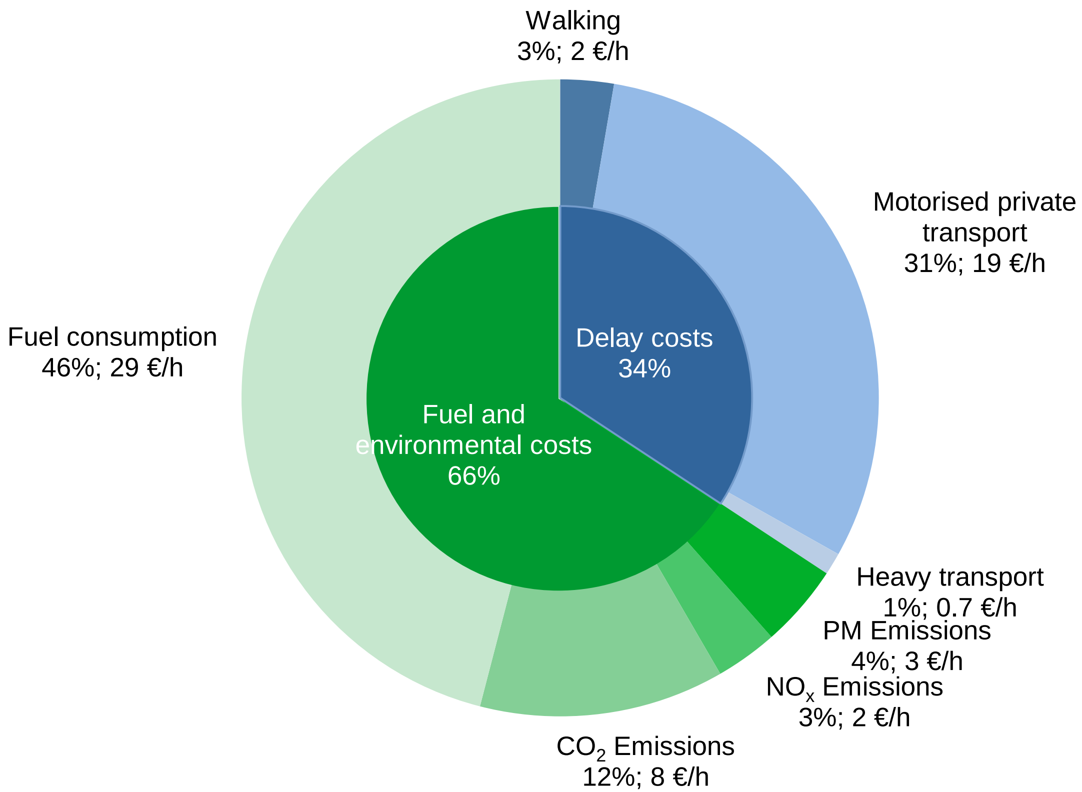
Current traffic signal program

Morning peak hour
Variable cycle time
Activated pedestrian request
Uncoordinated (for vehicles)

Traffic volume
in the investigated hour:
113 Pedestrians
1722 Persons in cars and LCV
17 Persons in HGV

Calculated total costs:
63 €/h

Optimum by applying a particular weighting for pedestrian delay (> factor 11)



Source: Boltze/Jiang 2017

Implementation of the Assessment Method: Pedestrian Crossing (2)

Cost-effective signal program

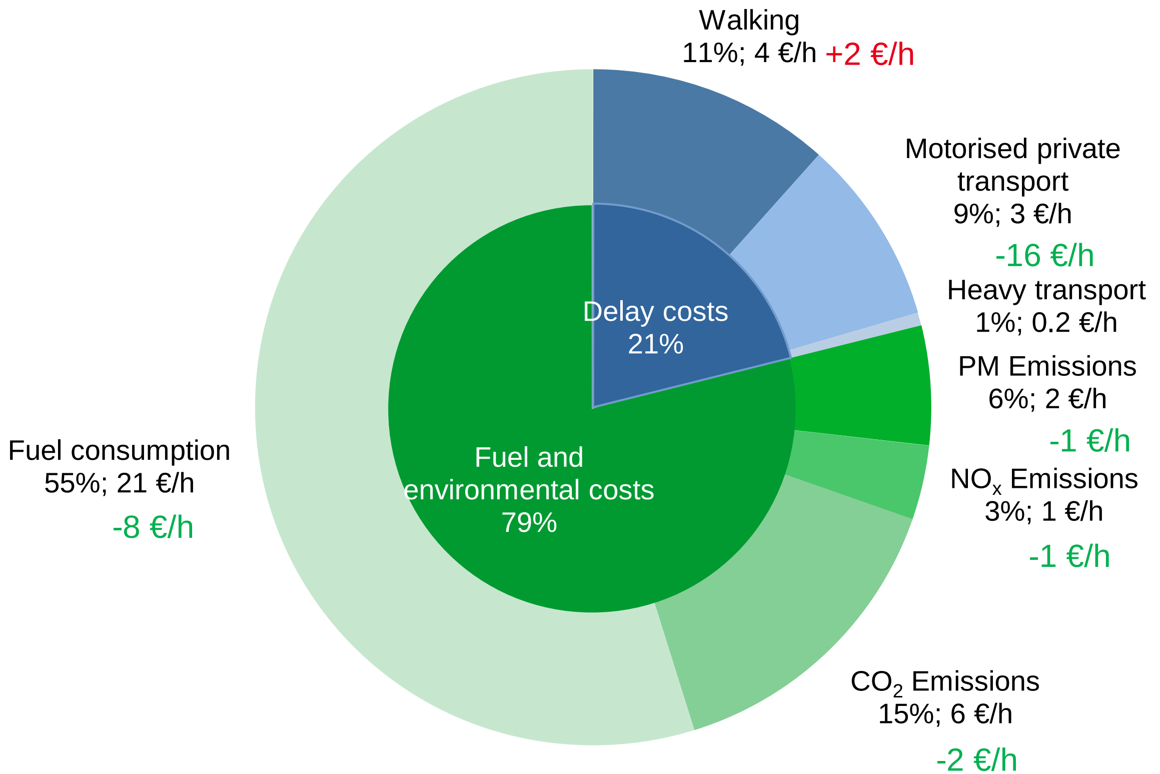
Morning peak hour
Cycle time 90 s
Deactivated pedestrian request
Coordinated (for vehicles)

Traffic volume
in the investigated hour:
113 Pedestrians
1722 Persons in cars and LCV
17 Persons in HGV

Calculated total costs:

38 €/h

Optimum by the same weighting for all cost components



Source: Boltze/Jiang 2017

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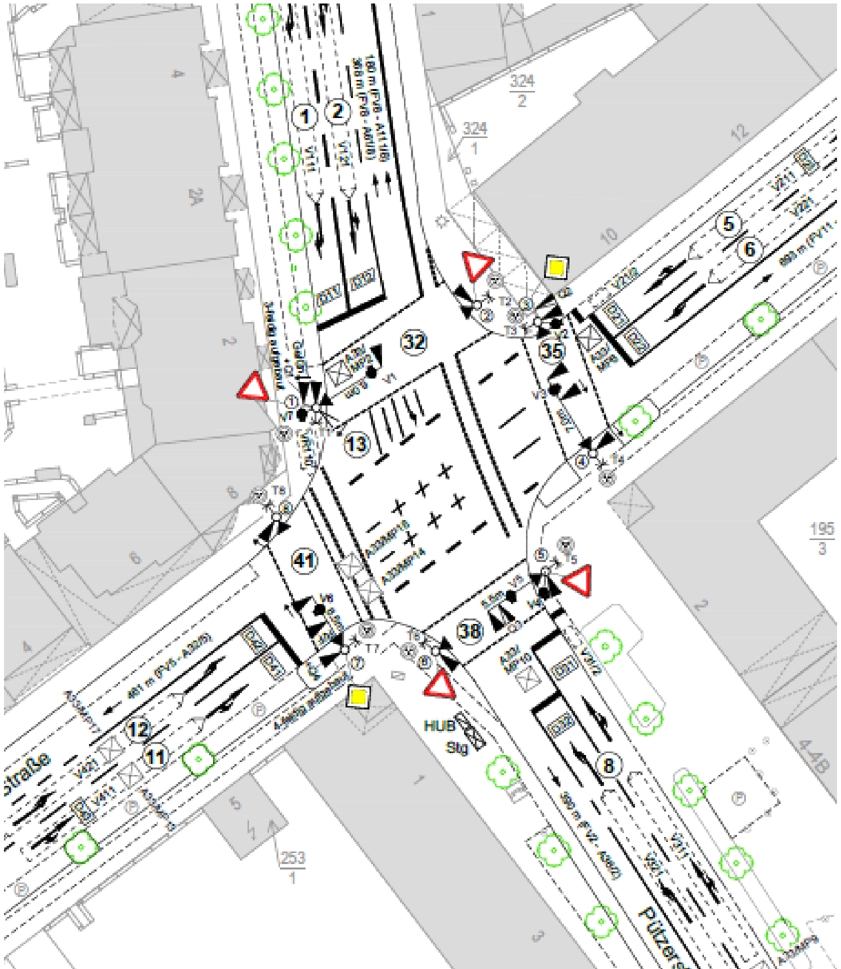
Results from Case Studies

Introduction to Case Study 2: Four-leg Intersection



- Typical four-leg intersection in the urban area
- Medium number of pedestrians
- Separated cycle lanes
- Feature to generate alternative signal programs:
  - transit signal priority

Source: Straßenverkehrs- und Tiefbauamt Stadt Darmstadt

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Implementation of the Assessment Method: Four-leg Intersection (1)

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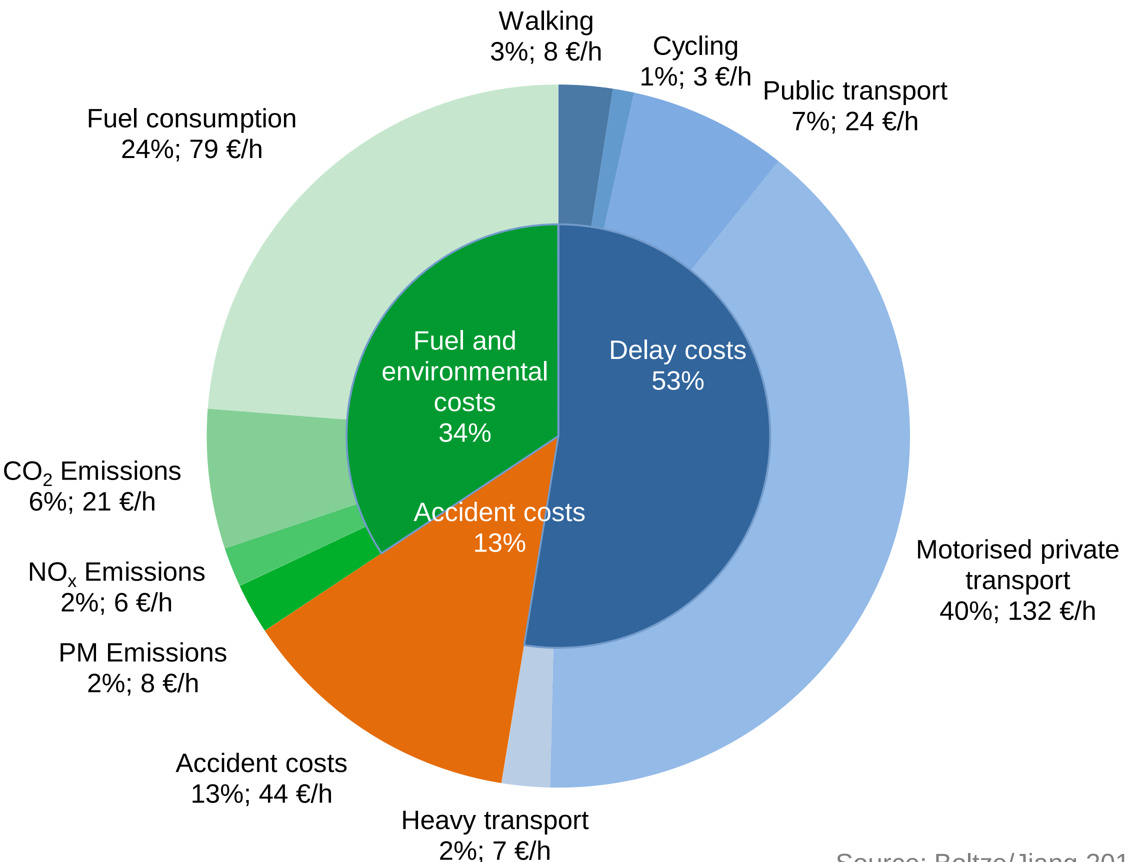
Current traffic signal program

Evening peak hour
Conditional transit signal priority

Traffic volume
in the investigated hour:
256 Pedestrians
105 Cyclists
943 Persons in buses
2743 Persons in cars and LCV
33 Persons in HGV

Calculated total costs:
333 €/h



Source: Boltze/Jiang 2017

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Implementation of the Assessment Method: Four-leg Intersection (2)

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Alternative signal program

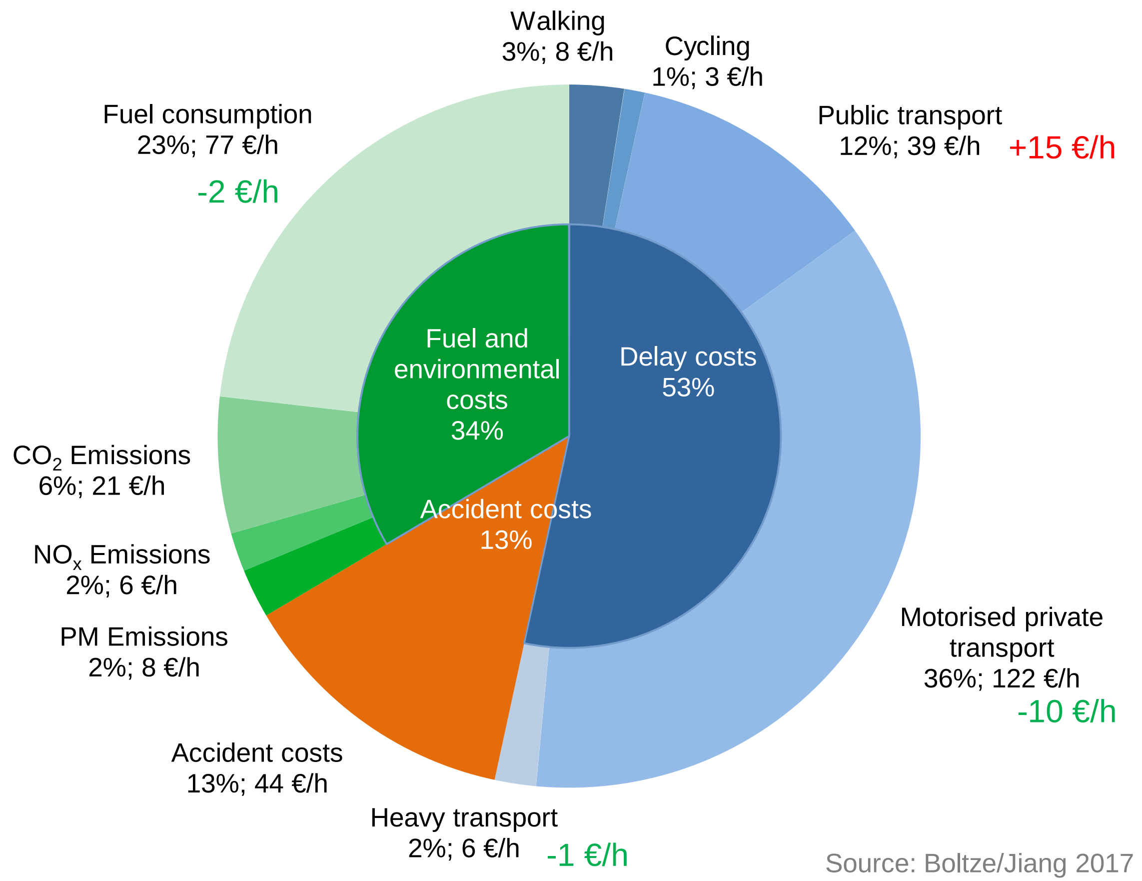
Evening peak hour
No transit signal priority

Traffic volume in the investigated hour:

256 Pedestrians
105 Cyclists
943 Persons in buses
2743 Persons in cars and LCV
33 Persons in HGV

Calculated total costs

334 €/h



Source: Boltze/Jiang 2017

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Conclusions from the Case Studies

- **Challenges can be tackled** by detailed assessment of traffic signal control
  - considering ~~*all*~~ *most* relevant impacts **(Challenge 1)**,
  - considering all road users **(Challenge 2)**,
  - identifying goal conflicts **(Challenge 3)**, and
  - achieving a fair balance **(Challenge 4)**.
- **Simulation tools are very supportive** to allow such assessment.
- The **number of people** that are present in different modes at intersections has significant impacts on the optimisation of traffic signal control.
- The **distribution of cost components** can vary for different intersection types and signal programs. Costs for fuel and emissions are between 1/3 and 2/3 (and unneglectable!).
- There is a **correlation between costs of delay and costs of fuel and emissions**, but this correlation is specific for each intersection and situation.
- **Weighting and aggregation of impacts can be done by monetarization.** **(Challenge 5)**
- **Additional prioritization of specific modes is not needed.** **(Challenge 6)**
- **Medium/long-term impacts on mode choice need additional research.** However, deterioration of traffic flow is not a proper mean to influence mode choice. **(Challenge 7)**
- Considering specific situations calls for **flexible, adaptive control**. **(Challenge 8)**

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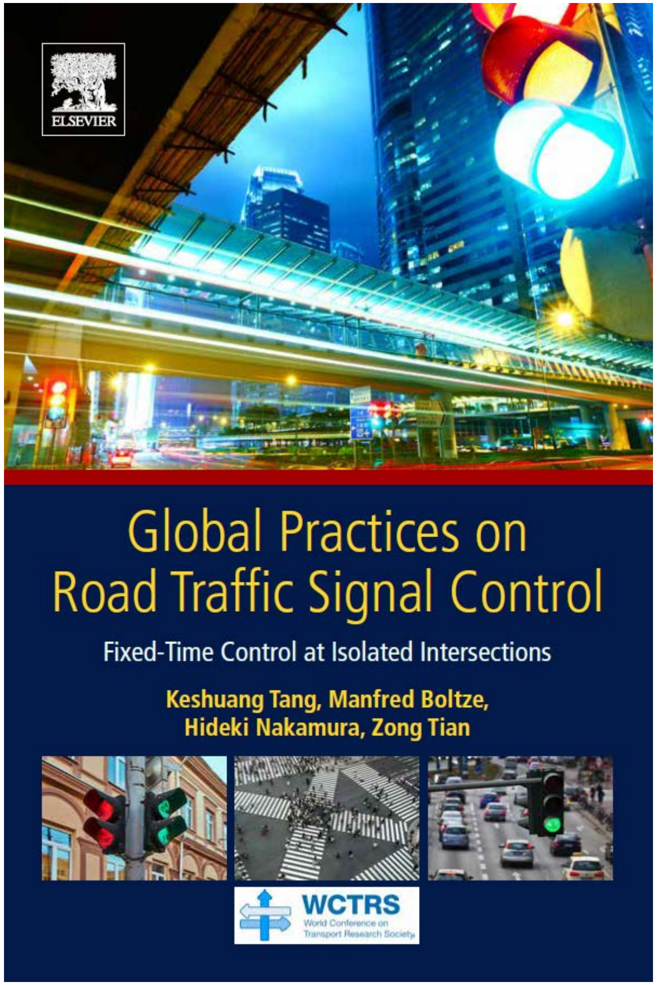
The End

Final Remarks

- **Making things better is our intrinsic motivation** to do research and to work as a transport planner or traffic engineer.
- Although it needs significant efforts, careful and **comprehensive impact assessment** is most important to make our work really beneficial for our societies.
- With adaptations of the cost values, the presented approach seems to be **transferable to other countries and to other traffic engineering systems**.
- **International exchange** on research and best practice in traffic engineering and specifically on assessment methods is very important.



Special Session of SIG C2 (ID: C2_SS1a, C2_SS1b)
International Practice on Road Traffic Signal Control
Room: LC 101, Time: 09:30~12:20, May 28, 2019

Multi-criteria Evaluation of Traffic Signal Control

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WCTRS Special Interest Group Meeting – SIG C2: Urban Transport Operations
Binh Duong (Vietnam), 21-22 September 2017

Thank you for your attention!

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