Exploitation of ACC systems towards improved traffic flow efficiency on motorways

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***Abstract*—This study presents an ACC (Adaptive Cruise Control)-based traffic control strategy which aims to adapt in real time the driving behavior of ACC-equipped vehicles to the prevailing traffic conditions so that the motorway traffic flow efficiency is improved. The potential benefits obtained by applying the proposed control concept are demonstrated for different ACC penetration rates by use of validated microscopic simulation applied to a real motorway stretch where recurrent traffic congestion is created due to an on-ramp bottleneck. The simulation results demonstrate that, even for low penetration rates of ACC vehicles, the proposed control concept improves the average vehicle delay and fuel consumption by reducing the space-time extent of congestion compared to the case of only manually driven or regular ACC vehicles.**

***Keywords*— Adaptive cruise control (ACC); motorway traffic control; microscopic simulation**

I. INTRODUCTION

The number of cars equipped with Adaptive Cruise Control (ACC) systems has increased in recent years and will further increase in the near future. The ACC systems extend the functionalities of earlier cruise control systems, enabling the drivers to adjust, except for the desired maximum speed, also the desired time-gap to the leading vehicle when following slower vehicles. Based on the driver's settings and the current measurements, the ACC system determines and applies automatically the appropriate acceleration or deceleration of the ACC-equipped vehicle.

At present, ACC systems are mainly designed to increase the driving safety and comfort, which may imply conservative values for the ACC system settings, i.e. comparatively large time-gaps and low accelerations. For example, while a range of time-gap values is available for the driver to select her desired one, the recommended time-gap value is typically 2 s. Such conservative parameter values, however, may eventually lead to the degradation of the static and dynamic road capacity compared with conventional manual-driving vehicle traffic. The higher the percentage of the ACC-equipped vehicles (penetration rate), the more pronounced will be the influence of their driving modus on the surrounding traffic flow.

The aim of this research work is to investigate the development of novel traffic management concepts which will enable the exploitation of the ACC systems towards increased traffic flow efficiency compared to both conventional manual-driving and to regular-ACC traffic. In particular, we present a real-time motorway traffic control strategy, which adapts the driving behavior of the ACC-equipped vehicles when and to the extent needed, based on the traffic situation on the motorway. More specifically, the control strategy receives real-time measurements (or estimates) about the current traffic conditions on the infrastructure and suggests to the drivers (or imposes directly) an appropriate value for the time-gap parameter. Clearly, the realization of this action is only possible if, at least a portion of, ACC-equipped cars are connected to receive the corresponding instructions. The proposed control strategy is implemented in a validated real network simulation model and is tested through microscopic simulation. The simulation results demonstrate that the application of the proposed strategy, improves the motorway traffic conditions significantly, even for low ACC penetration rates, compared to the case where the ACC-equipped vehicles are driving with their initial, default ACC settings.

The paper is organized as follows. Section II includes the review of relevant literature. The proposed ACC-based control concept is presented in Section III, while in Section IV, the simulation set-up is described first, followed by the results of the investigations. Section V contains the conclusions of this study, as well as the future research steps.

II. REVIEW OF LITERATURE

Over the last decades, there has been an enormous interest towards the development of advanced driver assistant systems such as Adaptive Cruise Control (ACC) and Cooperative Adaptive Cruise Control (CACC) systems. These systems were initially conceived and designed to increase the driving safety and comfort, by providing to the drivers of equipped vehicles assistance to follow other vehicles in a safe and comfortable manner. However, it is realized that some of these driver assistance systems may have a (positive or negative) impact on traffic flow efficiency; and, equally importantly, that they could be exploited to relieve the road networks from traffic congestion and its negative effects [1].

In contrast to the vast literature on ACC and CACC systems, which focuses on the design, functionality or architecture of these systems, there is a comparatively small number of works which investigate the impact of ACC and CACC systems on traffic flow. In [2], simulation results with both manual and 10% ACC-equipped vehicles are presented, which demonstrate that fuel consumption and air pollution are significantly improved, and the average traffic flow is increased compared to the case with 100% manually driven vehicles. This study is extended in [3], where similar

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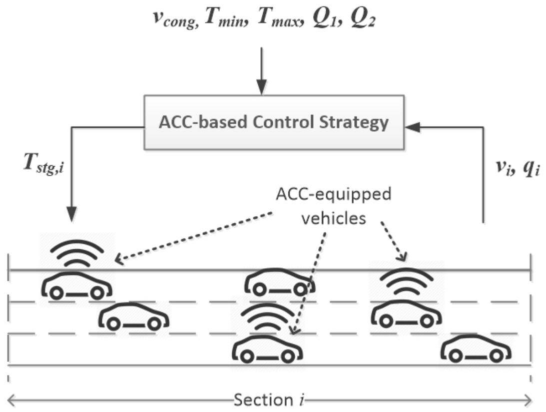

Fig. 1. Illustration of the control strategy operation.

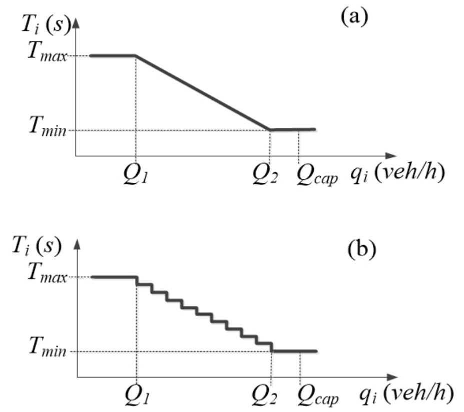

Fig. 2. Calculation of the suggested time-gap value using: (a) a linear, or (b) a stepwise function.

experiments are carried out, considering additional factors, such as the level of flow disturbance, the penetration rate etc.; [3] also evaluating the effect of lane changing on both the traffic flow and the environment. The simulation results demonstrate the beneficial effects of ACC-equipped vehicles, which may though vary with the levels of the disturbance, the penetration rate etc.

In [4] a CACC system is investigated, which is applied, through simulation, at a four-lane motorway stretch with a lane-drop bottleneck. Considering fixed values for the parameters of the CACC system and various penetration rates, the respective impact on the traffic flow performance is examined. The simulation results show that, as the penetration rate increases. the traffic flow stability is improved, along with a significant increase in average speed and traffic throughput compared to the scenario of 100% manually driven vehicles.

In [5] human drivers and CACC-equipped vehicles are simulated on an one-lane motorway stretch. After inducing an initial perturbation, the growth of shockwaves and the impact of the applied CACC system on traffic flow stability are examined. In the investigated scenarios, two different distributions for the headway parameter of the CACC system are tested, as well as various penetration rates, and it is concluded that shockwaves are damped quicker for higher penetration rates.

In [6] microscopic simulation is used to estimate the effect of ACC and CACC equipped vehicles on highway capacity for varying penetration rates. The time-gap settings for the ACC and the CACC systems were defined using a distribution obtained from a real field experiment. The simulation results showed that comparing the ACC with the CACC systems the second where more likely to significantly increase the capacity flow, for moderate to high penetration rates.

All above studies agree on the fact that ACC and CACC systems have the potential to improve the traffic flow conditions. However, the above studies do not systematically examine how the settings of the ACC and CACC systems affect the motorway operation, and how these setting should be actually specified. [7] advances towards this direction by proposing the offline optimization of the ACC system parameters. In particular, a genetic algorithm is used to estimate various optimal settings for different optimization criteria. The simulation results show that, depending on the control priorities and trade-offs (e.g. safety improvement versus mobility improvement), the corresponding optimal settings may lead to significant improvement in safety or traffic flow performance, especially in case of medium to high penetration rates.

[8] and [9] go a step further by considering the possibility of providing, in real time, action advice to vehicles featuring appropriate automation and connectivity capabilities. Different priorities are set, according to different appearing traffic situations, leading to corresponding adapted action advice for individual vehicles. In particular, they propose an advisory system, located in a traffic management centre, which, based on the identified traffic state on the motorway, provides advice on speed, headway (to facilitate lane changing), acceleration and lane use to the equipped vehicles. The system was tested in simulation and the obtained results showed considerable benefits, particularly for high penetration and compliance rates.

Another real-time approach was suggested in [10] and [11] where, for different identified traffic states, the ACC-equipped vehicles adapt their default settings. These traffic states are detected autonomously by each ACC-equipped vehicle using an appropriate detection algorithm. The strategy was tested through simulation for a motorway stretch with an on-ramp bottleneck, and it was found that the ACC-equipped vehicles with dynamic settings improve the traffic stability and the road capacity. However, due to the pursued autonomous operation (no vehicle connectivity), some complexity may be inevitable in the algorithm utilized by each individual ACC-equipped vehicle to identify the encountered traffic states, involving, except for vehicle sensor measurements, also spatial criteria, plus a heuristic approach in case multiple criteria are met simultaneously. Moreover, when a different traffic state is identified, the change of the settings of the ACC system is effectuated abruptly which might cause some discomfort to the drivers.

In this study, a simple but effective ACC-based control strategy is presented which aims to adjust in real time the ACC settings of equipped and connected vehicles, in particular the time-gap parameter, based on the prevailing traffic conditions.

The main philosophy behind the proposed concept is to: (i) leave the ACC-settings untouched at their driver-selected values if traffic flow is clearly under-critical so as to limit interventions only to traffic situations that call for efficiency increase; and (ii) change the ACC-settings gradually as appropriate to improve the flow capacity when critical traffic states are imminent; this latter action is only dependent on real-time information about the current traffic conditions and is expected to be activated only when, where and to the extent needed, e.g. at the start of the peak period at bottlenecks, at incident locations etc. The proposed strategy considers that the ACC-equipped vehicles communicate with a traffic management centre which suggests to the drivers or imposes directly appropriate values for the time-gap parameter. The strategy requires real-time flow and speed measurements (or estimates) for motorway sections, as a basis for the issued ACC-settings recommendations in each section. Next section describes in detail the proposed ACC-based control concept.

III. ACC-Based Control Concept

According to literature findings, the ACC systems have the potential, not only to increase the driving safety and comfort, but also to smooth traffic flow, decrease fuel consumption, and improve traffic flow efficiency. However, if conservative values are set for their parameters, then the ACC systems may actually lead to a deterioration rather than improvement of traffic flow efficiency. In fact, although drivers of ACC-equipped vehicles are offered a range of 0.8–2.2 s to select their desired time-gap to the front vehicle, the time-gap recommended by most automotive manufacturers is 2 s, which would lead to a significant reduction of motorway capacity per lane. This fact can be mitigated if the settings of the ACC-equipped vehicles could be updated dynamically in real time through the operation of an ACC-based control strategy.

The time-headway of two vehicles, following each other with time-gap T, equals $T + L/v$, where v is the speed of the following vehicle and L is the front vehicle length. The traffic volume on a motorway lane equals the inverse of the average time-headway, hence, assuming homogenous traffic and vehicle conditions, the traffic flow equals $(T + L/v)^{-1}$; while for the capacity per lane we have $Q_{cap} = (T + L/v_{cr})^{-1}$, where v_{cr} is the (critical) vehicle speed at capacity. For example, with $L = 5$ m and $v_{cr} = 20$ m/s, this relation yields a lane capacity of 1600 veh/h for a (recommended) time-gap of 2 s, which is drastically lower than the typical capacity of manually-driven vehicle traffic; while a time-gap of 0.8 s yields a capacity of 3429 veh/h which is drastically higher than the typical capacity of manually-driven vehicle traffic. Although these values are only rough estimates for heterogeneous and multilane traffic, they do indicate that, in a mixed context with both manually and ACC driven vehicles, any reduction of the time-gap applied by ACC-vehicles increases the motorway capacity; and that the adoption of the minimum time-gap of 0.8 s would lead to a maximum achievable capacity value for any percentage of ACC-vehicles.

The proposed control strategy aims to exploit this potential in presence of connected ACC-vehicles by determining in real time time-gaps leading to capacity increase when, where and to the extent deemed necessary. Consider a motorway which includes both manually driven and ACC-equipped vehicles. The ACC-vehicle drivers may introduce their desired ACC system settings, i.e. desired speed, v_d, and minimum time-gap, T_d, but the latter is subject to change if the control strategy recommends or orders a lower time-gap. The motorway is considered to be divided into sections (see for example Fig. 4), and the traffic management centre applies the proposed control strategy at every motorway section i=1,2,… independently, as illustrated in Fig. 1. In particular, at every period (or control interval) t_c, the strategy receives real-time measurements (or estimates) of the entering flow q_i and speed v_i of every section i. This information may be obtained through ordinary loop detectors, or may be estimated using V2I communication (see, e.g. [12]). In the light of the above discussion, the strategy calculates the suggested time-gap as a function of the current section flow, $T_i[q_i(k)]$, as shown in Fig. 2(a). This function implies that, as long as the flow prevailing in the section is low (i.e. $q_i \le Q_1$), the maximum time-gap, $T_{\max}$, is suggested. As the flow increases, the strategy gradually decreases the suggested time-gap value, while for high flow values (i.e. $q_i \ge Q_2$) the strategy suggests the minimum time-gap $T_{\min}$. Note that the suggested time-gap value is reduced to the minimum value before the flow reaches the nominal capacity of the section. In this way, the strategy aims to delay, or even prevent, the formation of congestion, by maximizing timely the section's capacity. It should be also noted that the adopted function $T_i[q_i(k)]$ of time-gap versus flow must be decreasing, but can, other than that, have any form deemed appropriate, e.g. deliver only a (high or low) number of discrete time-gap values, rather than being continuous, as the stepwise function shown in Fig. 2(b). It is easy to realize that in this case, higher numbers of discrete gap values would lead to more frequent but less abrupt gap changes for the advancing ACC-vehicles.

If, despite the intended capacity increase, the section becomes congested (e.g. due to even higher arriving demand or due to a shock wave arriving from downstream), then the actual flow values may decrease, hence the function $T_i[q_i(k)]$ may deliver accordingly increased time-gaps. In order to handle congested traffic situations in a univocal way, the strategy needs to also consider real-time information about the prevailing section speed v_i, based on which any desired time-gap policy for congested conditions may be implemented. For example, we will consider here that for congested traffic, i.e. if $v_i < v_{cong}$, the strategy suggests the minimum time-gap.

Regarding the specification of the motorway section length, it should be noted that shorter sections tend to reflect more homogeneous traffic conditions and may therefore lead to more pertinent suggested time-gaps; for the price of more frequent time-gap changes experienced by advancing ACC-vehicles. A similar trade-off applies also for the selection of the strategy's update period t_c.

The above control decisions are summarized by the following equation which determines the suggested time-gap:

$$T_{stg,i}(k) = \begin{cases} T_{\min} & if \;\; v_i(k) < v_{cong} \\ T_i[q_i(k)] & else \end{cases}, \qquad (1)$$

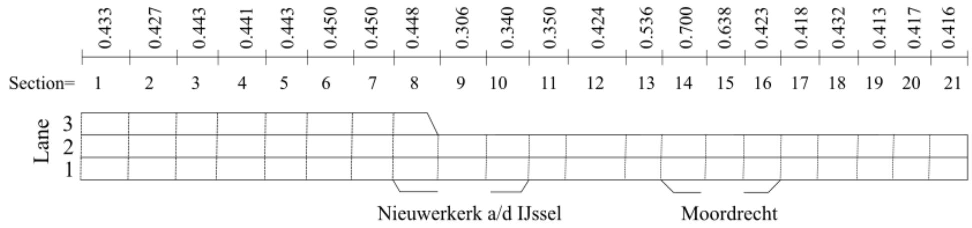

Fig. 3 Sketch of the motorway A20 in Netherlands.

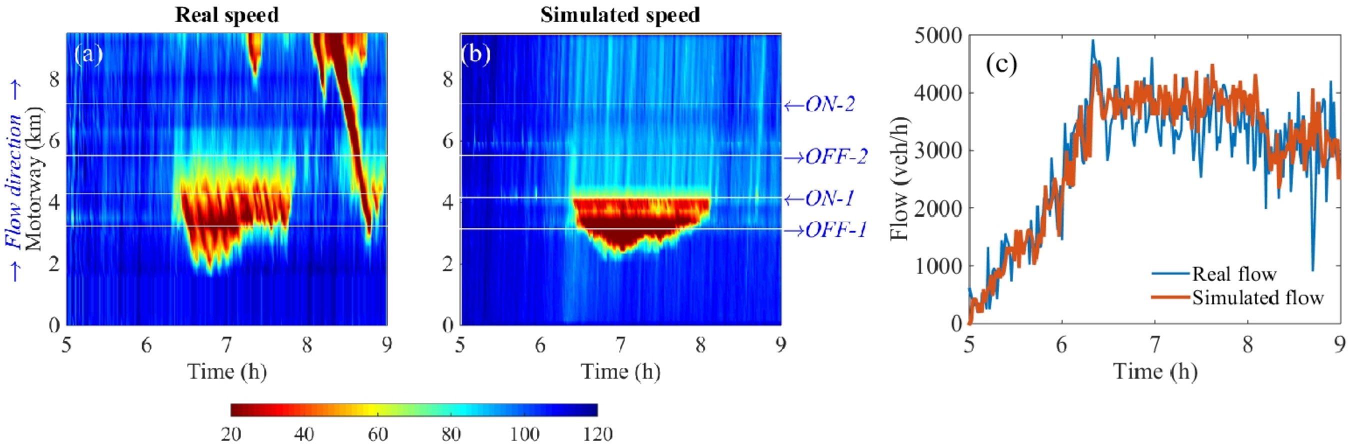

Fig. 4. (a) Spatio-temporal diagrams of real speed; (b) Spatio-temporal diagrams of simulated speed, and (c) real and simulated outflow from the merge area.

where k=1,2,…, is the discrete time index. Since the control strategy decisions are calculated externally, at an infrastructure-based traffic management centre, they must be disseminated to the ACC-equipped vehicles, e.g. via V2I communication. The ACC-equipped vehicles receive the suggested time-gap $T_{stg,i}$ and they apply it only if their individual time-gap setting, $T_{d,j}$, is higher than the time-gap calculated by the controller, i.e.

$$T_{applied,j} = \min\{T_{d,j}, T_{stg,i}\}, \tag{2}$$

where j= 1, 2,… is the ACC-equipped vehicle index. Note that the frequency that the advancing ACC-equipped vehicles update their time-gap settings may be higher than at every control interval t_c due to crossing of section boundaries, unless the broadcasting of centrally calculated time-gaps is only effectuated strictly every t_c.

The proposed control concept is simple and easy to implement and includes three parameters that should be appropriately specified, i.e. v_{cong}, Q_1, Q_2; while $T_{\min}$, $T_{\max}$ are naturally set equal to the bounds of commercial ACC systems. The sensitivity of results with respect to these parameters is minor, and corresponding trade-offs and results will be presented and discussed elsewhere.

IV. Simulation Investigations

The proposed control concept is tested using the microscopic simulation software AIMSUN (v8.0). The simulated network, the simulation set-up and the obtained investigation results are presented in the following sections.

A. Network Description and Simulation Set-up

The simulated network is a part of A20 motorway in the Netherlands, which connects Rotterdam and Gouda. The motorway stretch considered is about 9.3 km long and includes two on-ramps and two off-ramps. It features 3 lanes until its 3.6 km where the left-most lane drops (see also Fig. 3). Based on the analysis of [13], recurrent congestion is created on the examined stretch during the morning peak hours. The reason for congestion is the high demand on the first on-ramp which, in combination with the mainstream demand, exceeds the motorway capacity. This real motorway stretch is utilized to test and demonstrate the application of the proposed traffic control concept.

The simulation model was calibrated and validated using real traffic data so that it is able to reproduce the typical traffic conditions of the examined motorway (see [13], [14]). Fig. 4(a) illustrates the spatio-temporal diagram of the real speed on the examined network, while Fig. 4(b) illustrates the corresponding diagram obtained through the calibrated simulator. It is observed that the simulator is able to reproduce the formation of congestion at the first on-ramp for the correct time period and extent. Note that in this study we focus on the bottleneck due to the on-ramp merge, thus the second wave of congestion that enters the examined motorway stretch from the downstream boundary (see Fig. 4(a)) is out of interest for this work and is therefore not replicated in the simulated model which assumes free-flow traffic conditions downstream of the motorway stretch at all times. Moreover, Fig. 4(c) presents the time trajectory of the outflow from the merge area, i.e. downstream of the first on-ramp, and it is shown that, during

TABLE I. NO CONTROL CASE: AVERAGE VEHICLE DELAY AND FUEL CONSUMPTION CONSIDERING VARIOUS PENETRATION RATES.

Performance Indices	Penetration Rate (PR)				
	0%	**5%**	**10%**	**15%**	**25%**
AVD (*s/veh/km*)	19.1	20.3	23.7	24.7	30
Difference (%)	–	6.3%	24.1%	29.3%	57.1%
FC (*l*)	6551	6577	6654	6675	6787
Difference (%)	–	0.4	1.6	1.9	3.6

TABLE II. CONTROL CASE: AVERAGE VEHICLE DELAY AND FUEL CONSUMPTION CONSIDERING VARIOUS PENETRATION RATES.

Performance Indices	Penetration Rate (PR)						
	0%	**5%**	**10%**	**15%**	**20%**	**30%**	**60%**
AVD (*s/veh/km*)	19.1	13.9	13.3	12.4	11.5	6.6	6.2
Difference (%)	–	-27.2	-30.4	-35.1	-39.8	-65.4	-67.5
FC (*l*)	6551	6381	6269	6207	6169	5928	5885
Difference (%)	–	-2.6	-4.3	-5.3	-5.8	-9.5	-10.2

the congestion period, the outflow, in both the real and the simulated network, is reduced below the motorway capacity (capacity drop).

The calibration of the simulation model was carried out considering only manually driven vehicles, as the utilized traffic data did not contain any information about existing ACC-equipped vehicles. This corresponds to the base (no-control) case of the presented investigations. Then, the proposed control concept was applied examining different cases with regard to the proportion (penetration rate) of vehicles equipped with ACC technology.

Both manual and ACC-equipped vehicles are moving using the Intelligent Driver Model (IDM) [15], which is a simple, yet realistic, car-following model. The IDM calculates the vehicle acceleration $\dot{v}$ based on the following equation:

$$\dot{v}(s,v,\Delta v) = a\left[1-\left(\frac{v}{v_0}\right)^4-\left(\frac{s^*(v,\Delta v)}{s}\right)^2\right] \quad (3)$$

where a is the maximum acceleration, v_0 is the desired speed, s is the current distance to the preceding vehicle and $s^*(v,\Delta v)$ is the desired distance which is calculated by the following function:

$$s^*(v,\Delta v) = s_0 + vT + \frac{v\Delta v}{2\sqrt{ab}} \quad (4)$$

where s_0 is the minimum distance, T is the minimum time-gap and b is the comfortable deceleration. Note that all IDM parameters, i.e. v_0, T, s_0, a and b take positive values. Within AIMSUN simulator, these parameters are defined by a mean, maximum and minimum value, while the characteristics for each individual vehicle are sampled from a truncated normal distribution. In the presented investigations, the only difference between the driving characteristics of the manual and ACC-equipped vehicles are the respective utilized bounds for the time-gap parameter T. In particular, for the manual vehicles we have $T \in [0.68, 1.67]$ s, while for the ACC-equipped vehicles $T \in [0.8, 2.2]$ s. The range of values for the time-gap of the manual vehicles was actually derived from the calibration procedure and corresponds to typical values for manual driving; while the range of values for the ACC-equipped vehicles corresponds to the range of values that the car manufacturers recommend for the ACC-settings. The utilized simulation step was set to 0.4 s, while the measurements interval was set to 30 s.

B. Simulation Resutls

In the following sections, the simulation results of the no-control case are presented first, followed by the results of applying the proposed control algorithm considering various penetration rates (PR). It should be noted that AIMSUN is a stochastic simulator, thus different simulation runs (replications) with different random seeds may produce quite different results. To address this issue, 10 replications were carried out for each examined scenario, and the average values of the performance criteria are compared.

1) No control case

In the no control case, 100% manually driven vehicles are considered (i.e. 0% ACC-equipped vehicles). Table I includes the average vehicle delay (AVD) (in s/veh/km) and the fuel consumption (FC) (in *l*) which are the mean values over 10 replications and are equal to 19.1 s/veh/km and 6551 l, respectively. Fig. 4(b) illustrates the traffic situation on the motorway for the particular replication with AVD value closest to the mean value of the 10 replications. As mentioned in Section IV.A, it is observed that congestion is formed between 6:30 a.m. and 8:00 a.m. at the first on-ramp, which propagates upstream for about 2 km. Moreover, Fig. 4(c) shows that, during congestion, the merge area outflow is reduced below the motorway capacity (capacity drop).

As discussed earlier, the admissible range of values for the ACC time-gap parameter is [0.8, 2.2] s, whose bounds are higher than the aforementioned calibrated respective bounds of manually driven vehicles. This implies that the introduction of ACC-equipped vehicles may reduce the traffic flow efficiency. To investigate this issue, a series of simulation runs were carried out considering various respective penetration rates of ACC-equipped vehicles with time-gap settings in the range [0.8, 2.2] s. Table I presents, for each investigated penetration rate, the mean AVD and FC values over 10 replications. It may be seen that the higher the penetration rate, the bigger the mean AVD and FC values, which reflect the deterioration of the network traffic conditions. These findings reject the perception that the introduction of ACC-equipped vehicles will automatically improve the driving conditions, as it demonstrates that the "uncontrolled" behavior of ACC-equipped vehicles actually contributes to further degradation of the road infrastructure.

2) Control case

The proposed control concept described in Section III was applied to the investigated network. The control strategy (see

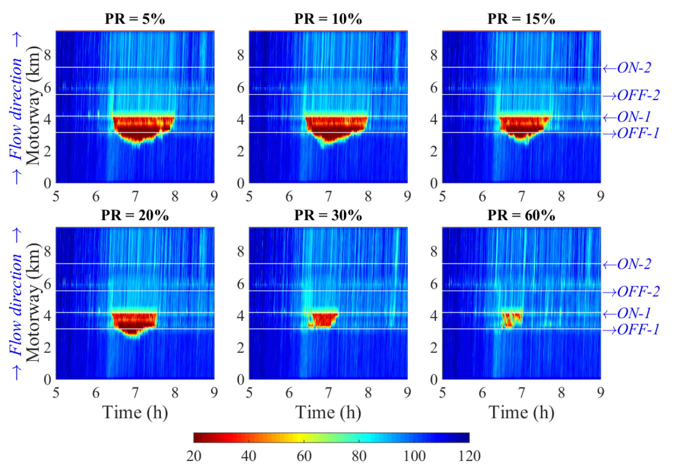

Fig. 5 Spatio-temporal diagrams of speed considering various penetration rates.

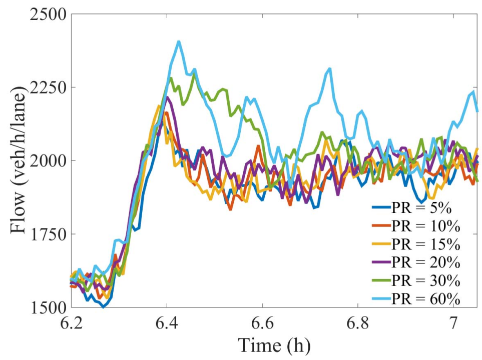

Fig. 6 Time-trajectory of the outflow from the merge area for various penetration rates.

(1)) is activated every t_c=30 s, receiving real-time measurements of flow and speed from every section of the motorway (see also Fig. 1), whereby section lengths are around 500 m. The parameters involved in the strategy equations are set as follows: v_{cong}=45 km/h, $T_{\min}$=0.8 s, $T_{\max}$=2.2 s, Q_1=1250 veh/h/lane, Q_2=1700 veh/h/lane. The strategy calculates the suggested time-gap T_{stg} using (1), using discrete time-gap values from the range [0.8, 2.2]*s* with increments of 0.1 *s* (see also Fig. 2(b)). The ACC-equipped vehicles receive, every simulation step, the strategy's decisions and update their individual time-gap setting according to (2).

Table II presents the control simulation results in terms of mean AVD and FC for various penetration rates. It is observed that the higher the penetration rate, the higher the improvement in mean AVD and FC. Note in particular that even for penetration rate as low as 5%, a considerable improvement of the traffic conditions is achieved, corresponding to 27.2% lower AVD and 2.6% less FC, compared to the case of 100% manually driven vehicles. Clearly, the calculated improvements would be even higher for a tighter space-time window around the congestion.

Fig. 5 illustrates the spatio-temporal diagrams of speed for various penetration rates. Each diagram corresponds to a particular replication with AVD value closest to the mean AVD value of the 10 replications for the corresponding penetration rate. Again, it may be seen that the higher the penetration rate, the bigger the improvement of the traffic conditions.

Another issue that is interesting to discuss is the influence of the proposed control approach on the merge area outflow during congestion. To address this issue, Fig. 6 presents the outflow from the merge around the onset of congestion for various penetration rates. Again, the presented results correspond to the replications with AVD values closest to the mean value of the 10 replications for each corresponding penetration rate. Fig. 6 illustrates that, for higher penetration rates, the onset of congestion is increasingly delayed, as in fact the capacity flow of the merge area is seen to increase. Moreover, Table III presents the average discharge flow during congestion for each investigated penetration rate. It may be seen that each increase of the penetration rate results in corresponding increase of the merge area discharge flow, which is though rather small. It is not clear at this point (and a matter of investigation) whether this small mitigation of capacity drop is actually the result of the implemented time-gap policy in congested traffic (see the upper part of (1)). In any case, other parameters, related to the vehicles' maximum acceleration, are expected to affect significantly the discharge flow, and corresponding investigations are indeed ongoing.

TABLE III. MERGE AREA DISCHARGE FLOW DURING CONGESTION FOR VARIOUS PENETRATION RATES.

Performance Index	**Penetration Rate (PR)**						
	0%	**5%**	**10%**	**15%**	**20%**	**30%**	**60%**
Discharge flow (*veh/km/lane*)	1944	1964	1968	1974	2009	2013	2023
Difference (%)	–	1.0%	1.2%	1.5%	3.3%	3.5%	4.1%

V. CONCLUSIONS

This paper presents an innovative ACC-based traffic control strategy, which aims to dynamically adapt the driving behavior of ACC-equipped vehicles so that the motorway traffic flow efficiency is improved. The proposed strategy was tested through microscopic simulation using a real traffic motorway stretch where congestion is created due to an on-ramp bottleneck. The simulation results showed that the higher the penetration rate, the bigger the improvement of the prevailing traffic conditions, both in terms of the average vehicle delay and the fuel consumption. In this research work, only the dynamic adaptation of the time-gap settings was considered, while ongoing research includes the dynamic adaptation of other ACC system settings as well.

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