Deutsches Zentrum für Luft- und Raumfahrt

DLR

IVS

Simulation and Evaluation of V2I Technology

for Traffic Light Optimisation Using AIMSUN Microsimulator v6.1.5

or

How to put 1,548,288 numbers into 1 information

KOLINE

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Research Project Overview

Coperative and → V2I & *I2V*

Optimised → Time, fuel, emissions

traffic **L**ight control → progression speed, programme

in urban **NE**tworks → Testbed ringroad Braunschweig

- AIMSUN Micro testbed
- LOS (HBS), Performance Index PI, Cost-Benefit-Analysis

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Simulation Building I

- requested output measures?
- →criteria of evaluation procedures!

Criteria	Measures	Evaluation Procedures			AIMSUN
		HBS	PI	EWS	
Travel Time	s; h			x	✓
Delay Time / Stop Time		x	x		
Number or Percentage of Stops	n; %		x		
Pollutant Emissions (No_x, CO, HC, PA)	g; t			x	
Climate Gas CO_2	g; t			x	
Fuel Consumption	l			x	
Accidents	n			x	*.trj→SSAM
Noise Emissions	db(A)			x	✗
Building / Acquisition Costs	€			x	
Operating + Maintenance Costs	€			x	
Vehicle Occupancy Rate	n; %		x	x	

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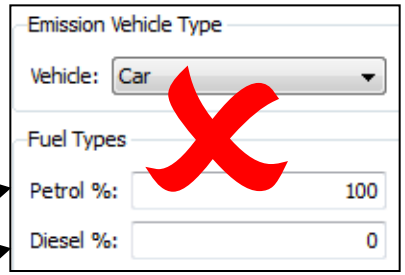
Simulation Building II

- procedure requests?



Vehicle Types	Evaluation Procedures HBS	PI	EWS	AIMSUN
Cars (Petrol)	x	x	x	✓
Cars (Diesel)			x	
Van-like Trucks ≤3.5 t			x	
Lorries >3.5 t			x	
Trailer Trucks			9	
Coaches			x	
Public transit buses	x	x	x	
Pedestrians	x	x	x	Crossings / Legion
Bikes	x	x	x	Crossings / Legion?
Cars (Hybrid, Electro, …?)	Future?			AIMSUN 9?

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Simulation Building III

- evaluated network: approaches of 3 nodes (1..5 lanes)

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Simulation Building IV

- time period 06:00-22:00 (16 h)
- optimisation interval 15 min
- base scenario + optimised scenario (9)
- 16 runs

64

2

16

$$n \geq \frac{t(\alpha,\infty)^2 \cdot s^2}{e^2}$$

7*9*12*64*2*16 = 1,548,288

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Simulation Adaption I

Scenario	Applied Traffic Control	C2X Vehicle Penetration Rate	Tailback Estimation & Forecast	Vehicle Approach Control
Status Quo Base Test 1	Status Quo TRANSYT optimised Signal Program Optimiser	0%	✗	✗
Test 2	Signal Program Optimiser	5%	detectors + vehicle data	✓
Test 3	Signal Program Optimiser	15%		
Test 4	Signal Program Optimiser	25%		
Test 5	Signal Program Optimiser	35%		+lateral control
Test 6	Signal Program Optimiser			
Test 7	TRANSYT optimised			✓
Test 8	Signal Program Optimiser		✗	
	TRANSYT: settings →TRL Link-Software €€€! SPO: API SignalPlan.csv, DetectorCounts.csv	Equipped Vehicles: 25 % <300m Ø	API: TRANSfusion.jar	→Desired speed →Forced lane change

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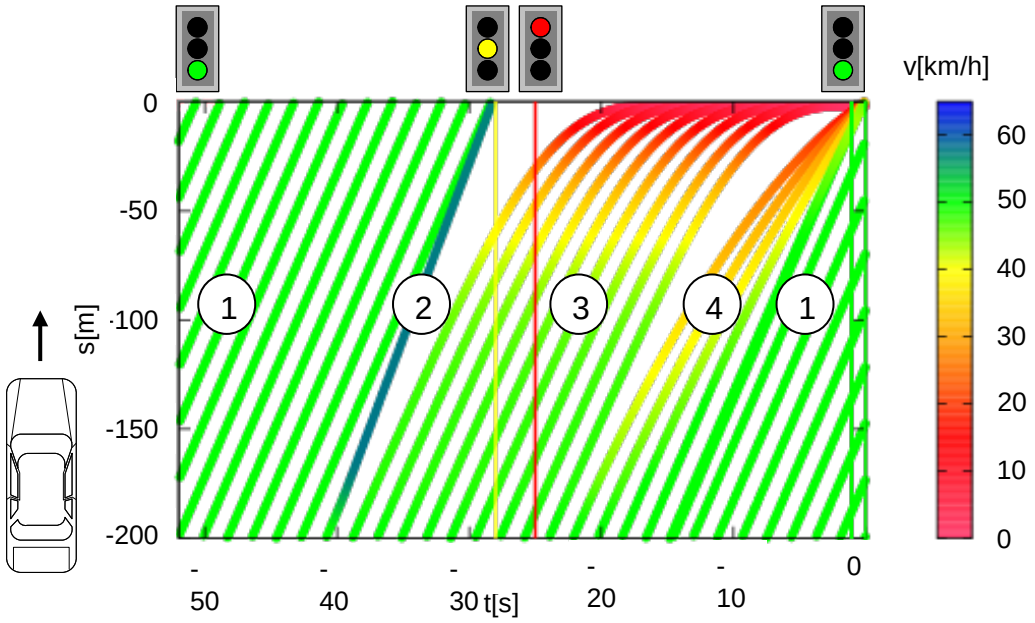
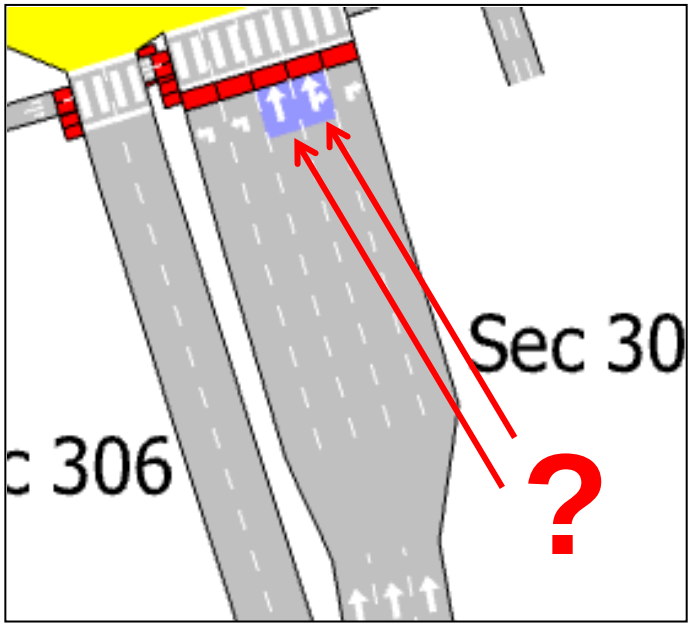
Simulation Adaption II

Longitudinal control



Lateral control



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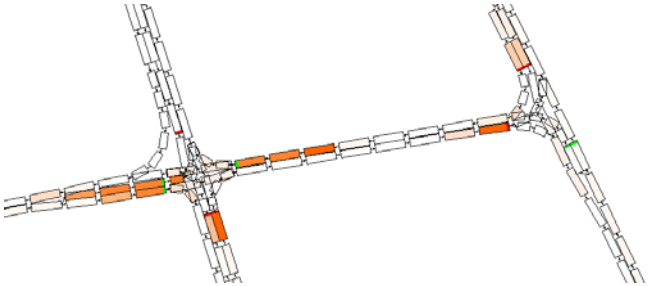
Simulation Adaption III

- Signal Program Optimser (TCA)
  - Traffic Demand estimation (OD-Matrix):
    - minimisation of information (principle of maximum entropy)
  - Traffic Demand Forecast:
    - pattern detection algorithm to find matching historical time series
  - Optimisation by Genetic Algorithm:
    - Cell Transmission Model for evaluating the fitness of every solution (set of signal plans for network)



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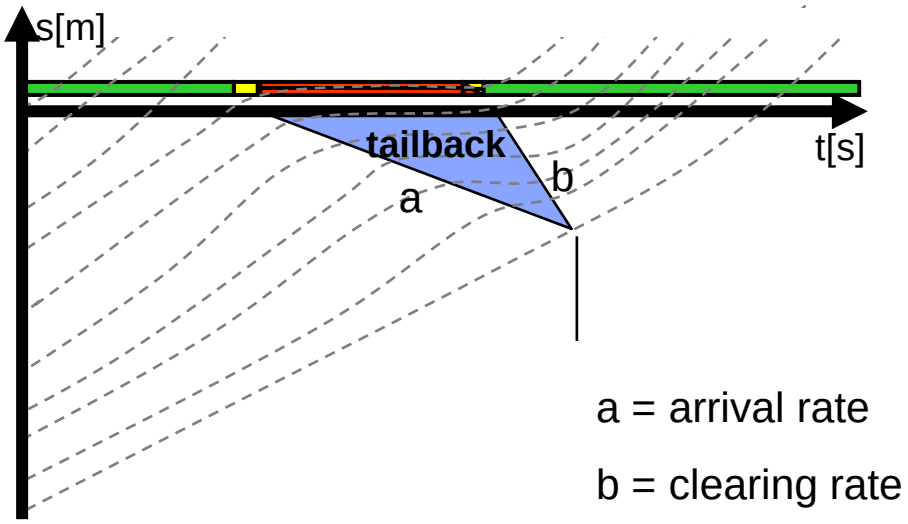
Simulation Adaption IV

- Tailback estimation and forecast (TRANSFUSION)
  - Use of vehicle information (time and position of stop) of equipped vehicles and detector information to estimate length of actual tailback on different approaches



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Simulation Verification I

- MITURN Average (did=111)
  - 25 runs
  - per vehicle vs. per interval

did	oid	flow	stime	qmean	qmax	nstops	travel	traveltime	fuelc
4	342	4	21,75	0,0255555548	1	1	0,21963875	42,490585327	0,0598990135
7	342	4	15,25	0,0084722219	0,5	1	0,21963875	35,498146057	0,0627613813
8	342	4	35	0,0427777767	0,5	1	0,21963875	56,110542297	0,0866677463
19	342	8	67,625	0,0274999999	0,5	1,5	0,4392774999	176,1343689	0,2606220245
25	342	4	33,5	0,0186111107	0,5	1	0,21963875	55,961746216	0,0752185062
111	342	0,96	34,625	0	0,22	0,22	0,0527133	14,647815552	0,010424881
			✓	!	?	✓	✓	✓	0,02074

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Simulation Verification II

- MISECTIEM Average
  - 25 runs

*length [km] (0.145)

did	oid	CO2	NOx	VOC	PM	CO2_Interu	NOx_Interu	VOC_Interu	PM_Interul
1	271	123,13119507	0,6255637407	0,0053395173	0,120514	850,91345215	4,3230361938	0,0368993990	0,8328284621
2	271	117,86347961	0,5700928569	0,0062282532	0,115473	814,51025391	3,9396977425	0,0430411212	0,7979881763
20	271	0	0	0	0	0	0	0	0
21	271	34,750404358	0,1788176745	0,0017248284	0,022038	240,14700317	1,2357418537	0,0119196409	0,1522976607
22	271	0	0	0	0	0	0	0	0
23	271	32,733146667	0,166981712	0,0017589268	0,021357	226,20648193	1,1539479494	0,0121552823	0,1475903839
24	271	51,451839447	0,2574274838	0,0021513158	0,055567	355,56435157	1,7788947821	0,0148623360	0,3840056658
25	271	71,447654724	0,3393732011	0,0023721515	0,08904	493,74789429	2,3452806473	0,0163930487	0,6153[illegible]656
111	271	78,890610733	0,3950420493	0	0,057383	545,183396	2,7299873352	0,0034808692	0,5640867656

*length [km] (0.102)

✓ ✓ ! 0,0816 ✓ ✓ ✓ 0,0235

Aimsun

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Simulation Verification III

- MISECTIEM

MISECTIEM

did	oid	sid	CO2	NOx	VOC	PM	CO2_Interu	NOx_Interu	VOC_Interu	PM_Interurl
1	271	0	18529,460938	41,494659424	18,551902771	2,5612437725	0	0	0	0
1	271	1	12578,583008	5,2282919884	17,905796051	0,4625090063	0	0	0	0
1	271	2	1165,9394531	8,1016101837	0,2585932612	0,1952707320	0	0	0	0
1	271	3	321,98562622	1,6458812952	0,0178201068	0,1365484446	0	0	0	0
1	271	6	3534,4179688	19,368988037	0,159800604	1,6341714859	0	0	0	0
1	271	8	928.53546143	7.1498856544	0.2098931670	0.1327441633	0	0	0	0

?

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Simulation Verification IV

- MISECTPO Average

MIPOLLS

ID	NAME
0	CO
1	NOx
2	PM
3	HC

MISECTPO

did	oid	npollutant_K	vpollutant
1	271	0	0,00073265
2	271	0	0,00060075
25	271	0	0,0005545
111	271	0	0
1	271	1	0,0002872750
2	271	1	0,0002355750
25	271	1	0,000217325
111	271	1	0
1	271	2	1,077500E-05
2	271	2	8,775000E-06
25	271	2	8,025000E-06
111	271	2	0
1	271	3	0,0003340500
2	271	3	0,00027405
25	271	3	0,0002533000
111	271	3	0

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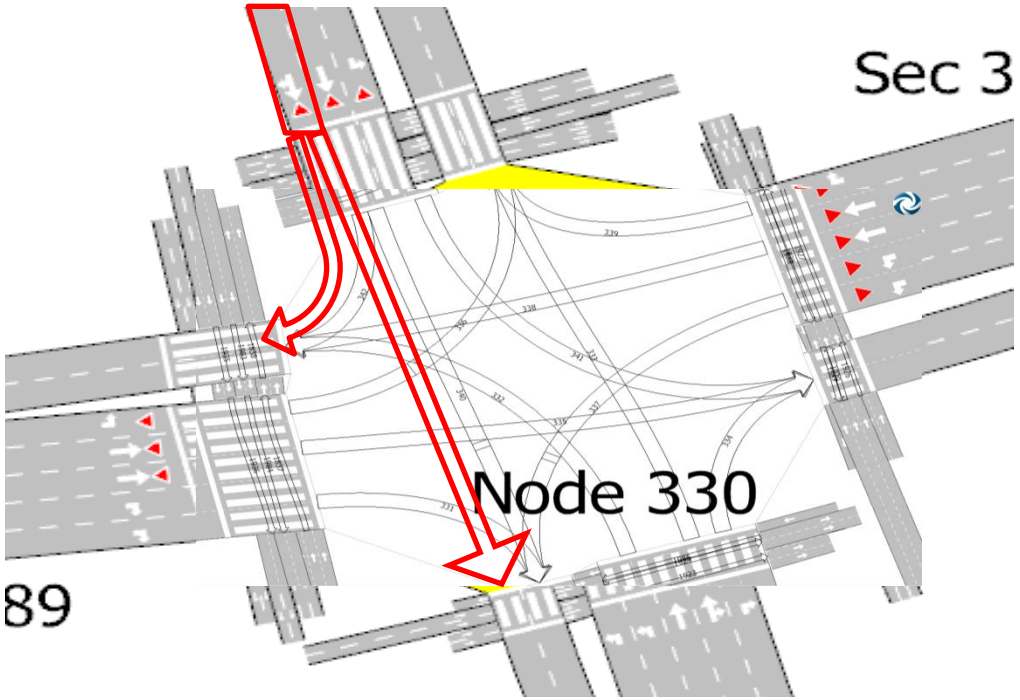
Simulation Verification V

- MITURN



oid	flow	stime	qmean	qmax	nstops	travel	traveltime	fuelc
340	4	36,75	0,0102083329	0,25	1	0,2419229895	59,110084534	0,1160396412
342	0	1	0,0284166658	0,5	0	0	-1? 0	0

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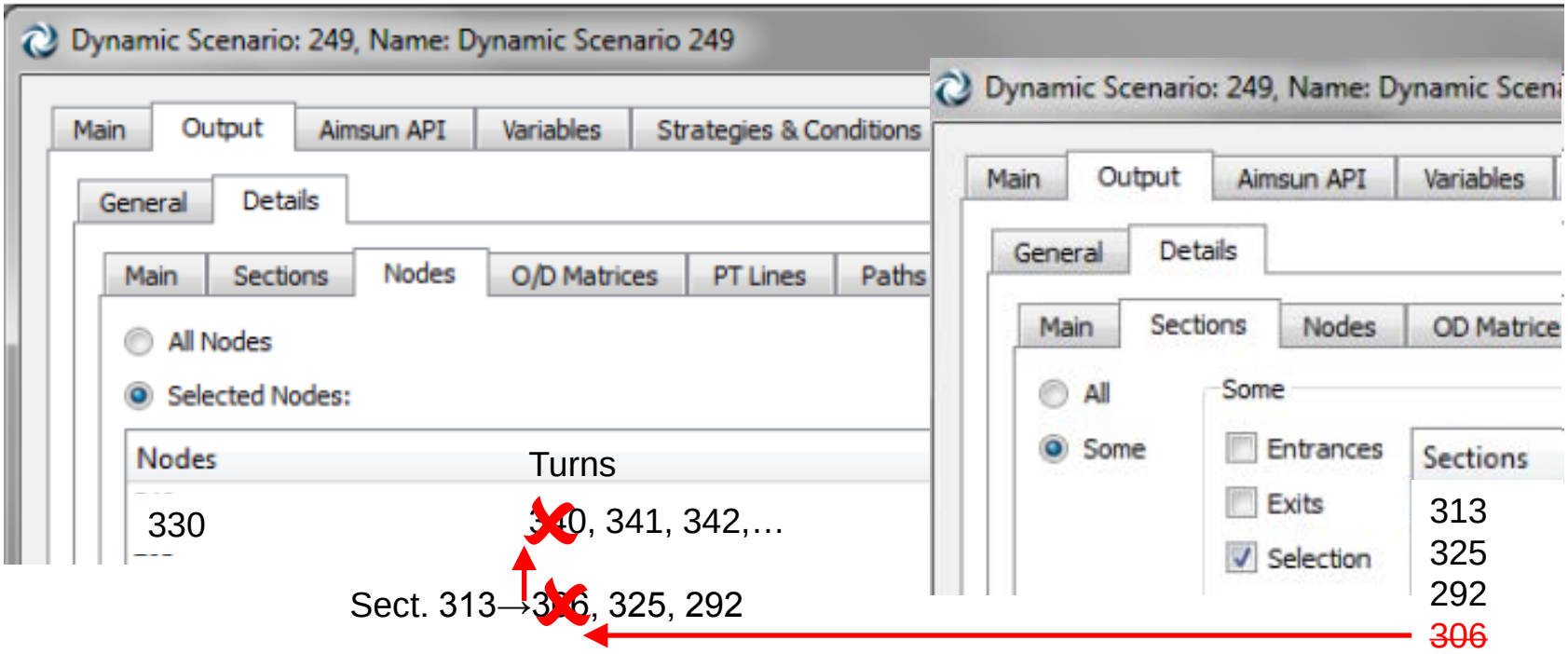
Simulation Verification VI



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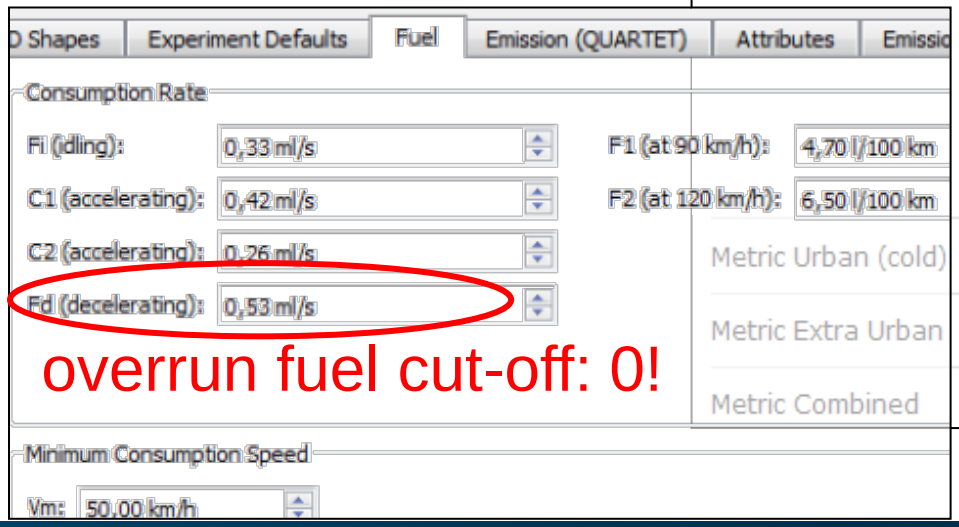
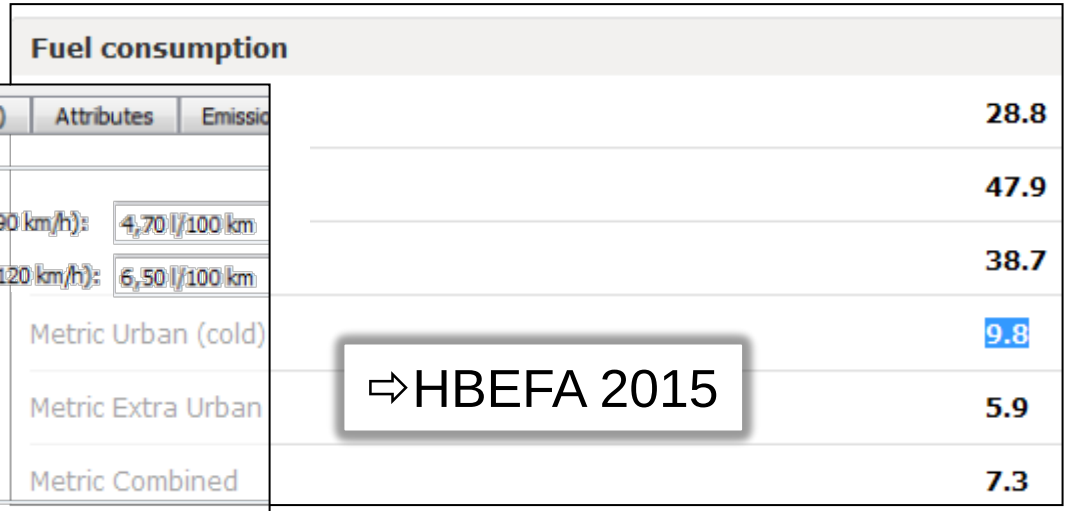
Simulation Validation I

- Fuel (editable)
  - Ferrerira 1982
  - UK DoT 1994
  - UK DfT 2012?





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Simulation Validation II

- MISECT.fuelc vs. MISECTIEM (fix)
  - 6:00-6:15 a.m.
  - 

MISECT

did	oid	flow	travel	fuelc [l]
1	271	12	0,5772505999	0,1905774921
2	271	12	0,577624023	0,2150767446
20	271	0	0	0
21	271	4	0,1924168766	0,0490530692
22	271	0	0	0
23	271	4	0,1924168766	0,0494258292
24	271	4	0,1786209941	0,0442562066
25	271	4	0,1924168766	0,0988239348
111	271	6,4	0,3068678737	0,0771544398

fuelc*2,6 [kg/l]
0,49550148
0,55919953
0
0,12753798
0
0,12850715
0,11506614
0,25694223
0,20060155

≠ !

MISECTIEM

did	oid	CO2 [kg]
1	271	123,13119507
2	271	117,86347961
20	271	0
21	271	34,750404358
22	271	0
23	271	32,733146667
24	271	51,451839447
25	271	71,447654724
111	271	78,890610733

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Simulation Validation III

- MISECTIEM (fix) vs. MISECTPO (editable)

MISECTIEM

did	oid	sid	NOx	VOC	PM
1	271	0	41,494659424	18,551902771	2,5612437725
1	271	1	5,2282919884	17,905796051	0,4625090063
1	271	2	8,1016101837	0,2585932612	0,1952707320
1	271	3	1,6458812952	0,0178201068	0,1365484446
1	271	6	19,368988037	0,159800604	1,6341714859
1	271	8	7,1498856544	0,2098931670	0,1327441633

~~SO_2~~ NOx HC⊂VOC PM

vpollutant	vpollutant	vpollutant
0,0018324500	0,0009403000	2,022500E-05
0,0007098501	0,000122975	0
0,000225125	0,000263375	8,750000E-06
7,085000E-05	3,502500E-05	2,175E-06
0,0005476250	0,0002781750	0
0,000279	0,0002407500	9,300001E-06

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Output Alteration I

- Filter MISECT: 12
- Calculate Average
- Filter DID: 16
- Recalculate sid=0 without 
- Calculate MILANE.stime/nstops
- Insert MISECT.flow/stime/nstops 

$$w = \frac{t_S^{\,2}}{2 \cdot t_U} \qquad (6\text{-}21)$$

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Output Alteration II

- LOS (HBS) @ each unique lane

MILANE

oid	lane	density	qmean	qmax
289	1	15,115735703	0,600044446	
289	2	23,636405487	1,7449999952	
289		32,380941086	2,0980333328	
289	3	17,239036064	0,9317444468	
289		11,350847187	0,6919666767	

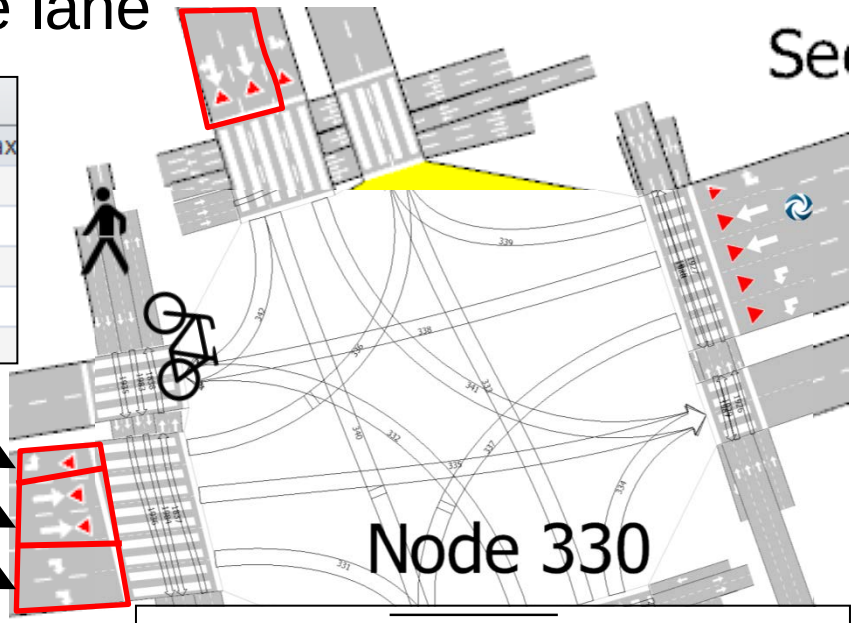
MITURN

oid	flow	stime	qmean	nstops
340	386,56	29,57331	1,30088889	0,9090772
342	62,88	32,58948	1,02485555	1,0591024

MILANE

oid	lane	qmean
313	2	1,5769222307
313	3	2,0497110987

lanefactor	Σflow
56,5%	254
43,5%	196



$$\frac{\overline{stime}_{lane1}}{\overline{stime}_{lane2}} = \frac{\overline{qmean}_{lane1}}{\overline{qmean}_{lane2}} = \frac{flow_{lane2}}{flow_{lane1}}$$

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Evaluation I

- Java-Software (*.jar)
- Config.txt
- Modular: alteration + each procedure

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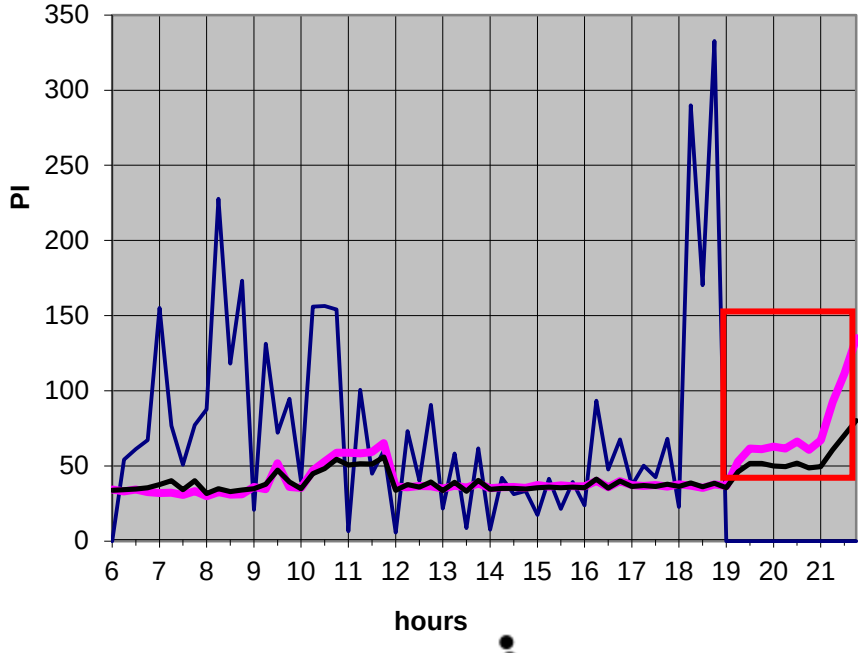
Evaluation II

- PI for Credibility / Plausibility



					Sim-Average			
oid	ent	flow	stime	nstops	flow	stime	qmax	nstops
4067	49	740	8,6	0,7	1004	9	9	0,7
4067	50	681	8,6	0,7	980	8	7	0,7
4067	51	743	8,6	0,7	972	10	10	0,7
4067	52	694	9,0	0,7	888	11	9	0,7
4067	53	596	10,1	0,7	664	41	16	1,2
4067	54	557	25,5	1,0	592	339	31	6,6
4067	55	524	41,8	1,1	384	655	30	8,6
4067	56	575	35,3	1,1	524	525	30	9,0
4067	57	377	42,2	1,1	436	651	32	9,4
4067	58	408	40,8	1,1	428	629	31	8,4
4067	59	396	44,0	1,1	568	687	32	8,7
4067	60	381	37,7	1,0	400	577	31	8,2
4067	61	278	48,7	1,1	172	790	31	8,5
4067	62	240	101,6	1,2	80	1691	31	10,6
4067	63	268	132,5	1,2	148	2255	31	10,1
4067	64	250	170,1	1,3	100	2901	30	12,1

Sim-did=10

  - unsignalized  @ western node

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Evaluation III

- CBA
  - Benefit-Cost-Ratio ≥1!
  - Costs?
  - Benefits:
    - $\Delta Criterion_x$ * €/unit
    - p.a. (365d)!
  - 64 intervals→365d (8,760h)
    - upscaling of hour periods t
    - flow similarity

Period t	T [h/a]	d/a	Factor k
1	30		0,0971
2	40		0,0927
3	130		0,0893
4	500		0,0826
5	4124		0,0343
	4824	201	
6	30		0,0941
7	40		0,0904
8	130		0,0846
9	500		0,0669
10	1724		0,0291
	2424	101	
11	30		0,1068
12	40		0,092
13	130		0,084
14	500		0,06
15	812		0,0187
	1512	63	

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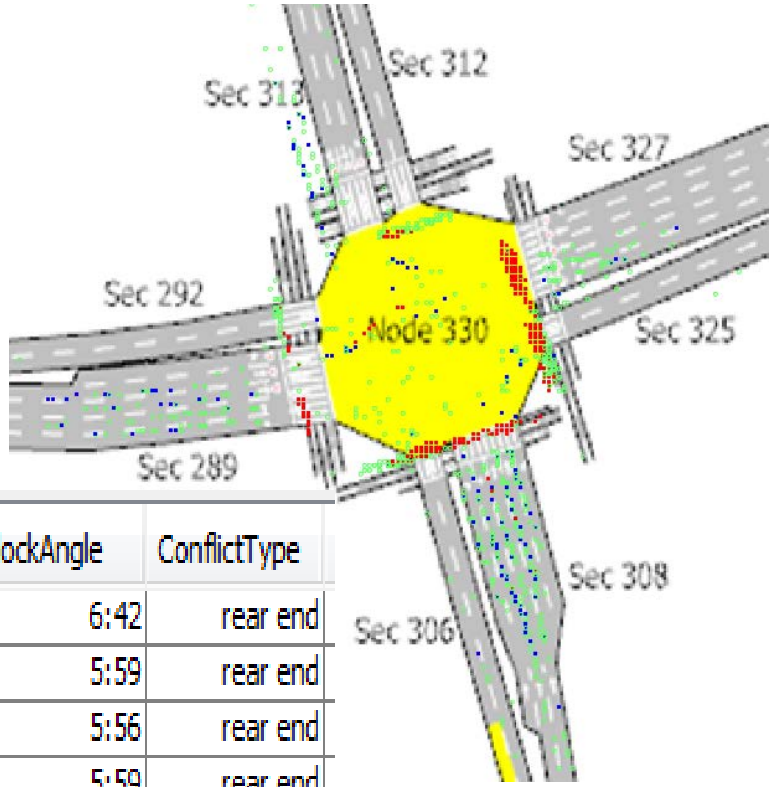
Evaluation IV

- Accidents
  - Conflicts by SSAM
  - FHWA-/Siemens-Freeware
  - $$\frac{Crashes}{Year} = 0.119 \times \left(\frac{Conflicts}{Hour} \right)^{1.419}$$



DeltaS	DR	MaxD	MaxDeltaV	ConflictAngle	ClockAngle	ConflictType
7,17	-56,94	-56,94	3,83	-21,02	6:42	rear end
8,78	-36,28	-36,28	4,44	0,00	5:59	rear end
3,09	-31,20	-31,20	2,35	1,98	5:56	rear end
3,97	-28,97	-28,97	2,06	0,34	5:59	rear end

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Evaluation V

- Noise
  - Emission modell (HarmoNoise, SonRoad) ✗
  - Transmission modell ✗
  - Immission ✗

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Contact

German Aerospace Center (DLR)

Institute of Transportation Systems, Department of Traffic Management

Dipl.-Ing. Wolfgang Niebel

Rutherfordstr. 2, 12489 Berlin, Germany

www.dlr.de/ts

dlr-ts-vm@dlr.de

Technische Universität Braunschweig

Institute of Transportation and Urban Engineering

Dipl.-Ing. Oliver Bley, Dipl.-Ing. Ralf Kutzner

Rebenring 31, 38106 Braunschweig, Germany