ANALYSIS METHOD FOR MULTIPLE FREEWAY WEAVING SECTIONS

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INTRODUCTION

Frequently, intersections, entries and exits cause congestions on motorways. Capacity analysis at weaving sections is continuously discussed. Although, the upcoming German guideline HBS (FGSV, 2012) and the American HCM 2010 touch multilane weaving sections, few papers deal with capacity analysis in the case of weaving across several lanes. Currently different simulation tools are calibrated undertaking new measurements emphasising weaving sections because of its complexity (Geistefeld et al., 2014). Since the Austrian motorway network operated by ASFINAG contains an increasing number of multilane weaving sections suitable guidelines are needed to compute weaving capacity. The Austrian guideline RVS 03.05.13 (FSV 2001) is limited to single (2-lane) weaving sections, while this paper deals with multilane entries or exits (Figure 1).

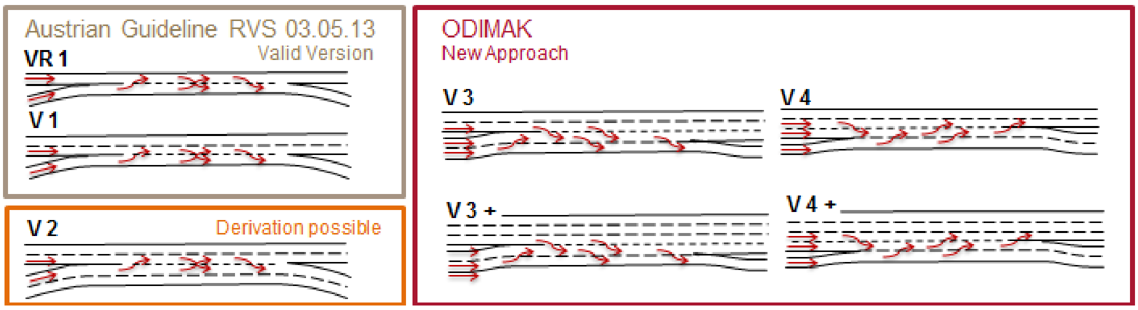


Figure 1: Different Types of Weaving Sections

METHODOLOGY

Empirical data as well as modelled data retrieved from various microscopic simulation applications were applied. Simulated data was required since the measurements covered only a subset of factors influencing capacity. Within the closed laboratory environment the impact of a variety of factor settings was tested systematically. Empirical data was used for calibration and validation as recently emphasized within the COST Action Multitude (Backstone & Punzo, 2014).

Lane specific point data (volume, speed) was evaluated in 1 min intervals over a period of one year at two different weaving sections. This data was applied to calibrate the car following and lane changing parameters of the microscopic traffic flow simulator Vissim (PTV, 2012). In a second step a variety of weaving examples was simulated with fixed, calibrated behavioural parameters including variations on number of lanes, traffic volumes, ratios of weaving movements, weaving speed and weaving length. Parameters of multiple linear regressions were estimated with vehicle speed at traffic breakdown as target value.

Finally maximum entrance volume over exit volume and through traffic is presented graphically as nomogram suitable for guidelines (Figure 2).

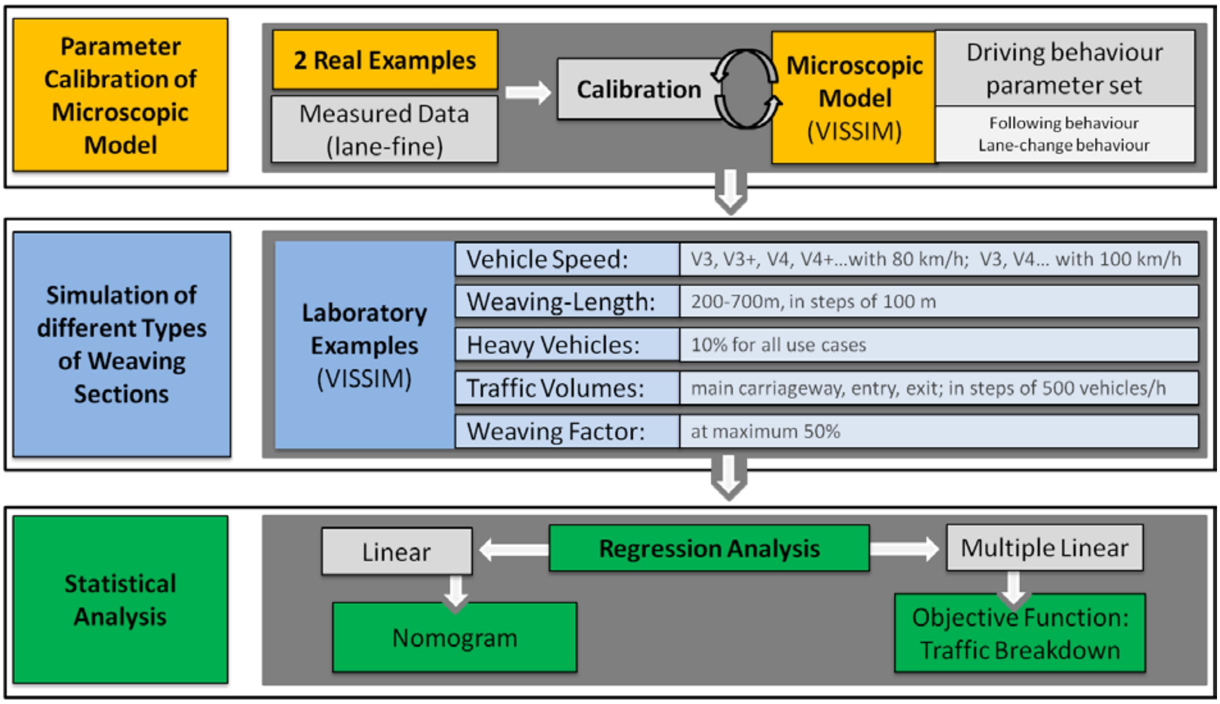


Figure 2: ODIMAK System Design

Parameter Calibration of the Microscopic Model

Traffic measurements were taken over a period of one year at two different weaving sections in Vienna (St. Marx-A23) and Linz (Voest-A7). Volume, speed and vehicle type was used to adjust car following and lane-change parameters of Vissim (Fig 3). For all behavioural parameters three different drivability-sets were matched among each other, to identify a parameter set which best matches weaving sections. Significance of parameter set results were calculated by sensitivity analysis.

Car following parameter set type 3	VISSIM Default	ODIMAK	
CC1: Headway time	0,90	0,80	[s]
CC3: Threshold for Follow-state	-8,00	-5,00	[s]
CC4: negative „following“ threshold	-0,35	-0,30	[m/s]
CC5: negative „following“ threshold	0,35	0,30	[m/s]

Lane changing parameter set type 2			
Parameter Car			
Maximum deceleration accepted	-4,00	-2,50	[m/s²]
Max deceleartion of trailing vehicle	-3,00	-2,25	[m/s²]
Min headway	0,50	2,00	[m]
Parameter HGV			
Maximum deceleration accepted	-4,00	-1,75	[m/s²]
Max deceleartion of trailing vehicle	-3,00	-1,50	[m/s²]
Min headway	0,50	4,00	[m]

Figure 3: Vissim 5.40 parameters calibrated for weaving sections in Austria

Simulation of different Weaving Sections

After the model was calibrated and the parameter set was fixed, different weaving sections were simulated. First four geometric setups (V3 – V4+ as in Fig 1) were tested with different weaving lengths (200 – 700 m). Secondly legal speed and input volumes was increased until a traffic breakdown was detected. A traffic breakdown is defined as speed reduction below a critical speed measured over a minimum time period. Empirical as well as simulation data showed that the critical speed depends on the lane layout and legal speed. The critical speed was set to 60 km/h for the type V4 and to 70 km/h for the type V3. The critical speed was chosen to detect just the breakdowns which originate from weaving movements and not from reaching capacity limit at the main carriageway.

STATISTICAL ANALYSIS and RESULTS

With known boundary conditions at which such breakdowns occur, regression analyses were conducted. Linear regression analysis was continued to develop graphical displays (nomograms) for upcoming guidelines.

Multiple Linear Regression Analysis – Objective Function with Target Value

The objective function (1) of traffic breakdown contains a number of independent variables with vehicle speed v_{veh} as dependent value. The formula includes:

- weaving factor *WF* [-] given as [(q_{in} + q_{out})/q_{total}]
- ratio of entering vehicles WF_{up} [-] given as [q_{in} /(q_{in} + $q_{main,up}$)]
- ratio of leaving vehicles WF_{below} [-] given as [q_{out} /(q_{out} + $q_{main,below}$)]
- traffic volume per lane q_{lane} [pcu/h]
- share of heavy vehicles *HV* [-]
- lane geometry *LG* [-]
- length of weaving section l_w [m]
- permissible (legal) speed v_{perm} [km/h]

$$\boldsymbol{v_{veh} = a + b * WF + c * WF_{up} + d * WF_{below} + e * q_{lane} + f * HV + g * LG + h * l_W + i * v_{perm}} \quad (1)$$

Compared to existing guidelines this approach contains additional values which describe the differences between weaving types V3, V3+, V4 and V4+ more precisely. In total about 20,000 different simulation experiments were tested with a total of about 10,000 breakdowns. Taking all breakdowns and using vehicle speed as target value the following statistics were generated within an ANOVA test (Table 1).

Table 1: Results of Linear Multiple Regression Analysis for weaving types V3, V3+, V4 and V4+

Regression-Statistics	
Multiple R	0,68708645
R Square	0,47208779
Adjusted R Square	0,471672887
Standard Error	5,973673218
Observations	10188

ANOVA

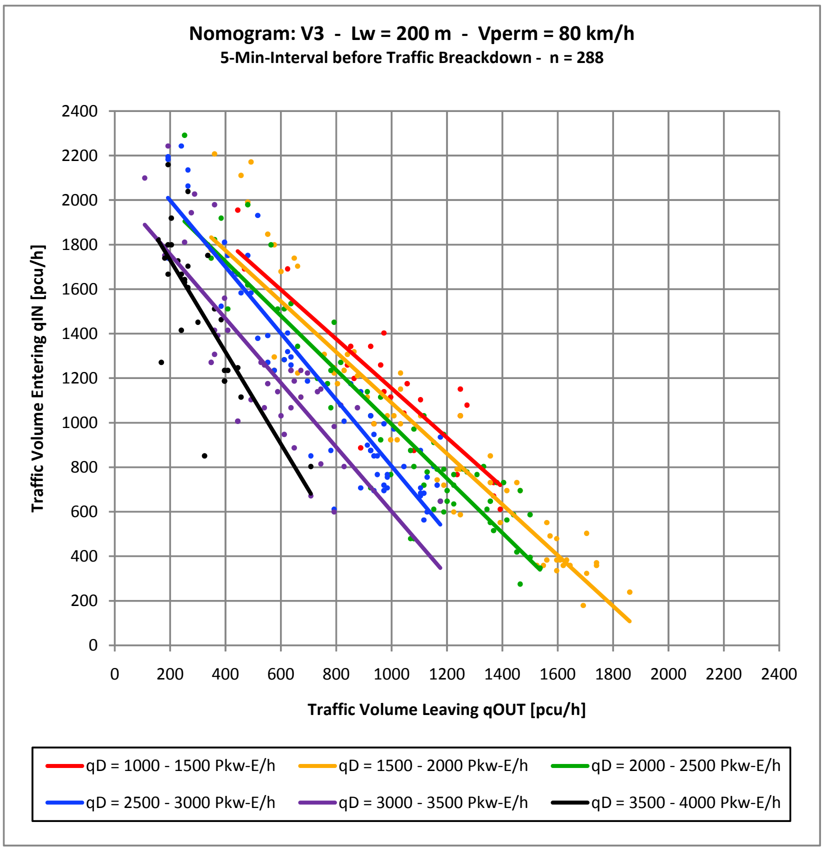
	df	*SS*	*MS*	*F*
Regression	8	324824,7387	40603,09234	1137,826877
Residual	10179	363235,2912	35,68477171	
Total	10187	688060,0299		

	Coefficients	*Standard Error*	*t-Stat*	*P-value*
Intercept	26,76044945	1,083256104	24,70371443	6,6446E-131
QVo	1,050970861	1,904526915	0,551827781	0,581078466
QVu	3,048341005	1,763480239	1,728593799	0,083912144
QV	-6,189482313	2,585619645	-2,393810058	0,016692371
qFst	0,001098364	0,000286426	3,834727335	0,000126462
SV	-13,68561852	3,758857924	-3,640898059	0,000273036
lV	0,004466599	0,000393883	11,33990942	1,25288E-29
FstGeo	-0,115374242	0,014799813	-7,795655253	7,03413E-15
vzul	0,571738583	0,007592734	75,3007519	0

Linear Regression Analysis –Graphs (Nomograms)

In German speaking countries graphical representations (nomograms) are preferably used in guidelines instead of mathematical equations. Therefore linear regression analysis was used to calculate such graphs.

The nomograms differentiate not just between weaving type but also between lengths of weaving section, which is a crucial parameter for capacity. Input values are capacity of access and exit ramp, as well as weaving section type and length. As output value capacity of passing traffic can be deduced from nomograms.



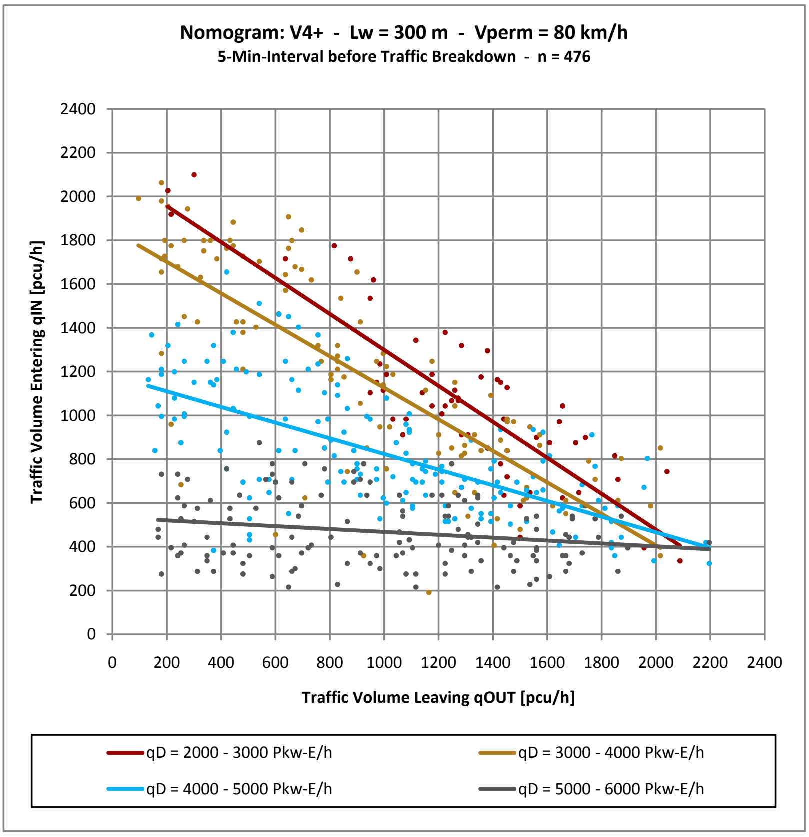


Figure 4: Two examples for V3 and V4+ nomograms

The following points will be added in the full paper / presentation:

a) *Sensitivity analysis of the Vissim calibration parameter set*
b) *Elaboration of the statistical results of the multiple linear regression*
c) *Further nomograms suited for guidelines*
d) *Discussion of the results on multilane weaving sections and transferability to other countries*

Acknowledgements

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