Analysis of Shockwaves on Motorways and Possibilities of Damping by C2X Application

Master‘s Thesis of Nassim Motamedidehkordi

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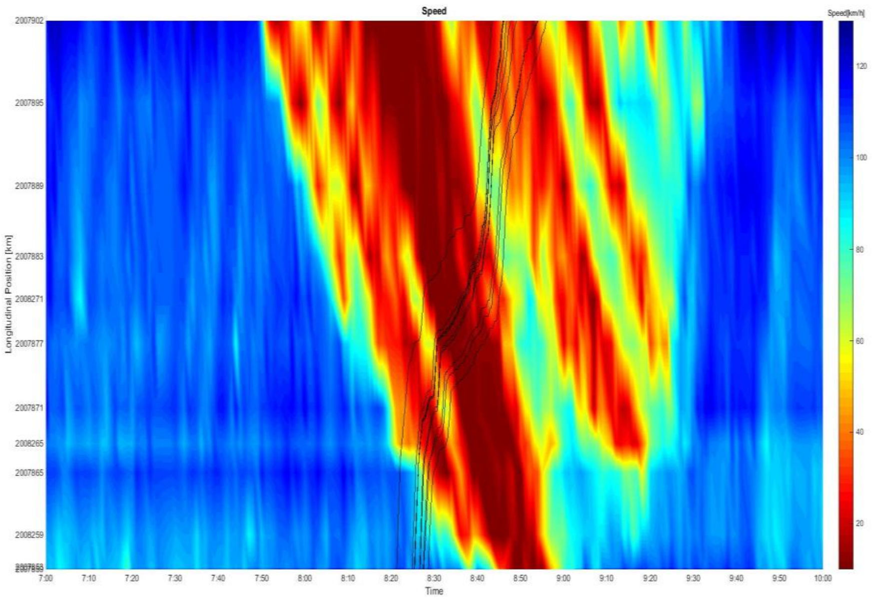
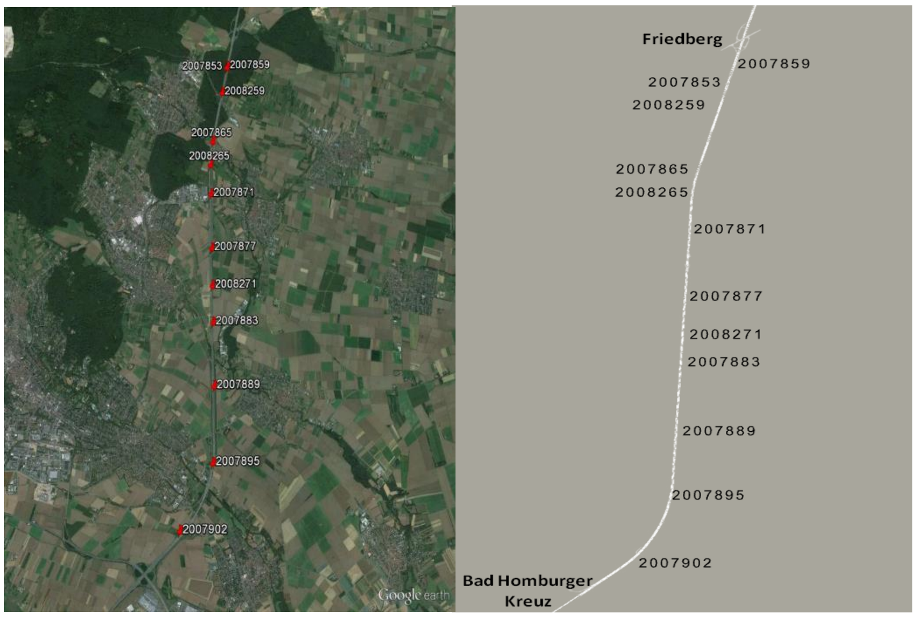


The physical realization of a shockwave is point in time and space at which vehicles change their speed abruptly. The formation and dissolving of congestion are the phenomena that are important for the traveler information and congestion management perspectives. Besides, shockwaves are major safety concerns for transportation because they are originated from a sudden, substantial change in the state of the traffic flow. Shockwave analysis is the method to identify congested areas and estimate the rate of formation and dissipation of the congestion. There are different categories of shockwaves: 1) Forward forming 2) Backward forming 3) Frontal stationary 4) Rear stationary 5) Forward recovery 6) Backward recovery. For this study the data from the German research project-sim^{TD} was used. Microscopic data included detailed sub-second information of equipped vehicles and macroscopic data included the aggregated data recorded by loop detectors. The major shockwave observed in empirical data on 11.10.2012 was chosen as a base for further analysis.

The motorway segment is an 8.5 kilometer long section of motorway A5 in Hessia, Germany between Friedberg and Bad Homburger Kreuz in the North of Frankfurt/Main. The microscopic traffic simulation tool Vissim was used to address the main objective of this study, namely to determine if and to what extent the driving behavior parameters influence the shockwaves on motorways. To achieve this goal, precise calibration of the car following behavior based on the detected shockwaves from the empirical data has been carried out and the comparison between simulation result and field data was investigated for each simulation scenario in order to find the best combination of the driving behavior parameters and reproduce shockwaves. Overall, 161 different combination of car following parameters were tested. Furthermore, the influence of autonomous driving and C2C Traffic Jam Ahead Warning application on shockwaves, for penetration rates of 5 %,10 %, 20 %, 50 %, 100 % was investigated.



Penetration Rate	Autonomous Driving		C2C Communication	
	Shockwave Propagation Speed [km/h]	Percentage Change	Shockwave Propagation Speed [km/h]	Percentage Change
0 %	-11.17	-	-11.17	-
5 %	-10.49	-6.1 %	-10.77	-3.6 %
10 %	-10.17	-9.0 %	-10.39	-7.0 %
20 %	-8.78	-21.4 %	-9.14	-18.2 %
50 %	-6.26	-44.0 %	-7.52	-32.7 %
100 %	-4.81	-56.9 %	-5.4	-51.7 %

It is difficult to notice a clear change at penetration rates below 20 %. As the penetration rate exceeds 20 %, considerable changes can be observed. It seems that having 20 % of equipped vehicles in the fleet is enough to influence the unequipped vehicles noticeably. The simulation results shows that autonomous driving decreases the propagation speed of the shockwave and also increased the average network speed significantly as their shorter reaction time allow them to safely ride a bit closer on the tail of the lead vehicle. When doing so, automated vehicles can pack far more cars on the same road and increase the capacity of the existing facility. On the other hand the C2C communication increases the safety as result of lowering the speed of vehicles approaching the tail of congestion but they can not have a considerable positive effect on the network performance. Shockwave propagation speed always decreases as the penetration rate increases. It seems that the dissolving speed of the shockwave did not change by any of these applications.