Examination of the viability of co-operative road-vehicle systems using qualitative data analysis

L. Walta*, C.J.G van Driel**, R.H. Krikke*, B. van Arem**
* Delft University of Technology
Faculty of Technology, Policy and Management
P.O. Box 5015
2600 GA Delft
The Netherlands
e-mail: l.walta@tbm.tudelft.nl

** University of Twente
Centre for Transport Studies – Applications of Integrated Driver Assistance
Enschede
The Netherlands

*** Goudappel Coffeng
Deventer
The Netherlands

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Co-operative road-vehicle systems, such as dynamic navigation and in a later stadium traffic-responsive adaptive cruise control, are expected to contribute to traffic safety and efficiency. However, it is not yet clear which concepts of co-operative systems would be viable from an implementation point of view. Therefore, the objective of the research presented in this paper was to gain knowledge into the expectations about co-operative road-vehicle systems and the driving forces and barriers of stakeholders. To obtain this information, semi-structured interviews were held with six experts and seventeen stakeholders. The qualitative interview data was structured in a database that was used to perform the analysis.

Of all the concepts of co-operative road-vehicle systems mentioned by the interview participants, five were recognised as potentially viable: Navigation systems, Intelligent Speed Adaptation (ISA), Traffic responsive Adaptive Cruise Control, Intersection support and Information systems. A deployment path for these systems was constructed based on the two main routes for deployment recognised that focused on Telematics and Advanced Driver Assistance Systems respectively.

Two viable concepts were identified at the point where positive expectations about cooperative road-vehicle systems and the driving forces of stakeholders coincided. Obligatory half-open ISA relieves barriers such as market penetration and profitability and is expected to have positive effects on efficiency and safety. A multifunctional information platform would increase efficiency for commercial transportation.

Keywords: Advanced Driver Assistance Systems, Co-operative road-vehicle systems, Qualitative analysis, Stakeholders

1. Introduction

Current traffic problems are growing rapidly. Accessibility decreases due to congestion, and quality of life in terms of traffic safety and the environment also suffers from the enormous demand for car travel. When conventional solutions for these problems in the field of road construction and traffic management no longer suffice, deploying Intelligent Transport Systems (ITS) may be an option. These systems, to be located at the interface between Information and Communication Technology (ICT) and the transport system, are expected to be able to contribute to a solution for many of the current transport problems (e.g. Jaaskelainen, 2002).

One of the subgroups of ITS are Advanced Driver Assistance Systems (ADAS). ADAS are systems that support the driver in performing the driving task. The development of these systems starts with autonomous systems, working only from the vehicle itself, but some applications may be extended to a co-operative system (Ehmanns et al., 2004). Co-operation can take place between the vehicle and the infrastructure (road-vehicle co-operation) or between vehicles (vehicle-vehicle co-operation). VanderWerf et al. (2002) describe a simulation experiment showing a substantially increased flow (100%) using vehicles equipped with co-operative Adaptive Cruise Control (ACC), where flow increases just marginally (7%) using vehicles equipped with autonomous ACC. Shladover (1997) states that co-operative systems make it easier to detect other vehicles (vehicle-vehicle co-operation) and roadside obstacles (road-vehicle co-operation) than with autonomous sensors only. Besides, information and recommendations could be provided from the roadside to the driver. These potentials of co-operative systems make it worthwhile assessing the possibilities for their introduction and deployment.

However, it is also recognised that there are significant deployment complexities incurred by co-operative systems (Shladover, 1997). For ITS in general non-technical issues are expected to be more challenging than technical issues where implementation is concerned (Marchau et al., 2001). When co-operative road-vehicle systems are considered, a major challenge is the co-operation between the different stakeholders (Bekiaris et al., 2004).

Several deployment scenarios for ITS or ADAS have been introduced. Van Arem & Jacob Tsao (1998) compare the different approaches of Automated Vehicle Guidance (AVG) in California and the Netherlands. It turns out that California prefers a revolutionary approach, in which a desired end-state is formulated, while in the Netherlands an evolutionary approach is adopted, concentrating on the achievability of deployment steps. The ADASE II Roadmap (Ehmanns et al., 2004) describes an evolutionary development path of ADAS with increasing level of support and complexity, starting off with Night Vision and developing towards Intersection support and visions for Autonomous Driving. In the People Mover Roadmap (Van Hylckama Vlieg et al., 2003), three generations of people movers are identified, based on increasing technological development, starting off with dedicated track and developing towards limited mixed traffic operation.

The correspondence of these scenarios is that they focus on technology development and consider a distant time horizon. They are an important means to provide a guideline for implementation, but there is a need to have more insight into the viability of individual deployment steps. This need is especially present for co-operative road-vehicle systems since having to equip both vehicles and infrastructure makes deployment more complex and the involvement of multiple stakeholders makes it harder for a single stakeholder to have an overview of the driving forces and barriers that influence the viability.

The main objective of the research presented in this paper was to gain knowledge into the expectations about co-operative road vehicle systems and the driving forces and barriers of stakeholders involved in the implementation of these systems. At the point where positive expectations and driving forces coincide, viable concepts of co-operative road vehicle systems were identified. A qualitative approach was used to assess the opinion of a limited number of stakeholders and experts. This resulted in a deployment path and the definition of two viable concepts of co-operative road-vehicle systems.

The focus of this research was on motor vehicles with more than two wheels using road infrastructure. Furthermore, those systems that directly concern driving behaviour were considered. Applications specific for public transport were not considered. In this paper 'co-operative systems' is used instead of 'co-operative road-vehicle systems'.

The next section describes the methodology used. The results are presented in section 3. In section 4 the deployment path is described based on the interview results. Furthermore two potentially viable concepts of co-operative systems were developed, that are described in section 5. Finally, in section 6, the conclusions are summarized.

2. Methodology

A qualitative analysis approach was used as the topic has an exploratory character. The methodology that was found most suitable for this research is based on the strategy of grounded theory approach (Wester, 1987). Grounded theory approach is aimed at theory development through comparison of research data with phenomena derived from research, in order to prove or disprove these phenomena. The phenomena will be updated and finally lead to a theory. This approach requires a searching attitude from the researcher. Grounded theory approach is mostly applied in social and medical sciences (e.g. Russell, 2003; Yeh, 2003), but there are other examples of its application in informatics (Nasirin et al., 2003), logistics (Halldórsson and Aastrup, 2003) and transportation planning (Lucas, 1998). In general it applies to areas in which knowledge has to be developed.

In this research, grounded theory approach was applied in the following way. First the most important themes with respect to co-operative systems were derived through a literature search (Walta, 2004). Taking these themes into account, semi-structured interviews were held with stakeholders and experts to derive inside-information, visions and opinions on these themes. The mainstream vision on a theme was derived through consideration of the different arguments elicited on aspects of the theme, while taking into account, if necessary, the interviewee's background. If not enough information was available on a certain theme to make such a consideration, the results on that theme were summarized. The consequence of a qualitative approach is that the results are generally presented in a narrative way.

Six themes were considered important to investigate with respect to the objective described above. These themes were: effects, added value, recognised co-operative systems, systems deployment, driving forces and barriers, and stakeholder roles and relations. It was considered valuable to derive a definition on co-operative systems first, as it is a condition that the interviewees see co-operative systems from the same perspective.

Interviews were held with stakeholders and experts in the field of intelligent vehicles. Experts were interviewed because they were expected to have a broader view on the subject and stakeholders were interviewed because they would see more practical issues. Because of the properties of the information that was desired, semi-structured and personal questioning was applied in the interviews. Interview participants were thus able to bring forward aspects that were not yet recognised, and the interviewer could use extra questions to refine these aspects. To be selected, the participants should either represent one of the eight relevant stakeholder groups (see table 1), or have expertise in the research area. A presumed willingness to participate was also taken into account. The starting point was to find two interviewees per stakeholder group. For the driver group, however, no representative was found, thus it was accepted that this group would not be included in this research. The co-operative organisations mentioned in the table are organisations that facilitate and manage projects and knowledge dissemination of research and development on Intelligent Transportation Systems, and in which many stakeholders are involved (such as the Japanese AHSRA and the European ERTICO). There were 6 experts and 17 stakeholders – from several European countries, the United States and Japan – willing to participate in the interviews.

Table 1. Number of interviewees per stakeholder group

Type of stakeholder	No.
Co-operative organisations	3
Automotive industry	2
Authorities (National and European)	2
Service providers	2
User (driver)	-
Vehicle system suppliers	3
Traffic management	1
Roadside system suppliers	4

The main questions of the interview focused on which functionalities of co-operative systems are viable, which technology and stakeholders will play a role in the development of co-operative systems, what is the added value with respect to autonomous vehicles and the traffic management system, what are the driving forces and barriers in the development of co-operative systems, which roles will the stakeholders play and what are the relations with other stakeholders. The way of questioning implied that the interviews would be performed face-to-face. This was however not feasible in some cases, so four of the twenty-three participants answered by e-mail and two were interviewed by telephone.

In order to perform this analysis the interview results were first processed in the following manner. The complete interviews were written out on paper, question by question. Due to the method of interviewing it occurred that answers to multiple questions were given in one answer. This was handled by allocating fragments of interview text to the relevant questions. To support the analysis process and include all relevant results of the interviews in it, the complete text of the interviews was coded using Kwalitan qualitative data analysis software which is used for qualitative research based on grounded theory approach (Peters, 2004). All interview text was divided into segments of text consisting of the answer an interviewee gave to a question. Codes were added to fragments (words or complete sentences) of these segments according to the issue they referred to. A database with codes and their associated fragments was thus created, to facilitate the analysis process. Per theme, the codes were selected that applied to it, which gave access to a complete overview of interview results relevant to that theme.

3. Results

In this section the results of the analysis of the interviews on the expectations about co-operative systems and stakeholders are presented. The results were grouped by the theme investigated. In some cases – added value and driving forces and barriers – the results were suitable for quantification. First the results on the definition of co-operative systems are presented.

3.1 Definition of co-operative systems

In order to define what co-operative systems are, some main characteristics were derived from literature. It was noticed that co-operation implies communication to the driver/vehicle via in-vehicle systems (Misener, unknown date; Harutoshi et al., 2003). If communication is also sent from the vehicle to the infrastructure this is called interaction (Blosseville et al., 2003), which would mean that interaction is not a condition for co-operation. Shladover (1997) makes a difference between passive and active co-operation, but generally, when co-operation is concerned, the active form is considered. This means that the information sent to the vehicles in a co-operative system is based on the current state of the transport system, which is determined from data collected by infrastructure-based sensors (Misener, unknown date) and/or from floating car data (Fischer et al., 2003). There are three levels of control often mentioned concerning Advanced Driver Assistance Systems (e.g. Marchau et al., 1997), which are Informing, Assisting (driver can overrule) and Complete Automation. Van Arem et al. (2004) define three co-operation models with increasing levels of co-operation. The first is Mutually Informing: road users and operator exchange information, but may adapt their actions separately; the second is Negotiating: there is a set of rules for the mutual exchange of goals, preferences, feasible actions and restrictions of the road, allowing for an exchange of data; and the third is Compelling: one actor is able to determine, restrict and enforce the others' actions.

This information was used to construct a definition of co-operative systems that lays down the minimal requirements of a system to be called co-operative. The categorisation in level of co-operation by van Arem et al. (2004) would imply that mutually informing is the minimal requirement. However, considering the other sources of literature, one-way communication from the roadside to the vehicle is already seen as co-operation. To leave room for applications moving towards the first level of co-operation defined by van Arem et al. (2004), one-way communication from the roadside to the vehicle is adopted as a minimal requirement in this definition of co-operative systems:

"Co-operation between the infrastructure and a vehicle, by means of communication of information – derived from the current state of the transport system – between a roadside system and an in-vehicle system, to support or enable the driver and/or vehicle to perform a certain traffic-related action. Dependent on the communication technology used, the roadside system can be located directly at the roadside (e.g. roadside beacons) or at a more centralized location (e.g. traffic information centre)."

From the interviews it appeared that not all systems proposed by the interviewees matched this definition. There were two main reasons for this.

Firstly, the perception of many stakeholders on what co-operative systems are seemed to be limited to 'getting information into the vehicle'. These stakeholders often refer to systems that are 'connected' rather than 'co-operative'. Systems are connected if there is a communication channel in the vehicle with which information could be sent or received. A system is co-operative if this information is used to operate the vehicle. If a vehicle is connected, this of course opens possibilities for co-operation. As experts generally use a longer time horizon than private companies, that could explain why the vision of the stakeholders may sometimes be limited to connected systems.

Secondly, systems like e-call and voice-communication between a captain and a port master in shipping and aviation were also called co-operative. E-call can be called co-operative in the sense that many different stakeholders are involved in the process. It is however only indirectly traffic related and therefore does not match the definition. In shipping and aviation, one could speak of co-operative processes. If they were automated, they could be considered as co-operative systems according to the definition. In road traffic voice-communication would not be feasible, which makes automation a condition for co-operative processes to be achieved.

It was assumed that these differences of opinion about co-operative systems did not affect the course of the interviews because of their open character: the interviewee could bring up the systems he thought would be viable, and different aspects of these systems were then discussed.

3.2 Expectations about co-operative systems

Effects

Concerning the effects of co-operative systems, the interviewees were asked which systems would be viable to meet the objectives of safety, efficiency, comfort. It turned out that most systems mentioned by the interviewees would match all three objectives, which implies that they would also have effects on all three of them. Substantial effects on efficiency and safety are however only expected at higher levels of control in which the driving task is partly or completely taken over by the vehicle. For systems on the information level of control, the effects on comfort seem to be more certain than the effects on efficiency and safety. That is remarkable as comfort is also seen as a secondary or side effect, for example by the automotive industry. However, some safety systems are currently sold as comfort systems as they are understood not to improve traffic safety and probably also to avoid liability problems. Summarizing: comfort may be the main motivation for the industry to introduce co-operative systems into vehicles.

Added value

The opinion on added value was derived by asking the interviewees what they thought the added value of co-operation would be with respect to autonomous systems. This added value was quantified by the number of interviewees that brought them up. The added values that were at least mentioned four times were considered here. They were divided into added value as seen by the driver and from a traffic management point of view, as differences occur between these. For the driver, the added value is seen as 'horizon extension' (10 interviewees) and 'better information' (5). For traffic management, the added value is seen as 'influencing driving behaviour' (7), 'data quality improvement' (6), 'efficiency improvement' (6) and 'cost savings' (4).

Recognised co-operative systems

The interviewees were asked which systems would be viable. Taking into account the different arguments of the interviewees and the definition of co-operative systems there were five systems brought up by the interviewees that can be considered as potentially viable. These are Navigation, Intelligent Speed Adaptation, Traffic responsive Adaptive Cruise Control, Intersection Support and Information Systems.

Navigation systems can be co-operative if current traffic information is used to make it dynamic. The effects of navigation may be in many directions: efficiency, safety and comfort. Comfort is not perceived as the main objective of these systems, although most effects do point in this direction. Where effects on efficiency are concerned there is the discussion on the individual versus the collective. When systems are providing information, they should be focused on the individual as he would not buy a system and follow the advice if it is not for his own benefit. Systems that pursue efficiency for the collective should therefore be obligatory and directive, and integrated in traffic management. The management strategies should be determined by the authorities, to assure it is best for society, and a large penetration is necessary to be effective. It is doubtful whether the individual would benefit from efficiency effects, and obligatory systems may yet be far in the future, so the effects on efficiency may remain uncertain for some time.

Intelligent Speed Adaptation (ISA) can be co-operative if the desired information on local or temporary speed limits is communicated from the roadside to the vehicle. The effects of informing ISA on safety may be limited. Intervening ISA is not yet perceived as viable. The private user will probably accept half-open systems (i.e. systems that intervene automatically but can be overruled by the driver); the idea is that this may lead to better efficiency. For commercial transport the effects can also be social and economical, and intervention may be accepted here.

Traffic responsive Adaptive Cruise Control (ACC) means the adaptation of the parameters of ACC, on certain locations such as merging areas, to the current traffic situation. It is worth noting that these systems were only mentioned by experts and authorities. As one of the authorities said their role is to permit ACC or make it obligatory, the industry will probably not do anything unless a decision about this is made.

Worth mentioning is that the automotive industry does see possibilities for Intersection Support systems. It is however not yet clear if this will be done by vehicle-vehicle or vehicle-roadside co-operation. The automotive industry says this depends on the country and the available infrastructure, but authorities and experts think that it can only be done by vehicle-roadside co-operation, as it is a complex situation.

Warning and information systems were perceived as viable applications. Information systems are expected to bring comfort. Warning systems cannot apply to hazards in the direct neighbourhood for liability reasons but do apply to situations that occur within several minutes ahead. The services mentioned were road conditions, queues/local hazard, curves, incidents (not only road incidents, but also general incidents), road works and speed limits.

Systems deployment

This theme emerged mainly while discussing other questions. The visions of the interviewees on co-operative systems deployment could be summarized into two main routes: a Telematics route and an Advanced Driver Assistance route. Both routes would start with an application such as Navigation. The first route advances in generating information that has higher quality and is more dynamic and personalised. In its first stages the system cannot be called co-operative, but in the end it will be, albeit only on the level of information exchange. The devices used are initially onboard, aftermarket, systems, but later on these devices may be portable. The second route evolves into Advanced Driver Assistance systems and in the end high level co-operation with the roadside. Here, the devices will first be sold aftermarket. Later on they will be integrated into the vehicle and in the end become standard. One argues that these systems should be standard and in-vehicle in the first place, as people will probably not buy such systems as an extra to a vehicle.

The discussion of automation versus assistance plays a role in the second route for deployment. To investigate what might be in store for road traffic in the field of co-operation, a comparison was made with aviation, of which it was supposed that automation is commonly accepted. However, it was concluded that in aviation assistance is preferred above complete automation (Suikat, 2003). The same opinion could be derived from the interviews. One of the reasons is that the driver is currently responsible by law, and because of legal concerns it may be undesirable to change this situation. Another is that direction should only take place when it is understandable by the driver, e.g. in extreme conditions to avoid danger. And finally it is said that humans are extremely good at driving a vehicle considering the driving task, and it may even be impossible to automate some parts of the driving task.

There is no discussion on whether or not there should be an open platform in the vehicle on which different applications can be run. Dedicated systems have shown to be too expensive to be profitable. To start up co-operative systems it was argued that there should be a "killer application" (i.e. an application generating a large market penetration, and therefore relieving barriers for related applications) bringing communication into the vehicle. This killer application will probably not be a co-operative system, as these are not expected to conquer the market independently. Probably an application such as tolling can bring communication into the vehicle. Another said that Navigation will be the core of co-operative systems development, as it introduces a large database and communication into the vehicle. This coincides with the idea of the two routes starting up with Navigation.

In the interviews it was generally said that systems are viable if they are profitable, or in other words, if there is a business case. However, it does not seem easy to find a business case. The main concern seems to be the willingness of the consumer to pay, because the business cases presented by the interviewees focus on how to moderate or even by-pass this barrier. These are hidden business cases in which traffic information is paid for by radio ads, state grants are made available for systems that have indirect positive effects on society, there is consumer compensation for delivery of Floating Car Data, one time fees instead of subscriptions and selling systems as standard instead of as an option to a car.

3.3 Stakeholders

Driving forces and barriers

The interviewees were asked to define what driving forces and barriers there were at different stages of working with co-operative systems - for the authorities stimulating, for the industry producing and for the consumer buying. This was done in two questions: one in which the stakeholders had to define their own driving forces and barriers and one in which the stakeholders and experts had to define the driving forces and barriers for the other stakeholders. It was found that these driving forces and barriers could be divided into motivations and requirements. Motivations often coincide with the objectives of a stakeholder. They are therefore fixed, unless the stakeholder changes his objectives. With requirements this is the other way around. Requirements are changeable in the sense that they may or may not be satisfied. Besides they are not the reason for stimulating, producing or buying systems, but are required for these actions to be feasible. A requirement is interpreted as a driving force when it becomes a driving force after being satisfied. A requirement is interpreted as a barrier if it is barrier when it is not satisfied. Of course the dividing line is not as sharp as sketched here, but the general idea is used to make a division between the requirements. The notion that there are motivations and requirements has been used in the overview on driving forces and barriers in table 2. Besides the three main groups of stakeholders – authorities, industry and consumer – there are also driving forces and barriers that apply to the entire process of co-operative systems development and deployment. These are grouped as "general" driving forces and barriers.

The driving forces and barriers were quantified by the number of interviewees that (spontaneously) brought them up. In table 4 the driving forces and barriers are presented that were mentioned at least four times. Most significance is attached to the driving forces and barriers that were mentioned most often.

Table 2. Overview of the most important driving forces and barriers

Stakeholders	**Driving forces**		**Barriers**	
	Motivations	*Requirements*	*Motivations*	*Requirements*
General			Automotive will not accept external control (4)	Co-operation among stakeholders (11) Market penetration (7)
Authorities	Efficiency (11) Safety (11) Cost savings (5)			
Industry	Competitive advantage (7) Unique selling points (7) Regulation (6) Comfort (5) Safety (4)	Profits (5)		
Consumer	Efficiency for business users (5) Comfort for private users (6) Gadget, image (6) Safety (5)	Benefits clear (7)		Cost/Willingness to pay (10) Privacy (7)

Where external control is considered, it is perceived as a barrier that the automotive industry will not accept external control, meaning when the vehicle is directed by a party outside the vehicle and the driver has no possibility to overrule.

The co-operation among stakeholders, and in some cases the co-operation between the authorities and the automotive industry, is perceived as a barrier, rather than a driving force. This is because the desired co-operation (platform of stakeholders and co-operation between automotive industry and authorities) does not exist yet and will probably be difficult to achieve because of the different importances. Market penetration is perceived as a barrier as high market penetration may be necessary to achieve the desired effects and to be cost-effective. The question of how to achieve high market penetration also plays a role here. There is a relation with two driving forces: regulation and installed base. If equipment is made obligatory or is already installed in vehicles (by the automotive industry or through regulation) the outlook for a high market penetration may be positive.

It is assumed that the policy goals efficiency, safety and environment (e.g. Bedaux, 2004) would probably be the main driving forces for the authorities. Of these three only environment cannot be recognised as relevant from the interviews. Terms used by the interviewees like traffic performance, mobility and better use of road infrastructure were regarded as efficiency. There are two forms of cost savings recognised for the authorities.

One is that implementation of in-vehicle systems may be cheaper than infrastructure. The other is the derivative effect that the cost of congestion could decrease.

As the existence of industry is based on generating profit it is obvious that competitive advantage was recognised here. It was mentioned as the driving force for industry to invest in new technologies such as co-operative systems. Terms such as market expansion and better market position were also regarded as competitive advantage.

The so-called Unique Selling Points (USP) were perceived as important to the automotive industry, as they want to distinguish themselves from others. Co-operative systems may be such a unique selling point. There is an obvious relation here with the consumer, as his motivations determine what are unique selling points. Regulation was recognised as a motivation as well as a condition. By regulation as a motivation we mean making certain systems obligatory. This is a clear motivation for industries to develop these systems. Regulation as a condition (which has only been mentioned once) is perceived as necessary to know what standards the product should satisfy in order to be sure it will not be forbidden and the investments are justified. Stimulation as a form of regulation was not recognised from the interviews. There is some discussion about what is the real driving force of the automotive industry. Some interviewees, including the automotive industry itself, recognised safety as being the main driving force of the industry. Some others, however, said that comfort is their main driving force. The explanation for this may be in the fact that comfort is a selling argument for safety systems, as consumers may not want to pay for safety.

It is obvious that the profitability of a system or service is an important motivation for all industries. It may be quite strange, therefore, that this driving force is not so often mentioned, but this could be due to the fact that people ‘forget’ to mention it because there is no discussion about its importance.

A difference is perceived in business users (which may also be commercial transportation), and private users concerning their motivations to purchase systems or services. The motivation for business users was mainly recognised as efficiency. Comfort is in second place for them. Efficiency means time and therefore money for business users. For private users comfort seems to be a more important motivation. Consumers may purchase products for subjective reasons such as it being new, or a gadget, or referring to a certain image. Safety is an interesting issue as there were five opinions in favour of it being a driving force and three were against it. The motivations against it were that safety is not an argument you will pay for, that consumers will choose improvements in traffic conditions rather than safety. Also safety is not a sufficient motive for accepting systems that are compelling. For consumers this makes safety a questionable driving force. However it is only questionable if safety is a main driving force: the arguments do not declare that safety is not a driving force, just not such a strong one.

It is thought that drivers have to see, understand or be confident in the benefits of the system in order to purchase it. This is a condition as it is also argued that drivers want benefits if they purchase a system or service or if it is imposed on them.

Cost seems to be an obvious barrier. Concerning willingness to pay, consumers are, for example, perceived not to be willing to pay for certain services such as traffic information. Some services are expected to be offered by the authorities, automotive or insurance companies. Consumers in the Netherlands are also said not to be willing to pay a fee per service or month. They would rather buy an expensive system for which they only have to pay once. It is remarkable that privacy was mentioned so often here, because in the literature there is no evidence of it being important (e.g. Marchau et al., 1998). Privacy is of course only relevant in situations where personal data are exchanged. There were no clear motivations from the interviewees as to why privacy was seen as a barrier.

Stakeholder roles and relations

Based on the interview results a stakeholders' network for the value chain of co-operative systems was constructed (see figure 1). The higher authorities (e.g. government) and co-operative organisations possess instruments to influence the complete network of stakeholders and are therefore placed outside of this network. In the co-operative organisations, most stakeholders are represented, which makes them important platforms for co-operative systems development. Roadside system suppliers are generally expected to take the role of service/content provider next to their traditional role. As well as the service providers they will have a business relation with system suppliers in providing a service which contains content and communication facilities supplied by telcos and broadcasters. Telcos and broadcasters will be contracted by service/content providers and have no business relation with other stakeholders. There are three different routes to approach the user, the traditional route via traffic management, via aftermarket systems (portable or to be built in) and via integration in the vehicle. The user is in the stakeholder network, represented by automobile clubs like ANWB (the Netherlands) or ADAC (Germany).

In the development process of co-operative systems the roles of the authorities and the automotive industry are seen as very important. The automotive industry is seen as a gatekeeper for anything that enters the vehicle. When it comes to systems influencing the driving task this can be a barrier. They may take the lead in such processes to remain in control. If the authorities make clear choices, for instance by regulation, stakeholders are more willing to participate.

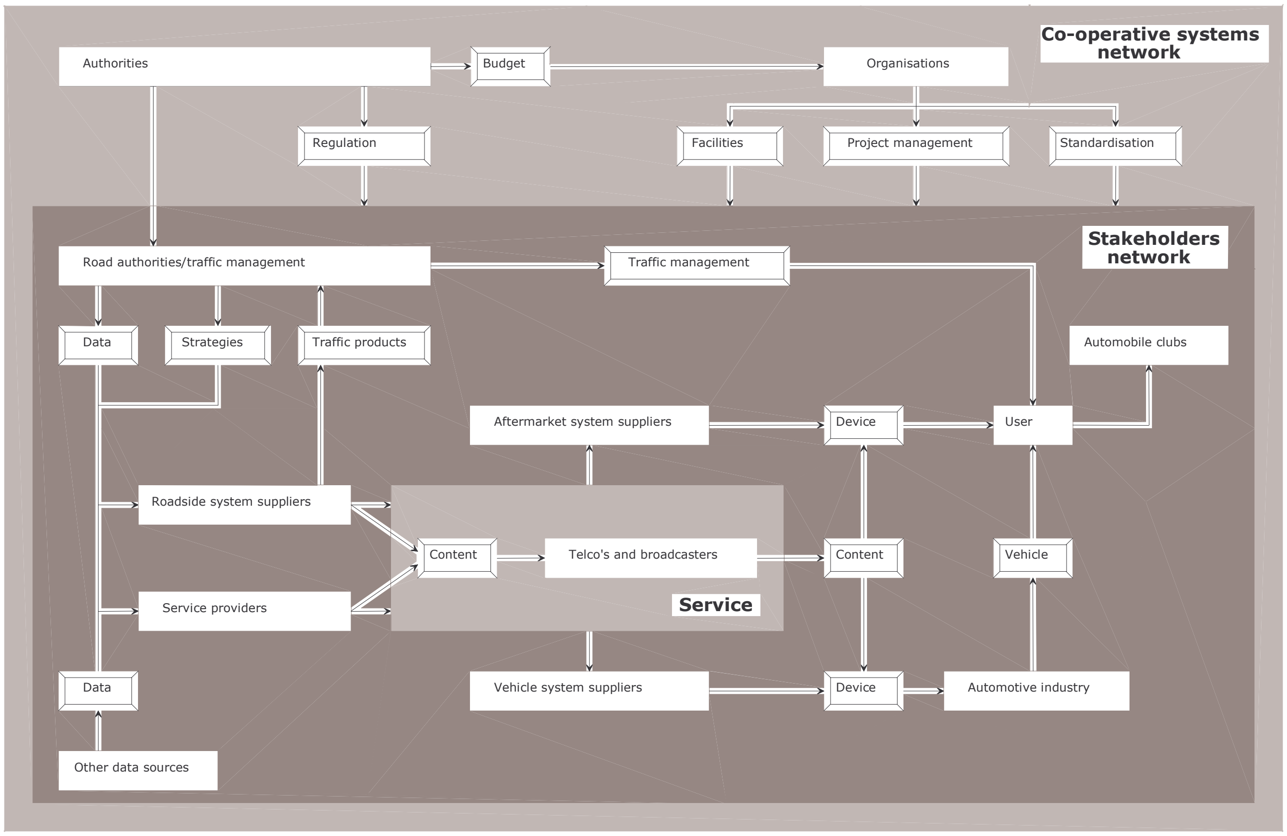

Figure 1. Stakeholder roles and relations

4. Deployment path

From the analysis results it was found that five co-operative systems are potentially viable: Navigation, ISA, Traffic responsive ACC, Intersection support, and Information systems. It was also concluded that there are two main routes for deployment: the Telematics route and the Advanced Driver Assistance route. This outcome was used as a starting point to design a deployment path for potentially viable concepts of co-operative systems.

Summarizing on the five proposed concepts it can be concluded that Navigation and Information systems hold a key position in the development of co-operative systems. Apart from giving information to the driver, the information can also directly serve as input to one of the four other systems. More specifically: the information system is what makes these systems co-operative. Information systems themselves are expected not to be introduced as a stand-alone system. It needs the Navigation system to add content to the information entering the vehicle, as the vehicle's position in the network is important to determine the relevance of the information. Navigation systems are also important for ISA systems. Traffic adaptive ACC and Intersection Support are not expected to be the first to emerge as they require a substantial market penetration of communication platforms (and ACC) to be effective. A visualisation of this deployment path is given in figure 2.

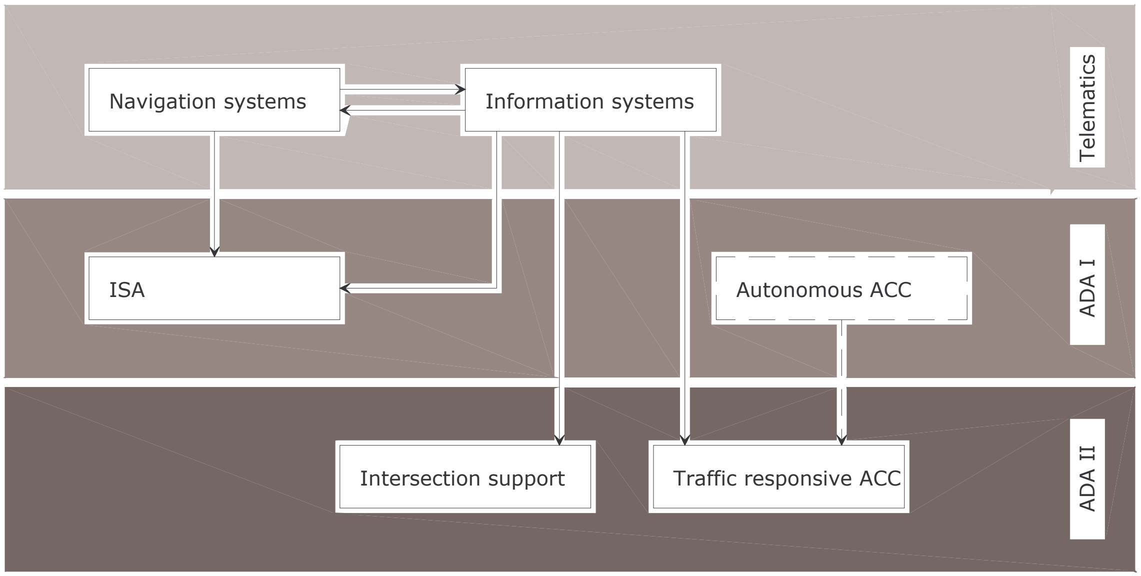

Figure 2. Relations between five potentially viable concepts for co-operative systems

Considering the key position of Information and Navigation it is not surprising that these were mentioned as the first to be deployed: they are a necessity for further co-operative systems development. They can both be seen as part of the Telematics route of deployment. As these systems are conditional to the development of the other concepts, that better fit into the Advanced Driver Assistance (ADA) route, it appears that both routes are not conflicting but the Telematics route is conditional to the ADA route. This was integrated in the figure by introducing phases of deployment. The two ADA phases (ADA I and ADA II) correspond to the time-horizon in which deployment is expected.

As was concluded from the interviews, co-operative systems will probably be developed in an evolutionary way, which means that each step should contain the possibility to perform the next step. Taking into account the central position of the information system, any concept should focus on getting an open communication platform into the vehicle, and not a dedicated system.

5. Viable concepts

To define the direction in which the most viable concepts can be found, a further analysis was made of the driving forces (see section 3). It was found that the motivations of the driving forces could be grouped into four profiles for implementation of co-operative systems, each with its own focus. These profiles are: obligation, comfort, commercial transportation and personal. Concerning obligation, effects on authority goals may only be expected at higher levels of control, and as industry is not expected to bring these systems to the market, obligation may be necessary to force it. Besides it guarantees industry income. Effects on comfort are quite certain and private users are interested in it. Commercial transportation can benefit from informative systems through increased efficiency as these systems can be integrated into a fleet management system. Finally, there is a trend for personal portable electronics devices.

These four profiles were tested on the requirements of the driving forces and barriers, because the degree to which these requirement are satisfied should give a clear indication of the feasibility of the profile. The requirements were reflected in the following six statements: benefits are clear to the user, profits can be earned, co-operation among stakeholders is easy to achieve, market penetration will be realised easily, privacy is not an issue, there is a business case possible that does not have to by-pass user willingness to pay. These statements were analysed using the research results and answered by certain or uncertain (see table 3).

Table 3. Profile scores on requirements

Profile	Benefits clear	Profits	Co-operation	Market penetration	Privacy	Business case	Total
Obligation	dna	+	+	+	0	+	++++
Comfort	+	0	+	0	+	0	+++
Commercial	+	+	+	+	+	+	++++++
Personal	0	0	+	0	+	0	++

Legend:
0 = uncertain
\+ = certain
dna = does not apply

The two profiles that turned out to be most feasible are Obligation and Commercial Transportation, both of which distinguish themselves on the three economic conditions (profits, market penetration and business case). This is not a surprise, as the general notion retrieved from the interviews is that anything is viable if you can generate profit with it. For both profiles the most viable concept is determined using the analysis results (section 3) and the deployment path (section 4). Before considering these concepts, it should be noticed that, where Obligation is concerned, there are two possible interpretations. The first is the obligation of a co-operative system, the second is the obligation of a system that opens possibilities for co-operative systems by bringing a communication platform into the vehicle, for example the obligation of a tolling system. The latter is not considered here.

As mentioned above, Obligation is related to the achievement of the authority goals efficiency and safety. The authorities will only make systems obligatory if they have clear benefits for society. Navigation and Information systems are both systems that operate only on the information level of control. The effects of these systems on efficiency and safety are thought to be limited, as effects on efficiency and safety are only expected at higher levels of control (see section 3). These two concepts can therefore not be considered as viable for obligation. When Intelligent Speed Adaptation is considered, there are better possibilities. The half-open ISA variant, in which the system will adapt to the speed limit but can be overruled by the driver, is expected to have positive effects on driver behaviour (Hjälmdal and Várhelyi, 2004) and to be accepted by the user after some experience with the system (STARDUST, 2004). This form of ISA will also be accepted by the automotive industry, as the external interference is limited to information. However, Obligation is necessary as the automotive industry will probably not implement these systems by themselves. Finally, the implementation is not a barrier because it is no problem if equipped and unequipped vehicles are both present in traffic. Half-open ISA can therefore be considered a viable option for Obligation.

This system will consist of an autonomous part that adapts the vehicle's speed, and a co-operative part which comprises the communication of the speed limits to the vehicle. As the deployment path shows, a navigation and information system should be integrated in the system. The navigation system for the digital map that contains the speed limits as an attribute to stretches of road and the information system for updating this map with current speed limits. There are three types of speed limits that can be communicated to the vehicle: static speed limits (new roads, speed limits changed by authorities), temporary speed limits (road works, schools) and dynamic speed limits (traffic responsive, road and/or weather conditions). The deployment of the system may take place stepwise, starting with static information and building up to dynamic information.

Considering Commercial Transportation, navigation will be more effective than for private users, as time is more directly related to money in this sector. Navigation is already implemented in fleet management systems but could be made more dynamic. These fleet management systems already provide a communication platform and interface so dynamic information on the traffic situation may easily be integrated. As there are already many developments towards these applications, such a multifunctional information platform can be considered as viable. It could integrate functions such as fleet management, dynamic navigation and information on road conditions, curves, local hazards and road works. With the implementation of the fleet management application, two-way communication will become available in the vehicle. This makes it possible to also integrate Floating Car Data into this concept. If the majority of commercial vehicles were equipped this can be feasible. In the Netherlands at least 10% of all vehicles are commercial vehicles (CBS, 2005), whereas the required percentage of vehicles that have to be equipped to derive reliable speed information is about 2-3% (Jansen et al., 2003).

6. Conclusions

The main conclusions that were drawn from this research are summarized below grouped by conclusions on expectations, stakeholders and methodology. Furthermore some suggestions were made to mitigate barriers to the implementation of co-operative systems.

Expectations about co-operative systems

- Level of control and level of co-operation were found to be the most important properties concerning effects, acceptance and therefore the viability of co-operative systems.
- At the informative level of control it is mainly effects on driver comfort that are expected for private users. For commercial transportation effects on efficiency are expected. Effects on efficiency and safety for private users are only expected at higher levels of control, which means that these effects are further away in time.

- The main added value for the driver is horizon extension. For the traffic manager the main added value is in being able to influence driving behaviour.
- Five systems are seen as viable by stakeholders and experts: Information systems, Navigation, Intelligent Speed Adaptation, Traffic responsive Adaptive Cruise Control and Intersection support.
- Developments like eSafety show the focus on safety systems. However no concrete safety applications that can be designated as co-operative systems were recognised. Safety might currently be a condition rather than an objective of co-operative systems.
- While this research focused on co-operative systems for private vehicles, this turned out not to be the market segment in which the first applications will enter, apart from applications that are obligatory. There is a better market for commercial vehicle applications. This is also reflected in the fact that most business cases for private users moderate or by-pass the consumer willingness to pay.
- There are two directions in which the first applications will be developed: Telematics and Advanced Driver Assistance (ADA). This conclusion from the interview analysis was even more underpinned by the results of concept development, because the two viable concepts – Obligation of Intelligent Speed Adaptation and a multifunctional information platform – each fit into one of these directions. There is no conflict between these directions, as Telematics may be conditional to Advanced Driver Assistance.
- Most stakeholders and experts believe in an evolutionary approach, starting with low level co-operation. This is different from what was found in the literature about co-operative systems coming into play at a complex level of automation. This difference could be prompted by a difference in the notion of what co-operative systems are. The evolution of systems should rather be on assistance than on complete automation.

Stakeholders

- There is no clear vision on what co-operative systems are as the perception of most stakeholders on co-operative systems is limited to ‘getting information into the vehicle’.
- The role of the Roadside/Traffic industry will shift partly to service/content provision. The roles of other stakeholders will generally stay the same with the Authorities and Automotive industry as the most powerful stakeholders.
- The main driving forces for the authorities are thought to be policy goals and cost savings, for the industry competitive advantage, regulation and profits, and for the consumer efficiency (business users), comfort (private users), safety and image. The main barriers are co-operation, market penetration, consumer willingness to pay and no acceptance of external control by the automotive industry. The driving forces and barriers can be divided into motivations and conditions.

Methodology

- Semi-structured interviewing has shown to be an appropriate method for knowledge development. Despite the time-consuming analysis of the interviews, the results of the interviews show several issues that would not have been retrieved from structured interviewing. It is therefore experienced as an appropriate method for research where knowledge development is the main objective.

The authors make some suggestions to mitigate barriers to implementation. To enable higher levels of control without having to replace a system, the information systems that are being developed should be able to send messages to the driver as well as to any system concerned in operating the vehicle. The focus should be first on systems for commercial transportation as this may be the sector in which co-operative systems are most viable. Obligatory use of ADA-systems for private users is further in the future, but should also be considered. It is important to continue research on consumer behaviour and consumer desires to be able to derive with more certainty the possible concepts for private users in the comfort and personal systems area. Furthermore research should concentrate on the viability of co-operative safety systems.

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