Examining Road Safety Impacts of Green Light Optimal Speed Advisory (GLOSA) System

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1. Introduction

Green Light Optimal Speed Advisory (GLOSA) is a Day 1 C-ITS signage application, enabled by the C-ITS service "Signalised Intersections". The application utilises traffic signal information and the current position of the vehicle to provide a speed recommendation in order for the drivers to pass the traffic lights during the green phase and therefore, reduce the number of stops, fuel consumption and emissions. The distance to stop, the plans for signal timing and the speed limit profile for the area are taken into account to calculate the speed recommendation displayed to the driver. GLOSA service is provided through ETSI G5 into the on-board computer of the vehicle or via mobile network into a smartphone application. In the era of CAVs, it would be useful for cities, various stakeholders, and transport planners to assess the societal impacts of such an application in an urban area and attempt to evaluate the benefits in relation to the relevant costs.

2. Key Findings from Literature Review

With regards to previous studies exploring the impacts of the GLOSA system, [1] provided a review of 64 publications between 2006 and 2019 investigating GLOSA. Most of them based their findings on simulation, with a much smaller amount using real-world methods (e.g., pilots, FOTs). The on-board GLOSA algorithm was proposed as the main solution in the majority of the studies, which involves determining advisory speed within a feasible range of minimum and maximum speeds to enable vehicles to move through the intersection through green phase with fewer of them proposing the whole system design including infrastructure for communication) and/or predicting signal changes as the solution. The focus was on the equipped vehicle in most studies, as opposed to fellow road users or other societal issues. In terms of impacts, many of the studies looked at the effect of varying traffic levels on GLOSA effectiveness. No publications examined drivers' ability to follow the advised speed.

The review also identified only a few studies which investigated the safety implications of GLOSA system. As indicated [1], most of the previous studies have examined impacts on energy consumption, travel time, stop time, and emissions. Many of them have reported benefits of GLOSA implementation in reducing average fuel consumption, travel times, and emissions [2-4]. In this regard, previous studies have also reported that benefits of GLOSA system can be achieved if used with fixed time signal controllers. For instance, Stevanovic et al. [5], used a calibrated simulation model (developed in VISSIM) of a network comprising of two signalised intersections. Results indicated better traffic performance in case of fixed time controllers but not under actuated-coordinated (difficult to accurately predict) signal operations. Under fixed-time controllers, the authors also reported improvement in traffic performance with higher market penetration rate (MPR) and increased frequency of GLOSA system activation.

Overall, limited literature exists specifically on road safety impacts of GLOSA or similar systems; however, the available evidence suggests potential reduction in rear-end crashes with the application of GLOSA on pre-timed signals.

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3. Methodology

Quantification of safety impacts was performed with surrogate safety assessment which involves processing vehicular trajectories to identify traffic conflicts in the surrogate safety assessment model (SSAM) by Federal Highway Administration through various parameters including time to collision (TTC), post-encroachment time (PET), variation in speed and acceleration, and conflict angle. In order to assess the impact of GLOSA application on safety, the surrogate safety assessment was performed with and without GLOSA application on the study network.

3.1. Study Area and Analysis Scenarios

The traffic microsimulation model used for this study was provided by Transport for Greater Manchester. The study area is around 1.22km² and contains 53 nodes, 95 road section, and an OD matrix of 11×11. Traffic data of evening peak hours (17:00 – 18:00) was used, with an estimated traffic demand of 3738 cars, 308 goods vehicles (LGV), and 127 heavy goods vehicle (HGV) trips. For implementing GLOSA, a corridor near the Salford area was selected in Manchester including three signalized intersections (Figure 1) where the distance between the first and second intersection is around 400m whereas that between the second and third intersection is around 800m. The impact of GLOSA was analysed under fixed time coordinated traffic control at these study locations signals.

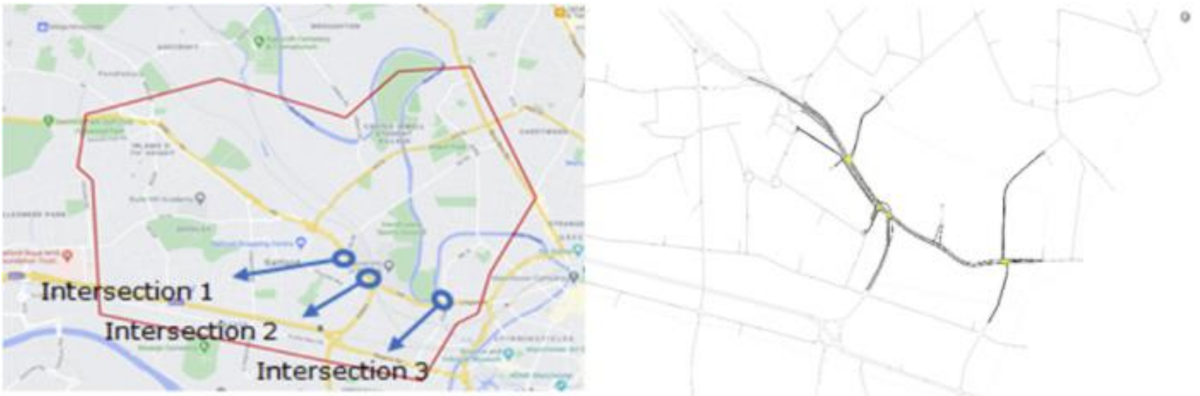

Figure 1: Test corridor in Manchester network for GLOSA application

The test scenarios on GLOSA implementation and CAV deployment are as follows:

- Baseline scenario – No GLOSA, CAV market penetration from 0% to 100% in 20% increments.
- Scenario 1 – GLOSA on intersection 1,
- Scenario 2 – GLOSA on intersections 1 and 2, and
- Scenario 3 – GLOSA on intersection 1, 2 and, 3.

Simulations were performed for the peak hours on baseline and all three analysis scenarios with CAV deployment as shown in Table 1.

Table 1: CAV Deployment scenarios

Type of Vehicle	CAV Deployment Scenarios							
	100-0-0	80-20-0	60-40-0	40-40-20	20-40-40	0-40-60	0-20-80	0-0-100
	Passenger vehicles							
Human-Driven Vehicle	100%	80%	60%	40%	20%	0%	0%	0%
1st Gen CAV	0%	20%	40%	40%	40%	40%	20%	0%
2nd Gen CAV	0%	0%	0%	20%	40%	60%	80%	100%
	Freight vehicles							
Human-Driven LGV	100%	80%	40%	0%	0%	0%	0%	0%
LGV-CAV	0%	20%	60%	100%	100%	100%	100%	100%
Human-Driven HGV	100%	80%	40%	0%	0%	0%	0%	0%
HGV-CAV	0%	20%	60%	100%	100%	100%	100%	100%

The following assumptions were made in the frame of GLOSA application.

1. The quality of communication between signals and vehicles is ideal and all messages are delivered successfully and without delay,
2. All the drivers accept and comply with the recommended speed,
3. GLOSA is applied at each simulation step, and
4. Only CAVs will have the capability to communicate with traffic signal controllers.
5. Simulations were run for the peak hours performing 10 replications under each scenario.

The CAVs behaviours were modelled using Gipps car-following model [6, 7]. To simulate HDV and CAV behaviours, various parameters of the car-following model were adjusted. The assumptions on CAV behavioural parameters and their values were derived based on a comprehensive literature, which included both empirical and simulation-based studies as well as discussion with experts during LEVITATE project meetings. The details on each parametric assumption, within LEVITATE project, on CAV driving behaviour can be found in [8].

3.2. GLOSA Algorithm

GLOSA Algorithm was developed based on reviewing some of the previously developed algorithms in literature [5] with modifications as deemed adequate for the test network. Before applying the GLOSA algorithm on the test network, the impact of activation distance and frequency of GLOSA on overall traffic performance was analysed. Based on the results, the activation distance was kept to 400m while GLOSA was applied on each simulation time step. Minimum speed threshold was kept as 50% of speed limit following the suggestions provided in some previous studies [9, 10] while upper limit was kept as speed limit +5mph.

4. Analysis and Results

The surrogate safety analysis was conducted using FHWA SSAM model which is a software application designed to perform statistical analysis of vehicle trajectory data output from microscopic traffic simulation models. The details of the surrogate safety assessment method and various parametric assumptions used for the analysis can be found in [11].

The effects on road safety of increasing automation of the vehicle fleet together with implementation of GLOSA are quantified using microsimulation in Aimsun combined with the SSAM tool which identifies potentially dangerous traffic interactions (traffic 'conflicts'). A prediction for the resulting change in conflicts is made for the test scenarios presented under section 3.1.

The analysis of TTC distributions of the conflicts results, obtained from microsimulation and SSAM analysis, indicated a large number of TTC events falling at 0 or below 0.1s (crash or near crash situation). Theoretically, the low value of TTC (0.1s) represents crash/near-crash situation, although the simulation software is not able to model the crash events. In addition, SSAM is likely to mark even safe interactions involving CAVs as conflicts due to shorter headways or potentially assign an event as conflict incorrectly when a vehicle is unable to complete an initiated lane change due to a congested environment [12]. Thus, the number of events with very low values of TTC (0.1) can be considered as noise/systematic bias which could be either from Aimsun or/and SSAM. Due to this reason, it was decided to remove the noise in the conflicts data with very low TTC values (TTC<=0.1s) within LEVITATE project. Additionally, a large number of conflicts were identified involving freight vehicles, which could be due to inadequate modelling to these vehicles. Further details on TTC distributions and conflicts involving freight vehicles can be found in the report on Road Safety related Impacts within the LEVITATE project [11].

The traffic conflicts results involving passenger cars, for the aforementioned analysis scenarios, are presented in Figure 2. The numbers in the plots represent percentage change in conflicts (normalised per 1000 veh-km) against varying fleet composition for the study network. The figures in fleet composition refers to percentage of human-driven vehicles, 1st Generation CAVs, and 2nd Generation CAVs, respectively. These results represent average of 10 simulation runs with different random seeds.

It can be observed through the trends in Figure 2 that the application of GLOSA system on multiple intersections indicate added benefits as opposed to single intersection implementation in the study network. The multiple implementation cases show almost 16-17 % reduction in conflicts at full MPR scenario. The results also show reduction in conflicts under GLOSA application (on multiple intersections) with low MPR of 1st and 2nd Generation CAVs, ranging 9-16% and 10-12% respectively. With higher MPRs of CAVs under GLOSA implementation on single intersection in the study corridor, safety was found to be negatively affected.

The results have been further segregated into conflict type. i.e., rear-end, lane-change or crossing conflict. As can be clearly seen, the rear-end conflicts dominate all scenarios. Overall, an interesting trend on conflicts type can be observed indicating a slight increase in lane change conflicts with GLOSA application as compared to the baseline scenario. Similar trends on lane change conflicts were also reported by an earlier study investigating the safety impacts of GLOSA system through surrogate safety assessment [13]. Rear end conflicts under GLOSA scenarios were only found to decrease at low MPRs of 1st and 2nd Generation CAVs where the maximum reduction was found to be 7% (under low MPR of 1st Gen CAVs) in case 3 when GLOSA is applied on all three intersections as compared to the baseline. Overall, a minor increase (not more than 3%) was observed on crossing conflicts with multiple intersections implementation as compared to the bassline and single intersection application; however, the increase was not found to be consistent across all the MPR scenarios.

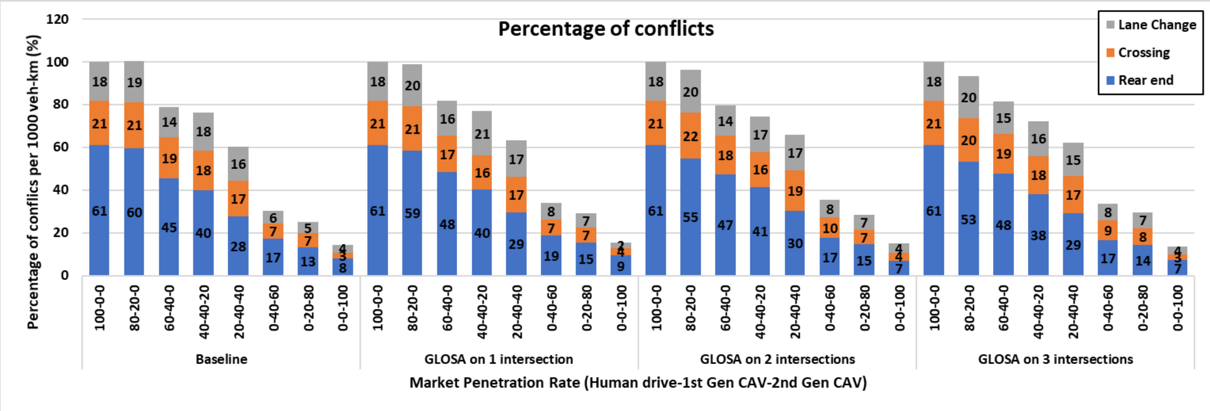

Figure 2: Percentage of conflicts w.r.t baseline (100-0-0) per 1000 veh-km travelled based on conflicts type

5. Discussion and Safety Implications

In general, GLOSA is expected to result in lesser number of stops (smoother traffic flow), which will likely decrease the number of crashes with increasing MPRs of GLOSA equipped vehicles. The results of this study show potential increase in safety (almost 16-17% reduction in conflicts at full CAV MPR as compared to the baseline scenario) when GLOSA was applied on multiple intersections along the study corridor. However, the results were not found to be consistent across all MPR scenarios. Most prominent impact was found to be either under low MPR of 1st and 2nd Gen CAVs or under full MPR of 2nd Gen CAVs. One potential reason could be the assumptions used on modelling behaviours of CAVs and the complexity of interactions under the mixed fleet scenarios with higher MPRs of 1st and 2nd Gen CAVs. The results rather showed an overall negative impact on safety when GLOSA was implemented on only first intersection along the study corridor. It was also found in the study and reported by the previous research [13], that the GLOSA application can potentially impact the proportion of conflict types, with potential decrease in rear-end conflicts and slight increase in lane-change conflicts. It is important to note that these results have several dependencies including network characteristics (e.g., intersection configuration, spacing between intersections, controller type), GLOSA activation frequency, as well as assumptions on the quality of communication between signals and vehicles (ideal and without delay), only CAVs to be GLOSA equipped, and the 100% advisory speed compliance rate.

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