MODELLING INTELLIGENT SPEED ADAPTATION

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ABSTRACT

This study aims at incorporating the ISA system into a simulation model and at identifying the system effects on a small network. The simulation model that has been selected is SIGSIM, which is a simulation tool based on Gipps' car-following model. Gipps' model is of a microscopic nature and forms the basis of several simulation tools. The methodology that has been followed involves a simulator experiment at TRL to identify several parameters of driver behaviour when using ISA systems. Following this the investigation of Gipps' model parameters and the manipulation of the experiment results to resemble and represent Gipps' model parameters took place. Last, the identification of the code in SIGSIM where such parameters can be changed or manipulated, and the simulation of several scenarios were performed. The effects of the use of the different ISA system functionalities are identified through measures of operational performance, and results indicate that the effect of the system on the road network mainly depends on the functionality of the ISA and on the traffic flow conditions. The intervening ISA demonstrated the highest performance, and as the traffic flow increased from light to heavy flow the effect of the system was reduced.

Keywords: intelligent speed adaptation, modelling, speed limiter, microsimulation, intelligent transport systems

INTRODUCTION

Intelligent transport systems (ITS) have emerged as a new solution towards improving road safety and reducing traffic congestion. Driver assistance systems are mainly employed for improving road safety whereas the reduction of traffic congestion (and through this environmental pollution) is mainly achieved with the use of traffic management systems. In addition, there is a wide range of ITS available that also serve other purposes such as driver comfort and convenience and integrating specific driver groups into the traffic system (Yannis et al, 2002; Spyropoulou et al, 2008).

System evaluation to assess their impact is performed in order to identify system effects on the driver and other road users. The most commonly used tools are driving simulators, instrumented vehicles, questionnaires, specific laboratory equipment and so on. The aforementioned studies can estimate the impact that the system has mainly on the user, hence at a microscopic scale. To estimate the effect at a macroscopic scale (for example in a city) traffic simulation techniques should be employed. Till today, there are several studies investigating the system impact on the user, however, there are only a few cases where simulation modelling has been applied to investigate the effects of system use on a network, and even fewer cases when this type of modelling incorporates driver behaviour and not just system operation characteristics.

This research attempts to model intelligent speed adaptation (ISA), through its impact on driver behaviour, using the microscopic traffic simulation software SIGSIM (Silcock, 1993; Law and Crosta, 1999) which uses Gipps' car-following model (Gipps, 1981). ISA has been modelled in the past, however only the system operational characteristics were included in the model (Liu and Tate, 2004; Wang et al, 2007). Intelligent speed adaptation is a quite "popular" and "promising" system, and has been thoroughly tested to identify system effects on the user (Brookhuis and Waard, 1999; Comte, 2000; Duynstee et al, 2000; Varhelyi, A., and Makinen, 2001; Jamson, 2006; Regan et al., 2006; Vlassenroot et al, 2007; Agerholm et al., 2008; Spyropoulou, 2008; Warner and Åberg, 2008). The system mainly aims at the reduction of accident/severity risk related to speeding. Its operation involves the continuous monitoring of driving speed and its comparison with a threshold speed. In the case the driving speed is detected to be higher than the threshold one, an action is triggered by the system, which depends on the system's functionality. Three main system functionalities have been designed: informative, warning and intervening. The first provides information indicating the prevailing speed limit, the second may provide this information but at the same time the system triggers a warning that might be in audio, visual or haptic format to warn the driver of speeding. The third functionality does not allow the driver to exceed the threshold speed limit.

In the next section of the paper the methodological steps towards modelling ISA are described. These include a short description of the driver simulator experiment, of Gipps' car-following model and of the traffic simulation software SIGSIM. Following this, analysis aiming at modifying observed parameters to resemble those of the model is presented. Last, the simulation scenarios are described and the simulation results are presented.

METHODOLOGY

Methodological procedure

The first step towards incorporating the intelligent speed adaptation system into a traffic simulation software is to select the appropriate simulation software. At the same time, the investigation of the suitability of the traffic model used by the simulation software should also be considered. In the present study, the use of a microscopic rather than macroscopic traffic model was decided to be of greater value, and between the different available traffic models, Gipps' car-following model was selected for use in this study and further investigation. Hence, the model dynamics and parameter characteristics were identified. At the same time, the traffic simulation software SIGSIM was selected to apply the appropriate modifications and simulate the use of intelligent speed adaptation systems.

The next step was to identify the different model parameters and define and implement a way for determining their values. Although several studies on driver behaviour, described through several parameters, have been conducted, no study where the values for several of Gipps' model parameters were determined exists. Hence, it was decided to design an experiment from which the appropriate data would be extracted. The tool used was TRL's driving simulator, and a simulator experiment was designed.

Once data was collected from the simulator study, a matching procedure between Gipps' model parameters and study results was attempted. This was achieved through the investigation of the actual dynamics of Gipps' model and its parameters and through the determination of the exact nature of the parameters/indicators that resulted from simulator study data analysis.

Last, a thorough examination of SIGSIM through its code, to determine the logic describing relevant procedures took place. This examination would allow the modification of the code in the relevant sections in order to incorporate the intelligent speed adaptation system in the traffic simulation software.

The present paper concentrates – assuming that the data provided by the simulator experiment is available – on the modification of the SIGSIM variables and "logic" to cater for the needs of the study, and the illustration of the respective simulation results.

Driver simulator experiment

The simulator experiment was conducted using the Transport Research Laboratory (TRL) driver simulator (Figure 1) and three different functionalities of the intelligent speed adaptation system were implemented. These were informative, warning and intervening ISA, and their operation was defined as follows:

1. Informative ISA: A pictogram indicating the prevailing speed limit as well as its justification (for example: "residential area") was transmitted at an in-vehicle screen throughout the drive.

2. Warning ISA: A tone repeated 3 times (0.5 sec on, 0.5sec off) the first time that the threshold limit was exceeded and a single tone (0.5 sec) every 8 seconds that the driver was continuously exceeding the limit were transmitted. The auditory warnings were also supported by visual information of the prevailing speed limit at the in-vehicle screen.

3. Intervening ISA: The system did not allow the driver to adopt speeds higher than the threshold limit. If the system determined that the accelerator pressure would cause the vehicle to exceed the limit, the pedal value was reduced automatically. In addition, a smooth deceleration was applied when the vehicle was about to enter a speed limit zone with speed higher than the threshold limit. The image of the prevailing speed limit was presented at the in-vehicle screen and a 0.5sec tone was transmitted, whenever the intervening functionality was triggered.

The threshold limit was different than the prevailing speed limit so as to avoid triggering the ISA operation in cases where the driver accidentally exceeds the prevailing speed limit by a small value. Such triggering could cause driver distraction. The threshold limit was set to be somewhat higher (about 2mph) than the prevailing speed limit.

Figure 1. The CarSim driving simulator at TRL

Each driver made four drives, one without a system which served as the "base condition" and one with each of the three ISA functionalities operating. A five minute familiarisation drive took place before the start of the drives so that drivers became familiar with the ISA operation as well as with the simulator environment.

In the current study, data that was recorded during rural road sections with 60mph speed limit was used. The road environment consisted of a 2-lane single carriageway road in a rural area. Three different types of incidents were also simulated within the 60mph speed limit areas and used for the purposes of this study. The first involved an accident blocking the lane, where the driver had to use the lane of the opposite direction for a short length in order to continue the ride. The second incident involved inserting a slow-moving vehicle in-front of the driven one that the driver had to overtake in order to maintain a desirable speed. The third incident involved the appearance of a green dot on the vehicle windscreen to which the driver was instructed – prior to the drive – to react by reducing vehicle speed to 10mph.

24 participants were recruited from the TRL database (23 finished all drives – 5 female and 18 male drivers), most of whom had driven the simulator in previous studies. Regarding driver age, the sample consisted of 7 young drivers aged 19-25years old, 7 drivers aged 26-34years old and 9 "older" drivers aged 35-46 years old. In addition, 6 drivers had driving experience of less than 5 years, 3 between 5-9 years, and 14 drivers had been driving for more than 9 years.

Gipps' car-following model (Gipps, 1981)

Gipps' car-following model is a microscopic model with discrete-time and continuous-space characteristics. The model was originally designed for simulation of free-flow traffic, and was implemented in simulating motorway roads. However, the model is now being used for traffic simulation in all types of road networks (for example urban networks with signal controlled junctions) and has been selected as the traffic model in various traffic simulation software such as AIMSUN (Barcelo et al., 1998), DRACULA (Liu, 2005), SIGSIM and SITRAS (Hidas, 1998).

Gipps' car-following model is quite detailed, resulting in long computational time but allowing for the vehicle/driver characteristics being considered in a more representative manner. The variables that are calculated in each time-step are the vehicle's speed and through this the vehicle's new position. The formula that is used to calculate the "updated" speed (speed at time $t+\tau$) is:

$$u_n(t+\tau) = \min\{$$

$$u_n(t) + 2.5 a_n \tau (1 - u_n(t)/V_n)(0.025 + u_n(t)/V_n)^{1/2}, \quad \text{(1a)}$$

$$b_n \tau + \sqrt{(b_n{}^2 \tau^2 - b_n \left[2\left[x_{n-1}(t) - s_{n-1} - x_n(t)\right] - u_n(t)\tau - u_{n-1}(t)^2 / \hat{b} \right])} \;\} \quad \text{(1b)}$$

where

$u_n(t)$ speed of vehicle n at time t,

a_n maximum acceleration which the driver of vehicle n wishes to undertake,

τ apparent reaction time, the same constant for all vehicles,

V_n speed at which the driver of vehicle n wishes to travel.

b_n most severe braking that the driver of vehicle n wishes to undertake (b_n<0),

$x_n(t)$ location of the front of vehicle n at time t,

s_n effective size of vehicle n, that is, the physical length plus a margin into which the following vehicle is not willing to intrude, even when at rest,

$\hat{b}$ value of b_{n-1} estimated by the driver of vehicle n who cannot know this value from direct observation.

The position of vehicle n at time $t+\tau$ is thus calculated to be:

$$x_n(t+\tau) = x_n(t) + 0.5\left[u_n(t) + u_n(t+\tau)\right]\tau \quad \text{(2)}$$

The parameters that have to be calibrated for the simulations are V_n, s_n, a_n, b_n, $\hat{b}$ and the reaction time which is the equivalent of the time-step used for the simulations τ. Gipps' validated his model using the following values presented in the format of (mean, variance):

V_n sampled from a normal population N (20.0, 3.2^2) m/sec

s_n sampled from a normal population N (6.5, 0.3^2) m

a_n sampled from a normal distribution N (1.7, 0.3^2) m/sec^2

b_n equated to -2.0 a_n

$\hat{b}$ minimum of -3.0 and (b_n-3.0)/2 m/sec^2

τ 2/3 seconds (about 0.6667 seconds)

The simulation model SIGSIM (Silcock, 1993; Law and Crosta, 1999)

SIGSIM is a microscopic traffic simulation software, which is mainly used for traffic signals optimization. Originally, SIGSIM was designed for the evaluation of traffic signal control strategies including several types of signal control such as the fixed time control and the non optimizing traffic responsive signal control strategies. In addition, the simulation software can be further modified to incorporate additional signal control strategies.

The traffic model part in SIGSIM is based on the formulae developed by Gipps' and described in the previous section. Hence, SIGISM uses the parameters described for Gipp's car-following model as the basic parameters for the traffic simulation. An additional feature of the software is that it allows for the simulation of several groups/types of drivers each for each of which a different value of the aforementioned parameters can be attributed.

The simulated network should consist of at least one link connecting nodes/junctions, which can be either signalized ones, or non-signalised ones operating with priority rules. Data input mainly involves network characteristics (number of lanes, link length, signal control timings etc), arrival rates and vehicle/driver characteristics as those have been described through Gipp's parameters.

ANALYSIS

Driver simulator study results vs traffic model parameters

Simulator study estimated parameters

Several parameters were estimated through the data extracted from the driver simulator experiment. However, the parameters that could be of value and support the research in the particular study follow:

1. Vehicle speed
2. Vehicle position
3. Vehicle position in the lane
4. Time and space headways
5. Brake activation
6. Distance between the driven vehicle and an approaching vehicle from the opposite direction

Parameter modification

In this sub-section Gipps' model parameters and the corresponding ones estimated from the simulator experiment are presented together with the required modifications so that they proposed parameter values represent the Gipps' parameters in the most effective manner.

The first formula presented in Gipps' car-following model is:
$u_n(t+\tau) \le u_n(t) + 2.5 a_n \tau (1 - u_n(t)/V_n)(0.025 + u_n(t)/V_n)^{1/2}$, where

$u_n(t)$ speed of vehicle n at time t,
a_n sampled from a normal distribution N (1.7, 0.3^2) m/sec^2
τ 2/3 seconds (about 0.6667 seconds)
V_n sampled from a normal population N (20.0, 3.2^2) m/sec

$u_n(t)$**:** speed of vehicle n at time t,

The parameter $u_n(t)$ is estimated at each model update from the traffic model formula and hence does not comprise an input parameter.

V_n: speed at which the driver of vehicle n wishes to travel.

The parameter V_n is an input parameter and hence its estimation from the simulator study data is required. In Gipps' car-following mode the speed at which the driver wishes to travel is distributed normally with N(20.0, 3.2^2)m/sec^2. Hence, the average and variance of the drivers' maximum speed need to be estimated. These are illustrated in Table 1.

Table1. Maximum speeds for the different ISA systems (m/sec)

	Base	Informative	Warning	Intervening
Mean	30.01	30.73	28.60	26.99
Variance	2.24^2	3.07^2	2.89^2	0.45^2

The prevailing speed limit at the investigated road section is 60miles per hour which corresponds to 26,82m/sec.It becomes evident that the mean value of the maximum speeds is higher than the prevailing speed limit regardless of the different ISA functionality.

The investigated parameter corresponds to the speed the vehicles would travel at free-flow conditions. Hence, according to the models dynamics a vehicle travelling under free-flow conditions would continuously travel at this speed and hence, this speed does not correspond to a maximum speed as this was estimated through the study data. The latter, represents a momentary speed, which does not agree with that of the Gipps' model. During the study, there were road sections where the driver drove at free-flow conditions, where there was no presence of any other vehicle or incident. At these sections, the driver would travel at the maximum speed that he/she wished to undertake. Hence, the speed that corresponds to parameter V_n is the mean driver speed, within the aforementioned sections, and is presented in Table 2.

Table2. Mean speeds for the different ISA systems (m/sec)

	Base	Informative	Warning	Intervening
Mean	28.01	28.04	26.70	26.45
Variance	2.34^2	2.10^2	2.72^2	0.74^2

In addition to the estimation of the mean speed value, the distribution of the estimated values should also be investigated. However, it should be noted that due to the small sample size an accurate estimation cannot be expected. The speed distributions of the base, informative and warning conditions were normal, whereas the speed corresponding to the intervening condition was not found to be represented by a know distribution.

a_n: maximum acceleration which the driver of vehicle n wishes to undertake

The parameter a_n is an input parameter and hence it should be estimated from the simulator study data. The parameter as defined in Gipps' model follows a normal distribution with N(1.7, 0.3^2)m/sec^2. The acceleration was estimated using the following equation:
$(u_n(t+\tau)+u_n(t))/(\tau)$
The estimated values are presented in Table 3.

Table3. Maximum acceleration for the different ISA systems (m/sec^2)

	Base	Informative	Warning	Intervening
Mean	3.16	2.96	3.13	2.90
Variance	2.09^2	1.84^2	1.54^2	1.45^2

The difference between the calibrated and estimated acceleration values is quite high. One of the reasons behind this difference can be that the speed maximum speed set in the experiment is higher than that defined by Gipps. In addition, the rules governing the model dynamics can differ from the actual recorded dynamics. In-depth investigation of Gipps' model (Spyropoulou, 2007) indicated that the maximum acceleration in Gipps' model appears when the vehicle travels with speed equal to $\frac{0.95}{3}V_n$. However, this "rule" was not confirmed by the study data. In Table 4 the corresponding acceleration when drivers travel with speed of about $\frac{0.95}{3}V_n$ (during the simulator study) are presented.

Table4. Maximum modified acceleration for the different ISA systems (m/ sec^2)

	Base	Informative	Warning	Intervening
Mean	2.06	2.23	2.24	1.97
Variance	1.06^2	1.07^2	0.96^2	0.54^2

The modified values are somewhat closer to those propose by Gipps. The selection between the two values involves whether the selection criteria should be using the observed/recorded accelerations or whether to use accelerations that are closer to the model dynamics. In the current study the modified acceleration will be used. However, it should be stated, that there is ground for further research through which the movement dynamics of the simulated drives should be determined and then compared and combined with those of Gipps' model.

τ : apparent reaction time

Reaction time in Gipps' model is set to be 2/3sec. However, several studies indicate that driver reaction time usually ranges between 1 and 2 seconds. Driver reaction time can be estimated from the study data using one of the simulated incidents. In particular, in the simulator experiment a green dot appeared on the vehicle windscreen to which the driver was instructed to react by reducing vehicle speed to 10mph. Hence, the time between the appearance of the green dot and brake activation is considered to be the driver reaction, and is illustrated in Table 5.

Table5. Driver reaction time for the different ISA systems (sec)

	Base	Informative	Warning	Intervening
Mean	1.49	1.55	1.60	1.80
Variance	0.49^2	0.50^2	0.46^2	0.76^2

The estimated values are much higher than those defined by Gipps, they however agree with the expected values. Hence, the input parameter of reaction time and hence of the simulation time-step equals the values estimated through the simulator experiment data. However, since it is more efficient to use one common time-step for the simulation, and as the differences between the estimated reaction times of the different ISA systems are not statistically significant it was decided to use as a time-step value the average value which is estimated to be 1.61sec.

The second formula presented in Gipps' car-following model is:

$$u_n(t+\tau) \le b_n\tau + \sqrt{b_n{}^2\tau^2 - b_n\left[2\left[x_{n-1}(t) - s_{n-1} - x_n(t)\right] - u_n(t)\tau - u_{n-1}(t)^2 / \hat{b}\right]},$$

s_n sampled from a normal population N (6.5, 0.3^2) m

a_n sampled from a normal distribution N (1.7, 0.3^2) m/sec^2

b_n equated to -2.0 a_n

$\hat{b}$ minimum of -3.0 and (b_n -3.0)/2 m/sec^2

τ 2/3 seconds (about 0.6667 seconds)

Model dynamics define b_n equal to -2.0 a_n. The values b_n using as a_n the modified acceleration, which will be used in the simulation, are presented in Table 6.

Table6. Maximum deceleration for the different ISA systems (m/ sec^2)

	Base	Informative	Warning	Intervening
Mean	- 4.13	- 4.45	- 4.47	- 3.94
Variance	2.13^2	2.14^2	1.91^2	1.08^2

$x_n(t)$ **:** location of the front of vehicle n at time t,

The parameter $x_n(t)$ is estimated by the model, and hence does not comprise and input parameter.

s_n : effective size of vehicle n

Gipps' defines s_n as a parameter sampled from a normal distribution with N (6.5, 0.3^2)m. This parameter represents the vehicle physical length plus a margin into which the following vehicle is not willing to intrude, even when at rest. The length of the vehicle used in the simulator experiment was equal to 4.28m. To estimate the corresponding effective size value, a safety margin should be estimated. For this reason, data corresponding to road sections where vehicles or incidents in front of the driven one appear will be used. However, study data indicated that this margin ranged from 0.2 to 315 metres, since in several circumstances drivers preferred to keep long headways with the vehicles in-front in order to overtake without having to slow down. However, there was no indicator that would allow a further analysis of the aforementioned margin to identify which were actual safety margins. Hence, vehicle effective size will not be modified, and the value proposed by Gipps will be used.

$\hat{b}$ **:** most severe braking that the driver of vehicle n wishes to undertake

This parameter cannot be estimated through simulator data, hence the value proposed by Gipps will be used. This value is equal to $\hat{b}$ =min(-3.0, (b_n -3.0)/2) m/sec^2, and is presented in Table 7.

Table7. Most severe braking of the preceding vehicle for the different ISA systems (m/ sec^2)

	Base	Informative	Warning	Intervening
Mean	- 5.63	- 5.95	- 5.97	-5.44

ISA SIMULATIONS

Impact indicators

SIGSIM output consists of several parameters describing network operational performance, from which the following ones are used to estimate the impact of the use of the different ISA systems:

1. Average delay (vehicles)

2. Stop rates (number of stops per second)

3. Fuel consumption (litters per hour)

4. Travel time (seconds)

Simulated scenarios

A simple road network will be simulated which consists of two links and a junction between them with 100% green indication allocated to the 101 movement (Figure 2).

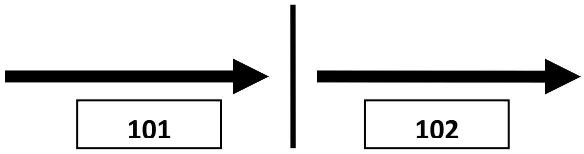

Figure 2. Simulated network

The simulated network characteristics are presented in Table 8.

Table8. Simulated variables

No of Links	Link ide	Link length (m)	Entering flow	Saturation flow (PCU/h of green time)
2	101	750	Vehicle generation	1800
	102	750	101 outflow	1800

The simulation period is 4500 seconds of which the first 900 seconds are not used for the estimation of the results as they are considered to comprise the warm-up period. One feature of SIGSIM is that it has been runs variability; in the present simulation 10 different random number seeds have been used. Last, a parameter employed by the software to achieve the desired saturation flow is the speed reduction factor which is applied in the proximity of the junction and is estimated to be about 62.2 so that the corresponding saturation flows reach 1800PCU per hour of green time. The aforementioned variables are inserted in the code mainly through the “Geomet” and “Junct files”, where the corresponding parameters are described.

Three types of scenarios in respect to traffic flow were simulated – namely, light, medium and heavy flow scenarios. For the light traffic flow scenario the flow entering link 101 is 600 veh/hour (in this study all vehicles are considered to be passenger cars), and the degree of saturation is 0,33. For the medium flow scenario the corresponding values are 1000 veh/hour and 0.56. Last, for the heavy flow scenario, entering flow equals 1600veh/hour and the corresponding degree of saturation is equal to 0.89.

Table 9 illustrates the input parameters of the different ISA systems.

Table9. Input parameters for the different ISA systems

ISA	V_n	SD	a_n	SD	time-step

functionality	(m/sec)		(m/sec^2)		(sec)
Base	28.0	2.3	2.1	1.1	1.6
Informative	28.0	2.1	2.2	1.1	1.6
Warning	26.7	2.7	2.2	1.0	1.6
Intervening	26.5	2.7	2.0	0.5	1.6

As mentioned in previous section, several modifications to the code had to be implemented. However, this is not considered to be of interest for the present paper.

Simulation results

Low flow

The simulation results of the light flow scenario (600veh/h) are presented in Table 10.

Table10. Simulation results for the different ISA systems (light flow)

ISA functionality	Average delay (vehicles)	S.D.	Stop rates (number of stops/sec)	S.D.
Base				
101	26.81	31.049	0.00466	0.000201
102	34.19	22.952	0.01289	0.000707
Total	61.00	32.002	0.01756	0.000744
Informative				
101	20.87	14.595	0.00443	0.000274
102	28.58	20.387	0.01179	0.000401
Total	49.45	19.000	0.01622	0.000557
Warning				
101	19.67	20.172	0.00309	0.000374
102	25.91	19.306	0.01157	0.000348
Total	45.58	19.369	0.01466	0.000383
Intervening				
101	2.55	0.0156	0.00239	0.0000598
102	2.73	0.0147	0.00324	0.0000745
Total	5.28	0.0302	0.00563	0.0000922
ISA functionality	Fuel consumption (litters/h)	S.D.	Travel time (sec)	S.D.
Base				
101	30.94	35.688		
102	39.61	26.321		
Total	70.55	36.742	69.43	15.4775309
Informative				
101	24.11	16.811		

102	33.13	23.460		
Total	57.24	21.876	89.41	40.6055246
Warning				
101	22.7	23.244		
102	30.06	22.190		
Total	52.75	22.263	111.24	55.0698248
Intervening				
101	2.99	0.0176		
102	3.21	0.0165		
Total	6.2	0.0338	63.29	1.8213399

Results suggest two significant trends. The first involves the effectiveness of the different ISA functionalities. The intervening ISA system seems to be quite effective compared to "base" conditions as has also been indicated in other studies (Liu and Tate, 2004). Moreover, the intervening system is also more effective than the rest of the ISA systems. The second trend involves the resulting stability of the intervening system which is demonstrated through the low values of the estimated standard deviations compared to that of the other ISA functionalities. This stability seems to be quite effective in respect with the operation performance of the network. Travel speed with low variations results in lower accelerations and decelerations and thus reduction in the number of stops (stop-and-go). Hence, travel time, average delay and fuel consumption are significantly lower with such movement characteristics.

The comparison between the other systems does not yield any conclusions other than that they seem to perform in a similar manner (as was also established through the analysed simulator study data) leading into small non-statistically significant differences in the estimated operational performance measures.

Medium flow

The simulation results of the light flow scenario (1000veh/h) are presented in Table 11.

Table11. Simulation results for the different ISA systems (medium flow)

ISA functionality	Average delay (vehicles)	S.D.	Stop rates (number of stops/sec)	S.D.
Base				
101	145.01	77.804	0.00639	0.000409
102	77.79	25.149	0.0143	0.000577
Total	222.79	64.073	0.02069	0.000775
Informative				
101	124.77	73.820	0.00526	0.000556
102	77.74	37.614	0.01358	0.000574
Total	202.51	57.502	0.01884	0.000913

Warning				
101	133.04	48.883	0.00486	0.000439
102	56.87	43.327	0.01177	0.000305
Total	189.91	38.734	0.01664	0.000619
Intervening				
101	4.49	0.0135	0.00224	6.18E-05
102	4.57	0.0122	0.00257	5.82E-05
Total	9.06	0.0245	0.00481	8.18E-05
ISA functionality	Fuel consumption (litters/h)	S.D.	Travel time (sec)	S.D.
Base				
101	166.9	89.503		
102	89.78	28.925		
Total	256.68	73.685	127.38	91.02332
Informative				
101	143.61	84.978		
102	89.71	43.308		
Total	233.32	66.204	127.22	109.3289
Warning				
101	153.1	56.253		
102	65.67	49.845		
Total	218.77	44.582	121.20	47.96121
Intervening				
101	5.21	0.0158		
102	5.31	0.0139		
Total	10.52	0.0285	65.38	3.032512

Under medium flow conditions, where traffic is not under free-flow conditions the results between the base, informative and warning conditions and closer than under light flow conditions. At the same time, the differences between the aforementioned conditions and the intervening ISA system increase especially regarding the average delay and fuel consumption measures.

Heavy flow

The simulation results of the heavy flow scenario (1600veh/h) are presented in Table 12.

Table12. Simulation results for the different ISA systems (medium flow)

ISA functionality	Average delay (vehicles)	S.D.	Stop rates (number of stops/sec)	S.D.
Base				
101	310.95	93.202	0.00373	0.00023

102	134.7	63.655	0.01636	0.00063
Total	445.65	44.188	0.02009	0.000587
Informative				
101	287.43	79.241	0.004	0.000216
102	146.15	57.654	0.01586	0.000375
Total	433.58	45.100	0.01986	0.000467
Warning				
101	319.2	60.506	0.00286	0.000345
102	102.78	54.944	0.01393	0.000315
Total	421.98	22.088	0.01678	0.000562
Intervening				
101	122.85	0.6636	0.00223	1.81E-05
102	5.97	0.0154	0.00371	0.000176
Total	128.82	0.6659	0.00595	0.000182
ISA functionality	Fuel consumption (litters/h)	S.D.	Travel time (sec)	S.D.
Base				
101	357.68	107.171		
102	155.28	73.178		
Total	512.96	50.806	94.48788	44.21748
Informative				
101	330.64	91.102		
102	168.43	66.316		
Total	499.07	51.830	121.3233	62.89922
Warning				
101	367.14	69.602		
102	118.51	63.165		
Total	485.66	25.403	137.79	94.48788
Intervening				
101	141.33	0.7632		
102	6.95	0.0211		
Total	148.28	0.7682	108.8937	2.582586

Results indicate that in the case of heavy flow (degree of saturation almost 0.9) the differences in the measures of operation performance of the different systems are reduced significantly. Still, the intervening system demonstrates the highest performance. However, the difference in performance between the intervening ISA and the other conditions is much smaller in this scenario as in an almost saturated network the margin for improved performance through systems of different dynamics reduces significantly.

DISCUSSION

Modelling intelligent speed adaptation was not found to be a straightforward task. This is not due to the characteristics of the system, but results from the difficulty in synchronisation of the model parameters and observed behaviour. Vehicle dynamics as governed by the model rules are not similar to the movement dynamics of vehicles (in this case in vehicles in a simulated environment). Hence, the representation of the model parameters through parameters resulting from recording driving behaviour is not always accurate. What needs to be said, is that still there is room for parameter modification – if both model dynamics and movement dynamics have been fully comprehended – which will allow a satisfactory representation of the use of the ISA system (or any similar system) through a traffic model and a traffic simulation software.

Simulation results indicate that the operational performance of a network is dependent on the ISA functionality, and on the traffic flow conditions. In terms of the ISA functionality, the biggest impact is achieved with the use of the intervening ISA which results in significantly improved network operational performance, compared to all other conditions (base, informative ISA and intervening ISA). The main difference between the intervening system and the other systems was found to be the low variance of driving speed. No substantial differences in network operation performance resulting from the use of the rest of the systems (base, informative ISA and warning ISA), was reported.

The effect of the system is maximized under light traffic flow conditions, as traffic does not interfere and hence limit the system capabilities. On the other hand, under heavy flow conditions, the margin for improvement is much lower and hence the system capabilities cannot be fully exploited. The differences in operational performance between the intervening ISA and the rest were found to be substantially reduced.

Future work – which is already underway – involves the simulation of more complex scenarios. The complexity can be inputted through simulating more complex networks, with junctions operating under signal controlled strategies, and identifying whether there are specific differences of interest. Furthermore, the inclusion of scenarios in which vehicles equipped with the different systems exist (under the same simulation) will also be considered.

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