Simulative Investigation of Shockwave Damping Measures on Freeways

Master‘s Thesis of Murtaza Sultani

Mentoring:

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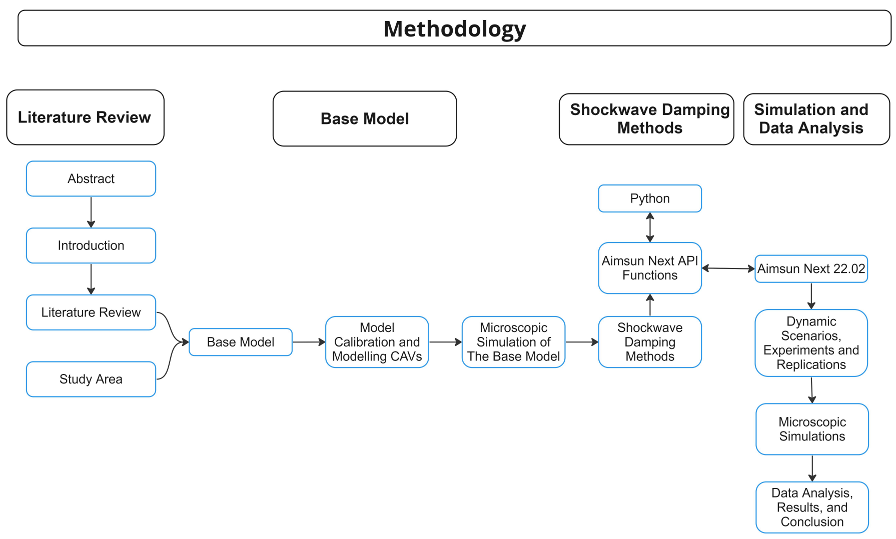

Fig. 1: Methodology for Simulative Investigation of Shockwave Damping Measures on Freeways

Results:

The study shows that with a capacity flow, CAVs with 25 % penetration rate and above dampen shockwaves on the freeway section. Higher volume of CAVs improve connectivity, intelligence, and capacity of the freeway section. They form platoons and move wisely and collectively in cooperative and coordinated way. A CAV moves smoother and safer than a human driven vehicle in an expected manner. CAVs brake and accelerate less frequently and can keep a safer and closer headway to the leader vehicle. Also, they reduce human related errors and therefore reduce delay, travel time and road crashes on freeways. However, with lower penetration rates, CAVs are unable to form platoons and cooperate effectively. Since they have less reaction time and their individual movement is unexpected; they cause local disturbances, and negatively affects the flow. The summary of the microscopic simulations is illustrated by the following table and fig. 2. Furthermore, a methodology to dampen the schockwaves on freeways is proposed. First, they are detected if certain conditions are met.Then, if there is one, mitigative algorithms are applied. The first algorithm adjusts the desired speed of CAVs based on the average speed of vehicles on a segment. The second one sets different speed limits for each lane, and then moves CAVs to the lane that serves them the most.

Scenarios	Delay Time (s)	Travel Time (s)	Speed (km/h)	Density (veh/km)
Base Model	39.36	61.43	73.61	8.71
1% CAVs	140%	66.9%	- 41.43%	111%
10% CAVs	117.4%	55.9%	-35.63%	107%
25% CAVs	-16.18%	-8.10%	10.39%	18.48%
50% CAVs	-21.49%	-10.97	12.65 %	20.89 %
100% CAVs	-3.33%	-2.89%	9.86%	59.7 %

Table 1: Microscopic Simulation Results of varying CAVs' penetration rates

Background:

Shockwaves on freeways form due to traffic congestion waves moving upstream. This negatively affects traffic safety and mobility. Shockwaves are caused by high traffic volumes, bottlenecks, or local disturbances due to drivers' failure to deal with traffic conditions. This thesis explores the influence of CAVs on damping the shockwaves by investigating scenarios in microscopic simulations. As Fig.1 elaborates, the study is conducted on a typical freeway section with three lanes and ramps, and a demand equal to capacity flow rate. The base model is built and calibrated in Aimsun Next 22.0.2 and then the simulation results of six scenarios are compared using KPIs of speed, density, delay, and travel time. Two damping methods that utilize CAVs and Aimsun Next API functions are developed in python. Besides, an optimal penetration rate is proposed. Besides, a detection algorithm within integrated V2V and V2I communication system are proposed. Finally, the limitation of the study, and further researches on this topic are discussed.

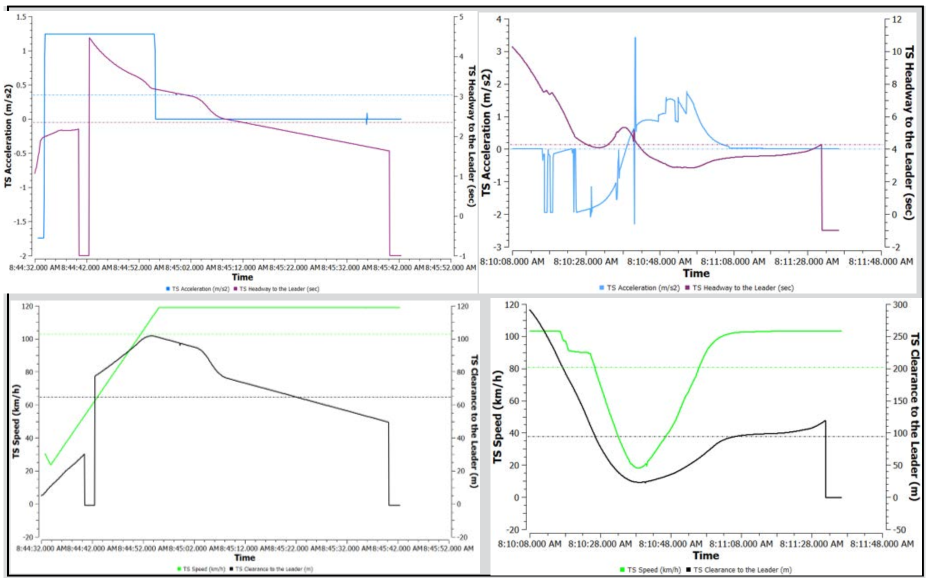

Fig. 2: Microscopic Characteristics of CAVs vs Human Driven Vehicle

Limitations and Future Research Directions:

The study is conducted on a freeway section and the model is not validated due to lack of data. It considers only cars and trucks; other transport modes are not considered. The study is performed for the capacity flow rate of 1800 veh/lane, and the results vary for different demands. Also, the Aimsun Next 22.0.2 expert edition has functionality limits. CAVs capability to adjust their dynamics – acceleration and deceleration at short time is questionable. The proposed methods run but are not effective, though the available API functions are applied. Nevertheless, CAVs application requires legislative reforms, advanced communication systems, technologies, and equipment. The study is conducted based on some assumptions. Further researches are proposed to improve Aimsun Next API Functionality, the communication systems, and CAVs capability in dampening the shockwaves with varying traffic demands.