A Public Transport Performance Measurement System for Switzerland and its Calibration

U. Weidmann , H. Orth, N. Carrasco, M. Schwertner

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Background

- ongoing effort to develop a consistent multimodal level of service (LOS) system in Switzerland,
- goal to develop LOS system for public transport
- preceding work and foundation published in TRR in 2012[1]
  - selection of indicators
  - evaluation framework

Indicators

Temporal measures

on time performance:

- reliability
- identify hot-spots of destabilizing effects
- **measure**: % of runs on time at stop
- on time margin at -30/+180 seconds

headway adherence

- reliability
- identify hot-spots of destabilizing effects
- evaluate operational stability
- **measure**: coefficient of variation of headways

speeds

- transit competitiveness, operation cost
- **measure**: transit speed relative to automobile speed

Spatial measure

passenger loads

- comfort
- obstructions at boarding/alighting
- **measure**: passenger density or load factor
- taken at vehicle arrival at stop

On time performance

- important for large headway services
- measure of reliability
- connections

- What levels are needed for a high quality service?
- What levels are achievable?

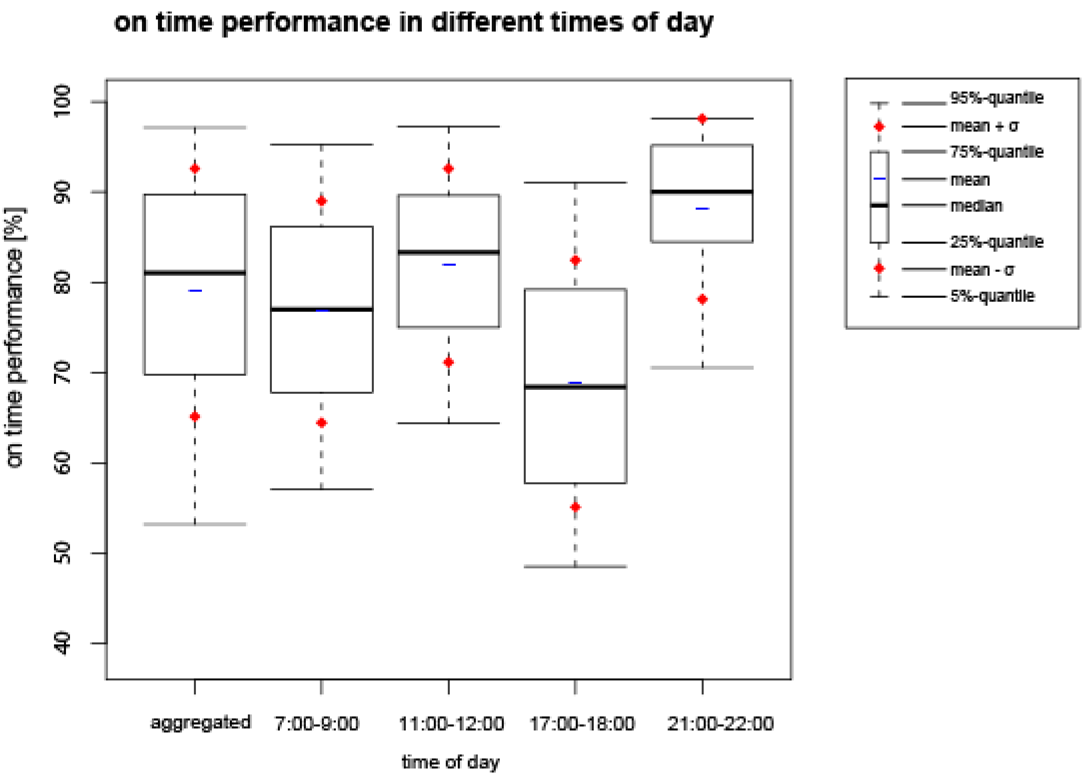
On time performance

City of Zurich data from 2010

- On time threshold of 180 seconds
- analysis of 10 lines, with data from every single run

Generally:

- high levels are quite possible
- peak dips are significant



on time performance

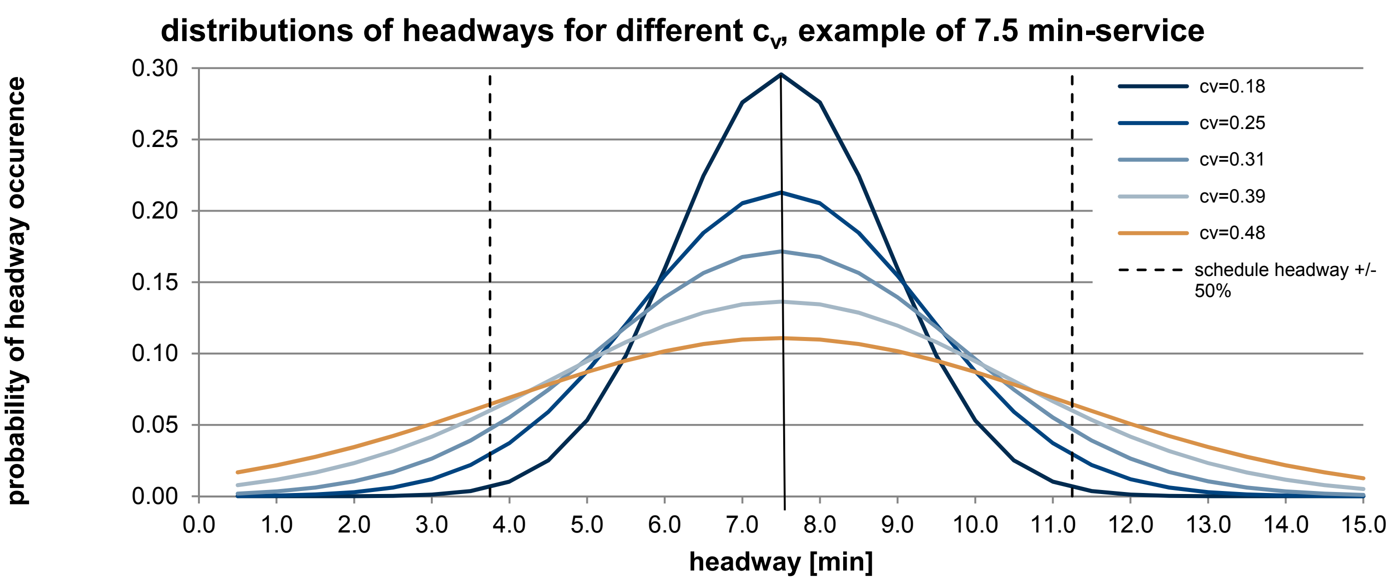
- Scale chosen based on needed/achievable levels of on time performance
- very high performance is possible and can be demanded for

LOS	% on time	Description of Service Level
A	≥ 95%	Almost all departures on time, commuters encounter delay less than once every two weeks
B	< 95%, ≥ 90%	Some delayed departures, commuters encounter delay no more than once a week
C	< 90%, ≥ 85%	Commuters encounter dely 1-2 times a week
D	< 85%, ≥ 80%	Frequent delays
E	< 80%, ≥ 75%	Very frequent delays, with commuters encoutering delays regularily
F	< 75%	Very frequent delays, at least every second day a commuter is delayed

A departure is considered on time, of it occurs no more than 180 seconds after and no more than 30 seconds before the scheduled time.
The assumption for the descriptions is that a commuter makes 10 trips per week

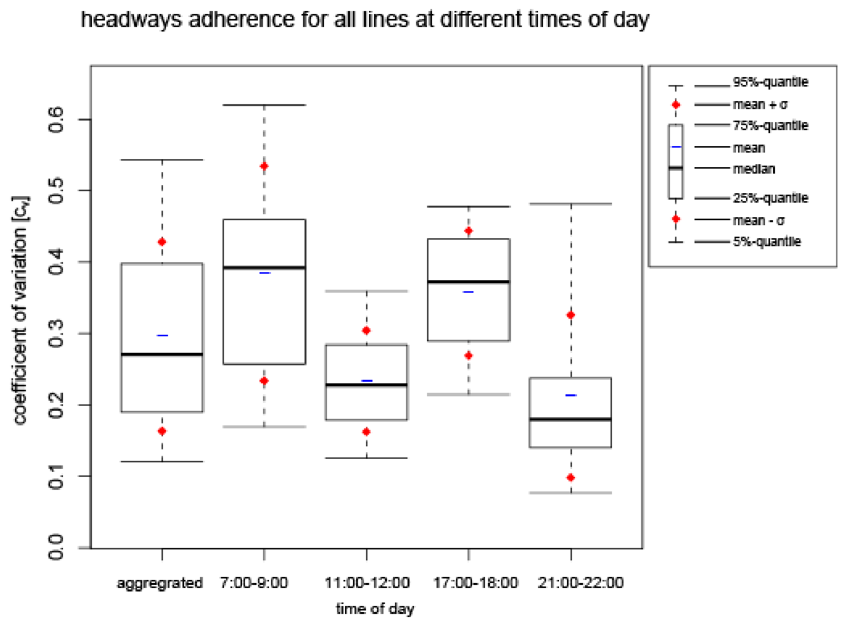
headway adherence

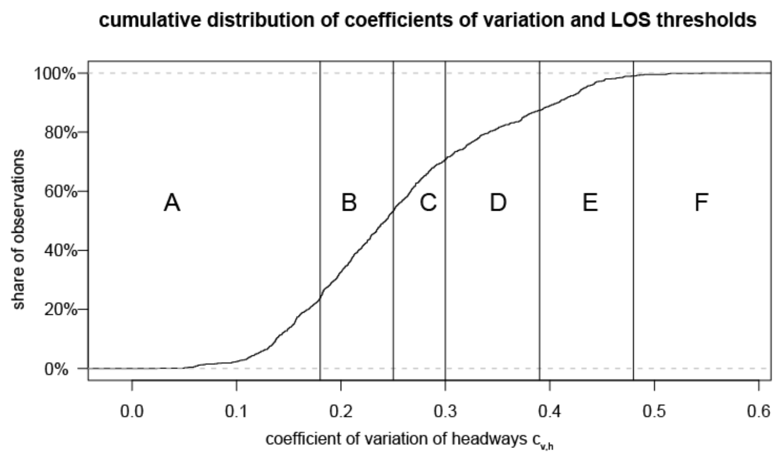
- important at short headways
- evaluation concept: what is the probability of a passenger having to wait more than the expected wait time and some buffer?
  - measurement using coefficient of variation c_v (analog to TCQSM/HCM[2,3])



headway adherence

- relatively low levels of variation, however increase during morning and evening peak times
- overall average of 0.27





headway adherence

LOS	Coefficient of variationt c_v,	Description of Service Level A: deviation from schedule head by more than 50% B: a passenger has to wait more than half the schedule headway + 50%	
		p(A)	**p(B)**
A	$c_v \leq 0.18$	p(A) ≤ 0.005	p(A) ≤ 0.004
B	$0.18 < c_v \leq 0.25$	0.005 < p(A) ≤ 0.05	0.004 < p(A) ≤ 0.034
C	$0.25 < c_v \leq 0.30$	0.05 < p(A) ≤ 0.10	0.034 < p(A) ≤ 0.08
D	$0.30 < c_v, \leq 0.39$	0.10 < p(A) ≤ 0.20	0.08 < p(A) ≤ 0.15
E	$0.39 < c_v, \leq 0.48$	0.20 < p(A) ≤ 0.30	0.15 < p(A) ≤ 0.22
F	$c_v < 0.48$	p(A)≤ 0.30	p(A)≤ 0.22

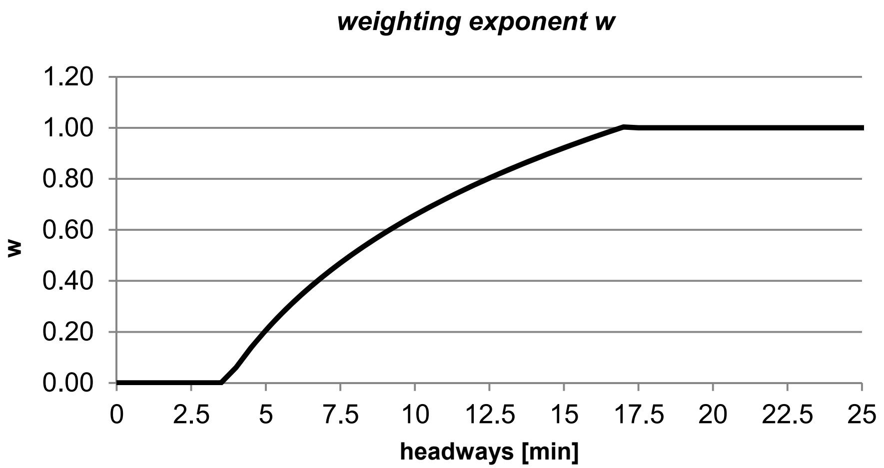
weighting between on time performance and headway adherence

- both are measures for reliability
- passenger arrival[4-7]:
  - at large headways for specific departures
  - at small headways rather randomly
- weighting by headways
  - analysis of passenger arrival
  - well approximated by logarithmic function (Weidmann, Lüthi, Nash 2006)

$$LOS_{reliability} = VQS_{headw.\,adh.}^{1-w} \cdot VQS_{on\ time.}^{w}$$

$$w\ (t_K) = \begin{cases} 0 & t_K < t_{K,min} \\ 0.65151 \cdot \ln(t_K) - 0.84259 & t_K \in [t_{K,min}, t_{K,max}] \\ 1 & t_K > t_{K,max} \end{cases}$$

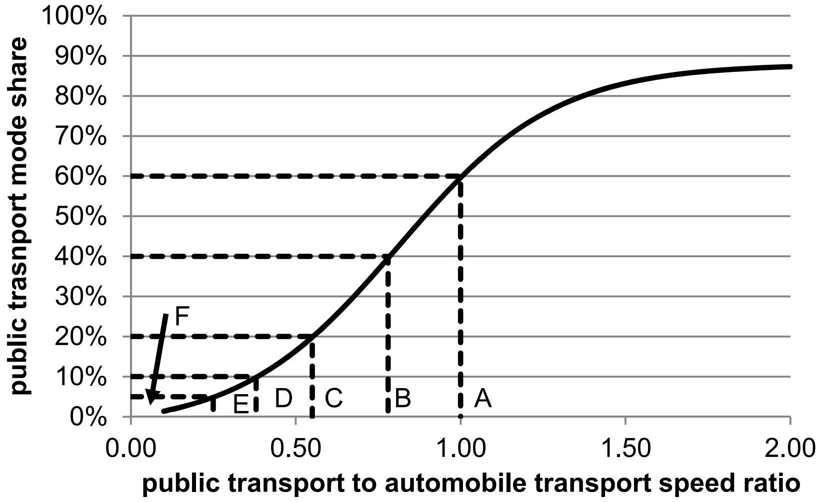
$$t_{K,min} = 4\ min \qquad t_{K,max} = 17\ min$$



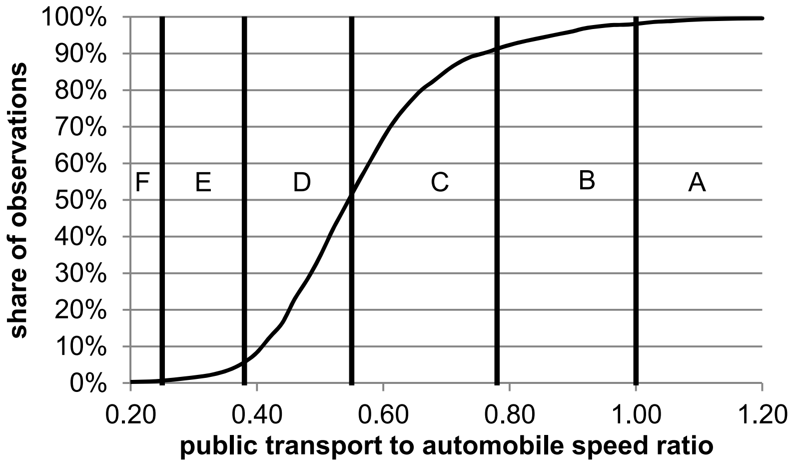
Speeds

- measure of competitiveness with automobile transport
- LOS based on expectable public transport mode share[11]
  - LOS A: 1.0 or better
  - LOS F: less than 5% PT mode share

Speed ratio and mode share



speed ratio distribution measured



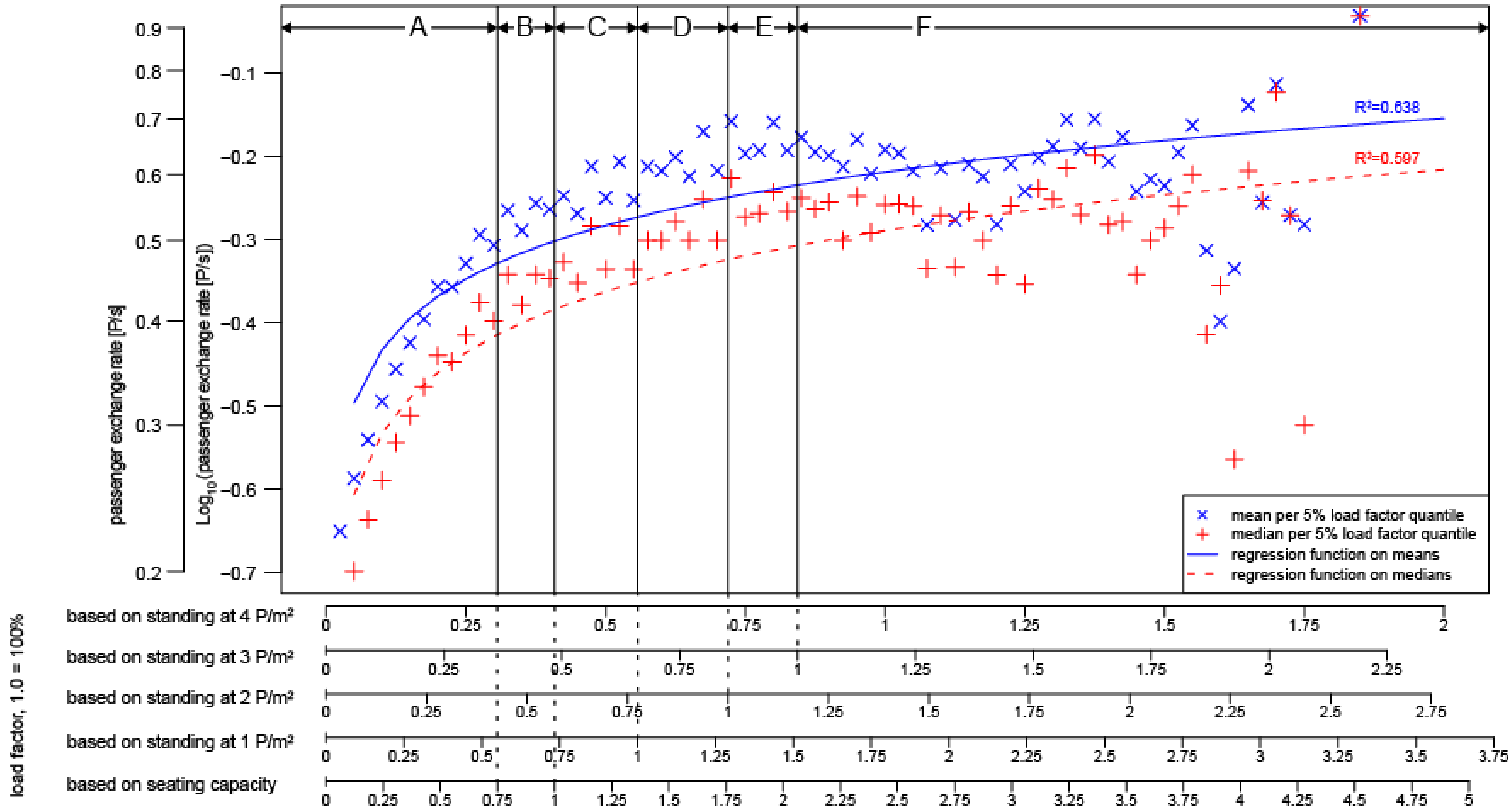
Speeds

LOS	Public Transport to Automobile Speed Ratio *r*	Description
A	v ≥ 1.00	Public transport as fast or faster than automobile travel
B	0.78 ≤ v < 1.00	Speed ratio at which a 40% public transport mode share can be expected
C	0.55 ≤ v < 0.78	Speed ratio at which a 20% public transport mode share can be expected
D	0.38 ≤ v < 0.55	Speed ratio at which a 10% public transport mode share can be expected
E	0.25 ≤ v < 0.38	Speed ratio at which a 5% public transport mode share can be expected
F	v < 0.25	Speed ratio at mode share is less than 5%

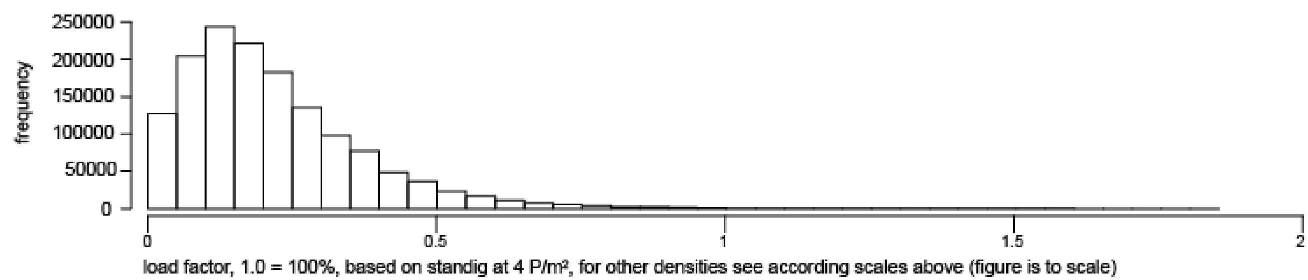
passengers loads

- comfort but also passenger flow and boarding/alighting times
  - LOS F: overloading and collapse of passenger exchange rates
  - LOS A: comfortably seated

passenger exchange rate over load factor and level of service thresholds for passenger density



histogram of observed load factors



passenger loads

Passenger Density d	Load* [P/m²]	LOS	Score	Description of Service Level
d < 0.75 P/seat	0.311	A	1.000	Comfortable seating, no neighbor for least 1/3 of passengers
0.75 ≤ d < 1 P/seat	0.409	B	0.833	Available seat for every passenger wishing to sit
1 P/seat ≤ d < 1 P/m²	0.557	C	0.667	Comfortable standing with plenty of space
1 P/m² ≤ d < 2 P/m²	0.719	D	0.500	Noticeable crowding, passengers begin to stand in corridors
2 P/m² ≤ d < 3 P/m²	0.844	E	0.333	Dense crowding, door areas filled, no open space in corridors
d ≥ 3P/m²	0.844	F	0.167	Excessive crowding, door areas overcrowded, passenger flow seriously inhibited, dwell times greatly extended

* Equivalent load factor based on full load at 4P/m², vehicles with relative capacity of 5.9 Passengers/m

LOS framework: multiple element evaluation

- LOS converted into scores for calculation, scores reconverted into letter LOS
- overall quality at single element

$$LOS_{temp} = LOS_{reliability} \cdot LOS_{speed}$$

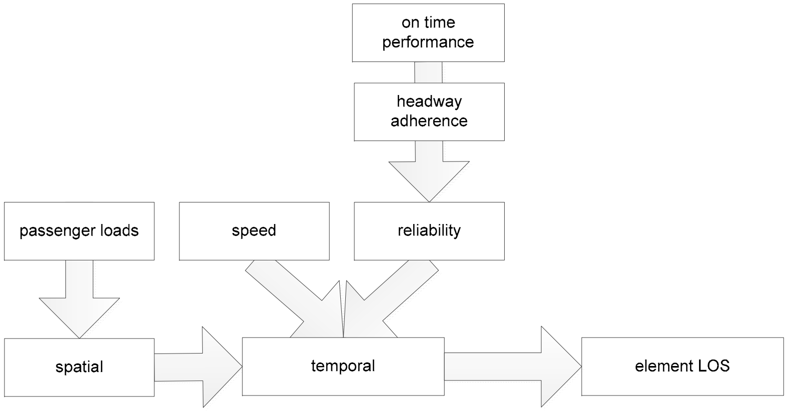
$$LOS_{spatial} = LOS_{passenger\ load}$$

$$LOS_{element} = \frac{LOS_{temp} + LOS_{spatial}}{2}$$

- For sets of multiple elements average
- thus highly flexible and scalable

Conversion from LOS to LOS score and back

LOS	LOS ➔ LOS score	LOS score ➔ LOS	
		≤	>
A	1.000	-	0.833
B	0.833	0.833	0.667
C	0.667	0.667	0.500
D	0.500	0.500	0.333
E	0.333	0.333	0.167
F	0.167	0.167	-



application example

(a) Example calculation of element LOS: Line 31, Bahnhof Altstetten, eastbound, 11.00-12.00

Indicator	**% on-time**	**$c_{v,h}$**	**Speed ratio**	**Load**
Observed value	88.13	0.21	0.64	0.20
LOS grade	C	B	C	A
LOS score	0.667	0.833	0.667	1.0
Service headway h	7.5 min			
Weighting factor w (Eq.2)	0.47			
Indicator LOS	Score $LOS_{reliability}$ (Eq. 2)		Score LOS_{speed}	Score $LOS_{spatial}$
	0.750		0.667	1.0
Dimension LOS	Score $LOS_{temporal}$ (Eq. 4)			
	0.500			
Score $LOS_{element}$ (Eq. 6)	0.750			
Total element LOS grade	B			

(b) Example calculation of trip LOS for two example trips.

Trip 1: From Bahnhof Altstetten to Hardplatz on line 31, between 17.00 and 18.00				Trip 2: From Limmatplatz to Kunsthaus on lines 13 and 31, between 11.00 and 12.00			
Stop	**Line**	**LOS score**	**LOS grade**	**Stop**	**Line**	**LOS score**	**LOS grade**
Bahnhof Altstetten	31	0.667	B	Kunsthaus	31	0.725	B
Luggwegstrasse	31	0.667	B	Neumarkt	31	0.663	C
Letzipark	31	0.542	C	Central	31	0.635	C
SBB-Werkstätte	31	0.554	C	Bahnhofplatz/HB (Transfer to line 13)			
Herdernstrasse	31	0.434	D	Bahnhofquai/HB	13	0.680	B
Arrival (Hardplatz)				Sihlquai/HB	13	0.680	B
				Museum für Gestaltung	13	0.694	C
				Arrival (Limmatplatz)			
Entire Trip 1		Avg. Score	LOS	Entire Trip 2		Avg. Score	LOS
		0.573	C			0.671	B

(c) Example calculation of sub-network LOS for lines 13 and 31 during midday and evening peak hour.

Time Period	Avg. Score of all elements	Sub-network LOS for time periods
11.00 – 12.00	0.691	B
17.00 – 18.00	0.549	C

Outlook

- Standards system now under evaluation
- work to be completed this year
- step towards multimodally consistent transport performance evaluation system

References

1. Orth, H., U. Weidmann, R. Dorbritz (2012) *Development of a Public Transport Performance Measurement System* Transportation Research Record: Journal of the Transportation Research Board, No. 2274, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 135–143
2. Transportation Research Board (2000) Highway Capacity Manual 2000, Washington, D.C.
3. Transportation Research Board (2003) Transit Capacity and Quality of Service Manual, Washington, D.C.
4. O'Flaherty, C. A. and D. O. Mangan. Bus Passenger Waiting Times in Greater Manchester. *Traffic Engineering and Control*, Vol. 11, No. 9, 1970, pp. 419-421
5. Weidmann, U., M. Lüthi and A. Nash. Passenger Arrival Rates at Public Transit Stations, presented at the 86th Annual Meeting of the Transportation Research Board, Washington, D.C., 2007.
6. Csikos, D. and C. Graham. Investigating Consistency of Transit Passenger Arrivals. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2042, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp.12-19
7. Fan, W and R. Machemehl. Do Transit Users Just Wait for Buses of Wait with Strategies? In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2111, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp.169-176
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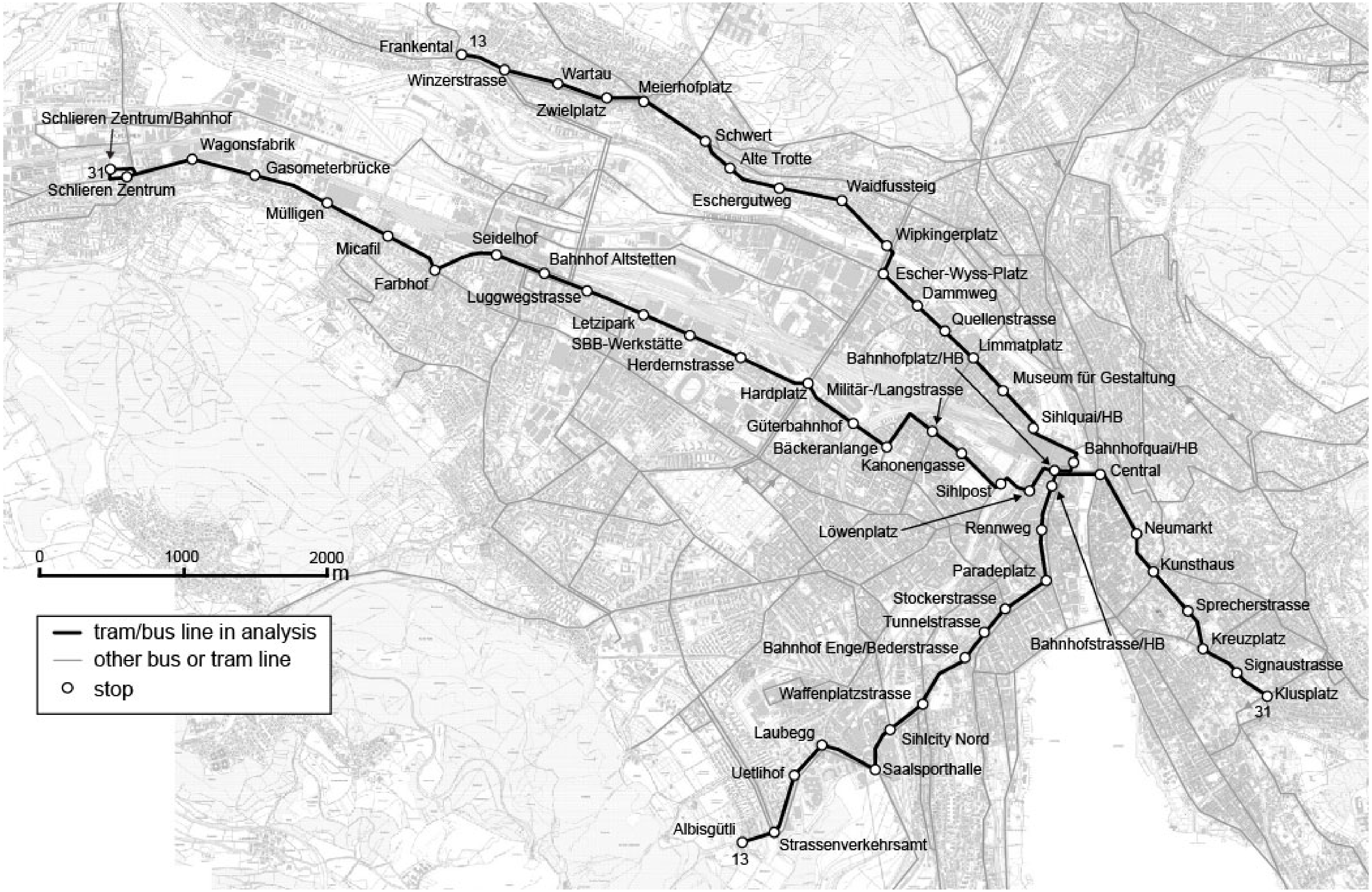
Extrafolien

Overview lines 13 and 31



Selection of indicators

- redundancies: some influences impact others
- not all with large impact on operational quality

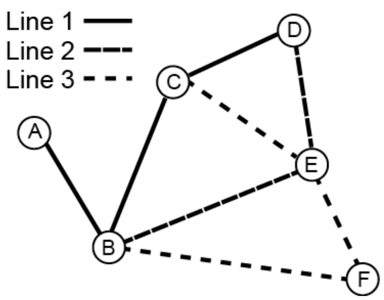
Selection of four main indicators

- measurement at single element allows for scaling across network levels

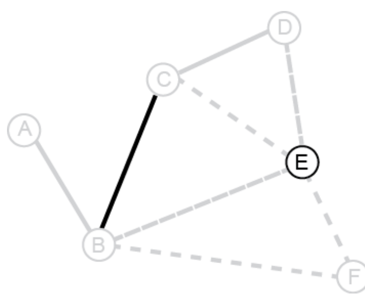
Influence	Indicator	Measurement	Network level: Single element	Network level: Route or route segment	Network level: network
Time					
Speed	Travel speed	[km/h] .	**x**	x	x
Speed	Acceleration and braking	[m/s^2]	x	x	
Frequency (service)	Temporal spacing between vehicles	[min]	x	x	x
Vehicle spacing (operationally)	Minimal buffer time between vehicles	[s]	x	x	
Space					
Available or designated space	Space within vehicle	Seats [1] or standing room [m^2]	x	x	x
Available or designated space	Share of dedicated right of ways	[%]		x	x
Available or designated space	Type of road	Qualitative	x	x	
Available or designated space	Type of transit stop	Qualitative	x		
Obstructions					
Passenger density	Density within vehicle	standing passengers [P/m^2]	**x**	x	x
Reliability					
Reliability	On time performance	[%] runs on time	**x**	x	x
Reliability	Headway adherence	[-] coefficient of variation of headways	**x**	x	x
Availability					
Availability	Service duration	[h/d]	x	x	x

Conceptual evaluation example

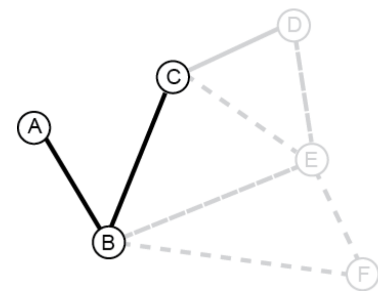
public transport network with 3 lines and 6 stops



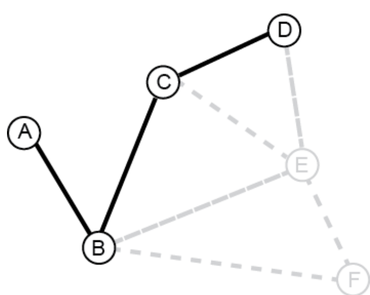
evaluation of segment B-C on line 1 or stop E



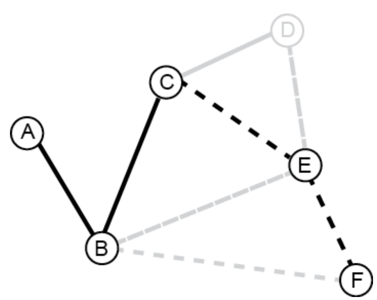
evaluation of segment A-B-C on line 1



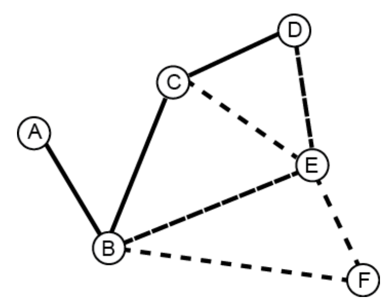
evaluation of line 1



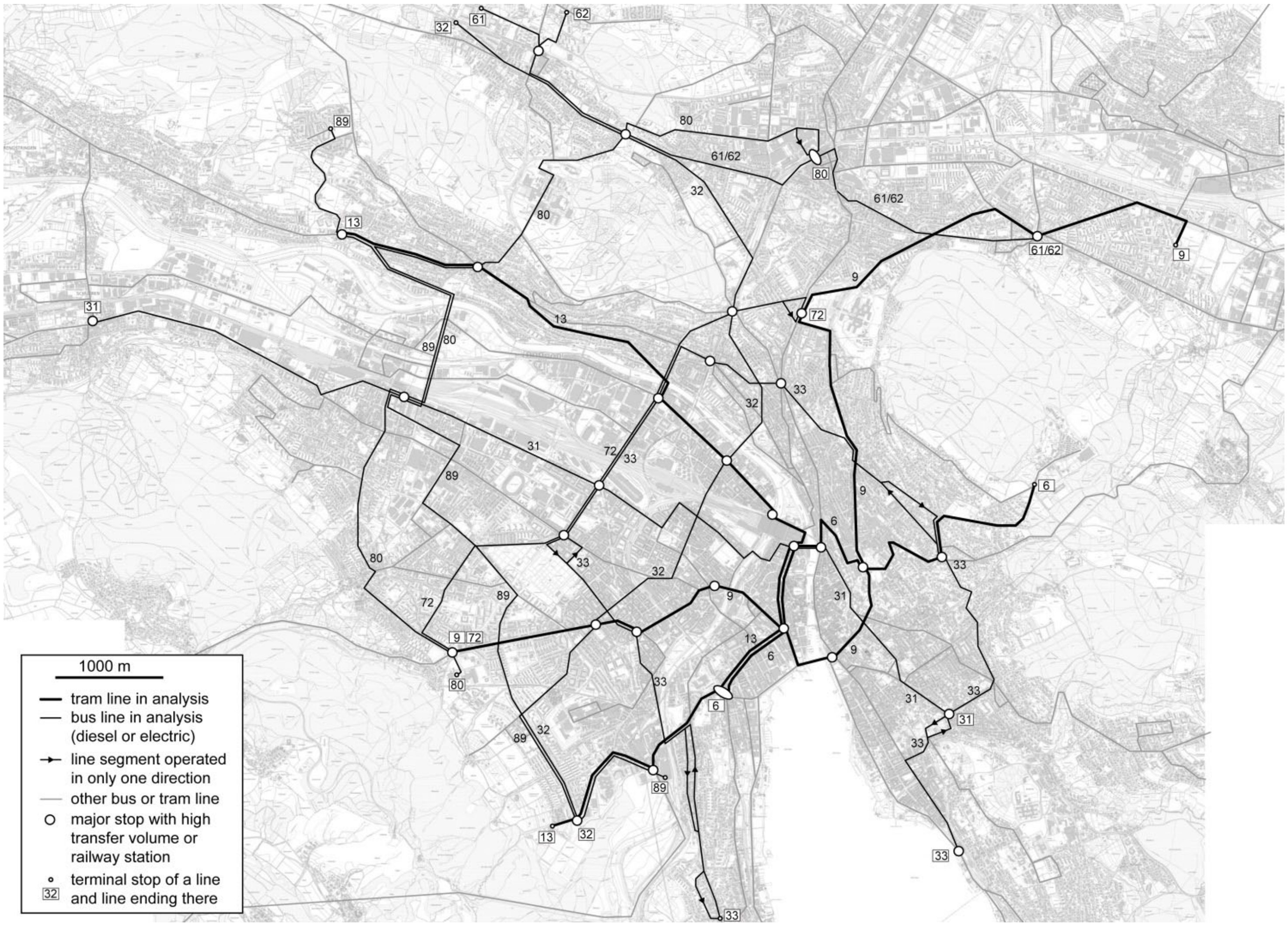
evaluation of a trip from A to F with a transfer at C



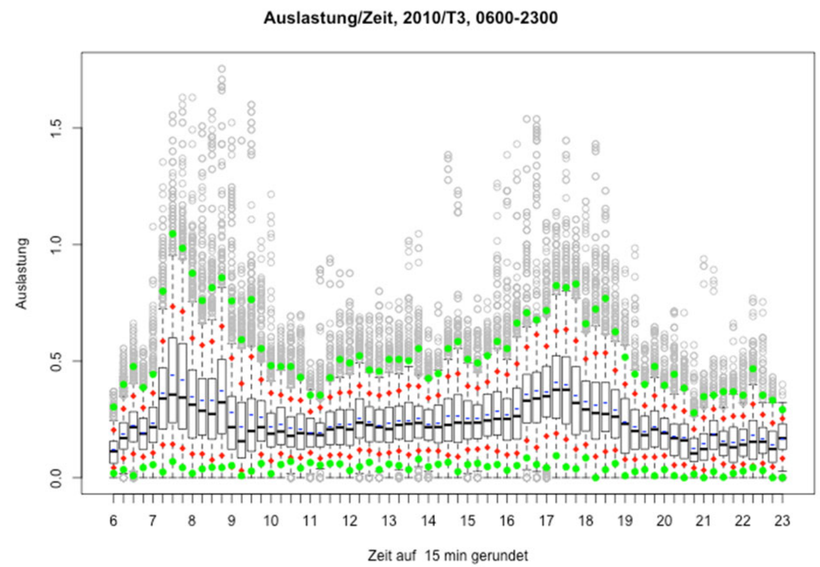
evaluation of the whole network

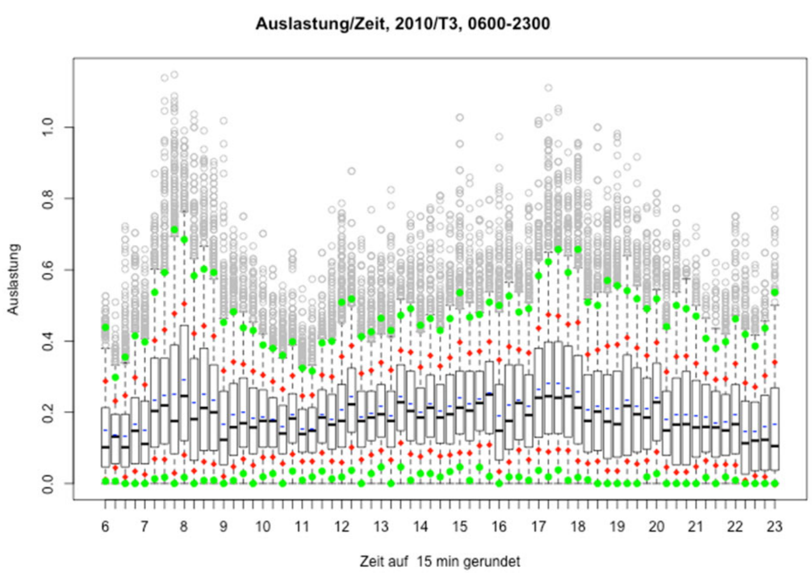


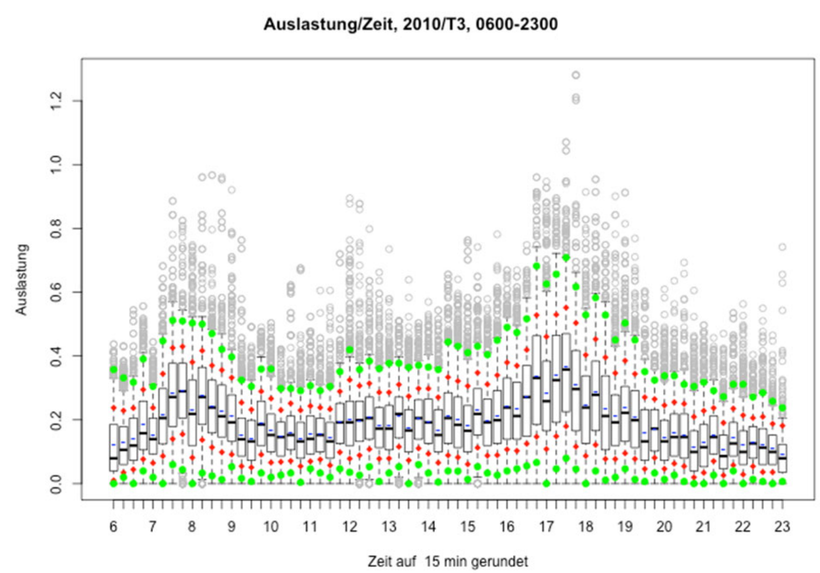
All lines considered



Some passenger load data

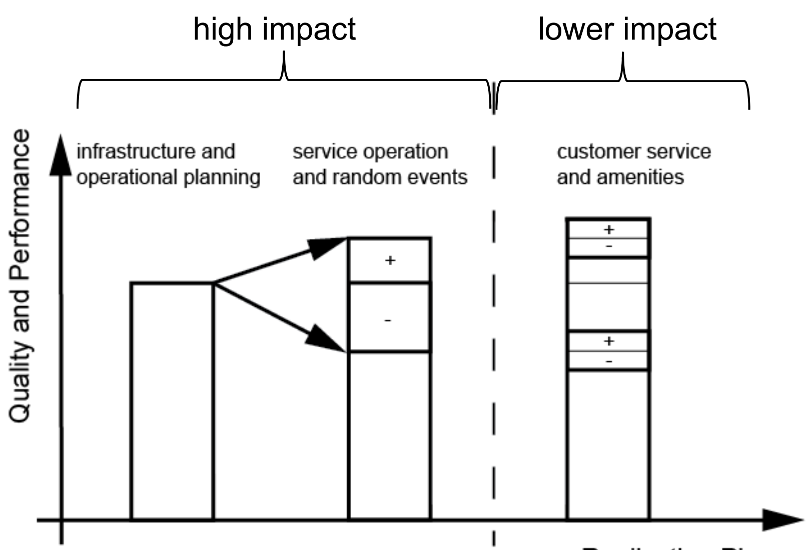






Public transport quality/performance realization

- three phases of quality and performance realization
  - Decreasing extent of controllability
  - Increasing influence of individuals
- but also
  - Decreasing extent of impact



source: [2]

- consideration of first two levels only

E.g.: „WIFI and comfortable seats do not compensate for a bad operation!"