Multi-criteria Evaluation of Traffic Signal Control

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Background

Questions: Value Orientation…

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?

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?

Shall we use traffic signals to influence modal split? How do we consider negative impacts on other road users and on air pollution? Shall we really deteriorate traffic flow to influence the modal share?

General Conclusions

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A comprehensive consideration of **various impacts** on the different road user groups is necessary.

➔ The impacts must be measured!
➔ Planning instruments must partially be further developed.

A **fair balance** is required to deal with goal conflicts.

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

Forschungsgesellschaft für Straßen- und Verkehrswesen

Arbeitsgruppe Verkehrsmanagement

FGSV

Richtlinien für Lichtsignalanlagen

R 1

RiLSA

Lichtzeichenanlagen für den Straßenverkehr

Ausgabe 2015

Fachgebiet Verkehrsplanung und Verkehrstechnik

Methods to Estimate/Measure Impacts During Planning

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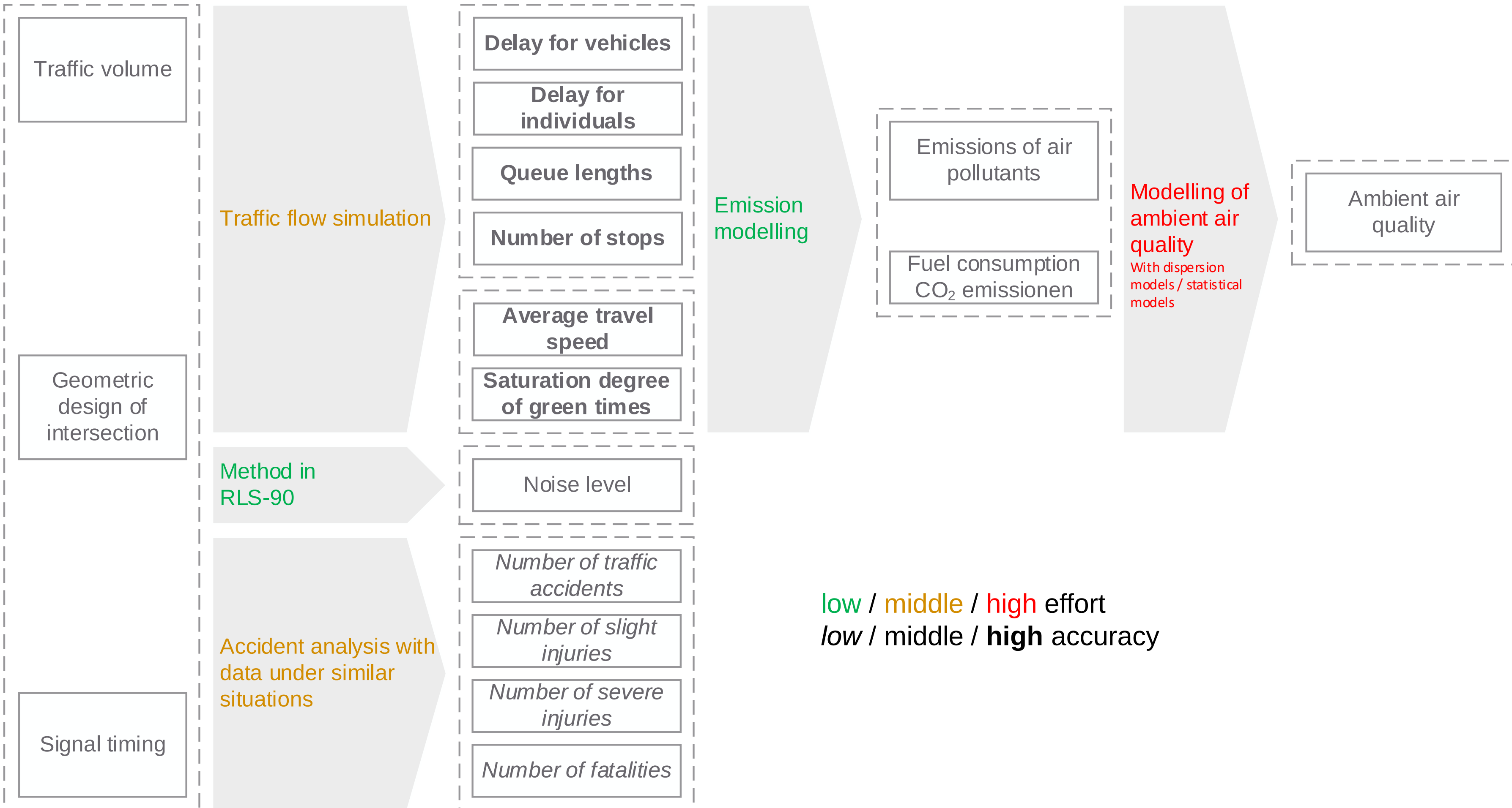
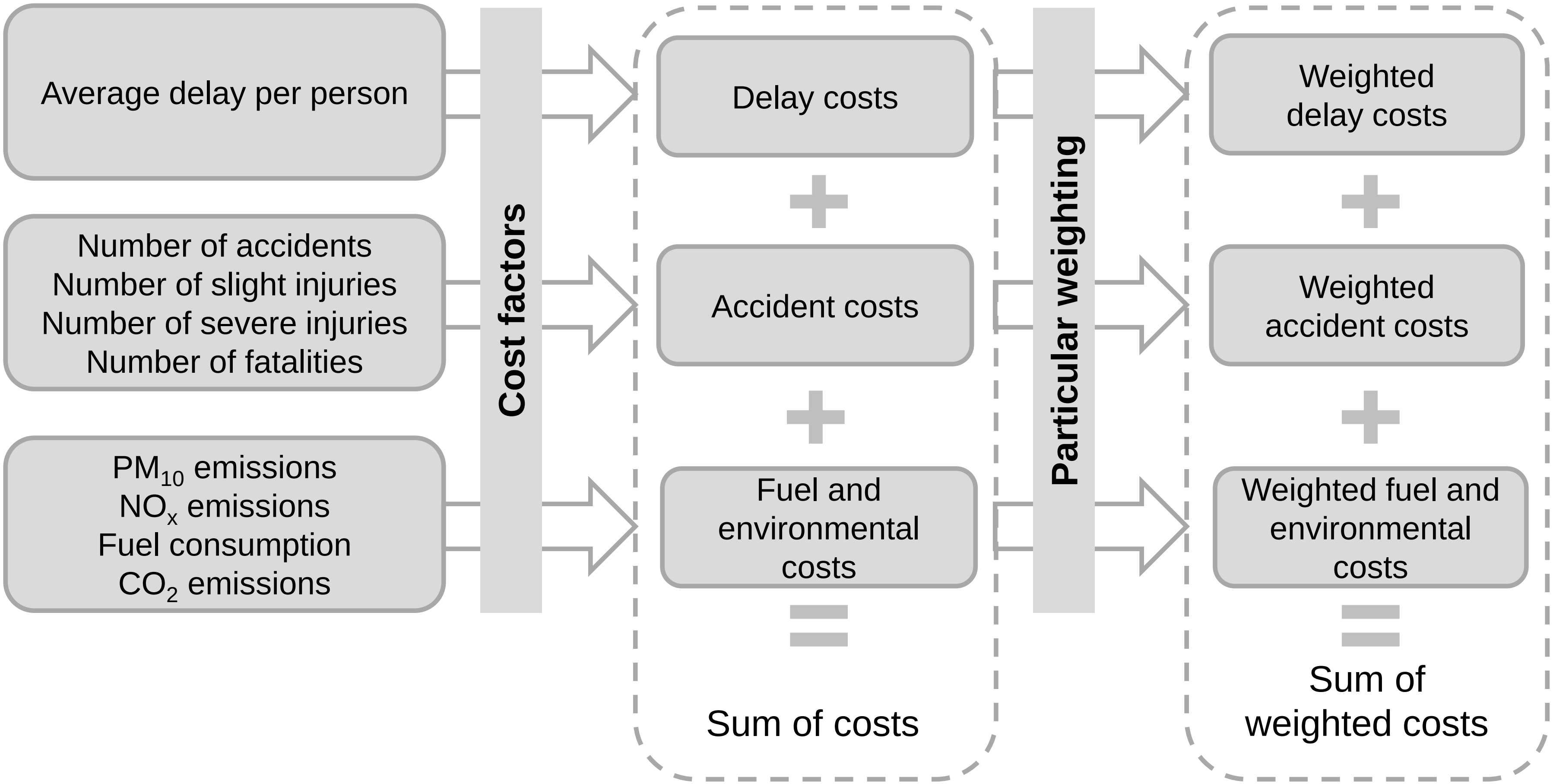


Source: own illustration

Fachgebiet Verkehrsplanung und Verkehrstechnik

Overview – Costs as the Leading Criteria



Assessment Method

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 (see slide 9).

Cost Factors for Accident Risks

The German Federal Highway Research Institute (BASt) annually caluclates 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

Cost Factors for Emissions and Energy Consumption

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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 correponds 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)

Particular Weighting

A particular weight can be applied due to political or planning reasons (permanent or situation-responsive). **A particular weight must always be justified.**

A **particular weight** can be applied on:		**Examples for planning or political reasons:**
Value of time for pedestrians and cyclists	⇨	▪ To promote non motorized traffic ▪ To promote non motorized traffic ▪ Near schools or bus stops etc.
Value of time for public transport passengers	⇨	▪ To promote public transport ▪ To avoid increase in costs due to extra vehicle demand
Value of time for motorized private transport and heavy transport	⇨	▪ To harmonize traffic flow
Accident costs	⇨	▪ To promote traffic safety
Environmental costs	⇨	▪ To strengthen environmental and climate protection ▪ Impending exceedance of threshold values

Introduction to Case Study 1: Pedestrian Crossing

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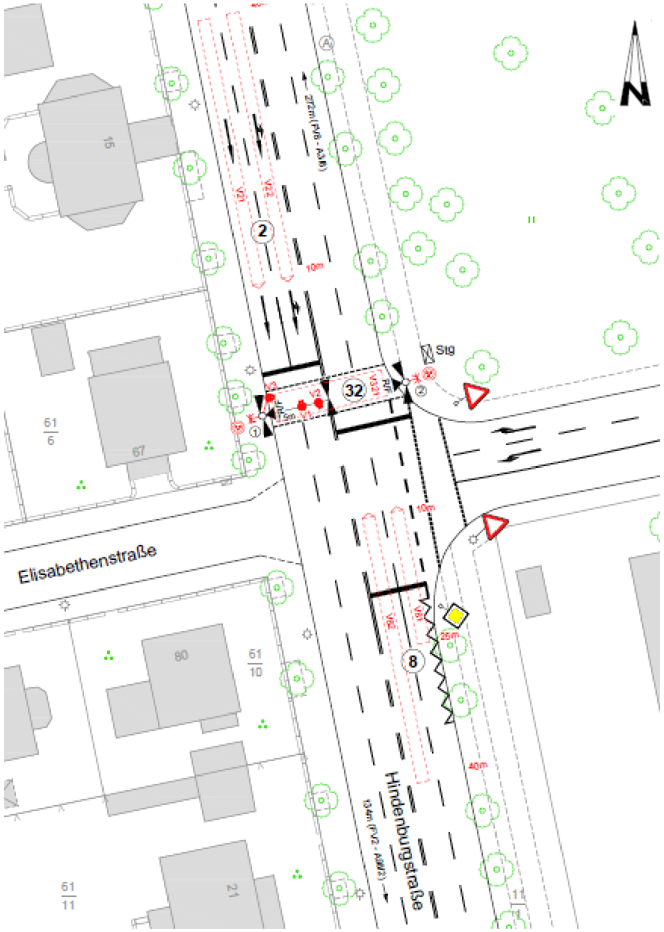

Quelle: Straßenverkehrs- und Tiefbauamt Stadt Darmstadt

- 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 (active/unactive)
  - coordination

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Implementation of the Assessment Method: Pedestrian Crossing (1)

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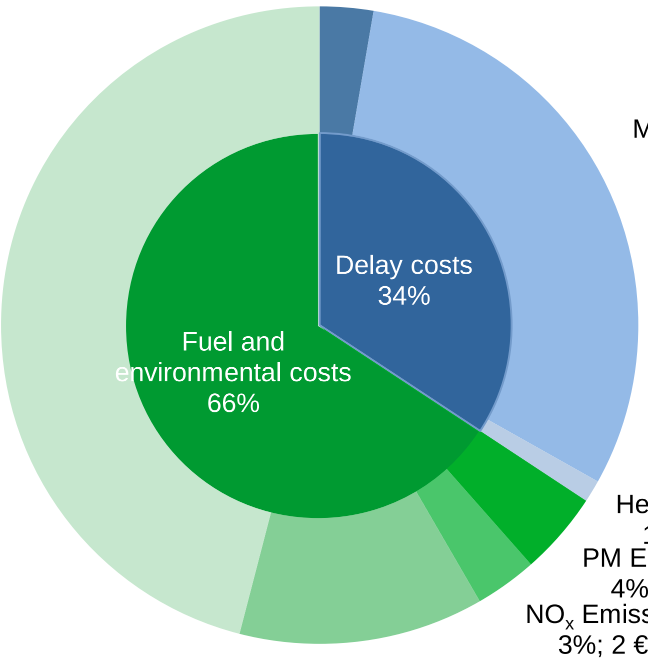
Current traffic signal program

Morning peak hour
Variable cycle time
Active 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: own illustration

FGVV Fachgebiet Verkehrsplanung und Verkehrstechnik

Implementation of the Assessment Method: Pedestrian Crossing (2)

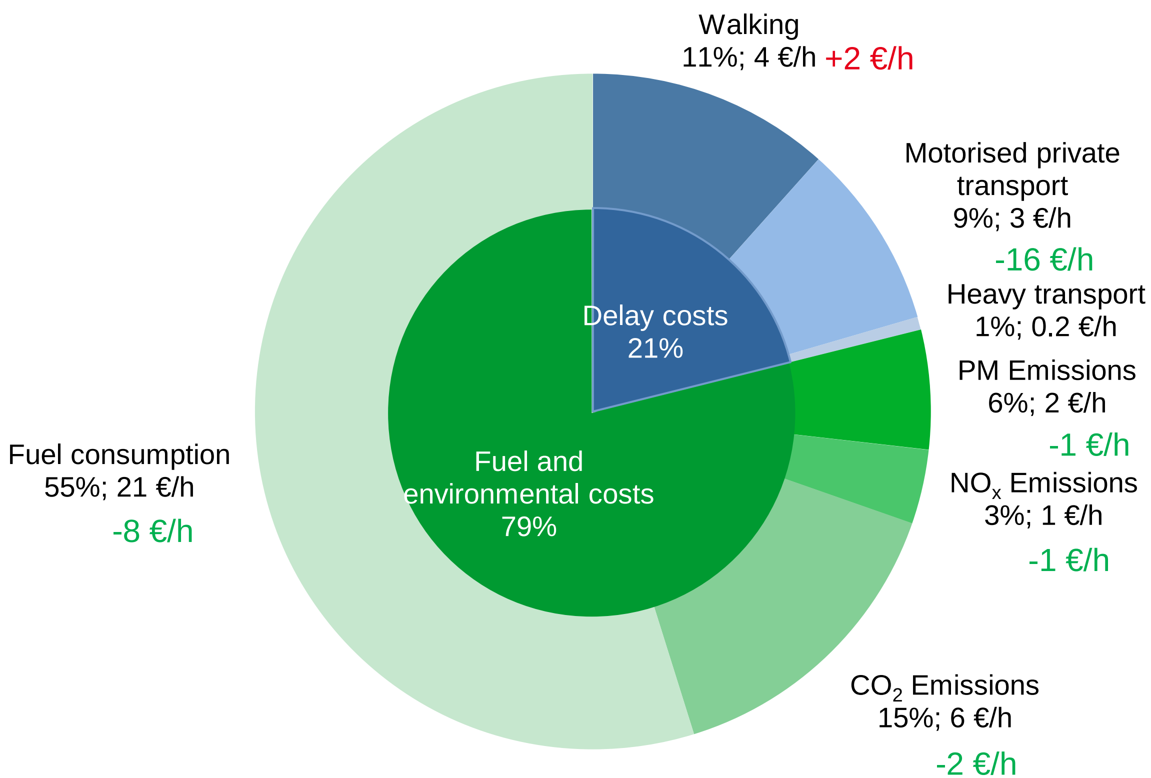
Cost-effective signal program

Morning peak hour
Cycle time 90 s
Unactive 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



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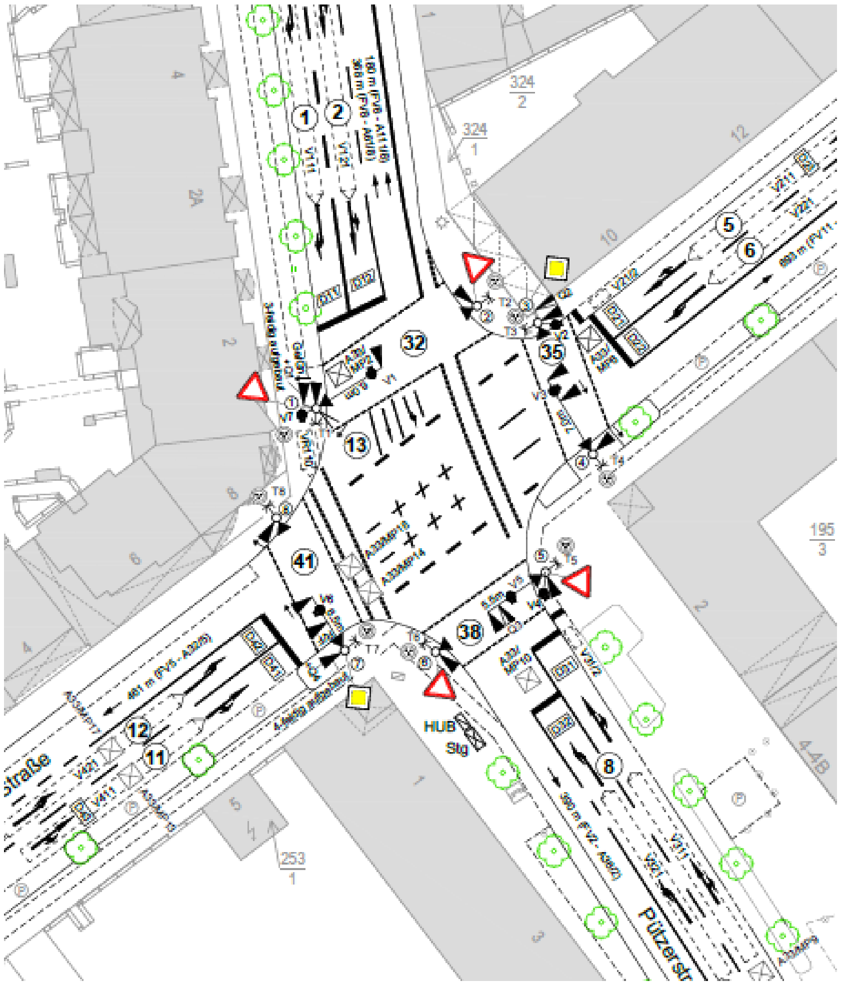
Introduction to Case Study 2: Four-legged Intersection



Source: Straßenverkehrs- und Tiefbauamt Stadt Darmstadt

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

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

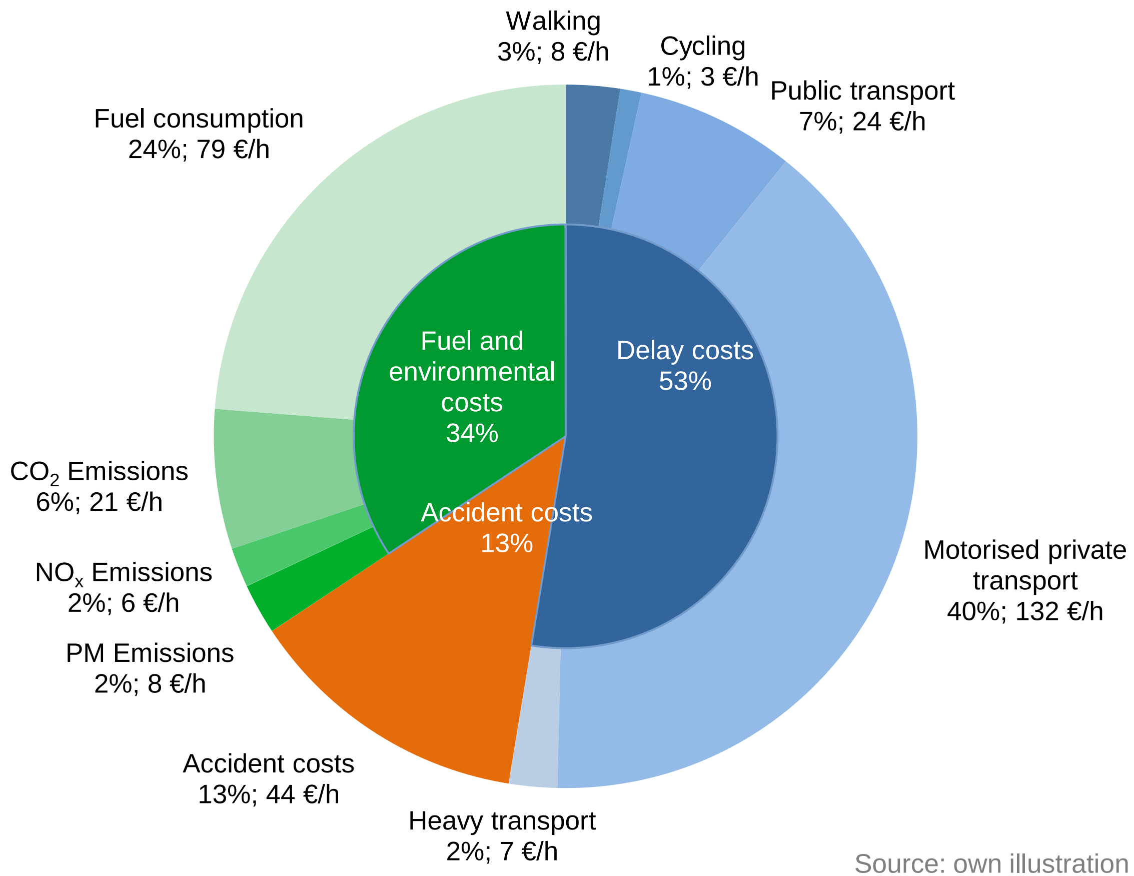
Current traffic signal program

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: own illustration

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

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Alternative signal program

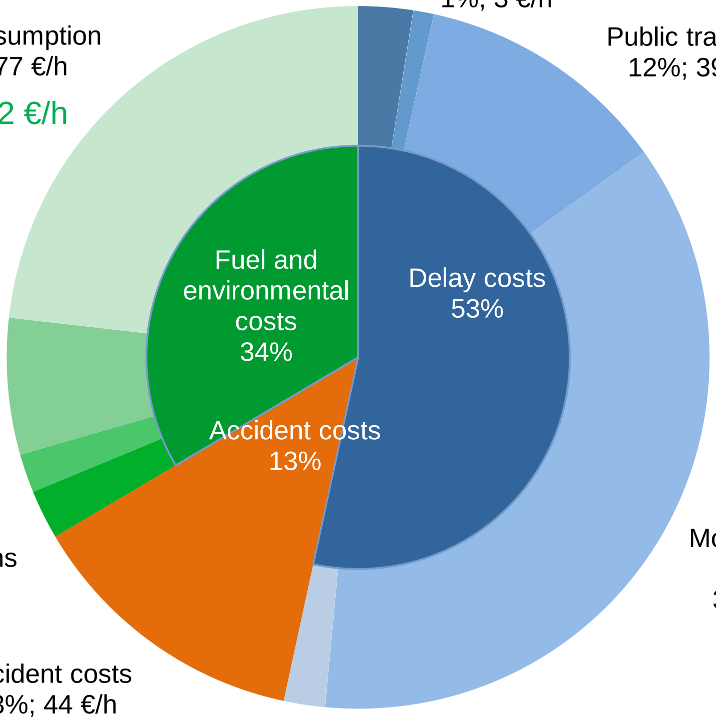
Evening peak hour
No transit signal priority

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: own illustration

Conclusions

- A **detailed assessment is needed** to consider the various impacts of traffic control on different road user groups and to gain a fair balance.
- Today´s **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.
- **Additional research** is necessary to reflect
  - the impacts of traffic signal control on mode choice,
  - the impacts in a network scale,
  - the impacts on public transport operations.
- With adaptations of the cost values, the general approach seems to be **transferable to other countries**.

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