Design of a Proactive Ramp Control Algorithm and the Assessment of its Effectiveness Compared to other Control Methods

Roland Trapp

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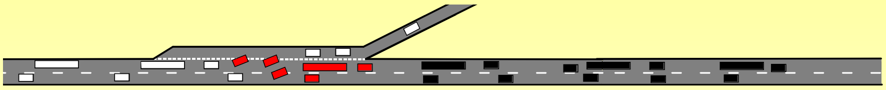
1. Basic Principles
   Traffic flow / Congestion
   Ramp metering
2. Algorithm Development
3. Effectiveness
   Evaluation concept
   Results
4. Conclusion

Formation of congestion at a freeway entrance



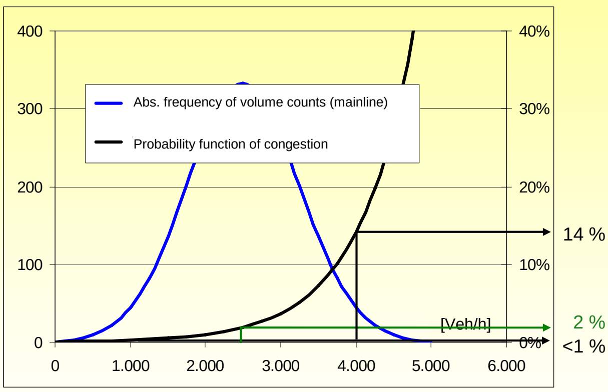
1. Step: „Incident“
Trigger:
Entering platoon meets platoon on 1st lane

The probability of an incident rises with volume in the merging area.

2. Step: „Congestion“
Trigger:
Incident followed by high volumes (for few minutes)

The higher the volume upstream of an incident, the more probable is the development to congestion

Probability function of congestion $p_C(q)$



Convexity $$p_C\left(\frac{q_1+q_2}{2}\right) \leq \frac{p_C(q_1)+p_C(q_2)}{2}$$

Goals

- Improvement of traffic safety
- Reduction of congestion on main carriageway

achieved by

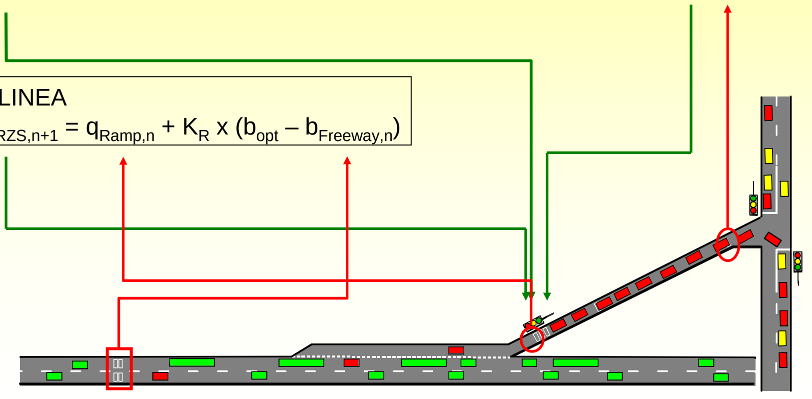
- Dispersion of platoons
- Controlling entrance flow

Control algorithms

Fixed Time Control (FTC)
$q_{RZS,n+1} = q_{RZS,n} = const$

Add-on function
„Queue Control“

ALINEA
$q_{RZS,n+1} = q_{Ramp,n} + K_R \times (b_{opt} - b_{Freeway,n})$



Resumee basics

Traffic flow

- Probability of the occurrence of congestion <u>increases progressively</u> with traffic volume in the merging area
- Measurements are stochastic

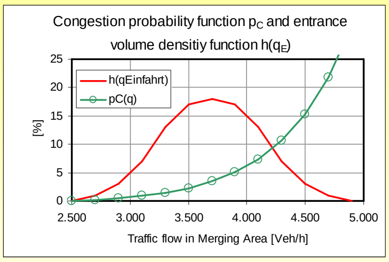
Ramp metering

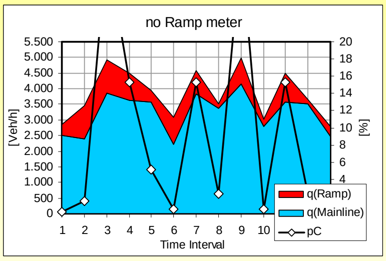
- RM reacts on situations that lie in the past (few minutes)
- Traditional control methods tend to „fill and flush" the entrance ramp

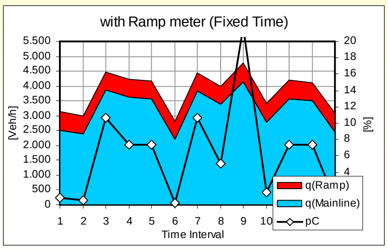
Goals for the new control method

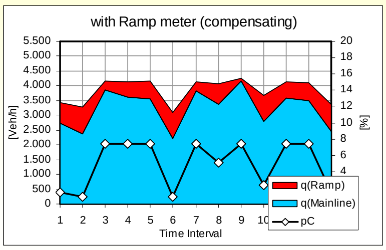
1. Compensation of extreme volumes in the merge area
2. Less, but more precise actions by anticipation of traffic situation
3. Less ramp queue by equal consideration of ramp and mainline flow

Goal 1: Compensation of extreme volumes

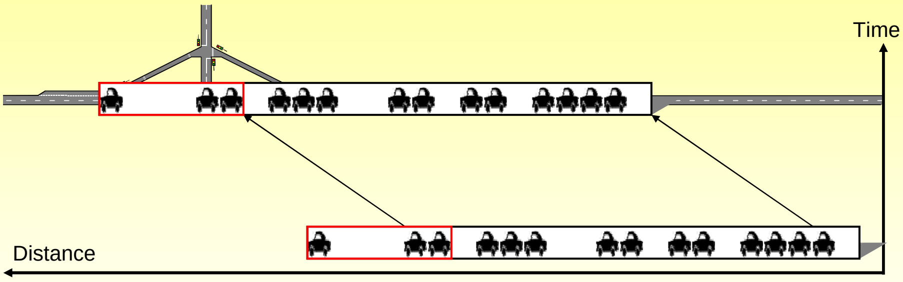






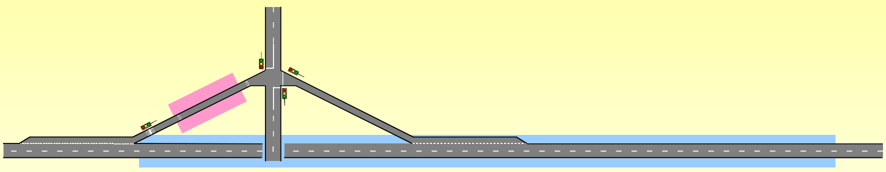


Goal 1: Compensation of extreme volumes
Goal 2: Anticipation of traffic situation



$$q_{RampMeter} = \left(f_q \cdot \frac{q_{Mainline,60s}}{q_{Mainline,15s}} \right)^{\lambda}$$

Goal 3: Equal consideration of both flows
– ramp and mainline



$$q_{RampMeter} = q_{Ramp} \cdot \left(f_q \cdot \frac{q_{Mainline,60s}}{q_{Mainline,15s}} \right)^{\lambda}$$

Evaluation concept

Scenarios Compared

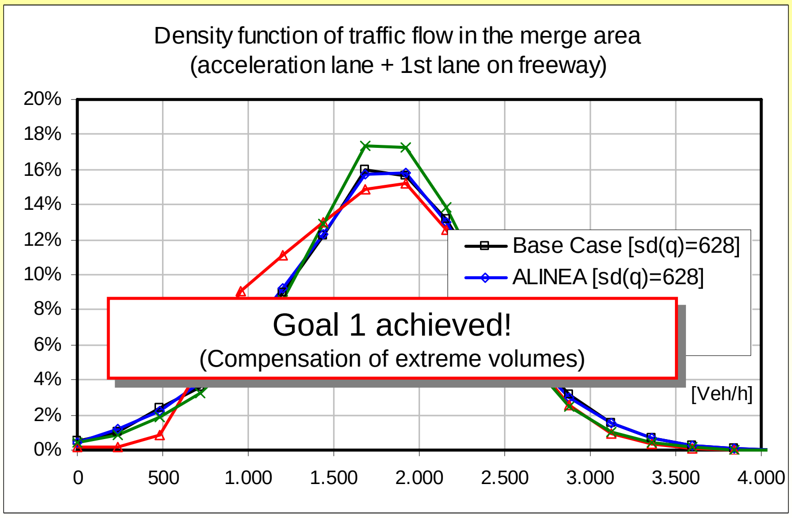
- No ramp metering
- Proactive Ramp Optimization (PRO)
- Fixed Time Control (FTC – 800 Veh/h)
- ALINEA

Measures of effectiveness

- stand. deviation of volume
- Ramp queue length
- Travel times (ramp, mainline, total)

Demand Scenarios (mean values)		
	Mainline	Ramp
1. High q_{Ramp}	3.000 Veh/h	750 Veh/h
2. Very High q_{Ramp}	2.500 Veh/h	1.000 Veh/h
3. Moderate q_{Ramp}	3.300 Veh/h	375 Veh/h

Shift in mainline volume density function by ramp metering



Measures of effectiveness

Measure	3.000 Mainline – 750 Ramp	2.500 Mainline – 1.000 Ramp	3.300 Mainline – 375 Ramp
Ramp Queue (% of tim[illegible]	PRO 0 % [illegible]	PRO 3 % [illegible]	PRO 0 % [illegible]
Change [illegible] Travel Ti[illegible] (Ramp)	[illegible]	[illegible]	[illegible]
Change in Travel Time (Mainline)	PRO –3,3 % FTC –5,5 % ALINEA –8,8 %	PRO –1,2 % FTC –2,7 % ALINEA –0,6 %	PRO –1,5 % FTC –0,2 % ALINEA –1,2 %
Change in Travel Time (Total)	PRO –2,5 % FTC –3,4 % ALINEA –3,7 %	PRO ±0,0 % FTC +72,7 % ALINEA +1,2 %	PRO –0,9 % FTC +0,2 % ALINEA +0,0 %

Goal 3 achieved!
(Reduction of ramp queues by equal consideration of both flows – ramp and mainline)

Conclusion

Proactive Ramp Optimization „PRO“

1. Effectively compensates extreme volumes
2. Anticipates traffic situation and allows for more precise and thus less restrictive control
3. Reduces ramp queues significantly by equal consideration of both – ramp and mainline

→ Goals accomplished

Comparison of algorithms

1. ALINEA advantageous when upstream congestion
2. PRO is useful in all demand scenarios – (flexibility)
3. PRO needs very few parameter (robustness, cost)

Further steps

Special case with $\lambda = 0$ when upstream congestion

Modification with one upstream detector

Variation of length of interval

. . . .

$$q_{RampMeter} = q_{Ramp} \cdot \left(f_q \cdot \frac{q_{Mainline,60s}}{q_{Mainline,15s}} \right)^{\lambda}$$

Thank you for your attention!

Roland Trapp
+49 (241) 60 83 26 -3
r.trapp@dr-ing-trapp.de