Transportation Research Procedia

Volume 15, 2016, Pages 36–50

ISEHP 2016. International Symposium on Enhancing Highway Performance

Capacity issues in Sweden - applications and research

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Abstract

This paper gives an overview of the Swedish trunk road system and present objectives, guidelines concerning capacity and level of service Procedures to assess these issues in the feasibility and design procedure are also described. An important goal in Sweden is investments and speed limit changes over a 10 year time scale to decrease the C02-exposure.

The long term speed limit overview with the objective to require median barriers at speed limits over 80 kph with results so far is presented. By now over 50 % of the former traffic load over 80 kph is decreased to 80 kph. Some 2,700 km have been retrofitted to 2+1 median barrier roads with speed limit mainly 100 kph.

An overview is also given of the updated Swedish Highway Capacity Manual with new chapters especially on jam densities, entry lanes, weaving areas and traffic signals. Some interesting research projects are also briefly covered. These are 2+1 median barrier roads, capacities at motorway work zones, speed harmonisation with variable speed limits on motorways to increase capacity, ramp metering and Drive Me (autonomous driving full scale tests).

Keywords: capacity, level-of-service, state of the art, manual

1 Introduction

The purpose of this country report is to give an overview of

- the present situation on Swedish trunk roads
- present Swedish policies on capacity related issues
- procedures and methods for highway capacity and traffic performance analysis and design.
- the ongoing speed limit review
- the new Swedish Highway Capacity Manual (SHCM) and the new Swedish Guideline for simulations

 Selection and peer-review under responsibility of the Scientific Programme Committee of ISEHP 2016

doi:10.1016/j.trpro.2016.06.004

- Swedish experience of variable speed limits and ramp metering on motorways.

Country reports for Sweden are also available from previous ISEP conferences (Bergh et al 2011). Some projects are also reported in more details at the conference.

2 Overview Swedish Trunk Roads

The Swedish Transport Administration (STA) is responsible for rural roads and major urban through roads, all together some 100 000 km. The highest traffic volume in Sweden is found on the E4 through Stockholm with sometimes 10 lanes and short interchange spacing with a peak AADT around 140 000 veh/day. At the other end there are almost 20 000 km gravel roads with AADT's below 200 veh/day. The average traffic growth is around 2 % during the last years with a long term forecast varying geographically between 0 and 2 %.

30 % of the yearly mileage is produced on some 2 000 km motorways and 14 % on some 2 700 km median barrier roads with overtaking lanes. Motorway AADT's vary from 65 000 at 50 kph to 17 000 at 120 kph and on median barrier roads from 12 000 at 70 kph to 7 000 at 110 kph with maximum flows around 20 000. There are only 1 500 km rural roads with AADT's over 4000 veh/day, see figure below.

Speed	Motorway			2+1 with median barrier			2 lane		
limit	km	Mfkm	AADT v	km	Mfkm	AADT v	km	Mfkm	AADT v
<=60	2	45		27	130		8888	4656	
70	58	1384	65042	136	587	11787	58799	10696	498
80	39	737	51586	70	232	8988	13844	7200	1425
90	132	1804	37536	148	543	9806	9895	7770	2151
100	153	1617	28960	1833	5280	7623	2194	825	1030
110	1279	9614	20592	453	1122	6620	16	43	
120	341	2069	16628	0	0	0	0	0	
Total	2006	17315		2668	7896		93639	31206	
%	2	30		3	14		95	54	
Over 80 kph %	12	49		15	22		73	28	

Figure 1: Main Swedish road types by speed limit, length (km), traffic load (Million vehicle km) and average AADT (source NVDB 131231).

The main current capacity and level-of-service issues on state roads relate to the design and operation of urban motorway sections with close interchange spacing including ITS-measures such as incident detection systems, variable speeds, ramp metering and also lane closures at road works. There are also a few median barrier roads at high traffic volumes creating some capacity problems. This is an obvious problem on a few sections with terminations from two lanes to one lane creating bottlenecks in between multilane roads.

3 Swedish Policies

The overall objective for the Swedish transport system is to produce sustainable, safe efficient accessibility for the whole country. STA report results (Trafikverket 2015), hopefully progress on a yearly basis to the government expressed for accessibility in four "qualities" for five road or transport types. These are punctuality, capacity, robustness and usefulness. The 2014 result by quality and transport/road type with definitions of the qualities is given in the figure below.

	Major cities	Trunk roads	Com-muting	Business roads	Low volume
punctuality			→		
capacity	↗				
robustness			↗		
usability			→		

punctuality = ability to fulfil expected travel and tarnsport times and rapidly to give correct incident information
capacity = ability to cope with demad
robustness = ability to cope with incidents
usability = ability to cope with customer groups requirements

Figure 2: Swedish capacity and level-of-service progress 2014 according to Annual report.

Many qualities for the indicators are missing and expert assessment is used instead. Punctuality is yellow interpreted as reasonable. The main improvements is claimed to be slightly better information on accidents and travel time problems due to these.

Capacity is not acceptable (red) though a number of major projects were opened in Stockholm and Gothenburg. Peak hour travel times decreased slightly in Stockholm and were unchanged in Gothenburg.

A travel time indicator is based on (Bergh et al 2011) measuring travel times on longer sections using license plate matching and traditional detector data. These data could indicate "punctuality" though no decisions are taken as yet. The graph below shows travel times over a busy section on the Gothenburg E6 motorway 2014. Real disturbances occur under small fraction of the year. Travel times are surprisingly stable compared with driver perception.

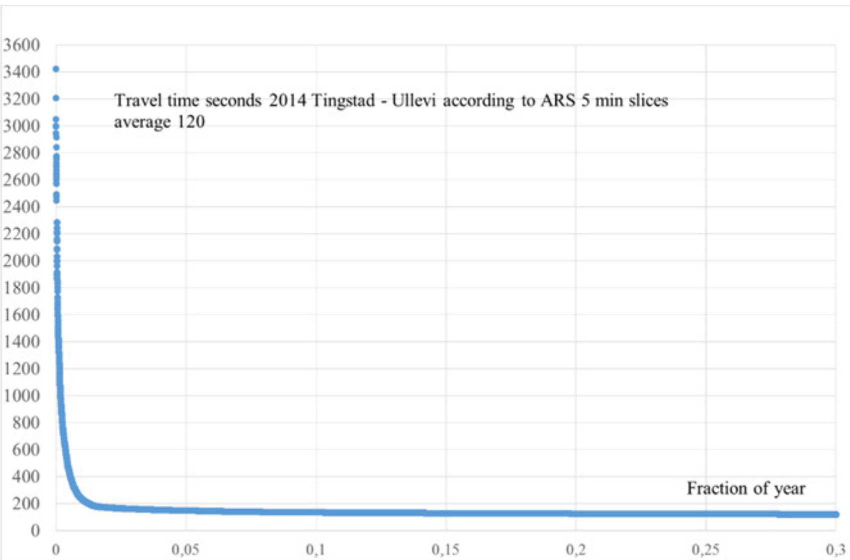


Figure 3: Travel time variation E6 Gothenburg (Tingstad-Ullevi) 2014.

Robustness is partly measured using the total number of vehicle hours in incident stops in the state network. Incidents with start and stop times are (should be) reported to the traffic control and information centres. The incident delay is estimated on a very rough basis. Numbers have decreased considerably (around 40 %) between 2013 and 2014.

Usability covers a wide spectrum from impaired users to bearing capacity problems for the forest and mining industry. Closed low volume roads due to frozen earths decreased substantially during 2014.

4 Swedish Capacity and Level-of-Service Procedures

All investment projects on state roads are assessed in a stepwise procedure including legal decisions in the feasibility and preliminary design stages as well as in a parallel economic planning procedure. There are no formal requirements on capacity analysis for urban municipality projects.

The design procedure applied by STA recommends a maximum degree of saturation for the design hour in the design year. This should normally be a degree of saturation maximum 0.8 for a theoretical 30th hour, 8-15 % of AADT due to road type, for year 20 after traffic opening. The travel speed should also preferably be less than 10 kph below the reference speed, normally the speed limit. This recommendation could be overruled by the cost-benefit analysis (CBA) and the objective analysis.

Capacities and degree of saturations are estimated using the recently published Swedish Highway Capacity Manual (SHCM) (Trafikverket 2015).

Travel times converted to travel costs are an essential part of the CBA. Travel times are also estimated using the SHCM. One-directional, hourly based speed-flow curves are defined for alternative road types for three vehicle types; passenger cars (including trailers), trucks and semi-trailers/doubles. An example is given below for cars for four common road types; two lane 9 m 80 and 90 kph with good alignment, normal median barrier road 100 kph with 40 % overtaking and 4 lane motorway 110 kph.

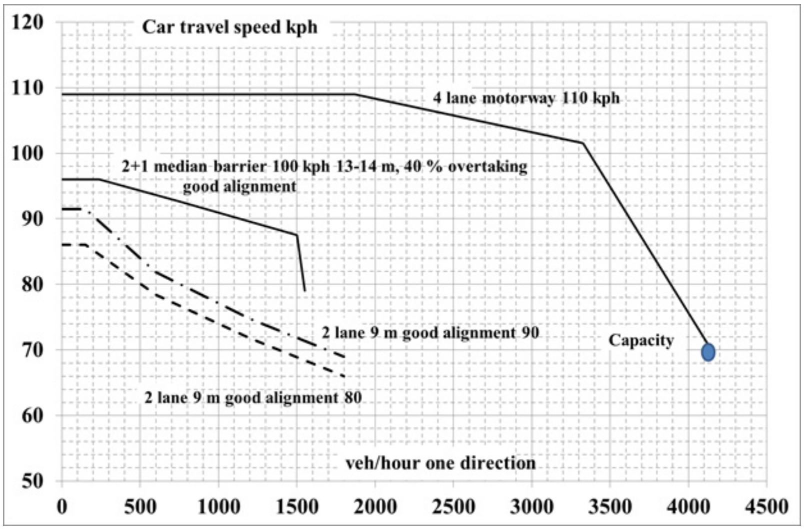


Figure 4: Speed flow curves for cars (including with trailers) for 4 lane motorway, normal median barrier 100 kph with 40 % overtaking and 2 lane 9 m with 80 and 90 kph with good alignment (sight class 1).

Delays at intersections are also estimated normally using a simplified Capcal model (the Swedish intersection capacity model).

Life expectance in CBA is 40 years. The following socio-economic values for time are used (Trafikverket 2015):

- Average passenger car travel time 177 SEK/hour (2010) increasing 1.8 % per year with queuing time (degree of saturation over 0.8) in private travel 50 % higher
- Rigid truck travel time 326 SEK/hour and articulated 272 SEK hour (2010) stable over time
- Truck cargo 10 SEK/hour and articulated truck cargo 50 SEK/hour (2010) stable over time

There is also a value for travel time uncertainty defined to be 0.9*standard deviation of travel time. This is calculated in a rough way.

5 Speeds and Speed Limit Overview

STA is working hard to improve drivers' compliance with the speed limit system using campaigns, speed cameras, variable speed limits and also a speed limit review. Efforts have been reasonably successful as the STA speeding index below shows. The index is based on the 83 continuous counting station claiming a 13 % decrease of speeding over the last 10 years. It is also clearly stated looking at our speed-flow graphs for 110 kph motorways with an approximately 3 kph speed decrease over 10 years (Olstam et al 2013 and Trafikverket 2015).

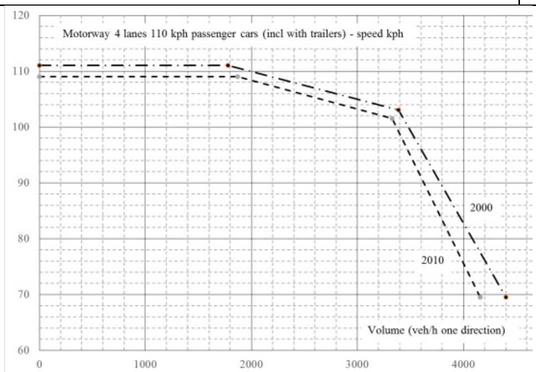
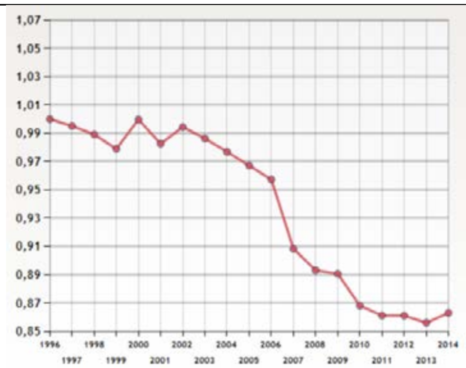
Motorway 110 speed-flow relationship 2000 and 2012	Speeding index cars from 1996 to 2014
	

Figure 5: Motorway speeds and speeding index over time.

The speed limit review, described more in detail in last country report (ref), is still on going. By now almost 14 000 km roads have been changed to 80 kph, mainly decreased from 90 and sometimes 100 kph. Some 2 700 km have been retrofitted to 2+1 median barrier roads, normally with speed limit 100 kph. The present objective is to decrease or retrofit remaining two lane roads with AADT's over 2000 by 2025. Before-after studies claim passenger car speed effects to be close to – 4 kph decreasing the speed limit from 90 to 80 kph with substantial safety effects. A negative effect is speeding on new 80-roads with free flow speeds around 86 kph (Vadeby 2010). The new speed camera program will partly focus on these roads.

6 New Swedish Capacity Manual (SHCM)

The first Swedish Highway Capacity Manual was published in 1977. Methods have improved over the years without any update of the manual. The Metcap-project efforts have now resulted in a new manual (Trafikverket 2014). Highway links and unsignalised intersections are mainly just taken from other sources without any substantial updates. The Metcap proposals on urban links and bicyclists and pedestrians have not been incorporated. The main news deal with jam density, fundamental diagram, weaving sections and traffic signals.

6.1 Motorway oversaturation

The jam density at motorways was estimated to 134.5 (pcu/lane/km) using airal photos and films from Stockholm and Gothenburg motorways. The value correlates well with HCM2010 and also traffic data from Denmark (Strömgren 2011). For the 15 different types of motorways capacity densities have been derived from the STA speed-flow relationships varying between 30 to 38 pcu/km/lane due to motorway type (Strömgren 2014). Data, mainly from Stockholm, have then been used to estimate speed flow relationships for oversaturated conditions, see table below, with speeds Vo=a*Qo^2-b*Qo with Qo = traffic flow (v/h).

Type of Motorway	*Density at capacity (pcu/km/lane)*	*Equation*
MV urban 6 ln 70 kph	35,4	$V_{ö} = 0{,}000016 \cdot Q_{ö}^{2} - 0{,}0016 \cdot Q_{ö}$
MV urban 6 ln 80 kph	33,9	$V_{ö} = 0{,}000016 \cdot Q_{ö}^{2} - 0{,}0014 \cdot Q_{ö}$
MV urban 6 ln 90 kph	32,8	$V_{ö} = 0{,}000016 \cdot Q_{ö}^{2} - 0{,}00094 \cdot Q_{ö}$
MV urban 6 ln 100 kph	30,6	$V_{ö} = 0{,}00001636 \cdot Q_{ö}^{2} - 0{,}0001 \cdot Q_{ö}$
MV rural 6 ln 90 kph	31,6	$V_{ö} = 0{,}000017 \cdot Q_{ö}^{2} - 0{,}0012 \cdot Q_{ö}$
MV rural 6 ln 100 kph	29,1	$V_{ö} = 0{,}0000187 \cdot Q_{ö}^{2} - 0{,}0017 \cdot Q_{ö}$
MV rural 6 ln 110 kph	27,8	$V_{ö} = 0{,}0000187 \cdot Q_{ö}^{2} - 0{,}00017 \cdot Q_{ö}$
MV urban 4 ln 70 kph	38,4	$V_{ö} = 0{,}0000088 \cdot Q_{ö}^{2} + 0{,}0082 \cdot Q_{ö}$
MV urban 4 ln 80 kph	37,3	$V_{ö} = 0{,}0000099 \cdot Q_{ö}^{2} + 0{,}0061 \cdot Q_{ö}$
MV urban 4 ln 90 kph	36,3	$V_{ö} = 0{,}0000089 \cdot Q_{ö}^{2} + 0{,}008 \cdot Q_{ö}$
MV urban 4 ln 100 kph	34,2	$V_{ö} = 0{,}000096 \cdot Q_{ö}^{2} + 0{,}0078 \cdot Q_{ö}$
MV rural 4 ln 90 kph	35,3	$V_{ö} = 0{,}000012 \cdot Q_{ö}^{2} + 0{,}0024 \cdot Q_{ö}$
MV rural 4 ln 100 kph	32,5	$V_{ö} = 0{,}0000147 \cdot Q_{ö}^{2} - 0{,}0006 \cdot Q_{ö}$
MV rural 4 ln 110 kph	31,1	$V_{ö} = 0{,}0000152 \cdot Q_{ö}^{2} - 0{,}00089 \cdot Q_{ö}$
MV rural 4 ln 120 kph	29,6	$V_{ö} = 0{,}0000157 \cdot Q_{ö}^{2} - 0{,}00042 \cdot Q_{ö}$

Table 1: Capacity densities and speed flow relationships at oversaturated conditions.

6.2 Entry lane capacity

The on-ramp model is derived from the TPMA-project (Traffic Performance on Major Arterials), performed around the millennium. The effect of on-ramp flow on the motorway is estimated by using (Carlsson et. al. 2000a):

$$q_{onar} = q_c - a \cdot q_{on}$$

where:

q_{onar} = Capacity for the through lanes after the on-ramp (pcu/h)

q_c = 4150 (pcu/h) at 2 trough lanes and 5600 (pcu/h) at 3 trough lanes
a = 0,25 if interchange density > 0,33 (interchanges/km)
0,20 if interchange density 0,2-0,33 (interchanges/km)
q_{on}= On-ramp flow (pcu/h)

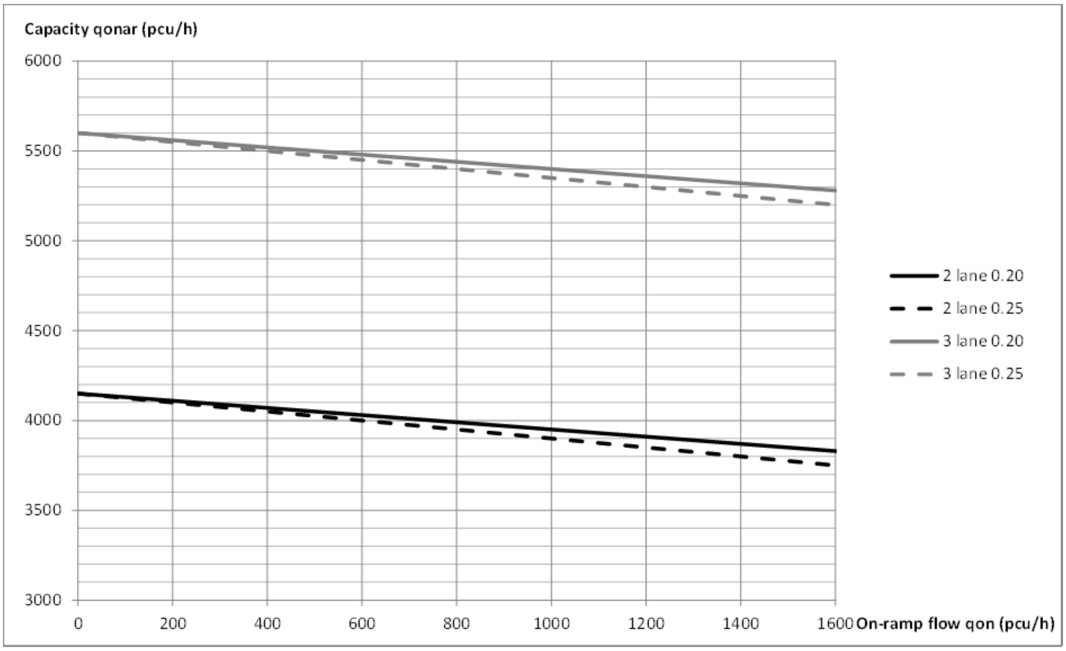


Figure 6: Entry lane capacity on two and three lane motorway due to entry lane flows.

6.3 Weaving capacity

The new weaving model (Strömgren 2011) was developed given flow between on-ramp and off-ramp should give the same result as the old one (Carlsson et. al. 2000). The new model also should give the same result as the capacity model for on-ramps, if there was no off-ramp flow. Data is mainly the same used in the TPMA-project.

$$C_W = C - 0.0065 \cdot \left(\frac{Q_{OFF}}{Q_{ON}+1}\right)^{0.1} \cdot (0.43 \cdot Q_{OFF}) + 1.87 \cdot Q_{ON}) \cdot \left(1 + \left({Q_{OFF}}^{1.4} \cdot Q_{ON}\right)^{0.3}\right) + 0.05 \cdot (L - 250)^{1.5}$$

where:
C = Capacity main link (pc/h) with 4150 for two lanes
Q_{ON}= On-ramp flow (pc/h)
Q_{OFF}= Off-ramp flow (pc/h)
L = Length of the weaving segment (m) with maximum value 1250 m, when capacity is the same as for a basic segment

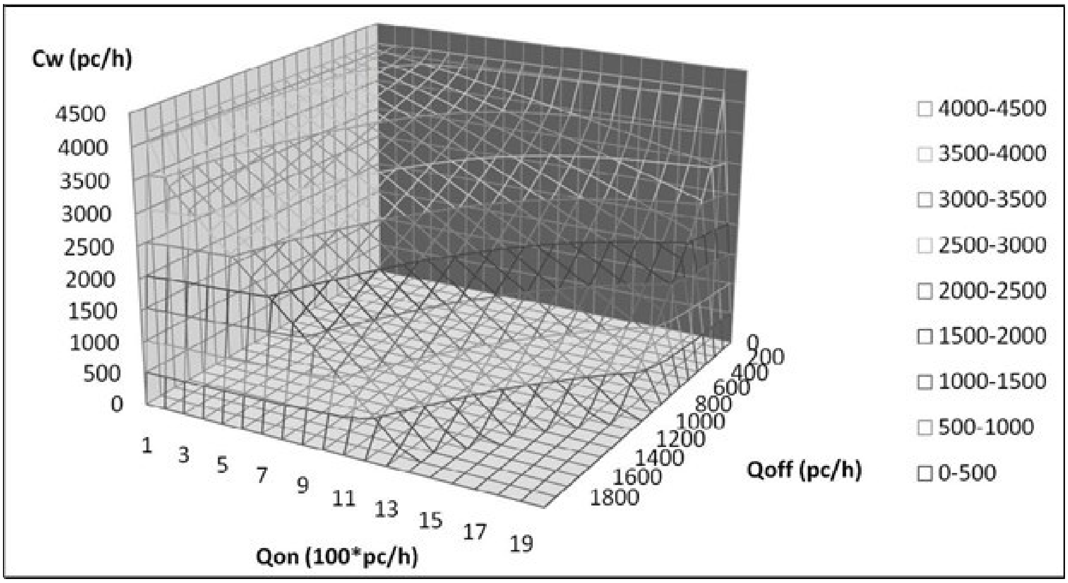


Figure 7: Weaving area capacity due to on and off ramp flows (Strömgren 2011).

6.4 Traffic Signals

The method is limited to isolated intersections, and based on fixed timed signals. The main differences with the old Capcal procedure are improved methods to find the critical intersection point, a step back to Webster optimisation and improved short lane procedures.

Impacts of Traffic Actuated signal control is approximated by signal timing corrections (max green, green time extension intervals) based on traffic simulation results for different types of control strategies. In further work those corrections will be enhanced and also include the impacts of bus priority in vehicle actuated signal control using a more complex probability based model.

Special consideration has been devoted to development of the following sub modules:

1. Automatic calculation of inter-green times and minimum green periods which give instant feedback of signal phasing and geometry changes

2. Saturation flow models for lane types with opposed discharge (vehicles and/or pedestrians and bicyclists)

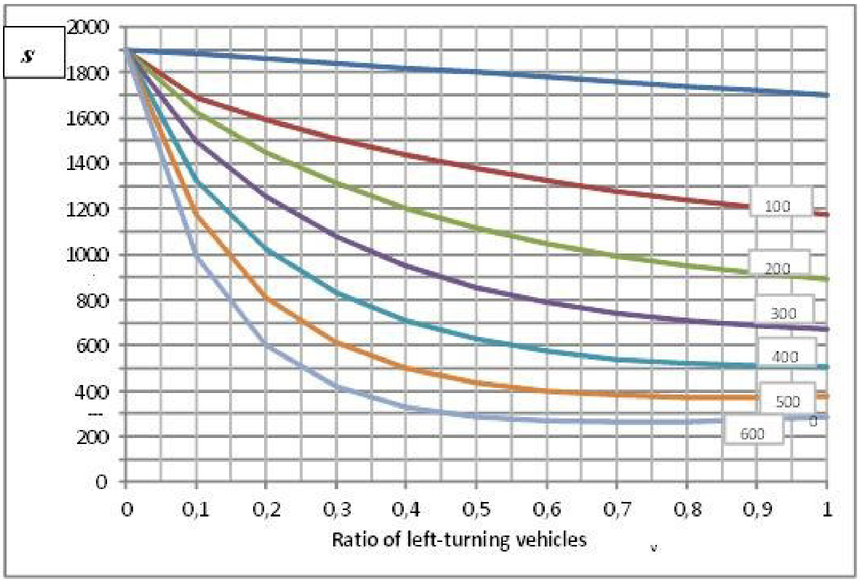


Figure 8: Saturation flow with opposing flow.

3. Short lane utilization and contribution to approach bottleneck capacity.

The contribution of a short lane to the saturation flow of an adjacent through lane is modelled for different intersection configurations and signal phasing. If a short lane serves only turning traffic and is discharged in the same phase as a nearby through lane it may not be fully utilised due to blockage caused by the through traffic lane. Models have therefore been developed focusing on the capacity of the bottleneck upstream of the short lane as a function of expected numbere of vehicles that can queue in this lane in a signal cycle. The saturation flow contribution of the short lane to the bottleneck lane is calculated as $\boldsymbol{s' = N_{queue} \cdot \frac{3600}{g}}$ (f/gh)

4. Procedure for identification of the critical conflict point for complex intersection configurations and phase schemes including extra or alternative phases for efficient discharge of turning movements.

The figure below illustrates a critical conflict point for an intersection with three main phases. The arrows represent the lane in each phase with the highest load factor (***q/s***)

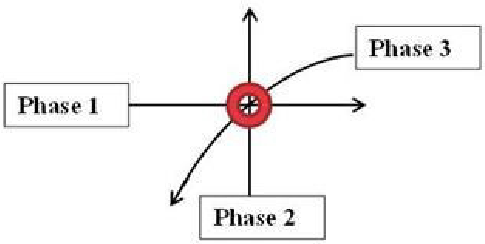


Figure 9: Determination of critical conflict point

The sum of the load factors for the main phases in the critical conflict point is calculated as $max \sum (^{q_j}/_{s_j})$ where ***j*** represents the phases that result in the highest sum. If the signal control includes alternative extra phasese.g. for major left turning movements, the scheme that gives the highest sum is identified and used for the signal timing process. This calculation process results in equal values for degree of saturation for all lanes included in the critical conflict point, which leads to minimum intersection delay.

7 Median Barrier Roads with Overtaking Lanes

The first median barrier road was opened for traffic in 1998. Some 2 700 km are now operating. The main part are retrofits of wide two lane paved roads, around 13 m paved width, sometime widened to 14 m. Lately existing 9 m paved width roads have been retrofitted adding overtaking lanes and sometimes also widening the 1+1-sections slightly. As yet some 15 projects are opened for traffic.

Empirical studies, analytical analysis and simulation studies using the VTI model are the basis for the present recommendations on speed-flow relationships for alternative types of median barrier roads due to width and overtaking. The present conclusions are given in the figure below. Estimates are:

- no difference in free flow speeds between the full and the narrow design, i.e due to 4.5 or 5.1 m wide one lane sections
- some 3 kph benefit of 10 % more overtaking at medium flows
- a capacity loss of some 15 % retrofitting from two lane

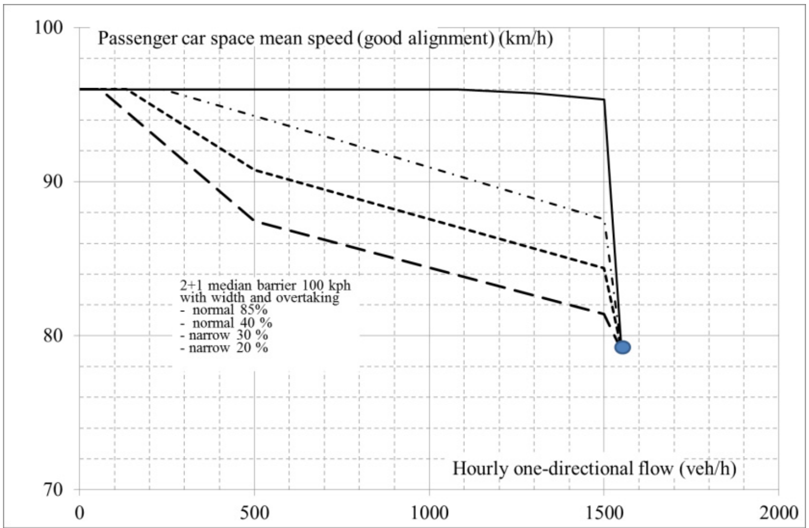


Figure 10: Average car speeds due to cross-section and overtaking % at good alignment

There has been some concern about breakdowns during some weekends on sections creating bottlenecks between roads with higher capacities. Overtaking lanes on the E4 north of Gävle, some 150 km’s north of Stockholm, have been temporarily closed during some peak week end hours. Traffic rhythm is considered to have eased according to the police. Simple follow up studies propose the average traffic output from the section probably to have decreased but the risk for collapses might also have decreased (Carlsson 2014). The road type is also critised to be less robust creating more emergency delays than normal two lane roads. Barrier repairs obviously create some delays though they are normally done during off-peaks. Traffic control centre data on emergency stop delays due to accidents and other unplanned occasions do not support the critics. The road type turn out better than normal two lane roads comparing an index defined as emergency stop delays divided with total mileage by road type, see figure below.

			Total 2009-14		index
	Average 2009-14		stop/	stop time/	ratio stop time/
Type	km	TL	Mapkm	Mapkm	ratio traffic load
MW	1961	18 096	0,02	21,4	0,9
Barrier	2168	7 008	0,04	15,5	0,7
2 lane	93786	34 290	0,04	22,8	1,0

TL=traffic load or mileage/year in Million axle pair kilometer/year (AADT*km*365/10^6) with 1 vehicle approximately 1.1 axle pair

Figure 11: Incident data motorways, barrier and 2 lane roads 2009-14

8 Capacity Reductions at Road Works

A new model for estimation of capacity reductions at roadwork zone has been developed for Swedish conditions (Strömgren et. al. 2016). The model is based upon several different sources, UK, US and Denmark.

$$q_{Red}^{i} = f_{rs} \cdot f_{\text{Co}} \cdot f_{Rnl} \cdot f_{C50} \cdot f_{l} \cdot f_{lw} \cdot f_{t} \cdot q_{cap}$$

where:
q_{cap} = Capacity (pcu/h) calculated according to equation (2)
f_{rs} = Correction parameter for closed road shoulder
f_{co} = Correction parameter for cross over
f_{rnl} = Correction parameter for reduction of the number of lanes
f_{c50} = Correction parameter for commuter traffic
f_{l} = Correction parameter for the length of the work zone
f_{lw} = Correction parameter for lane width
f_{t} = Correction parameter for type of roadwork

Correction parameter	Correction factor	Usage
Closed road shoulder (f_{rs})	0.8 (0.9 in combination with other measures)	Reduce the closest lane
Cross over (f_{co})	0.95	Reduce the capacity for the whole roadway
Reduction of number of lanes (f_{rnl})	0.95	Reduce the capacity for the whole roadway
Commuter traffic < 50 % (f_{c50})	0.90	Reduce the capacity for the whole roadway
Length of roadwork zone > 2000 m (f_{l})	0.95	Reduce the capacity for the whole roadway

Table 2: Correction parameters for motorway at various design of roadwork zone. Values based on BASt (2011) and Vejdirektoratet (2010).

Motorway	Average Lane width (m)				
	≥ 3.50	3.25	3.00	2.75	2.50
Correction factor f_{lw}	1.00	0.95	0.90	0.85	0.80

Table 3: Correction factor for the average lane width of the motorway with roadwork from the Danish capacity manual (Vejdirektoratet 2010).

Level	Type of roadwork	Correction factor f_t
1	"Easiest" (e.g. repair of barrier)	1
2	"Easy" (e.g. repair of pot hole)	0.97
3	"Average" (e.g. measures in median)	0.94
4	"Difficult" (e.g. measures of road markings)	0.91
5	"Very difficult" (e.g. paving)	0.88
6	"Most difficult" (e.g. bridge repair)	0.84

Table 4: Correction factor for type of roadwork for motorway with roadworks from OkDOT (Lindly & Clark, 2004).

The model developed was verified by comparing results from the model and the partly empirical based road work capacity published in the Dutch road work capacity manual (Rijkswaterstaat 2011). The model was then validated for Swedish road work traffic conditions by conducting a field trial on the motorway E6 in Gothenburg. Two correction parameters have been validated, closed road shoulder and reduction of the number of lanes. They showed a high correlation between the calculated value and the measured value of capacity reduction.

9 Variable Speed Limits on Motorways

A section of the E4 motorway between Hallunda and Moraberg just south of Stockholm has been improved during 2009-2013. The length is some 11 km with an average AADT of 75000 with 3 major interchanges. The expansion includes a rearranged lane configuration almost within the existing road section (25 m) and traffic management systems. Previous design with two lanes and a wide hard shoulder has been replaced with three lanes with minor shoulders. In addition, the road has been equipped with variable speed limits 80 and 100 (with red, compulsory ring) and a queue warning system with recommended speed of 70 or 50 kph (without red ring) and emergency refuge areas (ERAs).

The harmonization settings on E4 south of Stockholm has been iteratively designed and ultimately set to 325 vehicles/5 min, which has worked well. The variable speed limit is reduced to 80 kph and stabilizes the flow. The harmonization indicates a potential risk of queue for the road users, which becomes more prepared if the queue warning is activated further along the road due low speed and the risk of sudden braking.

The main results can be summarized as follows (Strömgren et. al. 2016):

- The average speed during rush hours on weekdays has increased by 2.5 kph after the installation of the traffic control system, of which 25 % is assumed to be attributable to the traffic management system
- The harmonization has delayed the onset of collapse.

- Maximum throughput has increased by 10% after installation of the traffic management system. It is probable that the homogenization contributed a few percent to this.
- The speed variance within each lane and in total decreases in proportion to the speed reduction of 7-10 km / h when activated. The effect is less than expected. It will probably require speed checks if a stronger effect is desired.
- The accidents have been reduced by half, of which 25 % is assumed to depend on traffic management (harmonization, queue warning and VMS

10 Ramp Metering

The first ramp metering section in Sweden was implemented 1995 on the E18 Roslagsvägen north-east of Stockholm. Based on loop detection on the motorway as well as on the ramp the system was activated during morning peak hour. By adjusting the signal cycle-time the ramp traffic flow was reduced to allow for non-congestion condition on the motorway. However, the ramp length was limited and the upstream intersection was blocked. The evaluation (Utvärdering av påfartsreglering vid Lahäll, Cedersund 1995) showed delay reduction on the motorway with 11s per vehicle and an increased delay on the ramp with 13,5s per vehicle during peak-hour. The congestion problems on the secondary road network was not acceptable and the system was closed down.

A more successful implementation of ramp metering could be reported from the Stockholm congestion charging trials in 2006. The anticipated increase in traffic flow out-side the cordon was partly handled with a more advanced ramp- metering system in several intersections based on the Utopia/Time algorithm, including facilities for coordinated ramp metering control. To avoid problems with queuing back the cycle time was adjusted based on both motorway occupancy and ramp queue length.

The system was evaluated using flow and travel-time measurements (Essingeledens påfartsreglering, Davidsson, 2006). The improvement in travel time, as well as some minor positive effects on traffic safety and emissions, was significant with delay savings in the range of 100 veh.hours during am peak. The ramp queue is managed by a detection system that adjust cycle time based on ramp occupancy. A socio-economic evaluation (Samhällsekonomisk kalkyl av trimningsåtgärder, Davidsson, Lindkvist 2007) estimated the yearly benefits to be in the range of 0,25 MEuro. The cost of the system was in the range of 0,5 MEuro and the system is still in operation.

The system in Stockholm will expand during 2016 as the new motorway tunnel Norra länken will be opened. The ambition is to control non-recurrent congesting that could impede the traffic in the tunnel exit by introducing ramp metering at several intersections downstream.

A feasibility study in the Gothenburg region has shown several location where ramp metering is likely to improve the traffic situation. Micro simulation has been used for tests and algorithm tuning but no implementation has been made so far.

11 Drive Me

STA and the city of Gothenburg cooperate with Volvo cars with a demonstration project with autonomous driving cars (AD). Some 200 AD cars with normal drivers will drive in normal traffic mainly on a motorway ring in Gothenburg starting 2017. Numerous data will be collected on driver behaviour. Simulation studies using VISSIM are underway trying to estimate impacts on capacity and level-of-service depending on AD-applications and penetration. Detailed analysis are also carried out on fuel consumption and traffic safety.

12 References

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