Towards Sustainable Town development: A Research on Deployment of Urban Sustainable Transport Systems
(http://www.trg.soton.ac.uk/stardust)

Deliverable 15

Final Report

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**Glossary**

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<td>ACAS</td>
<td>Automotive Collision Avoidance System</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
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<td>ACC</td>
<td>Adaptive Cruise Control</td>
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<td>AHS</td>
<td>Automated Highway Systems</td>
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<td>ASV</td>
<td>Advanced Safety Vehicle</td>
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<td>AVCSS</td>
<td>Advanced Vehicle Control and Safety Systems</td>
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<td>AVG</td>
<td>Automated Vehicle Guidance</td>
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<tr>
<td>BRT</td>
<td>Bus Rapid Transit</td>
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<td>CVHAS</td>
<td>Cooperative Vehicle-Highway Automation Systems</td>
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<td>DSRC</td>
<td>Digital Short Range Communication</td>
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<td>DSSS</td>
<td>Driving Safety Support System</td>
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<td>FCW</td>
<td>Forward Collision Warning</td>
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<td>FCWS</td>
<td>Frontal Collision Warning System</td>
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<td>FOT</td>
<td>Field Operational Test</td>
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<td>FVCW</td>
<td>Forward Vehicle Collision Warning Systems</td>
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<td>GPS</td>
<td>Global Positioning Systems</td>
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<td>HCB</td>
<td>High Capacity Buses</td>
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<td>HOV</td>
<td>High Occupancy Vehicle</td>
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<tr>
<td>ICW</td>
<td>Intersection Collision Warning</td>
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<td>ICVS</td>
<td>Intelligent Community Vehicle System</td>
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<tr>
<td>IDS</td>
<td>Intersection Decision Support</td>
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<tr>
<td>IMTS</td>
<td>Intelligent Multimode Transit System</td>
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<td>ISA</td>
<td>Intelligent Speed Adaptation</td>
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<td>ITS</td>
<td>Intelligent Transportation Systems</td>
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<tr>
<td>IVI</td>
<td>Intelligent Vehicle Initiative</td>
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<tr>
<td>LDWS</td>
<td>Lane Departure Warning Systems</td>
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<td>SOWS</td>
<td>Side-Obstacle Warning Systems</td>
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<td>SSVS</td>
<td>Super-Smart Vehicle Systems</td>
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<td>TTC</td>
<td>Time-to-collision</td>
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Executive Summary

The aim of STARDUST was to assess the extent to which ADAS (Advanced Driver Assistance Systems) and AVG (Automated Vehicle Guidance) systems can contribute to a sustainable urban development. The main focus in the STARDUST project has been the study of ADAS/AVG systems in an urban context in terms of traffic efficiency, environmental and safety impacts. The systems investigated include ACC, Stop&Go, Lane Keeping, ISA and Cybercars.

In the STARDUST project, a range of methodologies at behavioural, microscopic and macroscopic level have been applied so that comprehensive final recommendations could include actual driver behaviour where possible. The project has included assessment of user acceptance (by means of stated preference surveys), investigation of human factors issues (using data from instrumented vehicles, driving simulators, and microscopic modelling), and larger scale assessment of the impacts, at city-level (using semi-dynamic traffic assignment models).

Many of the new technologies evaluated are in a relatively early stage of development. The precise performance levels and specific functionalities are unknown. In this research, the assumptions are clearly stated, but, in general, it has been assumed that the systems can perform in ways in which are generally beneficial to traffic operations. In practice, market drivers may result in reduced network benefit, where such occurs. This, in some situations, the results reflect what is possible rather than what may be likely. However, they make the case for the development of as much vehicle/highway cooperation as possible.

System evaluation results

Intelligent Speed Adaptation (ISA)

The ISA effects of reducing excessive traffic speed for safety reasons results in increases in journey time in a network. Simulation results show that increases in journey times were greater on high speed roads (e.g. motorways) than on low speed roads (e.g. urban streets). Network journey times were found to increase in a range from 4.3% to 6.0% with a penetration level 80%. No significant changes in network distance were found, which indicated that ISA did not result in much change in the general pattern of assignments, with most of drivers keeping their original routes. ISA was found to be more effective in non-congested traffic conditions when it is easy for drivers to exceed a speed limit. Thus the effects of ISA are sensitive to levels of traffic demand.

From the modelling, ISA impacts on fuel consumption and pollutant emissions are dependent on characteristics. ISA was found to have positive impacts on fuel consumption on high speed roads, but negative impacts on low speed roads. CO₂ and NOx emissions exhibited similar trends with fuel consumptions.

ISA has positive impacts on safety in terms of limiting speed to the official limits. In addition, ISA can harmonize vehicle speeds between and within lanes, and therefore reduce the number of lane changes.
Stop&Go on urban roads

Stop&Go systems have potential to increase saturation flows of signal controlled junctions because of shorter and more consistent reaction times. Unlike infrastructure based measures, increases in saturation flow at a signal controlled junction occur because of cumulative effects of individual vehicles. Therefore, the impacts are dependent on levels of traffic demand and penetration rates of equipped vehicles. When 80% of vehicles use the system, the network queuing times were found to reduce by up to 19%-25%, and a reduction of journey times of 7.5%-15% (It is assumed that the system characteristics and traffic benefits lead to general use).

In general, Stop&Go can have positive impacts on environment. Stop&Go can contribute to environmental improvements by smoothing vehicle movements and reducing queuing time at junctions.

Stop&Go has positive impacts on safety in term of smoother vehicle movement, which can reduce the number of small time-gap and time-to-collision events in car following processes.

ACC+Stop&Go on urban arterial roads and motorways

A combined system of ACC+Stop&Go should make it possible to automate the task of car following at both high and low speeds. In general, traffic impacts of such combined systems are similar to those when a separated system is used. ACC+Stop&Go can smooth vehicle movements in both high and low speed traffic. The application of ACC+Stop&Go can have positive impacts on traffic efficiency in terms of reduced network journey times which depend on the headways chosen by drivers, and how extensive the system is used and, in urban cases the extent of higher speed roads.

As longitudinal control systems, ACC and Stop&Go can contribute to improving the environment by smoother vehicle movements. However, higher speed driving could result in negative impacts on environment.

ACC+Stop&Go could have positive impacts on safety in terms of smoothed vehicle movements, and reduction in the number of reduced small time-gaps and time-to-collision events during car following processes.

High Capacity Bus (lane keeping based)

High Capacity Bus based on Lane Keeping system could support modal change and leads to reduced private car use in urban areas. However, to achieve substantial improvement in network efficiency, significant modal shift is required. The use of High Capacity Buses will become more important when urban areas become restricted for example by congestion charging or banning physical restraint measures to reduce private car use.

High Capacity Bus could contribute to improve environment by reducing the number of private car use in the urban areas.

Cybercars in city centre areas

Cybercars can be used to supplement mass public transport by providing feeder and distribution services in city centre reserved largely for public transport. Simulation has shown
that Cybercars have positive impacts on traffic at a network level in terms of reduced total journey times and network distances. However compared to private car journeys, the multi-modal journey would take longer because of interchange times.

Cybercars could contribute to improving the urban environment by reducing private car trips. In addition, Cybercars are electric powered, this will further contribute to the improvements of environments in the urban areas.

It is clear from the study of user needs that people want new technologies in their cars when they understand the system and see a personal benefit. Thus, the deployment of driver support systems is market driven. Of the systems investigated, there is a rather positive perception of the systems, especially to what ISA and ACC can bring about regarding driver comfort and traffic safety. There is also a positive attitude to the implementation of cyber cars. However, there is however a slightly less positive attitudes towards Stop&Go systems and opinions are also less favourable for Lane Keeping systems.

Some systems such as ACC and Stop&Go can provide wider network benefits with regard to traffic flow and more throughput of traffic – but may as well provide disbenefits if not co-ordinated between manufacturers and government. The disbenefits and obstacles to deployment could be related both to liability issues and to how the systems actually are implemented and utilized in practice.

The functionality of Stop&Go can be used as an illustration of this. A semi automatic Stop&Go system where the driver has to activate the system after each stop could be a way of reducing liability. However, the consequence of not fully automatic stop and start could also lead to less improvements in regarding traffic flow and the environment. It is also important to be aware that the effect of ADAS / AVG systems to a great extent will be a function of the traffic demand in the network.

The STARDUST project has revealed some important issues regarding the deployment of ADAS/AVG systems. It seems clear that the driver support systems will come into in the coming years. To move forward and reach a level of use that will have a major influence on traffic flow and safety some concerns have to be dealt with. These were identified to include:

- Legislation (mandatory or not)
- Infrastructure investments
- Combination with other applications
- Robustness of the systems in different traffic situations
- Liability issues
- Market needs (user acceptance, training, long term effect, maintenance)

To make a substantial step forward in the rate of deployment, it will be necessary for government consider making some of the systems mandatory. It is also important that the infrastructure owners give ADAS /AVG systems priority in their investment budgets.

One key issue will be to consider the effects of different systems in order to achieve the benefits whilst minimizing liability. These strategies will probably also lead to development of more robust systems for a range of traffic situations. Another important issue is how market requirements will be met regarding information, training and user support.
The STARDUST project has revealed that driver support systems has a substantial potential in the urban environment regarding traffic flow and traffic safety. However, there is a need for more research on urban following processes and traffic flow mechanisms such as:

- influence on capacity (smoothing and increasing the flow)
- reliability of the systems under different traffic conditions and surroundings
- adaptation and interaction to the traffic environment
- effects of coupling between different systems
- safety (looking at the driver behaviour and traffic processes, long term database for incidents)
- user acceptance and understanding of new technologies

From the road keeper and governmental point of view there is a need for more research to understanding the traffic management: opportunities and how best handle and regulation to avoid inappropriate technologies

New technologies bring a need for new concepts to be developed for the allocation of road space/demand management and for the modification and enhancement of access control systems. These new concepts should be incorporated in traffic planning tools.

In addition to legal barriers and liability issues, there will also be privacy issues to be solved for some systems.

The appropriate introduction of new technology to the market is crucial, as many drivers still do not know how to operate ABS-brakes or ESP-systems, several years after they have become standard equipment. Some of the potential benefits may be reduced due to inappropriate system use.

It is important to issues regarding the mechanics of the traffic management (roadside installations, communication systems) that has to be focused in future R&D projects.

The STARDUST project has not focused on the socio economic benefits from the implementation of ADAS/AVG systems. There could be substantial social benefits from such systems and new approaches need to be developed to bring together economic and financial benefits in ways which enable business cases can be developed for all stakeholders to work together. Such a process will also drive forward the systems functionalities and specifications in ways best suitable to all stakeholder interests.
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1 Introduction

1.1 Background
Despite their differences, all European cities beyond a certain size are facing the same issues: air pollution, noise, congestion, management of waste, infrastructure maintenance, building maintenance, safety, viability of economic activities, protection of employment. 80% of Europeans live in cities facing increasing problems of traffic pollution and congestion. Almost forty millions Europeans are annually exposed to pollution exceeding at least one air quality guideline. The problem is also reflected in the 2% loss in GNP due to congestion and in the continuing growth of traffic.

European cities have therefore to implement efficient strategies in order to improve the quality of life in urban and suburban areas, whilst reducing social inequity, increasing the participation of citizens in decision-making process, and finally contributing to improve the economic competitiveness. These are the main objectives of a sustainable urban development.

The aim of STARDUST is to assess the extent to which ADAS (Advanced Driver Assistance Systems) and AVG (Automated Vehicle Guidance) systems can contribute to a sustainable urban development not only in terms of direct impacts on traffic conditions and environment but also in terms of impacts on social life, economic viability, safety, etc.

The majority of these systems were first designed to be used in an inter-urban context, i.e. on motorways. Now, progressively, they are considered for urban contexts and systems manufacturers are designing new prototypes adapted to urban contexts. For example, first Adaptive Cruise Control (ACC) systems were designed to be used on motorways, at speeds higher than 50 km/h. So do the first marketed ACC systems. Meanwhile, however, other systems aiming to adaptive longitudinal control of the vehicle have been developed (at a prototype stage) for use on urban networks. This again confirms how much the work proposed in STARDUST is a topical question.

1.2 Objectives
STARDUST will carry out a global and quantified evaluation of the opportunity of the deployment of some selected ADAS/AVG systems. The selection of the systems to be evaluated will be made on the basis of a review of ADAS and AVG options to 2010. The impacts of the systems will be assessed at a city-level, in 3 case study cities, using semi-dynamic assignment models. The systems will then be evaluated, using an evaluation framework specifically set up, which will include environmental (congestion, energy consumption, pollutants emission, …), social (safety, accessibility, …), and economic indicators (accessibility to economic activities, …).

The originality and the strength of the STARDUST approach are to combine analysis at behavioural, microscopic and macroscopic level, so that the final recommendations will be based on the actual driver behaviour, rather than on theoretical views. Most innovative in STARDUST is the integration of end user potential acceptance analysis (by means of stated preference surveys), investigation of the human factors issues (using data from instrumented vehicles, driving simulators, and microscopic modelling) and larger scale assessment of the impacts, at city-level (using semi-dynamic traffic assignment models). Besides, the results of
the impact assessment will be compared between three Northwest-European cities (Brussels, Southampton, Oslo), which again highly increases the reliability of the final conclusions.

Finally, STARDUST will also carry out a review and synthesis of the existing analysis on the legal and institutional aspects of the deployment of the selected ADAS and AVG systems.

1.3 Project partners

The STARDUST consortium combines a number of organisations recognised for their leading edge research and policy analysis of new transport systems. It combines partners from four European countries: UK (TRG, project co-ordinator), Belgium (STRATEC), France (INRETS, and INRA) and Norway (SINTEF) and a partner form US (PATH, California University).

The consortium brings together a multi-national blend of experts tailored specifically to address the needs of the task with an understanding of the difficulties and issues that the research programme will face. Within the consortium there are one SME (STRATEC), government linked research agencies (INRETS, INRIA), a research institute (SINTEF) and universities (TRG, PATH). Whilst the consortium does not contain any vehicle manufacturers, the strong network of contacts that already exists within the project will guarantee the full input of the relevant stakeholders to all stages of the project.

Table 1 Partners in STARDUST

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<th>Country</th>
<th>RTD Role in project</th>
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<td>UK</td>
<td>Co-ordination, Human factors, micro-simulation and large-scale simulations (Southampton)</td>
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<td>Belgium</td>
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2 Systems investigated and case cities

2.1 Systems investigated
Deliverable 1, “Critical Analysis of ADAS/AVG Options to 2015, Selection of Options to be investigated” identified several ADAS/AVG technologies/systems which are likely to be available in the next ten years. This was based on reviews of current literature in Europe, North America and Asia. The review has addressed private car oriented technologies as well as technologies targeted at assisting freight and public transport. The review gives a description of the following technologies:

- Adaptive Cruise Control (ACC) and Stop & Go Control
- Lane Departure Warning (including Lane Keeping Assistance)
- Intelligent Speed Adaptation (ISA)
- Fully-automated driving (Cyber cars)
- Forward Vehicle Collision Warning Systems
- Side-obstacle Warning Systems (Lane-change Assistance)
- Manoeuvring Aids for Low-speed Operation (Parking Assistance)
- Night Vision Enhancement Systems
- Driver Monitoring

Based on literature review and analysis of ADAS/AVG systems, the following scenarios/systems were identified for investigation in STARDUST:

- High Technology Vehicles;
- Intelligent Speed Adaptation (ISA);
- Urban Motorways and Related Roads;
- Urban Networks.

Criteria used for selecting system options include: whether or not the system has the potential to reach the market in the next five to ten years; (ii) whether or not the system has a significant impact on congestion. The systems selected for investigation in STARDUST include: ACC, Stop & Go, Lane Keeping, ISA and Cyber cars.

2.1.1 Adaptive Cruise Control
Adaptive Cruise Control (ACC) system automatically maintains a set time-headway between an ACC-equipped vehicle and a preceding vehicle. When traffic is encountered, ACC-equipped vehicles are provided the convenience of some relief from engaging, disengaging, or resetting speeds, as is the case of with traditional cruise control. When not in traffic, ACC function in a manner similar to traditional cruise control.

Currently, most ACC systems are on-board systems which take over part or all the control of the headway. The control of ACC is based on a sensor which measures the distance to the preceding vehicle and tries to reach the desired speed (set by the driver) while maintaining a selected gap (also usually set by the driver for given speed). The ACC is turned off automatically when the speed is below a certain threshold (about 30 km/h) and hence is not usable in city environments. The driver supervises the ACC and is in control of the steering.
2.1.2 Lane keeping

Lane keeping assistance helps drivers to keep the vehicle within the driving lane. Lane keeping could be used to improve traffic throughput by increasing the number of lanes and could also be used to increase traffic safety by reducing accidents caused by vehicles drifting off driving lane.

There are two main sub-systems for lane keeping: roadway detection and steering control. Most road detection is camera based systems, e.g. by detecting lane markings or roadside through vision systems. Compared to lane departure warning, lane keeping assistance is a more complex situation with many safety issues; especially if it is coupled with ACC (the driver could easily fall asleep while the car continues). One concern is about the legal issue for systems to take over the control.

It should be noted that evaluations in this project focus on single systems in operation. Safety issues related to coupling between ADAS systems may increase or decrease accident risk.

2.1.3 Stop & Go control

Stop&Go control is designed for use in dense traffic with slow speed (e.g. less than 10 km/h). Sensors are used to detect the preceding vehicle and to achieve longitudinal and lateral control. Based on detection and processing, the controller acts on the accelerator, brake, throttle and steering (jointly or separately) to move and stop vehicles. There are currently two variants of Stop & go available. One automatically starts and stops the vehicle when first activated. The other (semi automatic) must be reactivated by the driver by pushing a lever or button on the steering wheel after each stop. The semi automatic variant of Stop&Go is developed to meet current liability issues.

In urban areas, drivers spend large amounts of time in heavy traffic and constant attention is needed for what seems to be a very primitive task: start and stop to follow the previous vehicle. Stop&Go control is particularly appropriate for driving in urban roads. One concern is about the legal issue when the system takes the control. Pedestrian safety is another concern for the application of this system in urban environment. Pedestrians may try to cross the street between vehicles with automatic start. With current limitations to sensors inherent in Stop&Go systems, pedestrian accidents may occur. Coupling with e.g. proximity warning systems may remove this risk.

2.1.4 Intelligent Speed Adaptation

Intelligent Speed Adaptation (ISA) means speed limitation but under a more acceptable term. The concept now studied in various projects has basically three variants. The first one gives only a visual or audio warning if the speed limit is exceeded. The second variant implies a haptic accelerator pedal which allows the driver to maintain the maximum allowed speed without looking at the speedometer. At any moment, there is a possibility to go above the speed limit by pressing the accelerator above the threshold given by the system. This approach which can be sold as a comfort system has the preference of car manufacturers. The last approach is to limit the speed to the official limit without any possibility of override. All these systems are based either on a localisation through a navigation system where the maximum speed limit has been added by segments or on a local communication system with the infrastructure. This second system has the advantage of being more dynamic to take care of changing conditions (fog, rain, snow, road work, congestion, school hours, etc.).
Currently, there are two types of architecture for ISA: infrastructure based and vehicle based. For infrastructure-based ISA, the systems rely on roadside beacon to provide speed limit information to vehicles passing the beacons. In vehicle-based ISA, the vehicle would know its location from a GPS-based navigation system and would know the speed limit for that location from an on-board digital road map in which the speed limit for each link in the network had been encoded.

### 2.1.5 Cybercars

Cyber cars are fully automatic vehicles. They are equipped with a variety of systems including guiding systems, driving systems, obstacle detection and emergency systems to ensure maximum safety. They also contain practical information such as city and public transport maps. Passengers board at a stop point and pay using automatic payment devices. Because of using electricity to power the vehicle, it is less noisy and less pollutant emission. It is expected that the system has great potential to be used to reduce the use of private cars in the urban areas and improve traffic efficiency and environment impacts. The potential negative impacts of using Cyber cars could be the increase of number of changes and out of vehicle time.

### 2.2 Impacts to be assessed

#### 2.2.1 Behavioural acceptance

The objective of acceptance assessment is to identify user preference, potential acceptance for ADAS/AVG systems, and some potential barriers to deployment. The targeted groups for such assessments are end users of ADAS/AVG systems which include: individual drivers and transport operators/infrastructure owners. In assessing user behavioural acceptance to the ADAS/AVG systems under investigation, the main questions included:

- Do drivers consider driving with the ADAS/AVG systems more efficient, comfortable, reliable, and safer than without them?
- Are drivers willing to pay for the ADAS/AVG systems?
- Are drivers willing to use the ADAS/AVG systems?

Based on the assessments of user behavioural acceptance, realistic penetration rates and use rate of ADAS/AVG systems were derived, and introduced in the microscopic models (WP50) and large-scale traffic models for global assessment of impacts (WP60). Clearly, the impacts of the systems are dependent on the percentage of equipped vehicles and the rate and the way of using them. In addition, the results of user preference and acceptance of the selected ADAS/AVG systems were intended to feedback to systems manufacturers and traffic authorities (WP90).

#### 2.2.2 Traffic performance
The objective of such study is to assess the impacts of the ADAS/AVG systems on traffic performance e.g. traffic capacity, efficiency and stability. In assessing the impacts on traffic performance, the following questions will be addressed:

- Can ADAS/AVG systems to be used increase traffic capacities (e.g. using short time headways for driving or increasing efficiency from “stop” to “go” at junction/bottlenecks)?
- Can ADAS/AVG systems to be used increase infrastructure capacities (e.g. using introducing narrow lanes for those vehicle with Lane Keeping facility)?
- Can ADAS/AVG systems to be used increase or stabilise traffic speed?

Many indicators can be used for assessing impacts on traffic efficiency, e.g.

- Mean speed
- Standard deviation of speed
- Average travel time
- Mean volume
- Length of congestion
- Duration of congestion
- Time headway

### 2.2.3 Environmental impacts

In assessing the environmental impacts of the selected ADAS/AVG systems, the following questions were addressed:

- Can ADAS/AVG systems reduce energy consumption for vehicles?
- Can ADAS/AVG systems reduce pollutant emission of vehicles?

ADAS/AVG technologies can offer many potential benefits to the environment. At medium or long term, ADAS/AVG systems will likely contribute to decrease the energy consumption and the emission of pollutants, among others by influencing the way of driving. ADAS and AVG systems automate some or all of the driver’s tasks. In doing so, the vehicle is controlled in a known fashion that can be used to communicate with the on-board diagnostics systems but also surrounding vehicles and infrastructure. The environmental impact of imperfections in human driving skills has been somewhat overlooked. However, evidence exists to show that aggressive driving and unnecessary acceleration can produce much higher emissions than normal driving. Partial automation of the driving control task can reduce these accelerations and therefore emissions whilst improving the fuel efficiency of the vehicles.

STARDUST proposed to examine the emissions impacts of ADAS systems through a range of microscopic simulation and by using results from the analysis of real driver behaviour. The assessment will provide a tool by which cities and local authorities can select specific ADAS/AVG systems to meet clearly defined policy objectives.

Environmental assessment will be provided through estimates of the changes in emissions of key pollutants (CO, NO\textsubscript{x}, CO\textsubscript{2} etc.). Environmental performance will also be assessed through
estimations of the reduction in driver performance variation (e.g. acceleration) that will be provided by these systems compared with manual driving.

### 2.2.4 Traffic safety

The objective of safety assessment in this research include:

- Investigate the safety impacts when drivers are provided with the selected ADAS/AVG systems.
- Investigate whether drivers accept the selected ADAS/AVG systems from the point of the view of safety.
- Investigate whether widespread use of the selected ADAS/AVG systems would affect traffic safety.

Safety is one of the most common and sensitive issues for all of ADAS/AVG applications which has strong influences on the acceptance of both end users and decision makers. Safety has many factors including system function, technology reliability, human machine interface, and traffic conditions under which ADAS/AVGS systems being used. In STARDUST, safety assessment will be focused on traffic safety and human machine interface (HMI) issues. (Technical assessments of safety performance and technology reliability are normally carried out by manufacturer based on certain standards and guidelines).

The traffic safety of any ADAS/AVG systems will generally depend on the context in which they are implemented, e.g. network conditions, traffic load etc. The analysis should be therefore not only give the “overall” safety impact, but also give specific results for various background situations. This will enable decision makers in a particular situation to assess the appropriate safety impact for that case. Some options of safety indicator are listed in Table 2.

<table>
<thead>
<tr>
<th>Safety Performance Measures</th>
<th>Safety Implication</th>
</tr>
</thead>
</table>
| Time-Headway               | \* Longer headways allow the driver more time to respond to impending situations and to control the vehicle. They are thus associated with safer driving behavior.  
\* Traffic conditions may influence result. |
| Speed                      | \* Higher speed may increase the severity of collisions.  
\* Higher speed may increase closing rates and, thus, the probability and severity of collisions.  
\* Variations in velocity may increase the probability of rear-end collisions. |
| Acceleration               | \* Increased accelerations mean increased velocity fluctuations which may increase the probability of rear-end collisions. |
| Response Time              | \* Longer response times may be an indication of driver inattentiveness and could increase the probability of collision |
2.2.5 Legal issues

The objective of legal issue investigation is to consider the public interest issues with particular reference to infrastructure based systems operated by Highway Authorities. Legal issue will particular consider the extent to which national law would need to change to accommodate selected ADAS/AVG systems to be investigated (especially highway code), the principles that might direct any new legislation, the civil liability that might be appropriate to foster their introduction. The study will also need to address the insurance implications of these new systems.

2.3 Case cities

2.3.1 Brussels

The Brussels-Capital simulation model has been build and calibrated by STRATEC in 1997 on behalf on the Ministry of the Brussels-Capital Region. It considers the main Brussels-Capital network (Figure 5). The main road network is composed of four different hierarchical levels of road: motorway, metropolitan road, arterial streets and local streets. The SATURN software has been selected due to its capacities to simulate congestion on each junction of the network. The public transport (bus and tram) bicycles and pedestrians are also taken into account.

The network has been divided in two major zones: the “inner zone”, delimited by the Brussels’s region (administrative limit, dark coloured zone in Figure 4), and the “external zone” (light coloured zone in figure 1), also known as the “buffer”. An important distinction is to be made between these two zones because they are not simulated in the same way. The inner zone is simulated in a dynamic approach, whereas the external zone is simulated in a static approach.

Static models assume that demand (or any other element of the model) is constant over the modelled period and hence predict that link flows (and other outputs) are steady. Static models use speed-flow curves as congestion simulation method.

Dynamic models allow for a time-varying demand (or any other element of the model), usually by splitting the modelled period into a number of time intervals and inputting a trip matrix for each time interval. Outputs are therefore time dependent. Static models tend to overestimate the impact of route diversion while dynamic models with departure time flexibility downplay that impact and exhibit peak shifts.
The Brussels-Capital model includes 5305 links and 2032 junctions (1169 priority intersections, 575 traffic light intersections, 99 roundabouts and 189 intersections outside the limits of the dynamic model).

2.3.2 Oslo

Oslo covers an area of 454 km². The built-up area is 115 km². The open areas in the built-up zone amount to 22 km². The total population of Oslo is 507,467 residents. Oslo has a large harbour, and the city is Norway’s largest harbour for gods. In year 2000, 5800 ships arrived the port.

As of October 1999 366,899 people have Oslo as their place of work. 249,173 employees were living in Oslo while 117,283 employees made their daily work trips across the borders of Oslo. The number of municipal employees was 55,899, representing 44,825 man-years (Table 3).
Table 3 Job distribution in Oslo (1999):

<table>
<thead>
<tr>
<th>Job distribution</th>
<th>Expressed as percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade</td>
<td>20.2%</td>
</tr>
<tr>
<td>Industry, mining and quarrying</td>
<td>8.1%</td>
</tr>
<tr>
<td>Business services</td>
<td>22.8%</td>
</tr>
<tr>
<td>Transport and warehousing</td>
<td>9.7%</td>
</tr>
<tr>
<td>Building and construction/power and water supply</td>
<td>5.8%</td>
</tr>
<tr>
<td>Primary industries</td>
<td>0.2%</td>
</tr>
<tr>
<td>Public services</td>
<td>33.2%</td>
</tr>
</tbody>
</table>

In 1999 162 million passengers used the public transport system; trains, buses, trams, metro, boats and transport for the physically disabled. 2100 authorized taxis, including maxi- and reserve-taxis, make 13.5 million trips. Every day 237,000 vehicles pass through the turnpike ring on their way to the city center and 363,000 vehicles cross the city limits (Figure 2).

Figure 2 The network of Oslo

Two different CONTRAM models have been used in the case study of Oslo; model 1 at Skøyen, and model 2 at Grorud. Their location is shown in the figure on the next page.

The model of Skøyen is characterised by motorways, urban arterials and urban streets. The model consists of 43 zones, 92 nodes and 327 links. Among the 92 nodes there are 4 roundabouts and 13 signalised junctions. The sum of link length is split equally between urban arterial and urban streets, while the total length of motorway links is rather small. Because of heavy traffic during the peak period, a large proportion of the vehicle distance performed in the network is yet on motorway links. The arterial roads in the network are also rather congested during rush hours.
The model of Skøyen is characterised by motorways and arterials roads. The model consists of 61 zones, 209 nodes and 553 links. Among the 209 nodes there are 16 roundabouts and 6 signalised junctions. About 65% of the total vehicle distance performed in the Skøyen network is done on motorway links.

2.3.3 Paris

Each day go and come to Paris and its neighbourhood 11 million of travellers (more all visitors), more than 4 million cars, 630 000 professional vehicles, 185 000 motor bikes, 14 500 taxis, 7 400 buses, 14 subway lines, 5 lines of the RER, 5 000 trains, bicycles... on the whole approximately 37 million travels per day. And, for Paris citizens, one hour and half last each day on average in transport.

Many motorways allow reaching the city centre. The highway A6 is one of the main radial axes of the Paris area. As all the freeways around Paris, it supports a very high traffic. The geometrical complexity and the high demand generate bad traffic conditions on this part of the network, which is a place of frequent disturbances during the morning rush hours.

A part of this main motorway was used for the traffic simulation on micro level. The simulation site is a 12km 3-lane section of the highway A6 to Paris between the road N104 and the off-ramp to Wissous (towards the highway A10) (Figure 4). The profile in length is mainly characterised by the presence of important hillsides and, also, the highway design.
shows several curves. This section of the highway contains five entrances and three exits. Two of the entrances are double on-ramps, see Figure 5).

![Figure 4 Scheme of the studied network.](image)

![Figure 5 Scheme of the Savigny junction on the highway A6 to Paris (idem Chilly).](image)

The centre of Paris is characterised by several arterial road. One of them was used for both the behavioural studies and the traffic simulation. This database, which is then a current Paris avenue, is almost two kilometres long. There are more than 20 intersections along the network; 12 of these intersections are regulated by a traffic light. The Figure 6 below shows an outline of the urban network:

![Figure 6 Outline of Paris avenue.](image)

2.3.4 Southampton

Southampton covers 5,200 hectares with a population of some 207,000 residents and serving a hinterland of 0.5 million. As a port city, access to the centre is constrained by the Rivers Itchen and Test, which converge on Southampton Water. The road network is mainly radial in nature, with a motorway (M27) skirting the northern edge of the city. A short stretch of motorway (M271) links the M27 with the western area of the city, including the western dock of Southampton. The main roads connecting Central Southampton with surrounding areas include: the A33 (connecting M3), the A35, the A335 (connecting junction 5 of the M27), the A3024 (connecting junction 7/8 of the M27), the A3025, and A3057.
The Southampton CONTRAM network consists of 2484 links (525 signalised, 545 give-away, 1414 uncontrolled), 780 nodes (including 114 signal controlled junction, 48 round about, and other junctions). The total link length is 793 km for the whole network.
Figure 8 Southampton CONTRAM network
3 Research approach

3.1 Overview of the methods used
Because most of the systems to be investigated in STARDUST are still in the stage of research/developments, it is impractical and virtually impossible to measure the impacts of ADAS/AVG under full-scale, real-life operation. The following methods of measurements have been used throughout the evaluation process in STARDUST:

- The questionnaire (user acceptance, impact assessment)
- Field trials (floating vehicles)
- Driving simulator experiments
- Modelling (microscopic and macroscopic simulation)

The sites and approaches that have been applied are summarised in Table 4.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Behavioural acceptance analysis</th>
<th>Trials with floating vehicles</th>
<th>Trials with driving simulators</th>
<th>Micro-simulation</th>
<th>Large-scale city-level modelling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brussels</td>
<td>x</td>
<td></td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>Paris</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Southampton</td>
<td>x</td>
<td></td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>Oslo</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td>x</td>
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</tbody>
</table>

The assessment of the impacts starts from the investigation of user behavioural acceptance and human factors and finally integrates them in large-scale traffic models. It goes from the assessment of the potential penetration rate of the systems, and the analysis of the behaviour of individual drivers, when they are provided with selected ADAS/AVG systems: this will raise issues such as acceptability of the systems, willingness to pay for them, willingness to use them, safety issues, etc. Both the assessment of behavioural acceptance and the driving behaviour analysis are key elements of the methodology, as they introduce the end users perception and behaviour in the evaluation process. This prevents from unrealistic conclusions, which would not take into account the actual user preferences.

The overall evaluation methodology then goes through micro-simulation, and finally to the large-scale modelling of the impacts, at the level of a whole city. Micro-simulation models such as AIMSUN, ARCHISIM, allow representing traffic phenomena with a higher level of detail than the assignment models such as SATURN or CONTRAM, but within smaller areas.

The aim of the micro-simulation has been to sharpen the elements of the large-scale assignment models, so that they integrate the results on the penetration rate and the way the drivers behave with regard to the ADAS/AVG systems. The link between micro-simulation and assignment models has made the latter benefit from detailed modelling of micro-simulation such as time-flow relations, queues and delays.

For evaluation at city levels, the measurement of impacts is mainly based on the network results. These network results come from local impact modelling (e.g. microscopic simulation) first, and then the results are expanded to the network. When the results of
microscopic simulation make it possible to calibrate the parameters (capacity, speed/flow relationships, etc.) needed for macroscopic models, the assessment can be done from microscopic to macroscopic modelling as shown in Figure 9.

Figure 9 Method of evaluation at city levels
3.2 Questionnaire to assess acceptance of the systems

Driver questionnaire

Because most ADAS/AVG systems are in their early applications or in the stage of prototypes, stated preference surveys are very useful to investigate user acceptance to such systems in which users present their preference based on hypothetical situations.

In STARDUST, questionnaire has been used to

- Investigate user preference of individual drivers (for vehicle based systems e.g. ACC, Stop&Go) in terms of efficiency, safety, comfort, workload, easy to learn/adaptation, cost and willing to pay.
- Investigate the acceptance of transport operators (for infrastructure based and cooperative systems, e.g. Intersection Collision Warning system) in terms of efficiency, safety, energy consumption, pollutant emission and cost.
- To communicate with key stakeholders regarding the development and deployment of the selected ADAS/AVG system. The three main user groups include: (1) City and local authorities; (2) Vehicle and system manufacturers; (3) driver association and representatives.

Questionnaires have been carried out in the three case cities: Brussels, Oslo and Southampton. The results from such questionnaire have been used for the assessment of user acceptance and to predict the penetration rates which has been used as input in simulation work packages.

The objective of acceptance assessment is to identify user preference, potential acceptance for ADAS/AVG systems, and some potential barriers to deployment. The targeted groups for such assessments are end users of ADAS/AVG systems which include: individual drivers and transport operators/infrastructure owners. In assessing user behavioural acceptance to the ADAS/AVG systems under investigation, the main questions needed to be addressed include:

- Do drivers consider driving with the ADAS/AVG systems more efficient, comfortable, reliable, and safer than without them?
- Are drivers willing to pay for the ADAS/AVG systems?
- Are drivers willing to use the ADAS/AVG systems?

Based on the assessments of user behavioural acceptance, realistic penetration rates and use rate of ADAS/AVG systems will be derived, which will be introduced in the microscopic models and large-scale traffic models for global assessment of impacts. Clearly, the impacts of the systems are dependent on the percentage of equipped vehicles and the rate and the way of using them. In addition, the results of user preference and acceptance of the selected ADAS/AVG systems will be feedback to systems manufacturers and traffic authorities in the user group liaison.

Operator questionnaire

The main goal with the survey directed to public transport operators and infrastructure owners was to assess what are the barriers to implement ADAS/AVG systems from their point of view. The survey was carried out in Belgium, Great Britain and Norway where road transport
operators, infrastructure owners and other respondents working in the field of transportation were interviewed.

### 3.3 Driver behaviour studies through floating vehicle trials

The objective of field trials with floating vehicles was to provide a realistic behaviour database (especially in conditions of low speed traffic conditions) which has been used as a normative standard for human factor investigations, behavioural assessment, simulation and safety assessment in the later stage of this the project.

The instrumental vehicle has a high accuracy optical ground speed measuring device. Information on the vehicle speed is logged into the on-board computer ten times a second. Coupled with this information is data collected from radar. The radar has three beams, each of 3 degrees width capable of tracking up to 4 targets each at distance of up to 120m. Information on distance headway and relative speed of the vehicles is collected. The following parameters are measured and calculated for every update period:

- Distance Headway (measured)
- IV speed (measured)
- Relative speed (measured)
- Time to collision (calculated)
- Acceleration (calculated)
- Rate of change of visual angle (calculated)

![Figure 10 Instrumented Vehicle used TRG to collect traffic data in Oslo, Paris and Southampton](image)

### 3.4 Driving simulator experiments

Driving simulators are computer-based tools for collecting data on drivers’ behaviour. They achieve this by requiring subjects to ‘drive’ through a representation of a road network while providing them with a sequence of stimuli similar to those which they would receive, were they making the journey in a real network. Thus, in the most advanced driving simulators, the computer displays a sequence of views of the roadscape as the subjects progress down each link and provides auditory and visual and in some simulators also motion cues associated with these views. An artificial dashboard depicts the speed at which they are travelling and reports
on elapsed time and distance travelled. Driving simulators offer the experimenters a high degree of control over the network structure, the traffic conditions and the presence or absence of various ADAS/AVG systems. They thus constitute a very powerful aid to research into the impacts of each of these systems on driver’s behaviour, particularly for those systems which are difficult to do field trials (e.g. Intersection Collision Warning systems).

Models of driving behaviour suggest that behavioural adaptation can be expected when intervening with technology in the driving process. In a wider perspective, technology does not simply replace or “take over” a given function; rather it transforms human practice and forces people to adapt their skills and routines. The driver support systems focused in these simulator studies have all been studied before to a greater or lesser extent. However there is a lack of studies on how people adapt to these systems in an urban setting with an urban traffic flow, particularly those related to the learning phase and to the long term effects.

The understanding of how ADAS/AVG systems influence on the driver behaviour is a key to the further investigation both on micro-scopic and macro-scopic level, and the simulator studies is therefore an important basis for the investigation of the impacts of different systems.

In STARDUST, driving simulators has mainly been used to investigate the following effects:

- Investigate human factors and driver behaviour in existing situations (e.g. over-speed rates when without ISA)
- Investigate human factors and driver behaviour when drivers are provided with the selected ADAS/AVG systems;
- Investigate safety impacts of the selected ADAS/AVG system.

Driving simulators has been used in Paris and Oslo to investigate the behaviours in a particular European country, France and Norway. This will enable to check the transferability of the conclusions on driving behaviour within European countries. The systems studied by use of driving simulators in France and Norway include Intelligent Speed Adaptation (ISA), Advanced Cruise Control (ACC), Stop&Go, and Lane Keeping.
The GPS-based Position Unit is replaced by a simulated GPS system within the simulator.

Display, on the dashboard

GPS Antenna, up on the dashboard

Mechanical Unit, in the engine compartment.

Position Unit contains:
1. navigator
2. digital map with speed limits.
3. log memory for several months of driving.

CPU, controlling the mechanical unit and communicating with the position unit and the display.

Figure 11 ISA system installation in SINTEF simulator

Figure 12 INRETS’s Driving Simulator
3.5 Impact assessment through micro-simulation

In STARDUST, the micro/sub-micro simulation models to be used include AIMSUN, ARCHISIM and VISSIM. These simulation models allow representing traffic phenomena with a higher level of detail than the assignment models but within smaller areas. To predict driver’s behaviour in a new environment, different methods may be used such as stated preference surveys, observation of the driver’s reaction when placed in a simulator or driving a prototype. But those methods only provide individual, disaggregate results, or results by segment. They do not provide any mean aggregate values to be put in the formulas of the macro models; they do not either enable to predict the effect of a given penetration rate.

That is the role of the micro simulation tools: they fill this gap. The whole range of behaviours of different driver’s as well as the penetration rate will be introduced in the micro models in order to derive aggregate results compatible with the scale of the macro model: this makes up the process for calibrating the new basic rules for driver’s mean future behaviour.

In other words, the micro simulation tools are the necessary interfaces between the individual behaviours of different categories of drivers and the aggregate parameters which represent the whole of them at the scale of the macro simulation models. Cross-comparison of the results between the microscopic modelling tools will ensure that local calibration does not influence the modelling outcomes.

The aim of the micro-simulation is here to sharpen the elements of the large-scale assignment models, so that they integrate the results on the penetration rate and on the way the drivers behave with regard to the ADAS/AVG systems. In STARDUST, microscopic models will be mainly used for:

- Assessing the local impacts of the selected ADAS/AVG systems on driver performance, traffic performance, safety and environment.
- Determining the parameters which are needed by macroscopic models (e.g. capacity, speed-flow relationship, reaction time at signalised intersections) for city-level assessments.

3.6 Network modelling at a city level

The objective of macroscopic modelling is to provide an assessment of the impacts of new advanced driver assistance and automated vehicle guidance technologies on urban network efficiency, traffic safety and the urban environment. This will make use of assignment models applicable to large urban areas, based on software such as CONTRAM or SATURN. Thereafter, the large-scale traffic models of Brussels, Southampton and Oslo will be upgraded, through development of new behavioural algorithms or introduction of new values for key parameters. The performances of the selected systems will be assessed at a city-level; this will include an assessment of the efficiency (congestion, travel times), safety and environmental performances of the systems. The processes by which the changes in traffic performance occur will then be analysed to highlight any issues that may be a safety or legislative concern.

In assessing the impacts on traffic performance, the following questions have been addressed:
ADAS/AVG technologies can offer many potential benefits to the environment. At medium or long term, ADAS/AVG systems will likely contribute to decrease the energy consumption and the emission of pollutants, among others by influencing the way of driving. ADAS and AVG systems automate some or all of the driver’s tasks. In doing so, the vehicle is controlled in a known fashion that can be used to communicate with the on-board diagnostics systems but also surrounding vehicles and infrastructure. The environmental impact of imperfections in human driving skills has been somewhat overlooked. However, evidence exists to show that aggressive driving and unnecessary acceleration can produce much higher emissions than normal driving. Partial automation of the driving control task can reduce these accelerations and therefore emissions whilst improving the fuel efficiency of the vehicles.

In the assessment of the effects on city level the following indicators have been used:

- Network journey time
- Network distance
- Average speed
- Total fuel consumption
- Total emission of CO₂ and NOx

The macro-simulation is based on a comparison between the baseline situation and a 20 % and 80 % penetration rate to represent low and high levels of applications. A few calculations have also been made with 100 % equipped cars to show the trend.

The macro-simulations are based on the current demand in the road network consisting of motorways, arterial roads and urban streets. The calculations are partly made for peek traffic and partly off peak depending on the type of system. No assumptions have been made regarding traffic growth, but the sensitivity analysis is made for different degrees of traffic demand and thereby illustrates the consequences of different demand levels. The macro simulations have been run with 80%, 100% and 110% of the current demand level. Even if the results seems to be quite robust especially for the ISA system, it is important to be aware of the fact that similar calculations on a macro level can give different results for other cities.

3.7 Assessment of legal and institutional aspects
The objective of legal issue investigation has been to consider the public interest issues with particular reference to infrastructure based systems operated by Highway Authorities. Legal issue will particular consider the extent to which national law would need to change to accommodate selected ADAS/AVG systems to be investigated (especially highway code), the
principles that might direct any new legislation, the civil liability that might be appropriate to foster their introduction. The study will also need to address the insurance implications of these new systems.
4 Key results

4.1 ISA applications

4.1.1 User acceptance

There is a vested interest in ISA systems in the public. Based on UK and Norway results, from 50 to 60% of drivers believe that ISA would bring improvements in terms of safety. There is a clear preference for the less constraining system. In all 3 countries, there is a very strong support for warning systems, while the other options proposed (haptic accelerator or mandatory speed adaptation) found very few supporters.

However, when interviewing people after a test in the driving simulators, there is an improvement in the perceptions people have on ISA systems. In Norway, 78% of respondents preferred the warning system and 13% the haptic system. However, among the 18 persons interviewed after the driving simulator test in Norway, 56% preferred the haptic system and only 44% the warning system. Clearly, experience with haptic systems helps convincing drivers of the interest of such device. This fact suggests that correctly informing drivers about the new systems is a key towards their wide acceptability.

There is a clear age trend in the appreciation rate for ISA systems. In the three countries we surveyed, older drivers rate these systems higher than younger ones. In terms of revenues, evidences are contrasted. In the UK, respondents in high revenue classes had a higher willingness to pay for an ISA system than those in lower revenue classes, while in Norway, the contrary was observed.

Would the policy on speed enforcement change people attitude towards ISA? In the UK, 80% of respondents found ISA systems attractive if speed limits were aggressively enforced. In Norway, 62% of respondents had the same attitude. In Belgium, they were no attitude differences between the current situation (few speed controls) and an hypothetical situation where speed limits would be aggressively enforced. Attitudes are contrasted among countries, which could be explained by cultural differences, or because potential changes in public policies are difficult to anticipate.

Finally, when asked where they would use the ISA systems, UK respondents were mostly interested in using ISA systems in urban areas (70% to 85%, depending on the kind of zone), but only a third of respondents would use ISA on motorways (urban or inter-urban). Norwegian respondents showed a similar opinion: 50% to 70% would use ISA on urban roads, and 30% on motorways.

The interest for ISA in some situations is likely to be linked with the structure of land use. In the UK for example, there is a large number of wide residential areas around the major cities. These neighbourhood are usually equipped with good quality roads, where speeding is easy, which is seen as dangerous. ISA systems would be attractive to reduce that speed. Indeed, UK respondents would first use ISA in residential areas. The situation would be different in highly urbanised countries, such as Belgium. In that case, streets in residential are narrow and do not favour speeding. Belgian respondents favoured the use of ISA in the entire urban area.
4.1.2 Driver behaviour with ISA
The driver simulator trial with ISA indicates several behavioural adaptations to the new driver support system. There is a significant reduction in top speed for all urban settings studied (arterial roads, urban motorway, inner city streets) when driving with the Haptic ISA system. This variant of ISA makes the accelerator pedal hard to press when speed limits are exceeded. In addition, this variant of ISA gives the driver a noticeable “kick” under the foot at the moment the speed limit is passed. Analysis of separate urban road segments shows significant lower mean speeds on an urban four lane motorway with ISA in use.

Drivers appropriate a lower mean speed than the baseline condition and spend more time in their primary lane. Due to the speed limited by ISA system, overtaking other vehicles on urban motorways takes longer time with ISA. During overtaking manoeuvres on two-lane roads, drivers with ISA engaged spend more time in secondary lane. Whether this is an exclusive positive effect in terms of safety and traffic flow is open to discussion and will be followed up in the micro and macro simulations.

The reductions in top speed could be expected from previous studies of ISA. The way drivers adapt to driving on urban motorways with ISA is however valuable input to the micro and macro simulations, and could not be derived from previous studies. Driving on typical inner city streets shows a reduction in mean speed of about 5km/h. This result is in line with previous results from field studies with haptic ISA in Sweden.

Workload measurements show no difference with and without ISA. Post test questionnaires show that Norwegian drivers regard ISA as useful and assisting, but irritating, due to the “clicking” noise and the “slap” under the sole of the foot. Post test interviews revealed that the irritation was attributed to the “kick” feedback when passing the speed limit and not to the fact that the accelerator became heavy. The “kick” feedback is one of several possible variants of ISA. It is optional and thus possible to choose a system configuration causing less irritation. A system variant with only haptic feedback could have a positive effect on user acceptance.

4.1.3 Traffic impacts
Micro-simulations were conducted in Oslo and Paris and Southampton to assess ISA impacts on traffic in conditions of mixed traffic of equipped and un-equipped vehicles, and to provide an interface between results of individual behaviours of different categories of drivers and those at aggregate level when ISA systems were applied. Three types of road conditions were considered: urban motorways, urban arterial roads and urban streets. The assessments were based on comparisons of traffic performances between those at baseline conditions and those when ISA systems were applied. In the scenarios of urban arterial roads and urban streets, the typical urban traffic conditions of signal controlled junction and roundabout were considered. From the simulation results, the following conclusions can be made:

- ISA had significant effects on limiting driving speed to the official value. This result in reduction of speed variation, the harmonising of vehicle speeds between and within lanes, and the reduction of the number of lane changes.
- Lane changing is one of the main reasons for short TTC and short time-headway events. From this point of view, ISA applications will increase driving safety.
- The obvious negative impact of ISA applications was the increases in journey time. Based on the simulation results, the increase of journey time were in a range of 0%-15%
which depended on factors including ISA penetration levels, baseline speeds, and road types applied. On motorways, the biggest increases in journey time occurred to those travelling on the fast lane, although the average increase in journey time for all of the drivers were much smaller than those travelling on the fast lane. On arterial roads and urban streets, speed reduction could result in increase in travel time, but this could also mean decreases in queuing time, because the capacities of urban roads were much dominant by junctions.

![Speed distribution](image)

Figure 13 Speed distributions when at high penetration (AIMSUN, Oslo)

![Time headway distribution](image)

Figure 14 Distributions of time-gaps on motorways (AIMSUN, Southampton)
Figure 15 Distributions of TTC on motorways (AIMSUN, Southampton)

Figure 16 Lane change manoeuvre (AIMSUN, Southampton)
ISA impacts on city level were assessed by network modelling at three cites: Brussels, Oslo and Southampton, in off-peak traffic conditions. The results of network journey time, distance and speed in the three cities are shown in Figure 17 and Figure 18.

As expected, the network speeds decrease, but network journey times increase as penetration levels increase. Considering the changes in speeds and journey times, similar results were seen in the three sites with the changes being in the range of 0-5% as ISA penetration rate increases. It is interesting to note that there were no significant changes in network distance.

In all three cities there were more reductions in speeds on motorways than those on other roads, indicating that ISA has more impacts on motorways. This might be linked to the fact that most serious speeding occurred on motorways.
No significant changes in network distance were found in Southampton and Oslo which indicated that ISA did not cause much change in the general patterns of assignments, with most of drivers keeping their original routes. However in Brussels, simulations results show a slight increase in the travel distances (0.6% on arterial road at 20% penetration rate).

It is generally believed that ISA effects are influenced by traffic demands because of different traffic congestion levels. To prove this, the simulations were run at 80%, 100% and 110% of the current demands. It was found that both in Southampton and Oslo there were less reductions in journey time at 110% demand than those at 80% demand. This indicated that ISA effects at high traffic demand are less than those at low traffic demand. This can be explained that in conditions of light traffic, there are more opportunities of speeding. Using ISA can result in more reductions of speed. Whilst in situations of high demand, speeding becomes difficult because of

4.1.4 Environmental impacts

ISA impacts on fuel consumption were analysed by considering the three types of road applied: motorway, arterial roads and urban streets. Figure 19, Figure 20 and Figure 21 show the changes in fuel consumption in the three sites. In general, fuel consumption decreased on motorways, but increased on urban streets. On motorways, fuel consumption reduced by 0.4% in Brussels, 2.0% in Oslo and 3.5% in Southampton when at 80% penetration rate. On arterial roads, fuel consumption increased by 0.5% in Brussels, 1.2% in Oslo and 0.3% in Southampton. The relative large reductions in fuel consumption on motorway are linked to the high speed on motorways which causes excessive fuel to be consumed. With the IAS being used, vehicle speed is reduced to a value which is more close to the optimum speed of fuel consumption. However on urban roads, vehicle speeds were often at a level which is lower than the optimum speeds. Therefore, ISA has negative impacts on fuel consumption in this situation.

![Figure 19 Fuel consumption on different types of road (Brussels, SUTURN)]
At a city level, similar trend was seen in the results for Oslo and Southampton. The total fuel consumption and pollutant emission decreases as ISA penetration levels increase. Compared to those in baseline conditions, the total fuel consumption, CO2 and NOx decreased by 1.8%, 1.3% and 7.4% in Southampton when at 80% ISA penetration rate, the correspondent values are 1.1%, 0.6% and 4.2% in Oslo. In Brussels, the ISA application on an already congested network generates a low increase in fuel consumption and CO2 emission (0.6%, in correlation with the increase of travel distance) and a more significant increase in NOx emission (6.9%, in correlation with the increase of journey time).
4.1.5 Barriers to implementation

One of the main perceived barriers for ISA systems in the operator survey is the acceptability by drivers. Important barriers are also the cost, possible problems of liabilities and the reliability of the system. The perceived barriers are however relatively lower for ISA than for other systems investigated, and ISA is the system that the respondents were the most keen to promote.

From the public authorities point of view, ISA is the system that is perceived as having the most benefits to implementation with more than 75% of the respondents seeing a benefit to implement it. The reason for this is probably the concern over safety issues, as ISA is perceived as the system bringing the higher positive impact on safety (number of accidents/km), which is an important matter for European governments.

Overall, barriers to implement ISA systems were perceived as lower by respondents in Belgium and Norway than by respondents in the UK (average answer of 1.9). British respondents were particularly sensitive to barriers in four areas: funding, reliability of the system, the need for standardisation and the willingness of decision makers.
4.1.6 Legal issues

From the legal perspective ISA would appear to be the most feasible system from a legal point of view. It would appear that the system would be most beneficial when used in an urban environment as well as interurban/motorway environment.

**Use**

All variations of ISA dictate that the vehicle must be accurately located and provided with information about the speed limit on the section of road it is using. This can be achieved by using global positioning technology to inform the vehicle of its exact location, combined with either an on-board digital road map, detailing every single speed limit for each section of road, or the use of a sensor which detects messages given out by road-side beacons. In this way the system is able to detect the maximum speed limit for the vehicle’s current position and issue a warning or adjust the vehicle speed accordingly. ISA is particularly useful in urban environments as it allows for different speed controls at various times of the day and under different roadside and weather conditions. For example, the speed limit outside a school could be lowered from 30 to 15 kilometres per hour at school start and finish times, but raised to 45 kilometres per hour during school holidays. Additionally, speed limits could be lowered in cases of snow or fog, or in areas where roadworks are being carried out.

**Driver Behaviour**

Drivers may subconsciously become reliant upon ISA and develop bad habits by paying less attention to speed limit road signs. The system may also lead to motorists wrongly believing that it is safe to drive as quickly as is legally possible, without taking all the surrounding circumstances into account. Thorough training and manufacturer’s warnings will be necessary to reinforce the message that drivers must take into account all circumstances when deciding what speed to drive at.

As with Stop & Go and Lane Keeping, drivers need to be thoroughly trained in the use of ISA. The same considerations need to be given to using a manual to train drivers. The training must reinforce the fact that ISA should only be used as an driver aid, rather than being replied upon by drivers. This is easier with the non-haptic system, which only issues a warning for the driver to consider and act upon, as opposed to taking control of the vehicle. However, even with the haptic system, the driver must be ready at any time to override the system and regain control of the vehicle. The training should make it clear that the driver retains ultimate control over his vehicle and will, therefore be responsible for its speed.

**Some Liability Issues**

The liability of the driver of an ISA equipped vehicle if he relies on the system to keep him within the speed limit, but the system inadvertently fails and the driver is caught speeding.

Section 89(1) of the Road Traffic Regulation Act 1984 provides that “a person who drives a motor vehicle on a road at a speed exceeding a limit imposed by or under any enactment to which this section applies shall be guilty of an offence.” If the driver breaches section 89(1) he may be liable to a fine and / or the endorsement of his licence with 3-6 penalty points and / or discretionary disqualification, if the court believes this is necessary. The driver retains ultimate control over the speed of his vehicle, as the ISA system can be overridden at any time. The driver is also able to look at the speedometer to monitor his speed limit independently of the ISA system. Therefore it is unlikely that the court will accept the failure
of the ISA system as an acceptable defence to speeding. However, if the driver is fined for speeding, he could bring an action against the manufacturer of the ISA system for negligence, if he can prove that the manufacturer breached its duty of care, causing loss or damage which is not too remote. Again, the usual principles apply and, if there is no specific evidence of breach, other than the fact that the Lane Keeping system failed causing an accident as a result, the court may infer negligence. The manufacturer may also be liable under the CPA if the ISA system is found to be defective. Finally, the seller of a vehicle sold containing the defective ISA system may be liable for breaching an implied term of the contract with regard to the quality or fitness for purpose of the vehicle.

The liability of the driver of an ISA equipped vehicle if he relies on the system to keep him within the speed limit, but drives too fast for the road conditions (albeit within the speed limit) and causes an accident.

Where an accident occurs, the potential liability of the driver in negligence will depend upon the facts of each case. In deciding whether the driver has breached his duty of care, the court will consider whether he reacted in the same manner as an ordinary skilful driver in the same circumstances. In addition, the court will consider the limitations of the ISA system and assess whether the driver took note of and acted appropriately in relation to any warnings about the consequences of those limitations. Other issues will also be considered, such as whether the driver of another vehicle, or a pedestrian, acted negligently. The driver may also be found guilty of a criminal offence, such as dangerous driving, under the Road Traffic Act 1988, as amended by the Road Traffic Act 1991, if the prosecution is able to prove beyond reasonable doubt that the driver committed an offence.

Liability of the Local Authority for determining the road speed.

If the road-side beacon system of conveying speed limits to the ISA system is used, liability for any accident caused by the vehicle’s automatically controlled speed could be argued to rest with the Local Authority responsible for determining the speed limit. The court will determine whether the Local Authority acted negligently in setting the speed limit, applying the usual tests for negligence. In addition, it is likely that the Local Authority will be under a legal obligation with regard to the safe and efficient operation of the road-side beacons.

The liability of the manufacturer for ‘foreseeable misuse’

The driver of a vehicle equipped with an ISA system may rely upon the system to keep the vehicle within the speed limit and subconsciously pay less attention to road signs or the vehicle’s speedometer, inadvertently misusing the system. If it is foreseeable that a consumer may be harmed by misusing a product, such as dangerous driving, under the Road Traffic Act, the manufacturer is likely to be under a duty to warn the consumer of this risk. Therefore, to decrease the risk of attracting liability, the manufacturer should warn the driver of the foreseeable risks of misuse of the ISA system.

Feasibility and the inherent limitations of ISA.

Of the three ADAS / AVGS considered, from the legal perspective ISA would appear to be the most feasible system, in part because the extensive driver training needed to implement the complex Stop & Go and narrow Lane Keeping systems is not a prerequisite to the introduction of ISA. In addition and in contrast to Stop & Go and narrow Lane Keeping, its expense would be lower and amendments to current legislation may well be unnecessary. However, there are inherent limitations with all three versions of ISA which must be addressed, as far as possible, prior to implementation. The main limitation is the risk of driver reliance upon the system coupled with a disregard for surrounding circumstances. Driver training, warnings and promotional material should all reinforce the message that the
driver must not rely upon the system, but rather use it as an aid to driving, in a way not
dissimilar to parking sensor systems. In addition, it is imperative that the road-side beacons
or digital road map used to convey road speed limits are as up-to-date as possible. Again,
however, it would appear that the system would be most beneficial when used in an
interurban/motorway environment, rather than in an urban environment. In town, numerous
hazards such as pedestrian activity, roundabouts and traffic lights would mean that the driver
would constantly need to override the system to react appropriately to his surroundings.

4.1.7 ISA conclusion
Among the three types of ISA surveyed, warning ISA was the most welcome one with 64% to
76% of the drivers took it as a favoured; Mandatory ISA was the least welcome ISA with only
9% to 13% of the drivers preferred to it. In the situations of strictly enforced speed limits,
there could be an increase of 10% to 20% in the number of drivers who took ISA either
attractive or extremely attractive according to results from UK and Norway. 53% to 56% of
them said they would consider buying an ISA system for their next car. Concerning the
roadways for using an ISA, drivers would more like to use an ISA on roadways with lower
speed limits than those with higher speed limits. About two thirds of the drivers would like to
use an ISA on urban roads, compared to a third of the drivers who would like to use an ISA
on motorways. Driving in residential areas was the most favoured situation for drivers to use
ISA systems. Up to 70% and 85% of the drivers said they would like to use ISA systems in
residential areas. However, there were 5% to 10% of the drivers did not like to use an ISA on
any roadways.

The ISA effects of reducing excessive traffic speed in the network, hence improving safety
generally results in increases in journey time over the network. This was dependent on the
penetration level of ISA systems, and the simulation results showed that network journey time
increased as ISA penetration rates increased. At 80% penetration, network journey times
were found to increase in a range from 4.3% to 6.0% (the differences in these results could be
caused by the initial conditions or the specific modelling assumptions). No significant
changes in network distance were found in Southampton and Oslo which indicated that ISA
did not cause much change in the general patterns of assignments, with most of drivers
keeping their original routes. However in Brussels, simulations results show a slight increase
in the travel distances (0.6% on arterial road at 20% penetration rate).

ISA impacts on fuel consumption and pollutant emissions were dependent on road types
applied. ISA have positive impacts on fuel consumption on high speed roads, but negative
impacts on low speed roads. At 80% penetration rate, fuel consumption was found to reduce
in a range of 0.4%-3.5% on motorways, whilst increase in a range of 0.2%-1.2% on urban
streets. ISA impacts on arterial roads were different in the three cities. At 80% penetration
rate, fuel consumption increased by 0.1% and 0.6% in Oslo and Brussels respectively, but
decreased by 0.2% in Southampton. Such an inconsistence could be the results of different
speed limits applied in the three cities. CO2 and NOx emissions were found to have similar
trends with fuel consumptions.

ISA is more effective in non-congested traffic conditions when drivers are able to exceed a
speed limit, thus the effects of ISA are sensitive to traffic demands.

One of the main perceived barriers for ISA systems is the acceptability by drivers. Important
barriers are also the cost, possible problems of liabilities and the reliability of the system.
From the legal perspective ISA would appear to be the most feasible system. It would appear that the system would be most beneficial when used in an urban environment as well as interurban/motorway environment.

4.2 Stop&Go applications

4.2.1 User acceptance
Stop & Go systems are designed to provide assistance to drivers in congested « stop / start » traffic situations. Stop & Go systems detect vehicles ahead (moving and parked) using on-board sensors (radars, etc.) and automatically maintain a safe distance from a vehicle in front by adjusting the accelerator, brake and throttle to move / stop the vehicle. Because this happens automatically the driver is relieved from the strain of constantly accelerating and decelerating associated with congested conditions. However the driver is still in control of steering, and can override the Stop & Go system at any time by using the accelerator or the brake pedal.

Perceptions of Stop & Go systems by British and Norwegian motorists are positive, though not as much as for ACC, probably because this system is less well-known. About 40% of respondents believed Stop & Go systems would improve comfort and safety. Between 10% and 20% believed they would deteriorate comfort and safety.

In Belgium, we asked respondents how interested they would be by Stop & Go in different traffic situations: in a queue at a traffic light, on urban motorway and congested urban roads. From 64% to 72% of Belgian respondents found stop & go attractive in those situations. This is higher than in the UK or Norway, but as the questions were phrased differently, it is difficult to draw a conclusion from this.

Between 35% and 40% or respondent would consider stop & go when purchasing their next car. There is strong difference between drivers who frequently drive in congested situation and those who rarely do so. The interest in stop & go systems is twice as high in the former category than in the latter. The chart on left show how perception changes as drivers encounter congestion rarely or frequently.

4.2.2 Impact on driver behaviour
Stop&Go is an ACC system adapted to low speeds (e.g. <25km/h) e.g. traffic jam and slow moving traffic, which provides automated control of start/stop and headway. Stop&Go support was tried both by Norwegian and French simulator drivers. It must be noted that the Stop&Go scenarios studied differed in several aspects. Norwegian drivers experienced an urban scenario of a four lane motorway with slow traffic, stand stills and little opportunity to
change lanes. French drivers experienced a three-lane city boulevard with traffic lights and, in two of four scenarios, ample opportunity to change lanes.

In initial analysis, the Stop&Go part of the Norwegian studies show no significant behavioural adaptation in comparison with the baseline drive in terms of changes in headway, neither mean or variance. Yet, further investigation of subgroups of subjects revealed indications of Stop & Go system giving rise to behavioural adaptations such as lower mean speeds and lower variance of speed. The French studies showed, that the system has a strong impact on the start delay. The system homogenises the driver behaviour. It is interesting to note cultural differences. French drivers choose shorter headway's than Norwegian drivers using the same Stop & Go system.

In conclusion the overall pattern of behavioural effects for Stop & Go shows lower mean speed, and more importantly, analysis indicate lower variance of speed and shorter start delay, which may be considered as interesting effect regarding improvements of traffic flow.

The opinions of the Norwegian and French drivers are generally good. The drivers considered Stop&Go to be very useful, especially in urban environments with dense traffic. Concerning the French drivers, they experienced some irritation by cut-in of other vehicles and they felt loosing time in one of the test scenarios. This behaviour could possibly be related to the lack of both knowledge and faith in the system. However, the majority of the French drivers felt helped by the system, not constrained by the system and they did not want switch off the system.

### 4.2.3 Traffic impacts

Stop&Go impacts in conditions of a signal controlled link and a roundabout link were simulated in three case cities: Oslo, Paris and Southampton. From the micro simulation results, the following conclusions were drawn:

- **Stop&Go has positive impacts on traffic efficiency in terms of journey times on both a signal controlled link and a roundabout link.** The simulation results show that the journey time can be reduced in a range of 0-15% on a signal controlled link and 0-46% on roundabout link which are dependent on factors including penetration levels, congestion levels and control plans. Stop&Go’ positive impacts on traffic efficiency are reflected by the reduction of stops and stop-time per vehicle in the journey.

- **Stop&Go can increase efficiency for vehicle to start-up from stops due to short driver reaction time.** According to the measurements at a signal controlled junction in Southampton, the average time headways passing the stop-line of the junction could be shortened by up to 30% when all vehicles are equipped with the systems. Further research is needed to assess the safety implications of such reduction in time headways.

- **Stop&Go had strong effects on harmonising traffic movements which resulted in the reduction of short TTC events.**

- **At signal controlled junctions, saturation flow increases as Stop&Go penetration level increases.** Compared to that at baseline, saturation flow can be increased by up to 29% when all of the vehicles are equipped with Stop&Go systems.
In the micro simulation, it was assumed that Stop&Go systems were switched off after passing the stop-line or give-way line at the junctions. In reality, this might not be true. Some drivers might choose to make the systems switch-on whenever possible. Further research is needed to know the safety implications in such situations.

Network impacts of Stop&Go were simulated in two case cities: Brussels and Southampton. Figure 24 and Figure 25 show the changes of network journey times and speed in Brussels and Southampton at different levels of Stop&Go penetration (with average expectations of Stop&Go effects).

As can be seen, the network journey times decrease as the penetration rate increases. Compared to those in baseline conditions, the network journey times were reduced by 7.5% in Southampton and 15% in Brussels when at 80% penetration level. The large reduction of journey time in Brussels could be linked to the fact that there are more signal controlled
junctions (33.7%) in Brussels than those in Southampton (20.8%). More signal controlled junctions mean more opportunities of automatic Stop&Go and more journey time savings.

Stop&Go resulted in reduction of journey times on all three types of road. However, there were more reductions in journey times on urban streets than those on arterial roads. Taking Southampton as an example, at 80% penetration level, the journey times on the street roads were reduced by 8.8%, compared to 3.0% on the arterial roads. This was because that there are more signal controlled links and roundabout links on urban streets than those on arterial roads. Although there are no control on main carriageways on motorways, but many exit and entry ramp roads are controlled by signal in both cities.

To test the sensitivity of Stop&Go effects to traffic demands, Stop&Go effects at lower and higher demands were simulated. 80% of the AM peak demand was used in the lower demand case, and 110% of the AM peak demand in the higher demand case. Comparison of the results shows that there were more reductions in journey time at the higher demand than those at the lower demand. This indicated that Stop&Go effects at high traffic demand are stronger than those at low traffic demand. This can be explained that in conditions of higher traffic demand, there were more queues and queuing time at junctions in the baseline condition. In the case of Stop&Go scenarios, there were more equipped vehicles which contributed to more journey timesaving. If however the network is highly congested there could be a breakpoint leading to a decrease in the traffic impact if the traffic increases beyond a certain demand level.

4.2.4 Environmental impacts

For environment impacts, both fuel consumptions and pollutant emissions were simulated. The total fuel consumption and emissions of CO2 and NOx in the two sites are shown in Figure 26, Figure 27 and Figure 28 (with average expectation of ISA effects).
Similar trend was found in results of the two cities: fuel consumptions and pollutant emissions reduce as the penetration level of Stop&Go increases. Compared to those in baseline conditions, the total fuel consumption, CO2 and NOx decreased by 3.7%, 3.7% and 2.4% in Southampton when at 80% ISA penetration rate, the correspondent values are 6.5%, 6.7% and 2.2% in Brussels.

The reductions of fuel consumption and pollutant emission are linked to fact that Stop&Go reduced queuing length and queuing time because of increases in saturation flows. In reality, Stop&Go could also contribute to reductions of fuel consumption by using smooth acceleration/decelerations. However, such detailed movements of vehicles can not be simulated in macro-simulation. This means the there could be additional reductions in fuel consumptions and pollutant emissions from using Stop&Go.
4.2.5  **Barriers to implementation**

The three main barriers to implement Stop & Go from the transport operators and infrastructure owners point of view are the lack of reliability of the system, the juridical and civil liability issues and the research and technology.

4.2.6  **Legal issues**

Stop & Go is unable to detect bicycles or pedestrians, or negotiate roundabouts, and there is a risk of foreseeable misuse. For obvious reasons, the use of Stop&Go in an urban environment would only amplify these limitations. It is questionable whether the level of warnings and training necessary to allow manufacturers to discharge their duty could be achieved for a fully automated system without introducing supplementary systems as collision warning systems.

4.2.7  **Stop&Go conclusion**

The overall pattern of behavioural effects for Stop & Go studied in driving simulators shows lower mean speed, and more importantly, analysis indicate lower variance of speed and shorter start delay, which may be considered as interesting effect regarding improvements of traffic flow.

Based on the simulation results from Brussels and Southampton, it seems that using Stop&Go can substantially reduce queuing time at junctions which could contribute to reductions of journey time, fuel consumption and pollutant emissions. Stop&Go could also contribute to reductions in fuel consumptions and pollutant emissions by smoothed vehicle movements during start/stop processes. However, no evidence of this was available because the macroscopic models could not simulate movements and vehicle interactions in sufficient details.

The level of traffic demand has significant impacts on the benefits of Stop&Go. The higher the traffic demands, the more the benefits. This was because the increases in saturation flows result from the cumulative effects of equipped vehicles instead of being infrastructure dependent. If however the network is highly congested there could be a breakpoint leading to a decrease in the traffic impact if the traffic increases beyond a certain demand level.

A key assumption made for this simulation was that levels of traffic flow were sufficiently high to cause saturation on approaching arms of the junctions. If the flow was under saturation level, there would be fewer benefits from using Stop&Go. It was also assumed that Stop&Go had no significant differences in its effects on increasing saturation flows between ahead and turning traffic. Thus, the results should be interpreted with caution, and may be considered to represent the limit (7.5%-15% reduction in journey times) of the gains which could be made with a Stop&Go system designed both to support the driver and to optimise efficiency in network management.

There are three main barriers to implement Stop & Go and these are the lack of reliability of the system, the juridical and civil liability issues and the research and technology. From a legal point of view it is questionable whether the level of warnings and training necessary to allow manufacturers to discharge their duty could be achieved without introducing supplementary systems as collision warning systems.
4.3 Applications of ACC+Stop&Go

4.3.1 User acceptance

Adaptive Cruise Control (ACC) systems use on-board sensors (radars, etc.) to automatically maintain a safe distance from vehicles ahead by adjusting the accelerator and brake to control vehicle speed. This saves you from having to constantly adjust speed manually. Drivers are however still in control of steering, and can override the ACC system at any time by using the accelerator or the brake pedal. If there are no vehicles ahead, ACC-equipped vehicles travel at a speed pre-set by you. The ACC system is switched off automatically when the vehicle speed drops below a certain threshold (e.g. 50 km/h). The system is therefore unsuitable for slow moving, congested conditions.

Drivers have good perceptions of the potential impacts of ACC. From 50% to 60% of respondents believe ACC would improve comfort and safety. Conversely, few people think that ACC could decrease comfort or safety. In the UK, only 15% of respondents believed ACC would deteriorate comfort and safety. This share is below 10% in Norway.

ACC is a relatively well-known system. It is currently installed on some high range vehicles, and 5% of respondents already had experienced it. About a third of respondents had previous experience with ordinary cruise control. In the UK, previous experience with cruise control improves the interest in ACC, while in Norway, no clear relation can be established in either direction.

ACC is judged attractive by about half of the respondents, who would consider buying it for their next car. About 25% of them found the system unattractive. Among the drivers who had a chance to test ACC in a driving simulator (18 subjects in Norway), there is a better opinion of the system, with only 12% of them finding it unattractive and 55% finding it attractive.

ACC is not perceived as system for the city. Most respondents (about 70%) declared they would use it on motorways (interurban motorways and, to a lesser extent, urban motorways), but fewer (about 40%) were interested to use it in the city.
Impact on driver behaviour

Adaptive Cruise Control (ACC) is a system for automatic longitudinal control of headway and speed, set by the driver in terms of cruising speed and seconds of time headway. The simulator trial with ACC indicates that drivers choose significant lower top speed when using the driver support system. This was a finding not previously investigated in other studies. Further, ACC was linked to reduced mean speed in the majority of segments of the experimental scenario, yet not being a statistical significant pattern, rather, the difference was logical consistent in which drivers with the ACC system engaged had lower mean speeds. Previous studies have indicated reduced speeds as effects of ACC, the STARDUST findings are thus as expected.

Contrary to expectations the simulator trials indicate that drivers choose longer headway’s when driving with ACC than without. Further analysis of behavioural patterns suggested that variance of time headway was reduced. This patterns was not statistical significant, yet results indicated logical consistency in terms of the majority of segments showed lower variance with the ACC system engaged. Previous studies have not been conclusive in terms of effects of ACC on time headway, where effects have been found in some studies and not in others. The effects on time headway in this study may thus contribute to the body of data investigating the effects of ACC.

Traffic impacts

ACC+Stop&Go on urban motorways and urban arterial roads were simulated on micro level in situations where both cruise driving and Stop&Go driving exists. The main objectives of such studies were to assess the longitudinal impacts of ADAS systems on traffic efficiency and safety. Based on the micro simulation results, the following conclusions were made:

- ACC+Stop&Go has positive impacts on traffic efficiency in terms of journey times. Less stops and stop time are among the main factors contributing to the reduction of the journey times. The effects of ACC+Stop&Go on efficiency are much dependent on the congestion levels of the traffic. The more serious of congestion of the traffic, the more benefits of ACC+Stop&Go in increasing traffic efficiency.
- ACC+Stop&Go has positive impacts on traffic safety in terms of reducing the number of short time-gap and short TTC events.

Positive impacts on traffic efficiency have been noticed. On motorways, the journey times can be reduced by up to 9% and 15% in situations of ACC only and a combined system of ACC+Stop&Go respectively. The effects of ACC+Stop&Go on efficiency are much dependent on the congestion levels encountered during the journey. The more serious of congestion of the traffic, the more benefits of ACC+Stop&Go in increasing traffic efficiency. The applications of ACC+Stop&Go reduced the number of stops and stop time when in congested traffic. Again, significant reductions of small TTC events were found which could be attributed to the smooth movement of equipped vehicles.

Network impacts of ACC+Stop&Go were simulated in three case cites: Brussels, Oslo and Southampton. In Southampton, 54 links were identified as with stop/go traffic. At baseline, the total journey time over these links were 1189 veh-h. By applying the decrease rates, the journey time on the selected links was reduced by 3.5% and 12.5% when at 20% and 80% penetration level of the systems (average expectation of the effects) as shown in Figure 29.
Figure 29 ACC+Stop&Go impacts on journey timesaving on selected links (CONTRAM, Southampton)

Compared to those at baseline conditions, the network journey time for the ACC+Stop&Go scenario in Southampton decreased by 0.4% (low expectation) and 0.9% (high expectation) when at 80% penetration level.

The results of network journey time and speed in Brussels and Oslo are shown in Figure 30 and Figure 31 at different levels of ACC+Stop&Go penetration (with average expectations of ACC+Stop&Go effects).

Figure 30 Network journey time with ACC+Stop&Go application
As can be seen, the network journey times decrease as the penetration rate increases. Compared to those in baseline conditions, the network journey times were reduced by 22% in Brussels and 7% in Oslo when at 80% penetration level. Regarding vehicle distance, very little changes were found in Oslo with the largest change being less than 0.2% (80% penetration rate). However, substantial changes were found in Brussels. As penetration rate increased, network vehicle-distance decreased. At 80% penetration level, the network vehicle-distance reduced by 4.5%.

Overall, speed increased on all three types of road when the penetration rate increased. In Brussels, the largest increases occurred on arterial roads with the increase being 27% at 80% penetration level, compared to 16% and 21% on motorways and on urban streets. In Oslo, the largest speed increases are found on motorways and arterials with roundabouts. For the scenarios with 80% penetration rate and the high expectation level the increase is about 12%.

Compared to 0.2% at 80% demand in Southampton, the network journey time was reduced by 1.4% when at 120% demand. This indicated that ACC+Stop&Go effects at high traffic demand are slightly greater than those at low traffic demand. One explanation could be that in conditions of heavy traffic, there are more vehicles queues and more benefits of using ACC+Stop&Go.

The graphs in Figure 32 show the effects on journey time and average speed in Oslo related to traffic demand.
ACC+Stop&Go have a positive effect on journey time at all levels of demand. The effect increases as the demand increases from 80% to 100% of peak flow, but is decreased to 80% level when demand is increased to 120%. The reason is possibly that the network is highly congested with breakdown on several links, particularly on the motorway. The vehicle time in the baseline network is increased by almost 90% when demand increase from 100% to 120%. On urban streets, which is not that congested, the effect increase with increased demand.

Based on the simulation results from the three cities, the following conclusions can be made:

- The application of ACC+Stop&Go has positive impacts on traffic efficiency in terms of reduced network journey times. The network effects of ACC+Stop&Go depended on the penetration levels. As the penetration rate increased, network journey time savings increased. At an 80% penetration level, network journey times were reduced by 22.4%-6.4% in Brussels and Oslo respectively. In Southampton, the network journey timesaving was only 0.8%, much lower than in Brussels and Oslo, mainly because of the small number of ACC+Stop&Go links being considered.

- Traffic demand has significant impacts on the benefits of ACC+Stop&Go. The higher the traffic demands, the more the congested traffic, and the more the opportunities for using ACC+Stop&Go.

The main differences in the journey timesaving between Brussels/Oslo and Southampton come from assumptions made for the simulations. In Brussels and Oslo, ACC+Stop&Go was applied to the whole networks, assuming that Stop&Go traffic occurring on all motorway and arterial links, whilst in Southampton, ACC+Stop&Go was applied only to selected road sections which were identified as having with potential Stop&Go traffic.

### 4.3.4 Environmental impacts

Figure 33 shows the results of ACC+Stop&Go effects on fuel consumption and pollutant emission in Oslo. A major effect of ACC+Stop&Go was a significant increase in average speed, particularly on motorways at 80% penetration rate. The consequence of this speed increase is an increase in both emission and fuel consumption. However it should be noticed that this is the total effect. Looking at the fuel consumption on different road types, it shows a decrease on all road types except for motorways. This is also the general trend for all the
emission parameters. The reason that the total effect gives an increase in emission and fuel consumption is that about 70% of the vehicle distance is performed on motorway links. The large increase in emission of NOx may be explained by a large increase in the speed on motorway links. In AM peak this speed increase from 67 to 75 km/h. At this speed level there is a large increase in emission of NOx. Related to the high proportion of vehicle distance performed on motorway links this yields an increase in NOx of 10.6% when the average speed is increased by 8.6%.

![Graphs showing CO2 emission, NOx emission, and fuel consumption with ACC+Stop&Go application](image)

Figure 33 Fuel consumption and pollutant emissions (Oslo)

Figure 34 shows the results of ACC+Stop&Go effects on fuel consumption and pollutant emission in Brussels. As can be seen, fuel consumption and pollutant emission decreased as penetration rate increased. On the three types of roads studied, the same trend was found for the ACC+Stop&Go effects on fuel consumption, however, there were less reductions in fuel consumptions on motorways than those on other roads. At 80% penetration level, fuel consumption on motorways was reduced by 3% on average, compared to the correspondent reductions of 11% on arterial roads and 16% on urban streets.
Figure 34 ACC+Stop&Go effects on fuel consumptions and pollutant emissions (SATURN, Brussels)

4.3.5 Barriers to implementation
The three main barriers to implement ACC are the same as for Stop&Go, but the lack of reliability of the system, the juridical and civil liability issues and the research and technology is perceived with smaller barriers for the single ACC system than for Stop&Go. For a combined system one could assume that the degree of concern for Stop&Go is valid also for ACC+Stop&Go.

4.3.6 Legal issues
As for the barriers to implementation it seems logical to assume that the same concern is valid for the ACC+Stop&Go as for the single Stop&Go system. I.e. the ACC+Stop&Go system is unable to detect bicycles or pedestrians, or negotiate roundabouts, and there is a risk of foreseeable misuse, and the use of ACC+Stop&Go in an urban environment would only amplify these limitations. It is questionable whether the level of warnings and training necessary to allow manufacturers to discharge their duty could be achieved for a fully automated system without introducing supplementary systems.

4.3.7 Conclusion on ACC+Stop&Go
Adaptive Cruise Control (ACC) is a system for automatic longitudinal control of headway and speed, set by the driver in terms of cruising speed and seconds of time headway. The simulator trial with ACC indicates that drivers choose significant lower top speed when using the driver support system. Contrary to expectations the simulator trials indicate that drivers choose longer headway’s when driving with ACC than without. The modest influence on
driver behavior within the ACC speed range, implies that the effects of ACC+Stop&Go comes from the situations were the Stop&Go function is active.

Based on the simulation results from the three cities, the following conclusions can be made:

- The application of ACC+Stop&Go has positive impacts on traffic efficiency in terms of reduced network journey times. The network effects of ACC+Stop&Go depended on the penetration levels. As the penetration rate increased, network journey time savings increased. At an 80% penetration level, network journey times were reduced by 7.5%-15% in Brussels and Oslo respectively. In Southampton, the network journey timesaving was only 0.8%, much lower than in Brussels and Oslo, mainly because of the small number of ACC+Stop&Go links being considered.

- Traffic demand has significant impacts on the benefits of ACC+Stop&Go. The higher the traffic demands, the more the congested traffic, and the more the opportunities for using ACC+Stop&Go. If however the network is highly congested there could be a breakpoint leading to a decrease in the traffic impact if the traffic increases beyond a certain demand level.

The main differences in the journey timesaving between Brussels/Oslo and Southampton come from assumptions made for the simulations. In Brussels and Oslo, ACC+stop&Go was applied to the whole networks, assuming that Stop&Go traffic occurring on all motorway and arterial links and that Stop&Go changes the performance for the second car in queue and all other equipped cars. Whilst in Southampton, ACC+Stop&Go was applied only to selected road sections which were identified as having with potential Stop&Go traffic.

There are three main barriers to implement ACC+Stop&Go and these are the lack of reliability of the system, the juridical and civil liability issues and the research and technology. From a legal point of view it is questionable whether the level of warnings and training necessary to allow manufacturers to discharge their duty could be achieved for a fully automated system without introducing supplementary systems as collision warning systems.

4.4 High Capacity Buses (Lane Keeping systems based)
Lane Keeping systems help you to keep within the driving lane. They are composed of two sub-systems, roadway detection with on-board detectors (e.g. cameras) to monitor lane markings and roadsides, and steering control to automatically steer the vehicle within the driving lane. These systems allow narrower driving lanes to be used, freeing up space for bus / cycles lanes or wider pavements.

Benefits of lane keeping systems are much less obvious than those of other systems. In Norway and the UK, between 20% and 30% of respondents believed such systems would improve comfort or safety. As much as 40% of British respondents believed it would decrease driving confort, and 30% believed it would decrease safety. Few persons showed interest in considering such a system for their next car.
Opinions on this system were higher in Belgium, with 50% of the respondents finding the system attractive and 40% unattractive. This might be partly caused by the fact that the implementation scenario for lane keeping was slightly more elaborated in the Belgian questionnaire. Let us also note that in Belgium as in the other two countries, lane keeping received the lowest appreciation among the selected systems.

4.4.1 Introduction
The objective of using High Capacity Buses is to increase the attractiveness of public transport by providing efficient and puncture service, and reducing the use of private car use. It is assumed that the widths of current roads are reduced to create an additional narrow lane dedicated to buses. The study made in Oslo was limited to motorways and with an assumption that there is a reduction in private car use and corresponding increase in use of public transport. The selected roads are heavily congested during peak hours, and are two of the main roads to get to the City centre of Oslo.

In the Oslo cases it is seems to be possible to implement a narrow lane for high capacity buses for some motorway segments. A throughout lane from the suburbs to the city centre for the main roads in Oslo is however a challenging task due to physical restrictions in the network. It would require a high investment scheme and is not a current topic in Oslo.

The buses are equipped with Lane Keeping systems allowing the buses to run with fast speed on the bus lane. Because the widths of the existing lanes have been reduced, both capacity and speed of these lanes are assumed to be reduced as well.

Environmental effects are not included in the study of high capacity buses. The reason for this demarcation is that the simulation model does include sufficient reliable pollution data for buses.

4.4.2 Impact on driver behaviour
The Lane Keeping system helps the driver to keep its vehicle within the driving lane. To study the impacts of the system in the driving simulator, the French drivers had to drive on the possible “future” city boulevard, i.e. a dedicated vehicle lane becomes a dedicated bus lane and the other lanes are narrower. This case may induce a loss of level of service: due to the difficulty of vehicle guidance in narrow lanes, the drivers’ speeds would be lower; this decrease of speed would induce a loss of capacity. Studies of Lane Keeping aimed to evaluate the impacts of system relating both to the traffic capacity and the traffic safety. The main results from the French trials were:
- Lane Keeping as a driver support system was considered useful by French drivers;
- More subjects drove on the left side of the narrow lane without the system than with. The system helps them to keep the vehicle in the lane;
- More subjects maintain their average speed during the drive with the Lane Keeping system ON. With the system OFF, most subjects drove with a lower speed;
- The general feelings about the system are mainly positive. At least 50% of the subjects declared to be ready to use Lane Keeping on their own vehicle.

4.4.3 Traffic impacts
It is assumed that only the buses are equipped with lane keeping system in the study undertaken in Oslo. Because the widths of the existing lanes have been reduced, both capacity and speed of these lanes are assumed to be reduced as well. In the simulations the speed has been reduced by 5% and the capacity by 7.5%. This is implemented by changing the speed flow relationship on the affected links. Figure 35 show the impact of High capacity Buses in the morning peak hour.

![Figure 35: Traffic impacts of HC buses (AM Peak)](image)

The large scale simulations shows that total travel time is reduced by 3.5 % and the distance travel is reduced by 6.5 %. The average speed is reduced by 3 %. These results are based on the assumptions mentioned in the description of this case.

The reductions in private cars use is relatively small compared to what we could obtain with a full implementation. However it is questionable if these effects would be obtained in Oslo. Under current restrictions short segments with narrow lanes may just function as obstacles in the network. The estimated effects of high capacity buses are not as high as required for a full size implementation in Oslo.
4.4.4 Barriers to implementation

For Lane Keeping barriers related to cost are the most important. Progress in research and technology and the lack of willingness from the decision makers are two other high barriers to implementation.

Another interesting point to note is that the bus operators seem reluctant to the implementation of Lane Keeping, which is however thought to have positive impacts on bus driving.

4.4.5 Legal issues

Although the Lane Keeping system itself may function perfectly and keep the vehicle within the narrow lane, the inherent limitations of introducing such a system must be considered in order to assess the viability of the system. Therefore, the conclusion is that, although potentially viable, narrow lane keeping is best suited to a motorway / interurban environment.

4.4.6 Conclusion on High capacity Buses

Drivers express a positive attitude to Lane Keeping, and the system helps both in keeping the vehicle in the lane and in keeping a higher speed with the system active.

For Lane Keeping barriers related to cost are the most important. Progress in research and technology and the lack of willingness from the decision makers are two other high barriers to implementation. Another interesting point to note is that the bus operators seem reluctant to the implementation of Lane Keeping, which is however thought to have positive impacts on bus driving.

A system with High Capacity Buses based on Lane Keeping system in the buses seems to be an interesting solution and a technology that may reduce the distance travel in the network. A large modal shift requires however a substantial improvement in the travel time for buses compared to private cars. This may also be obtained by introducing more inconvenience for the cars users as higher toll prizing as well as congestion management.

4.5 Cybercar applications

4.5.1 User acceptance

Cybercars are fully automatic, driverless taxis. They are equipped with a variety of systems including guiding systems, driving systems, obstacle detection and emergency systems to ensure maximum safety. Passengers board at a stop point, or can even call them from home, and pay using automatic payment devices. In the long term, cybercars could be used across the entire road network, enabling you to specify your destination and use Cybercars in the same way as a normal taxi.

Though more futuristic than the other concepts presented in this study, most respondents were familiar with the idea of cybercars. 60% of UK respondents and 40% of those in Norway found the system attractive.
When given the choice to use a taxi or a cyber car, almost 80% of respondents chose cybercars if its cost was 30% lower than for a taxi with the same journey time. There are thus no resistance to the concept of cybercars, respondents were not afraid of using a high technology system (assuming technology was mature). The following scenarios were designed to simulate cybercars impacts:

Demand: AM peak from 07:30-09:00
Roads applied: Cybercars running in city centre areas
Mode change of private car travellers:

Table 5 Scenarios for Cybercars in city centre areas

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Short journey</th>
<th>Intermediate journey</th>
<th>Long journey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Cybercars</td>
<td>Car: 0%</td>
<td>Bus: 100%</td>
<td></td>
</tr>
</tbody>
</table>

Assessment indicators:

- Journey time (veh-h)
- Network distance (veh-km)
- Network speed (km/h)

4.5.2 Traffic impacts

The Southampton network simulation for cybercars shows a large potential of this technology for improving network conditions in view of reducing congestion and journey times as well as for providing environmental benefits.

In this simulation no environmental impacts were considered at this stage, but the large modal shift from private cars (with a typical average occupancy rate of 1.4 in urban areas!) towards buses connecting the P&R sites with the city centre suggest substantial reduction in emissions. This positive trend can be even further enhanced with the provision of buses using alternatives to internal combustion engines, e.g. use of compressed natural gas, etc.

The cybercars feeder application covering the ‘last mile’ from the main city centre bus stop to the respective final trip destinations is not modelled in this study, as only little impacts on a network-wide level can be expected, and because the capacity of roads within the car-free city centre can be assumed to be sufficient for this application.

The use of cybercars within the city centre suggest further environmental benefits, as the cybercars are highly likely to be electric vehicles in order to keep emissions and noise in the city centre to an absolute minimum. And although the production of the necessary energy is likely to generate emissions at the point of production (unless completely generated from
renewable resources – which is unlikely in the near future), at the point of operation no emissions will be generated.

As the cybercars application in the city centre is not simulated in this study, the main results and impacts relate mainly to the introduction of P&R sites on the outskirts of the city. From these P&R sites buses run on six main corridors into the city centre.

This consequently results in a large modal shift from the private car to public transport (private car for the whole trip is replaced by a multi-modal journey: private car + P&R + bus/ train + cybercars). Therefore this system is mainly aimed at commuters travelling from their homes to their place of work in the city centre in the morning (AM peak).

The percentage of trips using bus or train depends on the accessibility to train/ bus stations and their respective service frequency. This was defined separately for each of the six main bus corridords.

As described above, results from the cybercars network simulation can be grouped into network-wide impacts and impacts in view of bus corridors. These results relate only to traffic impacts as no environmental or other impacts were considered in this study.

4.5.2.1 Network-wide Traffic Impacts

In the following section the general network-wide traffic impacts of the cybercars scenario as compared to the baseline scenario will be described.

<table>
<thead>
<tr>
<th>Network-wide Results</th>
<th>Total Time [veh-hr]</th>
<th>Distance [veh-km]</th>
<th>Network Speed [km/hr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline Scenario</td>
<td>14029.80</td>
<td>916030.30</td>
<td>43.70</td>
</tr>
<tr>
<td>Cybercars Scenario</td>
<td>10636.30</td>
<td>749123.10</td>
<td>56.58</td>
</tr>
<tr>
<td>Improvements</td>
<td>24%</td>
<td>18%</td>
<td>-29%</td>
</tr>
</tbody>
</table>
The above table/figure shows that the introduction of a P&R service on six main corridors leads on a network-wide level to a reduction of 24% in total travel time, a 18% reduction in distance and an increase of 29% in network speed.

4.5.2.2 Traffic Impacts on Bus Corridors

In the following section the traffic impacts on the bus corridors of the cybercars scenario as compared to the baseline scenario will be described.
Table 7 Results on Bus Corridors for the Cybercars Application

<table>
<thead>
<tr>
<th></th>
<th>Baseline Scenario</th>
<th>Cybercars Scenario</th>
<th>Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inbound</td>
<td>Outbound</td>
<td>Inbound</td>
</tr>
<tr>
<td>Travel Time [min]</td>
<td>16.78</td>
<td>11.39</td>
<td>33%</td>
</tr>
<tr>
<td>Vehicle Speed [km/hr]</td>
<td>23.03</td>
<td>34.08</td>
<td>-48%</td>
</tr>
</tbody>
</table>

The above table/figure shows that the introduction of a P&R service on six main corridors leads on the corridor level to reductions in travel time of 33% and to an increase in vehicle speeds of 48% for inbound trips. For outbound trips only small changes can be observed, with a reduction in travel time of 2% and even a slight decrease in vehicle speeds of 1%.

The comparably low reduction in travel time and even slight increase in vehicle speeds for outbound trips can be explained by the fact that the demand data used is the AM peak, therefore inbound lanes are fairly congested and speeds are low, consequently the modal shift from private car to public transport (to buses and also to trains, which do not generate any additional road traffic at all) has a large impact on travel time and vehicle speeds. On the
other hand outbound lanes are free-flowing in the morning peak already and therefore there is no potential for any improvements in terms of travel times or vehicle speeds.

The analysis of results for the bus corridors only considers direct (without any stops) travel times from the six P&R sites to the main city centre bus station. While this helps to give a first idea of potential impacts of a cybercars application for urban areas, future work should analyse journey times in more detail.

The current results are based on the same bus routes connecting the P&R sites and the city centre bus stop for medium and long journeys, as well as providing transport within the city for short trips. Therefore whereas the assumption of a direct bus service is realistic for the P&R service for medium and long journeys, the bus trips generated by the short journeys will require bus stops on the way and will thus increase bus journey times.

Furthermore complete commuting trips from homes to places of work should be compared. With the baseline scenario being a direct trip using private car, and the cybercars scenario being a multimodal journey using private car + P&R + bus/ train + cybercars. When calculating the time for the multi-modal trip, transfer time, waiting time (for the bus/ train at the P&R site and for the cybercars in the city centre) and the travel time using the cybercars in the city centre have to be considered.

4.5.3 Barriers to implementation
There was usually little interest on Cybercars in the operator survey, perceived as too remote a system. Overall, reduced costs (both investment and operating) are perceived as more important for the respondents than further technical progress or adapting the legislative framework. Let us note however that very little is usually known about actual implementation costs of ITS.

4.5.4 Legal issues
Legal issues regarding Cybercars have not been investigated. It is likely however that on dedicated lanes separated from other traffic, the legal concern will be limited to the safety of the passengers.

4.5.5 Conclusion on Cybercars
Cybercars were used in this study as a convenient, user-friendly and non-polluting (at the point of operation) transport system to cover the ‘last mile’ of a commuting trip to workplaces in the city centre. The success of this application is based on the assumed large modal shift from private car towards a P&R application. The simulation has shown large potentials for improvements in network speeds and reductions in levels on congestion on a network-wide level. Due to the modal shift towards the use of buses large improvements were also possible for inbound trips in the morning peak on the six main bus corridors considered in this study.

But these journey time savings have to be reduced when considering the whole journey time for the multi-modal journey including waiting times, transfer times and cybercars travel times. This complete journey time is likely to be higher than the current journey by private car in the baseline scenario. Although this would still generate environmental benefits, the end-user would be unlikely to accept these increased journey times, unless the costs are much lower.
than costs for the private car. Therefore subsidies and/or instruments like road user charging or higher vehicle/petrol taxes might have to be applied.

Future large-scale applications of cybercars, based on this small-scale test or demonstration, replacing the multi-modal journey by a direct door-to-door cybercars service has the potential of providing lower or at least similar travel times compared to the private car, whilst still maintaining the environmental benefits.
5 Disseminations of STARDUST results

This deliverable summarises the key elements resulting from STARDUST dissemination activities. This document is split in few parts. First, a list of publications produced related to STARDUST is given; following by a list of workshops in which the STARDUST consortium involved and a list of exhibitions done by the project partners. Then short descriptions of the STARDUST web site, leaflet and newsletters are then provided. Finally, a list of STARDUST deliverables is given.

5.1 Website, leaflet and newsletter

5.1.1 Website
TRG created, hosted and updated the web site with the address of http://www.trg.soton.ac.uk/stardust/index.htm. The web site was designed to connect between STARDUST partners and other users of interest by Internet. As far as STARDUST results are concerned, two functions are provided. The first is to present project results that can be accessed publicly including STARDUST deliverables, newsletters, leaflets, and publications. The second is to be used for partners only in which STARDUST deliverables (restricted), meeting notes, and modelling results are held.
- Achieved at the end of 2002
- Deliverables approved by the Commission were put in line
- All newsletters were put in line
- All references of the stardust activities
- Links of Web page on partners and European project which are close to the stardust project
- Link of Web page on the cluster NETMOBIL

5.1.2 Leaflet
A4-page coloured brochure aimed at giving general information on the project and addressed to user groups, person to be interviewed, and other research projects... This brochure was based on Deliverable 1. The leaflet was produced by INRIA. At the 10th ITS World Congress in Madrid, the leaflet was distributed.

5.1.3 Newsletter
An electronic annual newsletter was send to local authorities, governments and to scientific community chosen by Stardust Partners. All partners gave a mailing list in which involved highway authorities, political and socio-economic stakeholders. This mailing-list consists of 100 electronic addresses approximately. At the 10th ITS World Congress in Madrid, the newsletters n°1, n°2 and an added sheet were distributed.
- newsletter n°1: STARDUST News may 2002 sent in July 2002
- newsletter n°2: STARDUST News may 2003 sent in July 2003
- complements to the newsletter n°2: STARDUST News October 2003 distributed at the ITS world congress in Madrid
- newsletter n°3: STARDUST News may 2004: results.
5.2 Workshop and exhibition

5.2.1 Workshop

Many partners of the project involved in or organised national workshop in their own country. Some of these events allowed to STARDUST partners to meet, in their country, people from Transport Ministry, local authorities (cities, network operators), car manufacturers...

**INRETS**

In June 2003, INRETS participated to a workshop dedicated to the traffic modelling in Spain, organised by TSS. INRETS presented both the methods used in the project and the results of the lane keeping studies.

Like for the European project In-Response, INRETS organised a French national workshop dedicated to the STARDUST project. This day, focused on the introduction of ITS in urban environment, allowed the participation of various actors: CERTU (public organisation on Transport networks, Town planning), cities of Lyon, Toulouse... The forum was held in January 2004.

Moreover, in March 2004, the INRETS members involved in the STARDUST project were invited to present the STARDUST results in a seminar dedicated to the traffic modelling organised by a research team of INRETS (which did not involved in the project).

- Workshop on traffic modeling: Trends and challenges, Sitges (Spain), June 2003;
- Journée d’étude : intégration de systèmes télématiques en milieu urbain, Bron (France), 2004, 19th January;
- Groupe Modèle de trafic, Arcueil (France), 2004, 29th March.

**SINTEF**

SINTEF together with the Norwegian Board of Technology organised September 2003 a scenario workshop presenting the STARDUST project and future ADAS/AVG deployment issues. The future workshop involved experts, decision-makers, interest groups, companies and road-users. The aim was to inform the Norwegian Parliament of the views of the public on these issues. Four STARDUST related scenarios concerning the car, the driver, the road and the organisation of the traffic system were developed and presented at the workshop.

The Future scenario workshop achieved media coverage from TV, radio and newspapers. Political interest was stimulated and two newsletters, as well as a longer report, were published to disseminate the findings of the expert group and the workshop to Parliamentarians and other interested parties. The two short films presenting ADAS/AVG systems that were used to stimulate discussion are freely available.

SINTEF was invited to present the STARDUST project at a Transport Policy workshop hosted by the Norwegian Transport Minister April 2004. The policy workshop involved experts, decision-makers, interest groups, and road authorities as well as 26 representatives of the national media. The aim was to inform the Norwegian Parliament of the views of the public on these issues. The workshop achieved media coverage from National TV, radio and newspapers and weekly/monthly Transport journals.
SINTEF is invited to hold a presentation of the STARDUST project at a National workshop hosted by one of the largest Insurance companies. The aim of the workshop is to look at safety and liability issues related to introduction of existing and future ADAS/AVG systems.

5.2.2 Exhibition
The INRETS low-cost driving simulator allowed INRETS to present in some events works done in the project; particularly the works focused on the driver behaviour studies.

- Workshop on traffic modeling: Trends and challenges, Sitges (Spain), June 2003;
- 10th ITS World Congress, Madrid (Spain), November 16-20, 2003;
- Journée d’étude : intégration de systèmes télématicques en milieu urbain, Bron (France), 2004, 19th January;
- STARDUST Workshop, Bruxelles (Belgium), June 2004.

5.3 Deliverables and Publications

5.3.1 Deliverables

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Contributing partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Critical analysis of ADAS and AVG Options to 2010, Selection of options to be investigated</td>
<td>TRG, INRIA, PATH</td>
</tr>
<tr>
<td>D2/3</td>
<td>Scenarios and Evaluation Framework for City Case Studies</td>
<td>TRG, STRATEC, SINTEF, INRIA, PATH</td>
</tr>
<tr>
<td>D4</td>
<td>Assessment of behavioural acceptance of intelligent infrastructure and ADAS/AVG systems</td>
<td>STRATEC, TRG, SINTEF</td>
</tr>
<tr>
<td>D5</td>
<td>Analysis of Driver Behaviour through Floating Vehicles</td>
<td>TRG, SINTEF, INRETS</td>
</tr>
<tr>
<td>D6</td>
<td>ADAS/AVG human factors investigation through driving</td>
<td>SINTEF, TRG, INRETS</td>
</tr>
<tr>
<td>D7</td>
<td>Micro-simulation of the impacts of ADAS/AVG on the functioning of elements of urban road networks</td>
<td>TRG, STRATEC, INRETS</td>
</tr>
<tr>
<td>D8</td>
<td>Simulation of the large scale impacts of ADAS/AVG on the case studies of Brussels, Oslo and Southampton urban road networks</td>
<td>TRG, STRATEC, SINTEF</td>
</tr>
<tr>
<td>D9</td>
<td>European and National Legal Implications of ADAS/AVG systems : Review of existing analysis</td>
<td>Barlow Lyde &amp; Gilbert, TRG</td>
</tr>
<tr>
<td>D10</td>
<td>Evaluation of scenarios to deployment of ADAS/AVG systems in urban contexts (Brussels, Oslo, Southampton)</td>
<td>SINTEF, TRG, STRATEC</td>
</tr>
<tr>
<td>D11</td>
<td>User Group Liaison Activity</td>
<td>INRIA, TRG, STRATEC</td>
</tr>
<tr>
<td>D12</td>
<td>Dissemination Activity</td>
<td>INRETS, TRG, STRATEC, SINTEF, INRIA</td>
</tr>
<tr>
<td>D13.1 to D13.6</td>
<td>Progress Reports</td>
<td>TRG, STRATEC, SINTEF, INRETS, INRIA</td>
</tr>
<tr>
<td>D14</td>
<td>Mid Term Assessment Report</td>
<td>TRG, STRATEC, SINTEF, INRETS, INRIA</td>
</tr>
<tr>
<td>D15</td>
<td>Final Report</td>
<td>TRG, STRATEC, SINTEF,</td>
</tr>
</tbody>
</table>
5.3.2 Publications

A publicity agreement was done in order to establish rules for agreeing the content of papers being used for publicity material and conferences. Below a list of past communications:

- Mike McDonald, Alain Henry, Stéphane Espié, Michel Parent and Torgeir Vaa. A Research on Deployment of Urban Sustainable Transport systems, In the proceedings of the 9th ITS Congress, October 14-17, 2002, Chicago (USA)
- Jinan Piao and Mike McDonald. Low Speed Car Following Behaviour from Floating Vehicle Data. In the proceedings of the IEEE Intelligent Vehicles Symposium (IV 2003), June 2003, Columbus OH (USA).
- Auberlet J.-M., Tripodi A., Espié S., Gattuso D., Analysis of Stop&Go Driving Behaviours through Floating Vehicle Approach, In the proceedings of the Summer Conference of Simulation Computer (SCSC03), July 20-24, 2003, Montreal (Canada)
- Jinan Piao and Mike McDonald. Stop and Go Driving Behaviour: Initial Findings from Floating Vehicle Trials. In the proceedings of the 10th ITS Congress, November 16-20, 2003, Madrid (Spain)
- Gunnar D. Jenssen, Cato A. Bjørkli, Terje Moen, Torgeir Vaa. Adaptive Cruise Control (ACC) and Driver Performance: Effects on Objective and Subjective Measures. In the proceedings of the 10th ITS Congress, November 16-20, 2003, Madrid (Spain)
- Antonino Tripodi, Jean Michel Auberlet, Stéphane Espié, Domenico Gattuso. Study of the Stop&Go System on driver’s behaviour in urban environment. In the proceedings of the 10th ITS Congress, November 16-20, 2003, Madrid (Spain)

Several papers were submitted in 2004. The acceptances of these papers were received. Below a list of these communications to be appear:

- Piao J and McDonald M. Stop&Go impacts at a signal controlled junction. ITS UK Summer Conference, 6-7 July 2004, Winchester, UK.
- Jean Michel Auberlet, Stéphane Espié, Antonino Tripodi, How to evaluate the impacts of a ITS ? Example of the Stop&Go system in Stardust project. Accepted for presentation at the 11th ITS Congress, October 18-22, Nagoya (Japan)
- Torgeir Vaa and Ørjan Tveit. Deployment of Intelligent Speed Adaptation in Urban Environment. Accepted for presentation at the 11th ITS Congress, October 18-22, Nagoya (Japan)
Furthermore, the dissemination activities relating to the publication will go on after the end of the project. Indeed several co-operative papers are foreseen to be published in Journals, Congress,... Below a table of these co-operative papers:

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Title of Paper</th>
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<tbody>
<tr>
<td>SINTEF, TRG, INRETS</td>
<td>Potentials for using Stop&amp;Go on urban roads</td>
</tr>
<tr>
<td>TRG, INRETS</td>
<td>Stop&amp;Go impacts on saturation flows of signal controlled junctions</td>
</tr>
<tr>
<td>TRG, PATH and INRIA</td>
<td>A literature review of ADAS/AVG systems</td>
</tr>
<tr>
<td>TRG, INRETS</td>
<td>Impacts of ACC+Stop&amp;Go on motorway and arterial traffic</td>
</tr>
<tr>
<td>SINTEF, TRG and STRATEC</td>
<td>An assessment of ISA impacts at a city level</td>
</tr>
<tr>
<td>TRG</td>
<td>Potential for ADAS/AVG in urban areas</td>
</tr>
<tr>
<td>INRIA and TRG</td>
<td>Network effects of Cybercars</td>
</tr>
<tr>
<td>STRATEC, TRG and SINTEF</td>
<td>From micro to macro ADAS/AVG simulation modeling.</td>
</tr>
<tr>
<td>SINTEF, INRETS</td>
<td>Driving simulators as a tool in assessing ADAS/AVG techniques</td>
</tr>
</tbody>
</table>

6 Conclusions and recommendations

6.1 Relating to specific systems

6.1.1 User acceptance

There is generally a positive opinions from drivers to driver supporting systems. Respondents have relatively positive perceptions on the improvements those systems could bring about. They also have positive overall perceptions of the systems. This is particularly true for ISA and ACC, as well as for cybercars, though this system is more long-term than the others. Respondent were slightly less positive towards Stop&Go systems. Opinions are less favourable for lane keeping systems.

Experience in STARDUST shows that, when correctly informed (for example after a trial in a driving simulator), perceptions and opinions of respondents were more favourable to the systems than without being informed. Information campaigns would thus be useful before launching systems on a wide scale.

6.1.2 Traffic impacts

*Intelligent Speed Adaptation (ISA):* The ISA effects of reducing excessive traffic speed in the network results in increases in journey time. There are more increases in journey times on high speed roads (e.g. motorways) than on low speed roads (e.g. urban streets). In the simulated scenario, network journey times were found to increase in a range from 4.3% to 6.0% at 80% of penetration level. No significant changes in network distance were found which indicated that ISA did not cause much change in the general patterns of assignments, with most of drivers keeping their original routes. ISA is more effective in non-congested...
traffic conditions when drivers are able to exceed a speed limit, thus the effects of ISA are sensitive to traffic demands;

**Stop&Go on urban roads**: Stop&Go have potentials to increase saturation flows of signal controlled junctions because of short reaction times. In addition, Stop&Go can smooth vehicle movements which result in reductions of small time-gap and time-to-collision events. Unlike infrastructure based measures, the impacts of increased saturation flows at a signal controlled junction are the cumulative effects of each individual vehicle. Therefore, such impacts are dependent on traffic demands and penetration levels of equipped vehicles. When 80% of vehicles operate the system, the network queuing times were reduced by up to 19%-25%, and a reduction of journey times of 7.5%-15% (it is assumed that the system characteristics and traffic benefits lead to general use).

**ACC+Stop&Go on urban arterial and motorways**: A combined system of ACC+Stop&Go makes it possible to automate the task of car following at both high and low speeds. In general, traffic impacts of such combined systems are similar to those when a separated system is used. ACC+Stop&Go can smooth vehicle movements in both high and low speed traffic. The application of ACC+Stop&Go can have positive impacts on traffic efficiency in terms of reduced network journey times which depend on the headways chosen by drivers and how extensive the system is used.

**Lane Keeping**: Lane Keeping can be used to help drivers to keep vehicles in narrow lanes which are assumed to be dedicated to public transport. A Lane Keeping based bus service has the potentials to reduce the private car use when urban roads become heavily congested or become restricted (e.g. congestion charges). To make it effective, large modal shifts are needed from private car to public transport. This requires however a substantial improvement in the travel time for buses compared to private cars.

**Cybercars in city centre area**: In the scenario of city centre areas being reserved for public transport, Cybercars can be used as a supplement to mass public transport by feeding and distribution. The simulation has shown Cybercars have positive impacts on traffic at a network level in terms of reduced total trips and increased speeds. In this condition, complete journey times is likely to be higher than the current journey by private car in the baseline scenario, because of the multi-modal journeys including waiting times, transfer times and cybercars travel times.

### 6.1.3 Environment impacts

One of the basic functions of an ADAS/AVG system is to automate some or all of the driver’s tasks. In doing so, the vehicle is controlled in a known fashion which can be used to communicate with the on-board diagnostics systems to achieve an operation with optimum mode in terms of fuel consumption and pollutant emission. ADAS/AVG impacts on environments can be achieved directly or indirectly in several ways: by smoothing vehicle movements (e.g. Stop&Go and ACC), changing speed profiles (e.g. ISA), and reducing private car trips (e.g. Lane Keeping and Cybercars). As longitudinal control supporting systems, Stop&Go have positive impacts on fuel consumption and pollutant emission because of smoothed vehicle movements. ISA impacts on environment are dependent on traffic conditions applied. Simulation results show that ISA have positive environment impacts.
when being applied on high speed roads (e.g. motorways), but negative impacts on low speed roads (e.g. urban streets).

6.1.4 Barriers to implementation
One of the main perceived barriers for ISA systems is the acceptability by drivers. Important barriers are also the cost, possible problems of liabilities and the reliability of the system. The perceived barriers are however relatively lower for ISA than for other systems investigated, and ISA is the system that the respondents were the most keen to promote. From the public authorities point of view, ISA is the system that is perceived as having the most benefits to implementation with more than 75% of the respondents seeing a benefit to implement it. The reason for this is probably the concern over safety issues, as ISA is perceived as the system bringing the higher positive impact on safety (number of accidents/km), which is an important matter for European governments.

The three main barriers to implement Stop&Go from the transport operators and infrastructure owners point of view are the lack of reliability of the system, the juridical and civil liability issues and the research and technology. It appears that Stop&Go is perceived as having higher barriers than ACC but the ranking of the issues is almost identical. These two systems are vehicle-based systems and quite similar in their working (only the speed range is different), so it is not surprising that the perceived barriers to their implementation are quite similar. Barriers to implementation of Stop&Go systems were perceived as quite low in Belgium and the UK but were perceived as very high in Norway.

The three main barriers to implement ACC are the same as for Stop&Go, but the lack of reliability of the system, the juridical and civil liability issues and the research and technology is perceived with smaller barriers for the single ACC system than for Stop&Go. For a combined system one could assume that the degree of concern for Stop&Go is valid also for ACC+Stop&Go.

For Lane Keeping barriers related to cost are the most important. Progress in research and technology and the lack of willingness from the decision makers are two other high barriers to implementation. Another interesting point to note is that the bus operators seem reluctant to the implementation of Lane Keeping, which is however thought to have positive impacts on bus driving.

There was usually little interest on Cybercars in the operator survey, perceived as too remote a system. Overall, reduced costs (both investment and operating) are perceived as more important for the respondents than further technical progress or adapting the legislative framework. Let us note however that very little is usually known about actual implementation costs of ITS.

6.1.5 Legal issues
From the legal perspective ISA would appear to be the most feasible system from a legal point of view. It would appear that the system would be most beneficial when used in an in an urban environment as well as interurban/motorway environment.
Stop & Go is unable to detect bicycles or pedestrians, or negotiate roundabouts, and there is a risk of foreseeable misuse. For obvious reasons, the use of Stop&Go in an urban environment would only amplify these limitations. It is questionable whether the level of warnings and training necessary to allow manufacturers to discharge their duty could be achieved for a fully automated system without introducing supplementary systems as collision warning systems.

Although the Lane Keeping system itself may function perfectly and keep the vehicle within the narrow lane, the inherent limitations of introducing such a system must be considered in order to assess the viability of the system. Therefore, the conclusion is that, although potentially viable, narrow lane keeping is best suited to a motorway / interurban environment.

Advisory, Overridable and Mandatory Systems. Where a vehicle is equipped with an ADAS / AVGS, responsibility for the driver’s behaviour will, in most cases, remain with the driver. Even where an ADAS / AVGS fails, if the system is merely advisory in nature (such as an ISA system which warns the driver that they are about to break the speed limit, but exerts no haptic control over the vehicle) then the driver is likely to remain liable for his response. This is because the driver retains ultimate control over his vehicle at all times and should only use the information provided by the system to assist him in reaching a reasoned decision on how to react, taking all the surrounding circumstances (such as weather conditions) into account. If an accident occurs in such circumstances, and the driver fails to react appropriately, he is likely to have breached his duty of care to his fellow road users. Where the ADAS / AVGS is haptic but overridable, the liability of the driver will depend upon the circumstances of each case. The court will consider any inherent system limitations, whether the driver was warned about these limitations and whether he reacted appropriately to any such warnings. In reaching a conclusion, the court will consider whether the driver acted in the same way that a reasonable man would have acted in the circumstances. Finally, where the ADAS / AVGS is mandatory, with no possibility of driver override, the driver’s liability for any accident caused as a result of the system’s intervention decreases, because he does not retain ultimate control over his vehicle. In direct contrast, the manufacturer’s liability will increase. As mandatory systems effectively leave the driver powerless to avert an accident, if they have inherent limitations they are likely to be considered defective products by the court.

Training. With each ADAS / AVGS, driver training would seem to be a vital prerequisite to use of the system. No matter how remarkable the design of the system, it will only be safe and beneficial if drivers are fully trained in its use. The numerous limitations of using a manual as method of training drivers have been highlighted throughout this Workpackage. An alternative would be to introduce compulsory training. This, however, would be costly and hard to implement, and, because compulsory training raises enforcement issues, it is likely to require a change in the current law. This will be time-consuming and may be difficult to instigate. It is as yet unclear whether the gradual introduction of systems on which training had been given would allow safe driving practices to be spread among the driving population. This gradual propagation method needs to be investigated further as an alternative to universal training.

Warnings. As has been demonstrated, warnings to the user from the system/vehicle manufacturer are extremely important. When assessing whether or not a product is defective the courts have regard to the nature of any warnings or instructions issued with the product. If a claimant chooses to disregard a manufacturer’s warning or instructions as to the use or limitations on use of a product, the court may decide that the product was not defective.
The Urban Environment. In the case of each ADAS/AVG, numerous difficulties arise when the system is considered in respect of an urban environment. The source of these difficulties is the number and complexity of interactions between the driver, the system and the external environment. This is particularly true in relation to Stop&Go. The challenge will be to introduce such a system with acceptable safety risks, given the inherent limitations of the technologies within the context of the urban environment. Where, on the other hand, the limitations of a system are relatively easy to appreciate and there are fewer requirements placed on the driver, the risk implications of the system will be correspondingly reduced.

General Approach. The remarks made in the previous paragraph suggest that in considering the risks of implementing these systems, they can be analysed systematically according to certain common factors. First, what are the inherent limitations of the system in the environment within which it is to be used? In other words, what situations may arise which lead to potential risk and which either the system cannot deal with or can only deal with following intervention by the driver. Secondly, how frequently are these limitations likely to manifest themselves? Thirdly, how reasonable is it for the average driver to make the correct intervention? The answer to this third question may rely in part on the feasibility of effective warnings/training in relation to the particular system and partly on the feasibility of the driver reacting promptly and properly to the situation. The answers to these questions may allow a systematic risk analysis to be performed on the various systems.

The effects shown in the STARDUST project is summarized in Table 8 and Table 9:
Table 8 Summary description of ISA, ACC and Stop&Go

<table>
<thead>
<tr>
<th>ADAS/AVG technology</th>
<th>Intentions</th>
<th>Effects shown in STARDUST project</th>
<th>Environmental effects</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA</td>
<td>Safety improvements</td>
<td>ISA reduces the average speed and increases the travel time. Overtaking may take longer time. This is a hazard factor for two lane roads.</td>
<td>ISA impacts on fuel consumption and pollutant emissions were dependent on road types applied. ISA have positive impacts on fuel consumption on motorways, but negative impacts on urban streets.</td>
<td>Driver’s willingness to buy and use the system, Governmental willingness to implement and enforce speeding. Technical challenge in creating the speed limit database. Liability for database information and system performance.</td>
</tr>
<tr>
<td>ACC</td>
<td>Driver comfort</td>
<td>Smooth traffic speed rather than to get an extra gains in traffic efficiency. Provides driver comfort.</td>
<td>Positive impacts on fuel consumption and pollutant emissions contributed by smoothed vehicle movement.</td>
<td>Technical collaboration is necessary to ensure a common functionality between different brands.</td>
</tr>
<tr>
<td>Stop&amp;Go</td>
<td>Driver comfort</td>
<td>Reduces lost time at start-up. May require some time to accustom drivers to the system.</td>
<td>Reducing fuel consumption and pollutant emissions from reduced queuing time and smoothed vehicle movements.</td>
<td>Legal aspects regarding safety issues like illegal pedestrian crossing. Technical limitations may give reduced impacts for the traffic flow at a system level.</td>
</tr>
</tbody>
</table>
Table 9 Summary description ACC+Stop&Go, Lane Keeping and Cyber

<table>
<thead>
<tr>
<th>ADAS/AVG technology</th>
<th>Intentions</th>
<th>Effects shown in STARDUST project</th>
<th>Environmental effects</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC and Stop&amp;Go</td>
<td>Combination of two techniques to provide driver comfort for a larger speed range. The combination may as well provide extra gains in efficiency.</td>
<td>ACC and Stop&amp;Go may increase the average speed in congested traffic and reduce the travel time. Reduces lost time at start-up.</td>
<td>Large improvements in traffic flow and intersection capacity if the system is applied to the whole road network. Minor improvement on city level if the application is limited to selected links with long queues</td>
<td>For average speed bellow optimal speed an increase in speed will reduce the pollution. Some motorway segments may experience higher pollution levels.</td>
</tr>
<tr>
<td>Lane keeping</td>
<td>Increase road capacity without widening the road profile.</td>
<td>Narrower lanes may reduce the travelling speed.</td>
<td>A case study on public transport has shown positive benefits. The level of efficiency is based on the potential for modal shift.</td>
<td>Reduced travel distance for private cars reduces the pollution. The total level is dependent on the pollution level for high capacity buses.</td>
</tr>
<tr>
<td>Cybercars</td>
<td>Create an environmental improvement in inner cities. Alternative flexible travel for urban trip making, an alternative to the car</td>
<td>As multi-modal journey, additional journey time needs to be considered including waiting times, transfer times.</td>
<td>Reduced private car trips could contribute to the reductions of fuel consumption and pollutant emissions. Cybercars can provide further environmental benefits in urban areas by using electricity.</td>
<td>Investments needed and safety issues with driverless vehicles. A big step change, not evolutionary.</td>
</tr>
</tbody>
</table>
6.2 Recommendations

6.2.1 Deployment of ADAS/AVG systems

The STARDUST project has revealed some important issues regarding the deployment of ADAS/AVG systems. It seems clear that the driver support systems will come into use in a certain extent in the coming years. To move forward and reach a level of use that will have a major influence on traffic flow and safety there are some main concerns that have to be dealt with.

The way these issues are solved will have an important impact on the development and deployment of driver support systems:

- Legislation (mandatory or not)
- Infrastructure investments
- Combination with other applications
- Robustness of the systems in different traffic situations
- Liability issues
- Market needs (user acceptance, training, long term effect, maintenance)

To governments

- Through the Kyoto agreement (1997), the EU has agreed to an 8% cut in emissions of a range of climate change gases (CO₂, CH₄, N₂O, HFCs, PFCs and SF₆) in the period 2008 to 2012, compared to the 1990 levels. The challenge to meet this within the transport sector is recognised by DGXI as “acute... where a significant growth in emissions has occurred and will continue to occur if no action is taken.” Most ADAS/AVG systems offer potential benefits to the environment. From this point of view, government polices should prioritized developments and implementation of environment-friendly systems such as Stop&Go, Lane Keeping and Cybercars, especially in urban areas.

- Many European countries are facing the problems of increasing congestion and pollution in urban areas (especially in city centres). Restricting private car trips to city centre areas has been recognised as a fundamental measure to control traffic demands in urban areas (e.g. congestion charge in London). It is possible that the idea of “A car free city centre” could be accepted by more and more cities. Under this condition, ADAS/AVG technology could be one of the solutions, for example High Capacity Bus (based on ADAS technologies such as Lane Keeping, Platoon) and Cybercars.

- For safety critical devices, such as ISA, Collision Warning and Collision Avoidance devices, the design of these products balances detecting rare unsafe situations and providing warnings and/or corrective control assistance to the driver with developing systems that do not create too many false alarms. Clearly, the introduction of such systems should have a positive net effect on safety within the EU urban road network. Other devices such as ACC, Stop&Go and Lane Keeping will help improve the quality of the driving experience and reduce unsafe situations brought about by human error. This has to be balanced by designing the systems to achieve optimum workload for the drivers and not developing latent problems through a loss of driver skill when operating without
the systems. Whilst this is a great challenge in the development of such systems, there is enormous potential to reduce the number, but also the severity of road traffic accidents.

- Most ADAS are developed to improve driving safety, comfort, and convenience. People buy new technologies when they see a personal benefit. In this way the deployment of driver support systems is market driven. From the systems investigated in STARDUST, there is a rather positive perception from end-users on the improvements of driving safety, comfort, and convenience, especially for ISA, ACC, and Stop&Go. It seems clear that driver support systems will come into use in a certain extent in the coming years. However, these systems can provide wider network benefits with regards to traffic flow and more throughput of traffic – but may as well cause disbenefits if not co-ordinated between manufacturers and government. On the background of the concern regarding legal and liability obstacles for the development of driver support systems, there seems to be a need to develop a robust policy to encourage the manufacturers to move in certain directions.

- The EU has a number of new approach Directives that detail the testing and certification of products and services particularly those that may have some impact on public safety. European states often implement the Directives in different ways to integrate within their existing legal framework. Technical regulations are often used to detail the performance requirements while other states rely on the National Standards Organisations documentation to detail the requirements. The alternative is to adopt harmonised standards. Harmonised Standards are European Standards, which are adopted by European standards organisations, prepared in accordance with the general guidelines agreed between the commission and the European standards organisations, and follow a mandate issued by the commission after consultation with member states. The level of importance attached to the health and safety issues determines the process for testing and whether self-certification is appropriate. The regulating body and the manufacturer need to address these issues.

- To make a substantial step forward regarding deployment rate, it seems necessary for the government to look at regulations making some of the systems mandatory (for safety systems such as ISA). It is also important that the infrastructure owners give ADAS/AVG systems priority in their investment budgets (e.g. Lane Keeping systems).

- On the background of the concern regarding legal and liability obstacles for the development of driver support systems, there seems to be a need to develop a robust policy to encourage the manufacturers to move in certain directions. This policy should be based on a compromised understanding between the government and the manufacturers. To reach this understanding and develop policies and strategies, it seems necessary to work with both local/regional/national/European authorities.

- Additional research is needed to identify optimum system characteristics and functionality and the processes to ensure effective deployment. Some of the important issues will be:
  - legal and institutional barriers
  - policy guidelines

To local governments
• Narrow bus lane could be one of the options for public transport to improve efficiency and reliability in urban areas. It is important for local government to provide road facilities for the deployment of Lane Keeping systems in buses. Polite trials should be supported to evaluate the effects of such implementation (the lane could be dedicated to bus (e.g. in the peak periods) or shared with other private cars equipped with the systems).

• What local government can do about other ADAS systems such as ACC, ISA, and Stop&Go which do not need special facilities?

• Accurate and dynamic information for speed limits are one of the key factors for successful implementation of ISA systems. To achieve this object, it is necessary to invest to support this job.

• Most longitudinal control systems can contribute to improve environment in urban areas e.g. Stop&Go systems. Some policies should be considered to encourage the use of such systems to increase the network effects.

• Stop&Go systems have great potentials to improve efficiency and environment in congested traffic which is featured in urban network. However, such systems could cause safety and liability issues if they are not properly utilised. It is important for local government to co-operate with manufacturers to

**To manufacturers**

• One key issue will probably be to look into how different systems can be combined in order to both achieve the benefits and minimize the liability concern. These strategies will probably also lead to development of more robust systems under different traffic situations.

• Another important part of the issue is the market needs and how market requirements are met regarding information, training and user support.

• System manufacturers are picking up small but still important gains for their own benefit. To make a substantial step forward however there is a need for infrastructural involvement regarding e.g.:
  - establishing data bases for speed limits
  - making the systems mandatory
  - initiate standardisation work

• It is an important issue, if or how, driving instructors and car manufacturers introduce drivers to the new technology. Many drivers still do not know how to operate ABS-brakes or the ESP-system, several years after they became standard equipment. Some of the potential benefits may be reduced due to faulty system use.

Different systems has come to different stages in the development phase, and the ADASE project has introduced the term technology road map categorising different systems according to contribution to safety enhancement and degree of complexity, see the Figure 38 below.
Based on the ADASE concept, the technologies studied in the STARDUST project can be illustrated as shown in Figure 39 on next page. Figure 39 also includes the parameters traffic efficiency and environmental aspects in the description of how the systems contribute to society goals in addition to safety enhancements.

The complexity indicator is a way of illustrating where each system stands in the development phase and the challenge in the further development of each system.
The STARDUST project has been focusing on traffic effects and environmental aspects and thereby targeting the more untested aspects of ADAS technologies. Safety aspects have been a main focus in many other EU projects.

The ADASE and STARDUST road maps are one dimensional and focus only on the benefit and complexity of the systems. For the purpose of giving advice to the different stakeholders how to act with regards to driver support systems it seems appropriate to introduce a time scale or time horizon. One way of doing this is illustrated in Figure 40 on next page.
In Figure 40 the high level product relates for instance to a fully automatic Stop&Go system that might be active for a journey through the city centre. The basic level product relates to a Stop&Go system that needs to be reactivated after each stop. The later technology might be activated by the driver to avoid legal problems within conflicts between cars and pedestrians.

6.2.2 Implementation path
To move forward and reach a level of use that will have a major influence on traffic flow and safety there are some main concerns that have to be dealt with. The way these issues are solved will have an important impact on the development and deployment of driver support systems:

- Legislation (mandatory or not)
- Infrastructure investments
- Combination with other applications
- Robustness of the systems in different traffic situations
- Liability issues
- Market needs (user acceptance, training, long term effect, maintenance)
To make a substantial step forward regarding deployment rate, it seems necessary for the government to look at regulations making some of the systems mandatory. It is also important that the infrastructure owners give ADAS/AVG systems priority in their investment budgets.

One key issue will probably be to look into how different systems can be combined in order to both achieve the benefits and minimize the liability concern. These strategies will probably also lead to development of more robust systems under different traffic situations. Another important part of the picture is the market needs and how market requirements are met regarding information, training and user support.

Figure 40 illustrates that the way forward is not a static process and the success measured in benefits to the road users and society and degree of implementation is dependant of a certain work process. This can be illustrated as shown in Figure 41 on next page based on an idea originally distributed for the NETMOBIL project where STARDUST is one of four cluster projects.

The implementation path diagram is a way of indicating the various key activities for various areas of research and development. The coloured keys detail the particular elements of the activity. These elements are based on the activity bar reproduced in section 5.2.3 from another NETMOBIL activity covering the three key sections: Users / feasibility, pilot and implementation. The activity bar details the process of developing standards as a consequence of directives - the third stage on the bar.

![Implementation Path Diagram](image)

**Figure 41: Possible approach to developing An Implementation Strategy**

It is anticipated that Stop&Go will be the first entry at about the 2005 point. This would be followed by lane keeping then ACC followed by ISA. The pilot trials for Stop&Go is indicated being about 2008. There is a connection between the system complexity and the time scale in the way that the more complex the feature the greater the time scales to initiate trials etc.

A simple bar comprising 4 stages and 2 break points is used in Figure 41, as follows:

```
<USER NEEDS><FEAS. STUDY>..................<PILOT TRIAL>..................<IMPLEMENTATION>
```
This shows the User Needs, followed by the Feasibility Study, Pilot Trial and finally Implementation stages. Break points (denoted by /////), corresponding to decision points, are shown following the Feasibility and Pilot stages. These are to a large extent, indeterminate:

- **Break point 1:** the Pilot stage will not proceed until the feasibility stage has been completed and shown the project is worthwhile in socio-economic, amongst other, terms.
- **Break point 2:** Implementation will not proceed until the results of an evaluation are available (and again, are favourable). Implementation also requires that any legal and institutional issues are resolved, and funding is available.

The proposed approach can be summarised as follows:

- identify and agree indicative future scenarios and an implementation path
- identify the barriers and risks from the common areas and elsewhere
- identify the critical activities and hence the critical path
- develop an implementation strategy
- identify the dissemination activities needed to support the strategy

### 6.2.3 Activity Bars

The structure shown in Figure 42, Figure 43 and Figure 44 describes an expanded version of the typical activity bars used in Figure 41 illustrating the implementation path. One of the objectives has been to develop a management process that can be used to monitor and assess the long term opportunities of individual facilities and systems being researched by the NETMOBIL cluster projects.
Figure 42: User needs and feasibility study phase

Figure 43: Pilot phase
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Figure 44: Implementation phase
Phase 1

Objectives of application and contribution to long term opportunities
Describing the function of a particular facility seems a relatively simple task for the individual. The problem arise when others attempt to interpret the description; variants in the understanding quite often due to the different depths of knowledge of the subject by others colouring the different views on the subject. This is, however, quite a healthy situation, providing the opportunity for discussion and resulting in a better appreciation of the objectives. The solution may be to allow a number of descriptions of the objectives to be retained as each one may require a different approach when considering the next stage of the activity bar. The output should however include a description making reference to the long term objectives and changes that may occur with time. It may be necessary to discuss these objectives with government officials as a pre-cursor to the final stage of the phase 1.

User surveys
There is a need to establish the target population, the depth of questioning, how the survey should be carried out and how many subjects. The foundation established by the objective descriptions will influence these processes. Different levels of questioning detail reflecting the different scope of objectives. Key features of EU requirements –social economic, benefits etc should be taken into account. Before completing this section it would be worth moving onto the evaluation and analysis. In order to achieve some measurable indication of the survey we must consider how to interviewee will interpretate the questions. Some time should be spent considering the interviewee’s use of the facility in different situations, stress and experience being key factors. It would be necessary to make sure that the interviewee understands the subject and be in a position to give a view about the long-term scenarios.

Analysis
This should be a report. The content being developed at the same time as the questionnaire process is being developed. All the common areas found in the many EU management report structures should be included. Implementation and policy development issues should be detailed.

Policy review
This will involve meetings with the users and key stakeholders. The findings of phase 1 need to be reviewed against the original objectives. Identification of gaps in the information chain recognised and if necessary action taken to cover the missing information. It would be necessary, in preparation for the next stage, to put some monetary values on the use of the various facilities.

Milestone 1 (M/S 1)
Presentation to key stakeholders. The duration of this period could be substantial. It is, however, essential that all the information presented is credible and can be tested under scrutiny by officials. The early discussions with officials at the first step should provide a sound base for dialogue.

The outcome of the deliberations can go a number of ways. Problems accepting the results may require further analysis or better interpretation of the results. This will have to be taken
as an action. The alternative would be some form of agreement to move onto the next stage. The framework for a pilot should be an output from the M/S 1 activity.

**Phase 2 / Phase 3**
The activity bar provides an outline of the possible activities in phases two and three. It is clear with the time scales involved that the future content of activity may change. The information provided should be considered at the phase one section as a means of checking that we can see a natural migration to the next stages. Any issue or activities identified in phases two and three should be reflected in the phase one activity.

### 6.3 Future research and other needs

The STARDUST project has revealed that driver support systems has a substantial potential in the urban environment regarding traffic flow and traffic safety, but also that there is a need for more research on urban following processes and traffic flow mechanisms:

- influence on capacity (smoothing and increasing the flow)
- reliability of the systems under different traffic conditions and surroundings
- adaptation and interaction to the traffic environment
- effects of coupling between different systems
- safety (looking at the driver behaviour and traffic processes, long term database for incidents)
- user acceptance and understanding of new technologies

From the road keeper and governmental point of view there is a need for more research in connection with the understanding of the traffic management implications:

- opportunities
- handling and regulating inappropriate technologies

New technologies bring up a need for new concepts to be developed for the allocation of road space/demand management and for modification and enhancement of access control systems. These new concepts should be incorporated in traffic planning tools.

In addition to legal barriers and liability issues, for some systems there may also be privacy issues to be solved. There is also an important issue regarding the mechanics of the traffic management (roadside installations, communication systems) that has to be focused in future R&D projects.

The STARDUST project has not focused on the socio economic benefits from the implementation of ADAS/AVG systems. It is however believed that this will be an important issue and also an assumption that there is a substantial gain from the society point of view for the government to support further development of these systems. From that point of view it will probably be of importance to show positive impacts not only on traffic flow in general and safety and environment but also for public transport in special.
Reference


STARDUST Deliverable 8 (2004) Simulation of the Large Scale Impacts of ADAS/AVG on the Case Studies of Brussels, Oslo and Southampton Urban Road Networks


Antonino Tripodi, Jean Michel Auberlet, Stéphane Espié, Domenico Gattuso. Study of the Stop&Go System on driver’s behaviour in urban environment. In the proceedings of the 10th ITS Congress, November 16-20, 2003, Madrid (Spain)


Jinan Piao and Mike McDonald. Low Speed Car Following Behaviour from Floating Vehicle Data. In the proceedings of the IEEE Intelligent Vehicles Symposium (IV 2003), June 2003, Columbus OH (USA)

Jinan Piao and Mike McDonald. Stop and Go Driving Behaviour: Initial Findings from Floating Vehicle Trials. In the proceedings of the 10th ITS Congress, November 16-20, 2003, Madrid (Spain)
Mike McDonald, Alain Henry, Stéphane Espié, Michel Parent and Torgeir Vaa. A Research on Deployment of Urban Sustainable Transport systems, In the proceedings of the 9th ITS Congress, October 14-17, 2002, Chicago (USA)
Appendix A  STARDUST user questionnaire

The objective of the user survey was to assess the attitude of drivers towards the systems surveyed. In three cities Brussels, Oslo and Southampton, questions were asked drivers if they would be interested in using such systems, on which circumstances they would use them, and what kind of benefits they saw in using them.

It is worth noting however that the Brussels survey was designed and performed first and with another main approach than in the other two cities. In Brussels, a stated preference survey was done to analyse modal choice of transport users in face of new technologies, in this case cyber cars. This survey was only performed in Brussels. Questions regarding other ITS-related issues in the Brussels study were adapted for the surveys in Oslo and Southampton later. The same questionnaire was used in Oslo and Southampton but differ somewhat from the questionnaire used in Brussels. The sample sizes for analysis in the three cities are shown in Table A-1:

<table>
<thead>
<tr>
<th></th>
<th>Brussels</th>
<th>Oslo</th>
<th>Southampton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>245</td>
<td>301</td>
<td>491</td>
</tr>
</tbody>
</table>

Results of user questionnaire

Intelligent Speed Adaptation

There is a large interest in ISA systems in the public. Based on UK and Norway results, from 50% to 60% of drivers believe that ISA would bring improvements in terms of safety. 62% and 81% of the drivers said ISA was attractive to them. However, only 53% to 56% of them said they would consider buying an ISA for their next car.
Driver’s acceptance of ISA by gender was not consistent between the three countries. In UK and Norway, there were more women than men interested in the ISA systems. Between 59% and 62% of the female drivers were willing to pay for the ISA systems, compared to 46% and 53% for male drivers ($\chi^2(1)=1.826$, $p=0.177$ for UK results, $\chi^2(1)=7.695$, $p=0.006$ for Norway results). In Brussels, 81% male drivers took warning ISA as attractive, compared to 76% for female drivers. The difference was not significant ($\chi^2(1)=0.812$, $p=0.368$).

There is a trend of increasing interest in ISA systems with age. As shown in Figure A.3, more old drivers than young drivers expressed interest in buying an ISA for their next cars in UK and Norway. In Belgium, such trend was shown for all the three types of ISA system.
There is a clear preference for the less constraining system. In all 3 countries, there is a very strong support for warning systems, while the other options proposed (haptic accelerator or mandatory speed adaptation) found much less supporters. Comparing driver opinions on the three types of ISA systems in UK, 63% of respondents taking warning ISA as a favourite, and this was followed by 24% for haptic ISA, and 9% for mandatory ISA. There was a similar trend in Norway with the favourite rates to the three types of ISA being 76%, 15% and 13%. It can be seen that warning ISA was the most welcome and mandatory ISA was the least one. Figure A.4 shows driver’s opinions to the three types of ISA questioned in Belgium. As with those in the other two countries, majority of drivers took warning ISA as either attractive (52%) or extremely attractive (27%). 34% of Belgium drivers took mandatory ISA as extremely unattractive, 25% for haptic ISA and 6% for warning ISA.

![Figure A.4 Drivers opinions to ISA systems in Belgium](image)

When interviewing people after a test in the driving simulators, there is an improvement in the perceptions people have on ISA systems. In Norway, 76% of respondents preferred the warning system and 13% the haptic system. However, among the 18 persons interviewed after the driving simulator test in Norway, 56% preferred the haptic system and only 44% the warning system. Clearly, experience with haptic systems helps convincing drivers of the interest of such device. This fact suggests that correctly informing drivers about the new systems is a key towards their wide acceptability.

When answering where drivers would like to use the ISA systems, UK respondents were more interested in using ISA systems in urban areas (70% to 85%, depending on the kind of zone), but only a third of respondents would use ISA on motorways (urban or inter-urban). Norwegian respondents showed a similar opinion: 50% to 70% would use ISA on urban roads, and 30% on motorways. Belgian respondents favoured the use of ISA in the entire urban area. The interest for ISA in some situations is likely to be linked with the structure of land use. In the UK for example, there is a large number of wide residential areas around the major cities. These residential areas are usually equipped with good quality roads, where speeding is easy, which is seen as dangerous. ISA systems would be attractive to reduce that
speed. Indeed, UK respondents would first use ISA in residential areas. The situation would be different in highly urbanised countries, such as Belgium. In that case, streets in residential are narrow and do not favour speeding.

**Adaptive cruise control**

Drivers have good perceptions of the potential impacts of ACC. From 50% to 60% of respondents believe ACC would improve comfort and safety. Conversely, few people think that ACC could decrease comfort or safety. In the UK, 15% of respondents believed ACC would deteriorate comfort and safety. This share is below 10% in Norway.

![Figure A.5 Drivers opinion on ACC regarding comfort and safety](image)

ACC is judged attractive by 46-53% of the respondents, who would consider buying it for their next car. About 23-26% of them found the system unattractive. Previous experience with cruise control improves the interest in ACC. About one third of the drivers had some experiences of using conventional cruise control (speed control) in both UK and Norway. Drivers with experiences of cruise control were significantly more willing to purchase the systems than those drivers without the experiences. For drivers with some experiences of cruise control, 52%-54% of them said they would consider buying an ACC for their next car, compared to 41%-43% for those drivers without ($\chi^2(2)=7.857, p=0.005$). This might be due to that drivers with some experiences of cruise control are more aware the systems and are more confident in using the systems.

Drives were asked whether or not they would like to use ACC on urban roads with higher speed limits (e.g. 64km/h or higher). ACC is not perceived as system for the city. Most respondents (about 72-80%) declared they would use it on motorways (interurban motorways and, to a lesser extent, urban motorways), only 40-45% were interested in using it on urban roads.

**Stop & go control**

Perceptions of Stop&Go systems by British and Norwegian motorists are positive, though not as much as for ACC, probably because this system is less well-known. About 40% of respondents believed Stop&Go systems would improve comfort and safety. Between 10% and 20% believed this system would deteriorate comfort and safety.
Figure A.6 Drivers opinion on Stop&Go regarding comfort and safety

Figure A.7 shows the percentages of drivers with positive attitude toward using a Stop&Go in the urban areas. Significant difference was found in the interests of using a Stop&Go in urban congested areas between the three cities. Compared to 50% of the drivers in both Southampton and Oslo, there were 64% of the respondents in Brussels saying it was attractive to use a Stop&Go in urban areas. One of the reasons could be that Brussels is a large city with more congestion than those in Southampton and Oslo. This could be taken as an indication of the strong desire of drivers in large urban areas to find some means to improve their traffic situations.

Figure A.7 Percentage of drivers positive to Stop&Go in urban areas

Overall, between 35% and 40% of respondents said that they would consider purchasing a Stop&go for their next car. There is a significant difference in driver’s willingness to pay for the system between those who often encounter congestions and those who do not. In UK, 44% of the respondents said that they would consider buying a Stop&Go for their next car for those drivers frequently encountering heavy congested traffic, compared to 27% for those drivers occasionally or rarely do so. The correspondent figures in Norway are 55% and 35% respectively.
Figure A.8 clearly shows the trend that driver’s interests in Stop&Go increase with their experiences of congestion.

![Interests in Stop&Go increase with congestion experience](image)

Figure A.8 Interest in Stop&Go depending on congestion experience

In the surveys in UK and Norway, one question was asked about driver’s interests in using a combined system of ACC and Stop&Go. It seemed that UK drivers were more interested in using such a combined system than those in Norway. Overall, about 45% of drivers said that the combined system of ACC+Stop&Go was attractive, and about 35% in Norway. In both UK and Norway, there were no significant differences in driver’s preferences were found between using ACC+Stop&Go on motorways and urban main roads (>64 km/h).

**Lane keeping**

In UK and the Norway, between 20% and 30% of respondents believed such systems would improve comfort or safety. As much as 40% of British respondents believed it would decrease driving comfort, and 30% believed it would decrease safety.

![Drivers opinion on Lane Keeping regarding comfort and safety](image)

Figure A.9 Drivers opinion on Lane Keeping regarding comfort and safety

In UK and Norway, between 20% and 25% of drivers said that Lane Keeping systems were attractive and consider purchasing the system for their next car. Compared to ISA, ACC and
Stop&Go, this was the system receiving the least acceptance among the drivers surveyed. Positive opinions on this system were higher in Belgium than those in UK and Norway, with about 50% of the respondents finding the system attractive. This might be partly caused by the fact that the implementation scenario for lane keeping was slightly more elaborated in the Belgian questionnaire. It should also be noted that in Belgium as in the other two countries, Lane Keeping received the lowest appreciation among the four ADAS systems surveyed. There could be many reasons for such low level of willingness to pay. Firstly, the use of Lane Keeping is constrained to special road conditions (e.g. with well marks for vision based the systems), unlike ISA, ACC and Stop&Go which can be used on normal roads. Secondly, not as much direct comfort or safety benefits as to other systems can be found from Lane Keeping system.

Cybercars

Cybercars are fully automatic, driverless taxis. They are equipped with a variety of systems including guiding systems, driving systems, obstacle detection and emergency systems to ensure maximum safety. Passengers board at a stop point, or can even call them from home, and pay using automatic payment devices. In the long term, Cybercars could be used across the entire road network, enabling you to specify your destination and use Cybercars in the same way as a normal taxi.

Though more futuristic than the other concepts presented in this study, most respondents were familiar with the idea of Cybercars. 60% of UK respondents and 40% of those in Norway found the system attractive.

When given the choice to use a taxi or a cyber car in the Belgium survey, almost 80% of respondents chose Cybercars if its cost was 30% lower than for a taxi with the same journey time. There are thus no resistance to the concept of Cybercars, respondents were not afraid of using a high technology system (assuming technology was mature).
Appendix B  STARDUST operator questionnaire

The objective of the operator survey was to investigate some policy issues related to ADAS/AVG systems and to highlight the expected impacts of such systems in urban environment and the potential barriers, as they are perceived by transport operators and infrastructure owners.

The survey was carried out in Belgium, Great Britain and Norway where road transport operators, infrastructure owners and other respondents working in the field of transportation were interviewed.

A total of sixteen interviews were held, which are distributed as follow:

- 10 owners
- 4 operators
- 1 drivers representative
- 1 transport consultant

Because of the qualitative nature of this survey and the small number of respondents, care must be taken to analyse the results. We cannot draw any statistical conclusion from such a small number of surveys. This fact is inherent to such a survey. The number of persons we could have interviewed in public transport companies or in public administrations responsible for road infrastructure is by definition limited.

Conclusions of operator questionnaire

There is generally a positive approach from drivers to intelligent transport systems. Respondents have relatively positive perceptions on the improvements those systems could bring about. They also have positive overall perceptions of the systems. This is particularly true for ISA and ACC, as well as for Cybercars, though this system is more long-term than the others. Respondent were slightly less positive towards Stop&Go systems. Opinions are less favourable for lane keeping systems.

Experience in STARDUST shows that, when correctly informed (for example after a trial in a driving simulator), perceptions and opinions of respondents were more favourable to ITS than without being informed. Information campaigns would thus be useful before launching systems on a wide scale. A large number of respondents in the user survey did not have an opinion on the changes driver support systems would bring. Those persons would particularly benefit from such information campaign, and are, in our opinion, likely to view ITS favourably. There are indeed very few respondents who systematically reject all the systems we proposed (0.3% in the UK, 1.6% in Norway).

From the public authorities point of view, ISA is the most likely system to receive support for implementation in the coming years. It is viewed as technologically more mature than ACC and Stop&Go, and bringing the most benefits. Lane keeping, though perceived as technology mature too, generates less interest. Lane Keeping is the systems received lest acceptance in both UK and Norway.
Appendix C  Analysis of driver behaviour through floating vehicles

The objective of this analysis was to provide a realistic behaviour database (especially in low speed traffic conditions) which will be used as a normative standard for human factors investigations, behavioural assessment, simulation and safety assessment in the later stage of the STARDUST project.

The data used for this analysis were collected by using an Instrumented Vehicle equipped with a laser radar rangefinder. Data collection covered urban motorways, urban arterial roads and city streets in three European cities: Oslo (Norway), Paris (France) and Southampton (UK). A total of over 65 hours of field data were collected in the three cities.

The analysis has focused on low speed traffic behaviour especially in stop&go traffic, the main parameters investigated included time gap, distance gap, acceleration, deceleration, braking frequency, start delays and stopping-distance-gaps.

Time gaps and distance gaps on motorways across wide speed ranges were investigated. The data used was extracted from car following time series in relatively stable conditions (acceleration $\leq 1\text{m/s}^2$). The results from the three sites show that time gaps decrease as following speeds increased when in low speed situations (e.g. $<60\text{km/h}$), and became relatively stable when at high speed (e.g. $>70\text{km/h}$). The results also show that time gaps were more variable when at low speeds than those when at high speeds. Whilst, distance gaps were less variable when at low speeds than those when at high speeds. The average time gaps and their standard deviations in the speed ranges between 10 and 40 km/h were 1.90 seconds and 0.74 seconds, compared to 1.15 seconds and 0.36 seconds when at speed higher than 70km/h. Constant time gap assumptions are used in many of the current studies on ACC and Stop&Go. The results from this research suggest that it might be worthwhile to try variable time gaps in simulating such systems.

Acceleration and its variation provide additional information on vehicle dynamics and potential impacts on driving comfort, safety and environment. Any reduction in acceleration and its variation would mean comfort, safety and environment benefits. On both motorways and city streets, higher variability of acceleration was identified when at low speed than that at high speed, and such variation decreases as the driving speed increases. This suggests that there could be more benefits to use ADAS systems when at low speed conditions, from the point of view of that such systems can be used to reduce speed variability and smooth traffic. As we know, traffic conditions at low speed are more complicated than those in high speed situations, this makes it a big challenge to assess the impacts of such driving assistance systems in low speed situations.

Braking frequency can also be taken as a safety, comfort, environment indicator. Any reduction in braking frequency would mean safety, comfort and environment benefits. The result show that braking frequency at low speeds was much higher than that at high speed. The braking frequency could be as high as 25 times per kilometres when at 10km/h compared to 0.25 time per kilometre when at speed over 60km/h. The obtained results about braking frequency and the maximum deceleration for each brake will be used as baseline for model calibration and assessing the impacts between with and without using ADAS/AVG system in this research.
Most vehicles experience delay when starting to move in a queuing event because of driver reaction time, maneuver delays, mechanic delays and human error. In this research, start delays at signalized intersections and on non-junction roads were investigated. The results from the three cities show that start delays on motorways were significantly higher than those on urban streets. The mean start delays on motorways was 1.27 seconds, compared to 0.93 on urban streets which implied that there could be greater benefit using Stop&Go on motorway than on urban streets, because Stop&Go systems use sensors to detect the movement of the preceding vehicle which can significantly reduce driver reaction time.

Stopped-distance gap is a parameter which concerns driver behaviour in static traffic conditions. The results show that the average stopped-distance gap on urban streets was 1.79 m, whilst on the motorways the average stopped-distance gap was 1.98 m. Distance gaps at stop on urban streets were compared between the three cities. The distance gaps at stop in Paris were found significantly higher than those in Oslo and Southampton. Stopped-distance gap is a parameter directly linked to the storage capacity of a road, any reductions in stopped-distance gap or its variability would suggest a benefit in increasing storage capacity and possibly the traffic capacity of the road link. These effects will be particularly strong in multilane situations either at signalized intersection or on motorways. There exist some potential to use ADAS (e.g. automatic Stop and Go) to shorten such distance gaps at stop or at least their variability. Compared to manual control, such systems are based on sensors which can increase the accuracy of the distance control.
Appendix D  Driving simulator experiments

Human Factors aspects of ADAS and AVG systems were studied in STARDUST. The systems studied by use of driving simulators in Norway and France include Intelligent Speed Adaptation (ISA), Advanced Cruise Control (ACC), Stop&Go, and Lane Keeping.

Models of driving behaviour suggest that behavioural adaptation can be expected when intervening with technology in the driving process. In a wider perspective, technology does not simply replace or “take over” a given function; rather it transforms human practice and forces people to adapt their skills and routines. The driver support systems focused in these simulator studies have all been studied before to a greater or lesser extent. However there is a lack of studies on how people adapt to these systems in an urban setting with an urban traffic flow, particularly those related to the learning phase and to the long term effects.

SINTEF simulator
The SINTEF simulator is based on a full scale and fully equipped Renault Scenic 1997 model with a motion system. 5 channels of visual information provide the Field of View (FoV). The size of each screen is 2.4 meter tall and 3.1 meter wide. The resolution of the visuals is 1024 x 768 pixels. The three front screens are rear projected and provide in sum 180 degrees horizontal FoV and 47 degree vertical FoV. The two screens behind the vehicle are front projected and supply in sum 90 degree vertical FoV and 47 degrees vertical FoV each (see figure 1).

Figure D1: The SINTEF Driving Simulator

The visual channels are driven by dedicated computers running Linux Redhat 7.2. and equipped with G-force 3 graphic processors. The sound system and instructor PC are Windows 2000 based computers.

The SINTEF driving simulator contains a visual database with over 500 km of various traffic scenarios with roads in urban and country settings. Further, a number of variations road surfaces are available, like snow, rain, asphalt, gravel etc. The simulated traffic scenarios include autonomous cars capable of acceleration, braking, steering, and taking over vehicles.

Log files from the simulator provide registration at 20 MHz rate of relevant variables.
INRETS’ driving simulator

The INRETS Sim² class driving simulator is located in Arcueil near Paris. The current configuration of the Arcueil prototype is fixed-base with 3 front screens with inlaid rear mirror. The software architecture is “traffic centred”; the driver is immersed in the Archisim traffic model. The 3D sound restitution is generated by the traffic model and thus takes into account the surrounding traffic (see figure 3).

Figure D2 INRETS Arcueil Sim² simulator:

The reproducible scenarios are described by scripts interpreted in real time by a supervisor. The scenario description and encoding are easy because, since the events / actions the script language uses are related to the road network, we can use road kilometric co-ordinates (road, kilometric position, relative lateral position and heading…) rather than Cartesian geometric coordinates (x, y, z). The recorded data can be of two types: on line data related to drivers’ actions (steering wheel and pedals position …) and to the surrounding (position on the road, speed,… and other vehicles relative position, speed…); off line questionnaire dealing with drivers feelings related to the roads profiles variants (visibility, subjective disturbance…).
Appendix E  Scenarios for micro-simulation

Applications to be considered

The systems to be investigated by micro simulation include: ISA, ACC and Stop&Go. These systems and the combinations of these systems will be simulated in the following three types of road:

- Urban motorways
- Urban arterial roads
- Urban streets (signal controlled link and roundabout link)

The selected systems were simulated under four penetration levels in different peak periods which are shown in the Table E1

Table E1 Targeted systems and simulation scenarios

<table>
<thead>
<tr>
<th>System</th>
<th>Urban motorway</th>
<th>Urban arterial</th>
<th>Urban streets</th>
<th>Penetration levels and demand levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>0% (baseline)</td>
</tr>
<tr>
<td>Stop&amp;Go</td>
<td></td>
<td></td>
<td>√</td>
<td>20%</td>
</tr>
<tr>
<td>ACC+Stop&amp;Go</td>
<td>√</td>
<td></td>
<td>√</td>
<td>80%</td>
</tr>
<tr>
<td>ISA+ACC+Stop&amp;Go</td>
<td>√</td>
<td>√</td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Assessment indicators

The performance indicators selected for the assessments are shown in Table E2 and E3:

Table E2 Indicators for ISA

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Nature</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average speed of equipped and unequipped vehicles</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
<tr>
<td>Standard deviation of the speed for equipped and unequipped vehicles (km/h)</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
<tr>
<td>Journey time (minutes)</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
<tr>
<td>Time headway and its distribution of equipped and unequipped vehicles (seconds)</td>
<td>Aggregating</td>
<td>At a detector at the middle of the road</td>
</tr>
</tbody>
</table>
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| Time-to-collision and its distribution of equipped and unequipped vehicles (seconds) | Aggregating | At a detector at the middle of the road section |

Table E3 Indicators for ACC and Stop&Go

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Nature</th>
<th>Measurement site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle speed and its distribution (equipped and unequipped vehicles, km/h)</td>
<td>Microscopic</td>
<td>Over the journey (the first 50 vehicles after 10 minutes of simulation)</td>
</tr>
<tr>
<td>Standard deviation of the speed (equipped and unequipped vehicles, km/h)</td>
<td>Microscopic</td>
<td>Over the journey (the first 50 vehicles after 10 minutes of simulation)</td>
</tr>
<tr>
<td>Time headway and its distribution (equipped and unequipped vehicles, seconds)</td>
<td>Microscopic</td>
<td>Over the journey (the first 50 vehicles after 10 minutes of simulation)</td>
</tr>
<tr>
<td>Time-to-collision and its distribution (equipped and unequipped vehicles, seconds)</td>
<td>Microscopic</td>
<td>Over the journey (the first 50 vehicles after 10 minutes of simulation)</td>
</tr>
<tr>
<td>Journey time (minutes)</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
<tr>
<td>Stop time: average time at as standstill per vehicle during travelling on a road section (seconds/vehicle)</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
<tr>
<td>Number of stops: average number of stops during travelling on a road section (number of stops/vehicle)</td>
<td>Aggregating</td>
<td>Between the two detectors at each end of the road section</td>
</tr>
</tbody>
</table>

**Geometry conditions for the simulation**

**Urban motorway**

For motorway simulation, a three-lane motorway will be targeted as shown in Figure E1, which does not include entry and exit points, no hill, and no curve. The length of the road should be longer than 3 km.
Urban arterial roads

For arterial simulation, the basic requirements are shown in Figure 3:
- Two lane in each direction
- With speed limits higher than urban streets
- Length > 500m
- Downstream junction: signalized junctions or roundabouts

Urban street

The urban streets simulation, the basic requirements are shown in Figure 4:
- Single-line in each direction
• With lower speed limit (e.g. <48 km in UK)
• Downstream junction: signalized junctions or roundabouts
• Length: >500m

Figure E3 Urban streets (U.K.)
Appendix F  Scenarios for macro-simulation

ISA applications

ISA can be used to help drivers to control their driving speeds by knowing the speed limits of roads (Varhelyi A, 2001). Using ISA could result in reduced maximum speed. In this ISA study, it is assumed that ISA is to be applied in urban network to reduce speeding. The objective was to assess ISA impacts on traffic efficiency and environment at a city level. It was expected that ISA effects could be influenced by many factors such as ISA penetration level, road types, traffic demands etc.

ISA is to be applied on all types of roads in the network (with different speed limits). The results from such baseline simulation will be compared to assess ISA effects. ISA equipped vehicles will run with non-equipped vehicles in the same environment. 20% and 80% penetration rates will be considered to represent low and high levels of ISA applications. Considering that there are more speeding in light traffic, non-peak traffic is simulated. Common scenarios were used in the three case cities which are summarised in Table F1.

To test the sensitivity of ISA effects to traffic demands, the simulation was run at three different levels of demand: 80%, 100% and 110% of the current demand level.

Table F1 Descriptions of the ISA scenarios for simulation

<table>
<thead>
<tr>
<th>Objectives and Assessment indicators</th>
<th>Network and demand</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Roads applied</td>
<td>Penetration level</td>
</tr>
<tr>
<td>To assess ISA impacts on</td>
<td>All road links in</td>
<td>0%, 20% and 80%</td>
</tr>
<tr>
<td>traffic efficiency and environment</td>
<td>the network</td>
<td></td>
</tr>
<tr>
<td>at network level</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Assessment indicators</strong></td>
<td></td>
<td>Demand sensitivity</td>
</tr>
<tr>
<td>▪ Network journey time</td>
<td>Demand</td>
<td>80%, 100%, 110%</td>
</tr>
<tr>
<td>▪ Network distance</td>
<td>Non-peak demand</td>
<td></td>
</tr>
<tr>
<td>▪ Average speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Total fuel consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Total emission of CO2 and NOx</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stop&Go applications on urban roads

The objective of this study was to assess the network impacts of Stop&Go in the context of urban roads. It was assumed that the saturation flows of signal controlled links and roundabout links increased because of reduced reaction time when starting-up from stop for
those vehicles equipped with Stop&Go systems. To simulate Stop&Go impacts by network modelling, the following common scenarios were used in the case cities:

**Table F2 Descriptions of the Stop&Go scenarios**

<table>
<thead>
<tr>
<th>Objectives and Assessment indicators</th>
<th>Network and demand</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Roads applied</td>
<td></td>
</tr>
<tr>
<td>To assess Stop&amp;Go impacts on traffic efficiency at network level</td>
<td>-Signal controlled junctions on main roads</td>
<td>Implementing Stop&amp;Go</td>
</tr>
<tr>
<td></td>
<td>-Roundabout on main roads</td>
<td>Adjust saturation flow of the signal controlled link and roundabout link based on WP50 results</td>
</tr>
<tr>
<td><strong>Assessment indicators</strong></td>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td>- Network journey time</td>
<td>Peak period demand of 7:30-9:00 AM</td>
<td>Penetration</td>
</tr>
<tr>
<td>- Network distance</td>
<td></td>
<td>0%, 20% and 80%</td>
</tr>
<tr>
<td>- Average speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Total fuel consumption</td>
<td></td>
<td>Demand sensitivity test:</td>
</tr>
<tr>
<td>- Total emission of CO2</td>
<td></td>
<td>80%, 100% and 120%</td>
</tr>
<tr>
<td>- Total emission of NOx</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Applications of ACC+Stop&Go**

It is assumed that an ACC+Stop&Go is to be applied in a situation where a long queue is built-up from a bottleneck section on a high-speed road (e.g. approaching to junctions on congested motorways or approaching to a large roundabout). For equipped vehicles, their longitudinal movements are controlled by ACC+Stop&Go system in both high and low speed following process. It is expected that using ACC+Stop&Go will have positive impacts on traffic efficiency and environment because of reduced reaction time and smooth movement of the vehicles. The objective of this study was to assess the network impacts of ACC+Stop&Go impacts on traffic efficiency and environment at network level. To simulate the network impacts of ACC+Stop&Go, the following scenarios were designed:
To test the sensitivity of ISA effects to traffic demands, the simulation was run at demand 80%, 100% and 120% of the current demand level.

### Table F3 Descriptions of the ACC+Stop&Go scenarios

<table>
<thead>
<tr>
<th>Objectives and Assessment indicators</th>
<th>Road conditions and demand</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Roads applied</td>
<td>Penetration level:</td>
</tr>
<tr>
<td>To assess ACC+Stop&amp;Go impacts on traffic efficiency and environment at network level</td>
<td>- Motorways</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Arterial roads (e.g. link length &gt; 1000m)</td>
<td>0%, 20%, 80% and 100%</td>
</tr>
<tr>
<td>Assessment indicators</td>
<td>Demand</td>
<td>Demand sensitivity test:</td>
</tr>
<tr>
<td>• Network journey time</td>
<td>Peak period demand of 7:30-9:00 AM</td>
<td>80%, 100% and 120%</td>
</tr>
</tbody>
</table>
**High capacity buses**

The objective of using High Capacity Buses is to increase the attractiveness of public transport by providing efficient and puncture service, and reducing the use of private car use. It is assumed that the widths of current roads are reduced to create an additional narrow lane dedicated to buses. The buses are equipped with lane keeping systems allowing the buses to run with fast speed on the bus lane. The scenarios of High Capacity Buses scenarios are described in Table F4.

### Table F4 Descriptions of the High Capacity Bus scenarios

<table>
<thead>
<tr>
<th>Objectives and Assessment indicators</th>
<th>Road conditions and demand</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>Roads applied</td>
<td></td>
</tr>
<tr>
<td>To assess the effects of high capacity buses on traffic efficiency and environments.</td>
<td>-Motorways</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Arterial roads</td>
<td></td>
</tr>
<tr>
<td>Assessment indicators</td>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td>Network journey time</td>
<td>Peak period traffic</td>
<td></td>
</tr>
<tr>
<td>Network distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It is assumed that the widths of current roads are reduced to create an additional narrow lane dedicated to buses. The buses are equipped with lane keeping systems allowing the buses to run with fast speed on the bus lane.</td>
<td></td>
</tr>
</tbody>
</table>

**Cybercars in city centre areas**

It is assumed that private cars are restricted in city centre areas. This means that all journeys between the city centre and all other areas have to be taken by public transport (train, bus or cybercars). Cybercars in this situation work as a supplement to major public transport in the city centre area being responsible for feeding or collection to/ from major stations (bus, coach, train etc), high streets and other attraction points within the city centre. To cooperate with the cybercars application, it is assumed that Park&Ride facilities are to be provided at location of outskirt of urban areas. It is expected that the bus traffic to/ from city centre will become more efficient and positive impacts on environment in city centre area because of less private car traffic. The objective of this study is to assess the traffic impacts (for the network in general and for specific bus corridors) of applying cybercars in city centre areas. The following scenarios were designed to simulate cybercars impacts:

Demand: AM peak from 07:30-09:00
Roads applied: Cybercars running in city centre areas
Mode change of private car travellers:
Table F5 Cybercars in city centre areas

<table>
<thead>
<tr>
<th>Objectives and Assessment indicators</th>
<th>Road conditions and demand for cybercars</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objectives</strong></td>
<td>Roads applied</td>
<td>Car-free city centre</td>
</tr>
<tr>
<td>To assess cybercars impacts on traffic efficiency at network level and in view of bus corridors</td>
<td>Private car trips to/from city centre</td>
<td>Car-free city centre, therefore all journeys between the city centre and all other areas have to be taken by public transport (e.g. train, bus or cybercars). The cybercars in this situation work as a supplement to major public transport in the city centre area being responsible for feeding or collection to/from major stations (bus, coach, train etc), high streets and other attraction points in the city centre.</td>
</tr>
<tr>
<td>Assessment indicators</td>
<td>Additional bus corridors</td>
<td></td>
</tr>
<tr>
<td>- Network-wide (total)</td>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AM Peak period (7:30-9:00 AM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trips to/from city centre</td>
<td></td>
</tr>
<tr>
<td>- Bus-Corridors (in/outbound)</td>
<td>Short journey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Walk+bus+cybercars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium/Long journey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car+P&amp;R+bus+cybercars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Car+P&amp;R+train+cybercars</td>
<td></td>
</tr>
</tbody>
</table>
Appendix G  The Legal & Institutional Aspects Of The Deployment Of ADAS/AVG systems

Advisory, Overridable and Mandatory Systems

Where a vehicle is equipped with an ADAS / AVGS, responsibility for the driver’s behaviour will, in most cases, remain with the driver. Even where an ADAS / AVGS fails, if the system is merely advisory in nature (such as an ISA system which warns the driver that they are about to break the speed limit, but exerts no haptic control over the vehicle) then the driver is likely to remain liable for his response. This is because the driver retains ultimate control over his vehicle at all times and should only use the information provided by the system to assist him in reaching a reasoned decision on how to react, taking all the surrounding circumstances (such as weather conditions) into account. If an accident occurs in such circumstances, and the driver fails to react appropriately, he is likely to have breached his duty of care to his fellow road users.

Where the ADAS / AVGS is haptic but overridable, the liability of the driver will depend upon the circumstances of each case. The court will consider any inherent system limitations, whether the driver was warned about these limitations and whether he reacted appropriately to any such warnings. In reaching a conclusion, the court will consider whether the driver acted in the same way that a reasonable man would have acted in the circumstances.

Finally, where the ADAS / AVGS is mandatory, with no possibility of driver override, the driver’s liability for any accident caused as a result of the system’s intervention decreases, because he does not retain ultimate control over his vehicle. In direct contrast, the manufacturer’s liability will increase. As mandatory systems effectively leave the driver powerless to avert an accident, if they have inherent limitations they are likely to be considered defective products by the court.

Training

With each ADAS / AVGS, driver training would seem to be a vital prerequisite to use of the system. No matter how remarkable the design of the system, it will only be safe and beneficial if drivers are fully trained in its use. The numerous limitations of using a manual as method of training drivers have been highlighted throughout this Workpackage. An alternative would be to introduce compulsory training. This, however, would be costly and hard to implement, and, because compulsory training raises enforcement issues, it is likely to require a change in the current law. This will be time-consuming and may be difficult to instigate.

It is as yet unclear whether the gradual introduction of systems on which training had been given would allow safe driving practices to be spread among the driving population. This gradual propagation method needs to be investigated further as an alternative to universal training.

Warnings
As has been demonstrated throughout this Workpackage, warnings to the user from the system/vehicle manufacturer are extremely important. When assessing whether or not a product is defective the courts have regard to the nature of any warnings or instructions issued with the product. If a claimant chooses to disregard a manufacturer’s warning or instructions as to the use or limitations on use of a product, the court may decide that the product was not defective.

**The Urban Environment**

In the case of each ADAS / AVGS, numerous difficulties arise when the system is considered in respect of an urban environment. The source of these difficulties is the number and complexity of interactions between the driver, the system and the external environment. This is particularly true in relation to Stop & Go. The challenge will be to introduce such a system with acceptable safety risks, given the inherent limitations of the technologies within the context of the urban environment. Where, on the other hand, the limitations of a system are relatively easy to appreciate and there are fewer requirements placed on the driver, the risk implications of the system will be correspondingly reduced.

**General Approach**

The remarks made in the previous paragraph suggest that in considering the risks of implementing these systems, they can be analysed systematically according to certain common factors. First, what are the inherent limitations of the system in the environment within which it is to be used? In other words, what situations may arise which lead to potential risk and which either the system cannot deal with or can only deal with following intervention by the driver. Secondly, how frequently are these limitations likely to manifest themselves?

Thirdly, where the system requires regular driver intervention, how reasonable is it for the average driver to make the correct intervention? The answer to this third question may rely in part on the feasibility of effective warnings/training in relation to the particular system and partly on the feasibility of the driver reacting promptly and properly to the situation.

The answers to these questions may allow a systematic risk analysis to be performed on the various systems.
Appendix H  STARDUST leaflet

(to be included)
Appendix I  STARDUST newsletters

(To be included)
### Appendix J  Main activities conducted in STARDUST

<table>
<thead>
<tr>
<th>No</th>
<th>Workpackage Title</th>
<th>Participant</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP10</td>
<td>Critical analysis of ADAS and AVG options to 2010</td>
<td>TRG, INRIA, PATH</td>
</tr>
<tr>
<td>WP20</td>
<td>Definitions of Scenarios for Deployment of ADAS/AVG systems and related Evaluation Framework</td>
<td>TRG, INRIA, PATH</td>
</tr>
<tr>
<td>WP30</td>
<td>Assessment of Behavioural Acceptance for ADAS/AVG systems</td>
<td>STRATEC, TRG, SINTEF</td>
</tr>
<tr>
<td>WP40</td>
<td>Human Factors Investigation of ADAS and AVG systems</td>
<td>SINTEF, TRG, INRETS</td>
</tr>
<tr>
<td>WP50</td>
<td>Towards Assignment tools through micro-simulation</td>
<td>TRG, SINTEF, INRETS</td>
</tr>
<tr>
<td>WP60</td>
<td>Assessment of Large-Scale Deployment of ADAS and AVG by simulation</td>
<td>TRG</td>
</tr>
<tr>
<td>WP70</td>
<td>Legal and Institutional Aspects of the Deployment of ADAS/AVG : Review and synthesis of existing analysis</td>
<td>TRG, Barlow Lyde &amp; Gilbert</td>
</tr>
<tr>
<td>WP80</td>
<td>Systems Evaluation</td>
<td>SINTEF, TRG, STRATEC</td>
</tr>
<tr>
<td>WP90</td>
<td>User Group Liaison</td>
<td>INRIA, TRG, STRATEC, SINTEF and INRETS</td>
</tr>
<tr>
<td>WP100</td>
<td>Dissemination Activities</td>
<td>INRETS, TRG, STRATEC, SINTEF, INRIA</td>
</tr>
<tr>
<td>WP110</td>
<td>Project Management</td>
<td>TRG, STRATEC, SINTEF, INRETS, INRIA</td>
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</table>