ITS POLICY STRATEGIES FOR URBAN REGIONS:A CREATIVE EXPLORATION

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Abstract

This paper explores future concepts of Intelligent Transport Systems (ITS) for passenger transport. ITS systems are divided into the three main categories: Advanced Driver Assistance Systems (ADAS), Advanced Traveller Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS). There is much evidence that future ITS concepts will depend upon technological improvement of ADAS and integration between ADAS and ATMS and ATIS. To explore the future of ITS concepts the method of morphological analysis is used. The outcome of this analysis has resulted in five sets of plausible ITS concepts that range from an ITS based public transport scenario to controlled car driving within activity areas of urban regions.

Keywords: ITS; Passenger transport policy; Urban region
Topic area: C8 ITS, morphological analysis, passenger transport policy

1. Introduction

The development of Intelligent Transport Systems (ITS) has taken a leap in the past decade. Under strong influence of new Information and Communication Technology (ICT), industries and scientific institutes have put much effort on developing a range of applications of advanced ICT for vehicles to drive safer, more comfortable, to make more efficient use of current and future infrastructure and to manage fleets more accurately. Generally, ITS can be described as '*systems consisting of electronics, communications or information processing used singly or integrated to improve the efficiency or safety of surface transportation*' (Tindemans *et al*, 2003: 2). The range of ITS applications is wide (see e.g. Ertico, 2002). ITS applications are being developed for public transport, private vehicles, commercial vehicles and infrastructure. Their purposes differ strongly.

From a scientific point of view, ITS applications seem to hold many keys to solve transport policy problems. However, many uncertainties still exist including which future ITS functionalities will be implemented, the technological performance of ITS applications, the level to which ITS will improve transport system performance, legislation needed for implementation, as well as the willingness of actors to accept ITS (Marchau & Van der Heijden, 2003). A major uncertainty is the spatial effects of ITS in terms of how ITS will affect future decisions on residing, working, shopping, etc. Until now this topic has hardly been investigated. An interesting consideration is whether and how the spatial distribution of office locations will change if ITS are deployed at large scale. This is the main research question of a sub project of the Dutch BAMADAS[1] program. To answer this question we need insight into the behaviour of actors that influence changes in spatial patterns of economic activities. Argiolu *et al.* (2004) argue that we can use location theory to hypothesize that ITS influences perception of accessibility and consequently might have influence on location attractiveness. Our study aims to investigate this hypothesis in order to improve our knowledge of ITS.

This paper's purpose is to discuss from a theoretical point of view the specification of future concepts of ITS in urban areas. It touches on issues of scenario building. However, we want to save that exciting task for later work. Instead, this paper goes deeper in alternative ITS concepts which could be used to build scenarios on. Section 2 describes long term ITS-based applications that are important for this research. What do we know about the current situation of ITS-based development? The specific method and approach of research is set out in section 3. Consequently, section 4 applies this method on ITS developments. Section 5 describes a second step in reducing the total amount of possible concepts that are left after morphological analysis. In doing so, trends in both regional transport policy and ITS are described that are relevant at the regional level. Section 6 then describes a set of five resulting concepts. Section 7 ends with a conclusion on the results and discussion about uncertainties and further research.

2. Long term ITS development

According to the definition of ITS in section 1, ITS systems cover[2], among others, systems that support the driver in controlling his/her vehicle in a better way (Advanced Driver Assistance Systems: ADAS), systems that support the traveller in finding an optimal mode and route, (Advance Traveller Information Systems: ATIS) and systems that are concerned with a more efficient organisation of traffic flows throughout the existing road infrastructure network (Advanced Transport and Traffic Management Systems: ATMS). Van der Heijden & Wiethoff (1999) use a structured view of ITS services, which forms the basis for the overview of ITS in table 1 (see also Van der Heijden & Marchau, 2002). They conceptualise the transport system by seven subsystems: four subsystems comprising the transport system's physical features (infrastructure, vehicles, goods or passengers and spatial and economic organisation) and three markets representing the interactions between the transport system's physical features. The three markets are the transport need market, the transport market and the traffic market.

A higher service level in transportation is expected on the long term and is expected to result from combinations of different ADAS within vehicles and the integration of ADAS with ATIS and ATMS. Examples of ADAS are Intelligent Speed Adaptation (ISA) and Adaptive Cruise Control (ACC). ISA is an in-car system that assists or controls a vehicles speed limit. If a car is equipped with ISA and enters for instance an 80 km/u road, the car slows down and adjusts its speed to what is permitted, either by getting a signal from infrastructural devices or by using the digital map in the vehicle on which maximum posted speed have been pre-programmed. Large safety potentials are expected when ISA would be used at large scale.

The use of full-automatic speed control devices could lead to as much as 40% reduction in injury accidents (Varhelyi and Makinen, 2001) and a 59% reduction in fatal accidents (Carsten *et al.* 2000). ACC is an intelligent cruise control system. It detects vehicles in front and back of the car and anticipates their speed. Instant breaking of a front car could warn the driver or intervene by slowing down the speed. Like ISA, ACC has large safety potentials. It is designed for car driving and is based on a Cruise Control that, in addition, adapts the vehicle speed to the car in front of the vehicle.

Table 1. Indicative relationship between transportation subsystems, ITS functionality and the variety of ITS applications (based on Van der Heijden & Wiethoff, 1999: 3/6)

Subsystem	**ITS functionality**	**Examples ITS application**
Transport need market	Systems for facilitating virtual mobility	Electronic commerce; tele-working; tele-education
Freight and passengers	**ATIS**	
	Information supply on transport services; booking services	Park and ride information; public transport services information; traffic information on radio, teletext; internet booking services
Transport service market	**ATIS/ATMS**	
	Pre-trip planning support systems	Trip reservation and route planning systems
	Systems for logistic optimisation	Telecommunications for fleet management; trip matching systems
Vehicles	**ADAS**	
	Smart Motor Technology Driver support systems	Self-diagnostic engine control systems, crash recorders; Reverse parking aid; tutoring systems; navigation systems; adaptive cruise/speed control; lateral and longitudinal control; cooperative driving; intersection collisions warning; forward collision warning; intelligent speed adaptation; passenger warning systems
Traffic flow market	**ATMS/ATIS**	
	Dynamic traffic management systems	Dynamic route information screens; traffic information on radio; differentiated electronic payment; dynamic (directional) lane assignment; ramp metering; speed control (radar detection, cameras); VMS; incident detection; aid coordination systems
Physical transport infrastructure	**ATMS/ADAS**	
	Lane optimisation technology; infrastructure status control systems	dynamic lane configuration adaptation; surface measurement and deterioration detection

ATIS are for example systems that inform drivers or passengers about the trip. Examples of such systems are Variable Message Signs (VMS) and Personal Intelligent Travel Assistant (PITA). VMS are traffic control panels used to deliver real-time information to motorists. VMS can range from simple one- or two-line manually changed message signs to sophisticated, fully economic models that can include graphic displays (Ertico, 2002). The type of information can include for example information on accidents, route diversions and congestion, travel time estimation and information on events. Although the benefits of such a system are not considered to be impressive, they do contribute to a more efficient traffic flow in usage of variable roads. PITA is a GSM system that gives real-time route information to passengers on arrival and departure of different public transport systems. In case of delay for example, alternative route information is provided.

ATMS systems mainly focus at improving operational transport and traffic management. Examples are ramp metering and Automatic Vehicle Location (AVL). Ramp metering regulates input of cars on motorways by allowing one car per time interval, for example every three seconds. The system prevents instant pressures which could lead to a network overload. AVL enables the continuous monitoring of a vehicle position within a road network (e.g. using GPS), enabling improvements in among others service scheduling and vehicle usage efficiency in public transport and freight transport.

A first stage of full integration of ADAS and ATIS and ATMS is co-operative speed headway driving. Capacity gains under lower penetration rates are achieved by co-operative speed headway control, for which the subject vehicle and preceding vehicle are both equipped and communicate on acceleration, velocity, and maximum braking rate. This enables closer vehicle following (up to time headways of 0.5 s). It has been estimated that the capacity of a lane could double if all vehicles in this lane are equipped with cooperative speed headway control (Shladover *et al.*, 2001).

A final stage of ADAS integration could result in fully automated driving without use of infrastructure communication. Although such a concept is not plausible to become reality on a large scale in the near future (Marchau, 2000), its potentials are sufficiently great to conduct much research on. Similar to the integration of different ADAS we expect large gains from new ITS concepts that combine applications from other user service bundles with ADAS. As table 1 shows, these other services are mainly ATMS and ATIS. Contrary to the implementation of ADAS in transport, ATMS and ATIS systems are becoming rather common devices (Bishop, 2000). Mainly due to the uncertainties regarding the development of ADAS, in practice, examples of integration between ADAS, ATIS and ATMS are rare. Since we consider ADAS, ATIS and ATMS as promising future ITS applications within reach, the question is how we should look at the combination of the three in ITS concepts. Section 3 therefore describes a way to integrate the three subsystems into plausible and perhaps even promising ITS concepts for the future.

3. Methods to explore the future

As we argued earlier, future exploration of ITS-based transport concepts is needed to answer our main hypothesis on ITS, which is explained in section 1. However, there are different ways to explore the future. Before making a choice on which method is preferred and suitable to explore the future, it is important to think about the basic assumptions that underlie our approach and criteria for the usage of the future exploration.

In this research we have made three assumptions. Firstly, we assume that there is and there will be continuity of ICT development within the field of transportation. Next, this technological development will eventually result in certain combinations of (sub)systems of ADAS, ATIS and ATMS. A third assumption is that public investments within transportation systems will be selective with regard to where and when. Municipalities and other governmental bodies face limited budgets. Therefore, they are forced to choose between various options for the support of ICT-based innovation of the transport system.

Next, we specified two criteria for our future exploration, resulting from our study aim. The aim is to investigate the reactions to possible ITS developments of actors involved in office area development and of actors involved in firm (re)location in a certain urban region[3]. A first criterion is that the exploration must lead to images and narratives of a future situation in an urban region that is comprehensible for actors (companies, municipalities and real estate developers) to react on in survey research. It is expected that the majority of the actors that will be questioned have no or little background information on ITS. Therefore, the future images must speak for themselves. That brings us to the second criterion. Each resulting future exploration must provide some quantifiable estimation, expressed in ranges, for indicators of the changed attractiveness of locations in the study area, due to the ICT-based changes in the regional transportation system. By attractiveness we primarily refer to the notion of accessibility measured in terms of resistance (distances and related travel time, the comfort level, safety) Secondly the attractiveness of a location can be considered in terms of image (see Argiolu *et al.*, 2004).

Although we considered different typologies of future research (see table 2 for an overview) (see e.g. Van Doorn & Van Vught eds., 1981; Van Vught, 1985), it seems that an inductive approach is most suitable to construct future concepts of ITS with. To work with this inductive approach extensive use is made from a systematic method that is among others used by Marchau (2000) and is based on the morphological analysis that is set out by Fritz Zwicky (1969).

Table 2. Brief overview of approaches for future research and possible techniques

Type of research	**Explorative**, research on logic alternative futures **Speculative**, estimates of future possibilities **Explicative**, explications of desirable futures and development paths towards that future **Integrative**, research on implications en relation between different forecasts
Techniques	**Scenario building**: method to build from current situation to hypothetical future situations based on logic **Probabilistic forecasting**: a pronouncement about the future conditioned by probability (similar to predicting) **Delphi techniques**: this technique tries to gather normative judgements from 'experts' about the future. Core feature of Delphi is by repeating an anonymous, controlled en written procedure, to gain consensus among experts about future situations. **Simulation**: simulation is an elaborate type of role-playing, gaming, and socio-drama in which learners simulate models of real-life situations. **Extrapolation techniques**: technique using current empirical data to calculate current trends into the future. **Brainstorming**: a group problem-solving technique in which members sit around a let fly with ideas and solutions to a problem **Causal modelling**: type of explorative forecasting, for example (multi)-regression models consisting of simple econometric and other calculating models **Cross-impact analysis**: generic term for techniques in which is tried to link changes in the probability of events with the events itself. **Morphological analysis**: a method in which a problem is unfolded into dimensions. Combinations of sub dimensions result in alternative solutions to the problem. **Signal monitoring**: this method is aimed at comparing the differences between actual development with the calculated development to determine and estimate the effect of the deviation between the two.

The procedure followed for morphological analysis is as follows: (1) the identification of basic dimensions constituting the variety of concepts; (2) the specification of values of these dimensions; (3) assess internal consistency of all pairs of variable conditions; (4) synthesise an internally consistent outcome space; (5) iterate the process if necessary. Step 1 and 2 form the analysis phase: defining the nature of the problem in terms of variables and variable outcomes. An outcome of step 1 and 2 is the morphological field, a matrix of dimensions and values. Step 3 and 4 form the synthesis phase: linking values with cross-consistency assessments and synthesising an outcome or 'solution' space. The iterating process is scrutinising the solution space by returning to earlier steps to adjust variables, alternatives and consistency measures. After step 5 '*one has created a non-quantified "if-then" laboratory within which one can define drivers, assume certain conditions, and find the range of associated solutions*' (Ritchey *et al*. 2003: 2). Note that in this contact a 'driver' is regarded as an 'independent variable' (Ritchey, 2003a). This morphological term should not be mistaken with the notion of the driver of a vehicle (which is a key-term used in this paper).

Each step is further explained in detail by Van Doorn & Van Vught (1978), Marchau (2000), Eriksson (2002), Ritchey (2003a; 2003b; 2003c) and Ritchey *et al*. (2003). Section 4 deals with step 1 and 2. Section 5 deals with step 3 and 4. Although it is not described explicitly, we have run through step 5 multiple times. The results are described in this paper. Section 5 also deals with specification of 'drivers' and the conditions.

4. Key elements for future ITS concepts using morphological analysis

The identification of the basic dimensions is based on a systems approach of future ITS concepts. We take into account that the outcome of the analysis describes a limited set of spatially distributed transportation concepts. The aim is to start from combinations of ADAS, ATIS and ATMS and to further conceptualize transport systems that are similar to what we notice in our everyday live. In order to do this we used a systems perspective which is set out in table 1 and the references mentioned earlier. Although table 1 offers a first insight into the result of the synthesising stage or, in less morphological terms, our ITS concepts, we need more dimensions and related values to analyse and construct the possible ways and paths that lead to these concepts more specifically. Table 1 does not, for example, distinguish between public transport and car driving. Nor does it include a spatial dimension. The benefit of the morphological analysis is that it helps us identifying all relevant dimensions (see table 3) so that we can unfold the problem of future ITS concepts in a much larger spectrum. Note that the first three dimensions are ITS specific and dimension four to six cover more general transport elements.

Our first dimension is *travel information support* and covers most of the ATIS. The reason to distinguish between different travel support systems is that these systems can help drivers by either giving information related to their road and traffic situation and route choice or his travel decisions that are related to destination activities. Examples of road and traffic information systems are: navigation routing, integrated navigation, real-time traffic and traveller information, state of the road information and driver monitoring systems. The so-called additional services can for example relate to mode changing opportunities (park and ride), hotel reservation, guiding for car parking, cultural event based information etcetera. Whereas the first value of information supply is dominated by generic information, the second information type might be much more tailor-made for the specific traveller. A third value is the use of both systems in one concept such as PITA.

Table 3. Morphological field of ITS conceptualisation with its dimensions and values

Dimensions	*Values*		
	(1)	(2)	(3)
travel information support	road and traffic information	additional services information	both
vehicle control	longitudinal	lateral	longitudinal & lateral
traffic support	single road management	network management	
user	individual	collective	
vehicle	light	heavy	
infrastructure	activity areas	connecting links	flow/motorways

The second dimension of future ITS concepts is *vehicle control* and covers most of the ADAS. Within vehicle control we distinguish between lateral support, longitudinal support and a combination of both. Lateral systems are for example Lane Keeping, Lane changing, Lane Departure warning, Side obstacle warning and Lane merging. Longitudinal systems are for example Intersection Collision Avoidance, ACC, Stop & Go, ISA, Forward collision avoidance, parking and reversing aid, electronic mirror and many more. A combination of both is for example automatic driving.

The third dimension of future ITS concepts is *traffic support* and covers most of the ATMS. Traffic support systems are divided into management of traffic that is focussed on a single road or management of traffic on network scale. A network is defined as a set of interconnected roads. The scale of management is mostly determined by governmental policy levels. In the Netherlands four levels are distinguished: national, provincial, regional and municipal. The regional level of governance is rather new and was among others called into being to match the governance level with the level of transport problems (flows). Examples of single road management are lane assignment, speed control and ramp metering. An example of network management is differentiated electronic payment.

The fourth dimension of ITS concepts is based on a distinction between vehicle types. A relevant distinction can be made between buses, cars and freight vehicles. Since the future concepts are used as input for a large-scale survey on location preferences the research topic would be fruitfully demarcated by only focussing on car driving and public transport vehicles and consequently excluding freight vehicles. Consequently we only distinguish between light and heavy vehicles with the purpose to transport people.

The fifth dimension is the *user* dimension, representing whether one is travelling alone or collective. Most of the public transport system is exploited for collective use. However, we consider taxi services, which are focussed at individual travel behaviour, as public transport too. The use of luxury cars for transport (including car pooling) are considered as an individual means of transport.

The sixth is the *spatial* dimension. It implies that ITS concepts can be implemented within activity areas, on connecting network links or on motorways. Activity areas are for example residential areas, business areas and city centres. Links within networks refer to infrastructure facilities that connect these activities. Motorways refer to infrastructure networks that connect large urban areas and are used for longer distance traffic flows. For the Netherlands, this distinction can be interpreted as follows: (a) roads in activity areas with a maximum speed of 30 – 50 km/h; (b) connecting network links with a maximum speed of 50 – 80 km/h; (c) motorways with a maximum speed ranging from 100 – 120 km/h.

Especially the first three dimensions of the morphological field (see table 3) were difficult to fill in, considering the wide range of typologies that seem to be used and differ per article or report (see e.g. differences between Marchau 2000, Golias *et al*. 2002, OECD, 2003, ADVISORS, 2003 and STARDUST, 2002). These differences result from a different use or alternative perception on future development of ITS. Some mainly focus on ADAS, some integrate between ADAS, ATIS and ATMS and still others only focus on safety related systems (see e.g. OECD, 2003). We show our colour by the fact that we only focus on *future ITS concepts* supportive to passengers transport at the regional level.

As we have argued before, we focus on specifying three to six future ITS concepts, because of methodological reasons. Our focus in the next analysis is to eliminate those ITS concepts for passenger transport which are unlikely to become reality. In this analysis the first step is to eliminate combinations of values by screening. Due to the systematic derivation of ITS concepts from basic dimensions, it is assumed that a future ITS concept is implausible in case one of the combinations of levels of constituting dimensions is illogical or impossible. This simplifies the screening considerably, because it becomes possible to analyse a limited set of pairs of values. The number of different pairs of values which can be derived from two dimensions with each three values is 3*3 = 9; for dimensions with two respectively three values, the number of possible pairs is 2*3 = 6. Hence, for the defined dimensions and values, the number of pairs is 3*3*2*2*2*3 = 216. In the next paragraph we will reduce the amount of future ITS concepts systematically by walking through steps 3 to 5 of the morphological analysis method.

5. Reducing the amount of future ITS concepts (from n =216 to n≤6)

The purpose of the concepts is to use them in a survey to gain insight on office location preferences. Our second step is to look at combinations of pairs that lead to plausible passenger transport concepts that could possibly be implemented at the regional level in the next twenty years. In this second step we ask ourselves: what development paths will this large range of technical functionalities and specific ITS applications follow in the next twenty years? Will new concepts emerge? Or will current transport concepts evolve? What issues are considered to be important influencing this technical development? Our effort in answering these questions reliably must lead to concepts and estimated effects in terms of accessibility.

Table 4.Cross-consistency matrix of future ITS concepts

Dimensions	Values	vc1: longitudinal	vc2: lateral	vc3: long.&lat.	ts1:single road	ts 2:network	u1:single	u2:collective	v1: light	v2: heavy	i1: activity	i2: connecting	i3: motorways
ds: travel information support	ds1: road/traffic info	1	1	1	1	1	1	1	1	1	1	1	1
	ds2: additional services	1	1	1	0	1	1	1	1	1	1	1	1
	ds3: road/traffic & additional services	1	1	1	0	1	1	1	1	1	1	1	1
vc: vehicle control	vc1: longitudinal				1	1	1	1	1	1	1	1	1
	vc2: lateral				1	1	1	1	1	1	1	1	1
	vc3: long.& lat.				1	0	1	1	1	1	1	1	1
ts: traffic support	ts1:single road						1	1	1	1	1	1	1
	ts2:network						1	1	1	1	0	1	1
u: user number	u1:single								1	0	1	1	1
	u2:collective								1	1	1	1	0
v: vehicle	v1: light										1	1	1
	v2: heavy										1	1	0

** a '1' refers to logical combinations and a '0' refers to illogical combinations*

** a black box means that a combination is not logically consistent*

Table 4 is illustrative for the reframing of logical concepts. The boxes that are filled in with black are not considered to be *logical* given the combined values of the underlying variables.

First, we think that a combination of single road management and travel information focused on additional services is illogical (no combinations of ds1/ds2 with ts1). Basically, the scales of services do not logically match.

Secondly, we don not think that a combination between vc3 (longitudinal & lateral systems) and ts2 (network) is very likely to become reality within the next twenty years.

Thirdly a combination between network management and application at the level of activity areas makes no sense. In our paper the traffic management of an activity area is regarded similar to a closed system (for instance a single road). Thus, a combination of single road management and activity area *is* logical. An example of traffic management focussing on just one part of the network is for example access restriction polices illustrated by the London case.

Fourthly, the single user system here is not logical with heavy systems. Heavy vehicles are for example buses that are used in public transport. The driver of such a bus is considered as being part of the system. It is not considered as being plausible that heavy vehicles are being used by individuals[4].

A final set of illogical pairs is caused by the fact that we do not think that heavy vehicles (such as buses) are suited for operational use of passenger transport on motorways/flows. This means that a combination of both u2 (collective use) and v2 (heavy vehicles) with i3 (motorways) is not logical.

Although the seven illogical pairs (see the cross-consistency matrix) leave out a considerable amount of alternative concepts, we still are in need of a final step (5) to really reduce the set[5] (n=47). Therefore, we add specific assumptions on crucial conditions to be fulfilled for implementation in order to find a workable range of concepts. In essence we define assumptions that are related to regional transport policy priorities and secondly, trends that are related to the technological development of ITS within the next twenty years.

Policy priorities for passenger transport at the regional level

At first, an important assumption is that, on the regional scale, governmental bodies keep formulating transport policies because they maintain their responsibility regarding transport problem solving. Given a continuing growth of car driving and the fact of the stiff competition between regions for funding of new infrastructure, the increase of infrastructure will be limited and other solutions focus on better management of the existing transport system will find more support. What does this mean for the future of transport concepts if we link this assumption to the information in table 4? The most important criterion in defining the future development of transportation concepts is possibly the importance of the role of regional government and provincial governing. We use two main alternatives regarding the influence of regional government, based on experiences from current policies.

A first option is that no consensus is reached between municipalities and money is lacking to make a real difference in solving transport problems. Since this alternative closely resembles the present situation in many western urban areas, this alternative functions as a so called ‘0-scenario’. Basically, nothing changes in fundamental way. It implies in our empirical survey that the Arnhem/Nijmegen-region[6] will continue to face problems in terms of safety, pollution and decreased accessibility of important economic centres and dwellings.

The second alternative is the case were governmental bodies gain consensus on solutions and make a clear choice for changing mobility management. This would for example imply strong investments in new concepts for either car driving or public transport[7]. Investments in public transport relates to single (for example taxis) or collective use (for example buses).

Investments in for example car driving are for instance, development of new dedicated infrastructure or the re-development of existing infrastructure into dedicated or technology supportive infrastructure[8]. These investments can be related to activity areas, connecting network links and motorways. A second investment strategy of governments in car driving could be focussed on traffic management and/or travel support by accurate and dynamic information supply. Moreover, we assume that these investments will focus at parts of activity areas (parking information, or area restriction or payment) and management of traffic through the network (accident management, ramp metering and/or dynamic information supply).

Investments in public transport could be: the upgrading of existing transport concepts and the development of new transport concepts for public use. From an ITS point of view, these could be concepts focussing at light and heavy vehicles. Light vehicles are for example People Movers or ‘smart’ Taxi’s and are used within activity areas and heavier vehicles like buses that can be used on rural roads or underlying road network at somewhat longer distances, up to 40 kilometres, depending on speed and capacity (for a list of innovative public transport concepts see e.g. FANTASIE, 2000).

Important technology trends for future ITS concepts

Four notions (or trends) that are strongly related to the future development of new ITS concepts are *automation* of technology, traffic and transport *control*, *integration* of driver support systems and *co-operation* between in-vehicle technology and infrastructure. We shall explain these notions consecutively.

The first trend is automation, which is linked to the extent of technological support of the driver. This refers to the degree of assistance: *informative*, *assisting* and *automotive*. *Informing* systems alarm or advise the driver by giving signals. The driver has to decide what to do with the information, for example about speed, traffic, road condition, approaching vehicles, pedestrians or animals, the driver's situation and more. This can be done auditory by for example beeping, visually by using symbol or icons, haptic by using counter-force on accelerator pedal when speed is exceeded or tactile by vibrations in the driver's seat (Van Driel & Van Arem, 2004). *Assisting* systems are characterised by the fact that the technology influences the vehicle behaviour on parts. However an intervention from the system that cannot be overruled by the driver is impossible. An example is that the vehicle slows down automatically when exceeding the speed limit. In that situation the driver has the possibility to 'switch off' the system or to use it as an assistant. The *autonomous* technology is intelligent and takes over certain driving tasks, without intervention options for the driver.

The tendency is to intensify R&D on assisting and autonomous systems. For example, in the Netherlands pilots with automated people movers and freight trucks have been initiated in recent years. The more attention for autonomous driving is intensifying, the more the link with the infrastructure system becomes important (co-operation) and the more the discussion on the transport services level and organisation (the second market in table 1) is triggered. Further it depends on the traffic manager, mostly being the government, whether the level of automation is mandatory and legally forced. One can for example imagine that transport policies that include mandatory ITS will aim at certain user groups to increase road safety. One example is controlled speed keeping for repetitive violators or people who are under the age of 25. Another example is a mandatory use of semi-controlled (for instance only on motorways) Lane Keeping for trucks.

The second trend extrapolation is the level of *control*. Once car drivers are participating in traffic, compliance of these drivers to norm behaviour assumed in general traffic rules is in the interest of traffic management. It is for instance not allowed to exceed speed limits, drive under influence of drugs, or changing lanes unnecessarily. Traditionally, education, engineering and enforcement by the police have been the main instruments to reach this goal. Nowadays ITS are increasingly considered to be a promising instrument too (Van der Heijden & Marchau, 2003). From the perspective of traffic management, a more controlling influence on driver behaviour is desired in certain situations. For instance the combination of enforced speed limitation and lane keeping can contribute to road safety. Keeping a fixed speed has two advantages: it can increase safety if an Intelligent Speed Adapter is installed which does not allow the driver to extend a certain speed limit. The second advantage is a fixed time interval in speed headway keeping. If for example an ACC is installed in 50% of the vehicles significant gains in terms of road use efficiency can be obtained (Shladover *et al.*, 2001). Making ITS mandatory implies that government has clear ideas of their policy goals. A government approach that focuses on more control implies in some cases more automation of driver tasks and in other cases mandatory control over some tasks, for example speed keeping for repetitive violators.

The third trend is the integration of different support and control systems. Van Driel & Van Arem (2004) distinguish between integration of driver support functions related to technology, Human-Machine Interface (HMI) and functional operation. Technical integration relates to using the same components, such as sensors and processors. An integrated HMI consists of the integration of the interfaces of separate functions. Benefits for the *functional* operation can be twofold. A first example is the extension of operative scenarios for single systems: for instance the operation of an ACC depending on information about the road shape from a navigation system or the lane width from a Lane Departure Warning Assistant (LDWA). Secondly, the performance of single systems might be improved: for instance with the use of data from extra sensors a better execution of the system functions, in terms of false and missing alarms or misinterpretations of the driving scenario (Van Driel & Van Arem, 2004).

Again, regarding the integration of different support and control systems, roughly two main developments are important: integration of functions in light/private vehicles and integration of functionalities within heavy vehicles, which consist of mainly public vehicles[9]. Integration and/or combination of complementary driving task technology (for example lateral and longitudinal support) still demands a conditioned environment which is easier to supply in public transport (heavy vehicles) than in car driving due to the use of dedicated infrastructure. A promising integration possibility within car driving is described by ADVISORS (2003). It consists of a highway ACC, urban and peri-urban stop & go functions, operating in high flows, to complement the ACC in these environments. Next the scenario consists of lateral support (warning) on motorways and rural roads, lane change support (warning), an ISA that provides dynamic information using infrastructure, and dynamic route navigation and route guidance, also based on extended navigation maps, that are dynamically upgraded. This integrated scenario was best rated[10] in research before other scenarios that were focussed on single systems (ADVISORS, 2003).

As we have already stated, public transport offers more possibilities with respect to integration of driver support systems and the combination of these systems with vehicle and traffic support systems than car driving. The reason for this lies in the systems fleet and dedicated infrastructure management, which is mostly controlled by one organisation, in this case the public transport company. Although not at a large scale, combinations of lateral and longitudinal functions have already been introduced in public transport modes. These examples are introduced on dedicated lanes within activity areas whereas semi-automated vehicles are functional at connecting links, or the underlying road network. Other ITS systems that are used in those examples are the tracking and tracing of systems and a first variant of platooning by electronic linking, were driverless buses follow a bus with driver.

The fourth trend is *co-operation* of technology between vehicles and infrastructure. We distinguish between physical infrastructure (such as roads, junctions and toll ports) and semi-physical infrastructure (such as traffic control centres). Over the years an increasing amount of information is provided to car drivers through radio and road-side information. Dependent upon the technological development of current in-vehicle systems, the level of automation and control, co-operation between infrastructures and vehicles will increase further. Regarding the technological development of current in-vehicle systems we give the example of ISA meant to increase road safety. ISA is an intelligent speed adapter which can be informing, assisting or complete controlling by nature. It is quite logical that ISA needs information about the maximum speed of the road the vehicle is driving on. There are three different ways in which it can obtain this information. The first is that the vehicle uses data on which ISA is based and can be stored on a CD-ROM or DVD. Or, a second alternative is that the data is transmitted from a regional centre having the most up-to-date data. This software is linked to a Global Positioning System (GPS). Combinations are also possible, for instance GPS for positioning, road network stored on CD-DOM/DVD and road works, traffic and weather data being sent from regional control centre. A third option is that data on speed limits is received via roadside transmitters that are mounted to traffic signs along the road. The second and the third option need co-operation by either a traffic control centre or infrastructure facilities. An example of co-operation that is used in need for a better throughput in networks is a co-operative form of Adaptive Cruise Control. A first lane that would use such a system would need both vehicle to vehicle communication and vehicle to roadside communication (Shladover *et al.*, 2001). The infrastructure that is used for vehicle following and longitudinal and lateral control in public transport in the Netherlands also needs magnetic transponders for deviation corrections.

Summarising, we distinguish between: car driving investments and investments in public transport. This investment can be focussed at developing new concepts or investments in current concepts. Regarding the technology we can distinguish five relevant trends: from assisting to automation, from in-vehicle to co-operation, from one system to integration of various systems and from an ‘open’ application to the development of more controlled use of systems.

6. Construction of plausible concepts

If we look back at table 4 we argue that all three dimensions that are derived from the transport system in general (vehicle type (v), user number (u) and infrastructure (i)) can be regarded as ‘drivers’; the independent variables that form the core of the concepts. This results in 5 possible concepts: (I) light vehicle, individual use and motorways; (II) light vehicle, individual use and rural roads; (III) light vehicle, individual use and activity areas; (IV) heavy vehicle, collective use and rural roads (V) light vehicles, collective use and activity areas. To define which technology values (driver support (ds), vehicle control (vc) and traffic support (ts), see table 4) can be expected most logically, we have to look at the trends that are set out in section 5.

First of all, if the trend of full automation of lateral and longitudinal control in car driving becomes reality, it will probably first be implemented on motorways. Public transport concepts that are fully automated are designed for the underlying road network as well as within activity areas.

Secondly considering car driving, the integration of travel support, vehicle control and traffic support systems is applicable at all levels, except in case lateral and longitudinal control are combined in an automated mode. Such a mode is only expected to be applicable in the context of controlled traffic on dedicated roads, such as on the motorway or on a dedicated public transport network.

Thirdly, co-operation of infrastructure within car driving at the underlying road network and within activity areas will probably include travel support by giving travel information and information on additional services. A higher service level in information provision (e.g. dynamically and personalized) would either need a regional traffic control centre or improved in-car technology combined with GPS to filter out irrelevant information. Other systems that need infrastructure are designed for traffic situations within activity areas like intersection collision avoidance or detection of obstacles and pedestrians. Co-operation of infrastructure and vehicle control is more advanced in public transport. In theory, both concept designs could be based on a more advanced level of co-operation. An example of such a co-operation is for example tracking, tracing and control of the fleet on distance, for instance from the public transport control centre. However, the provision of personalized travel information could remain a problem since the public transport company will be dependent on information from other (public transport) companies.

As said, both public transport concepts (as a whole) could include a high level of control. Of the three car driving concepts, only the automated motorway concept demands a high level of management or control. The other two concepts could include specific systems, like ISA, that in certain situations, for example to keep repetitive violators from speeding, might be mandatory and therefore a higher level of control.

Car driving concept I

Car driving concept I is built up from light vehicles (v1), single users (u1) and motorways (i3). One of the trends is to automate car driving on a dedicated lane on motorways, only meant for private vehicles that use the appropriate technology. The vehicle support can be both lateral and longitudinal (m3) and management is focussed on the single road (ts1). The road and traffic information support is strong (ds1), whereas information supply on additional services is limited to static pre-trip information. Considering the trend of co-operation the lateral and longitudinal assistance (m3) are dependent on infrastructure support. An example of a future policy investment strategy of a region that is similar to this car driving concept (see table 5) is described by Shladover *et al.* (2001). That concept consists of a dedicated lane for vehicles equipped with a Co-operative Adaptive Cruise Control. As the main purpose of such a system is to increase throughput in networks, this dedicated lane would be managed as a single road (ts1) and developed on motorways (i3). This car scenario includes 'common' or a static navigation system using GPS and CD/DVD ROM data. The traffic control centre only regulates the demand for dedicated lane use.

Shladover *et al*. (2001) have conducted research on such a CACC lane. *'If the cooperative ACC and protected lane are augmented with vehicle steering actuation (combined with the lane-tracking function already developed for lane departure warning), there is a possibility for getting close to the first really automated operations on a protected lane. Adding some more intensive vehicle-roadside communication…for condition checking at entry, the means for automatically coordinating entering traffic with the traffic already in the lane, and some enhanced traffic management capabilities for integrating operations with the rest of the traffic system (ATMS+) we have the makings of the first single-lane automated highway system'* (Shladover *et al*., 2001: v).

Table 5. Construction elements for car driving concept I

Morphological elements	*Trends*	*Estimation of expected effects*[11]
ds1: road and traffic information	Car driving investments (CDI)	Safety: –/+
m3: long.& lat.	New concept (NC)	Accessibility: +++
ts1:single road	Full Automation (A)	Environment: no score
u1:single	Fully Co-operative (C-O)	Comfort: ++
v1: light	Integrated (Int)	
i3: motorways/flows	Fully Controlled (Contr)	

Scale: – – – very bad, – – bad, – mediocre, –/+neutral, reasonable +, good ++, very good +++

It should be mentioned that this system is not designed for safety purposes. The safety of the system is similar to what we experience on 'normal' motorways with manually controlled vehicles. Its main goal is to increase efficiency and to obtain a high level of comfort for the driver. The estimated effects on accessibility are based on a study which was performed by Shladover *et al.* (2001). They estimated that the effect of this concept on the throughput in the transport system could be as high as 200%! This maximum effect was based on a decreased time gap between following cars to 0,5 seconds[12] and a 100% market penetration of CACC.

Car driving concept II: safety rules

Car driving in this scenario is based on a transport policy strategy focusing on the performance of the underlying road network (i2). The most common policy problem on this road is the relative (un)safety. The focus is on single users (u1), light vehicles (v1) by using network traffic support (ts2). Next, drivers are supported with both road and traffic information & information on additional services (ds3). Travel information concerns dynamic route navigation and real time traffic and traveller information.

Additional services information is supported by real-time information on park and ride alternatives, hotel reservation and information on events. The road and traffic information system needs co-operation from a regional traffic control centre (ts2) that monitors traffic and provides real-time information.

Table 6. Construction elements for car driving concept I

Morphological elements	*Trends*	*Estimation of expected effects*
ds3: information	Car driving investments (CDI)	Safety: +++
m3: longitudinal and lateral support	Evolving concepts (EC)	Accessibility: –/+
ts2: single road	Assisting (A)	Environment: no score
u1: single	Co-operative (C-O)	Comfort: ++
v1: light	Partially integrated (Int)	
i2: underlying road network	Minimum control (Contr)	

Scale: – – – very bad, – – bad, – mediocre, –/+neutral, reasonable +, good ++, very good +++

Car driving concept II (see table 6) consists of vehicles equipped with both longitudinal and lateral control. As concept I is primarily designed to stimulate throughput and comfort in motorways, concept II aims for more safety and comfort on the underlying network. This difference results in the fact that the mandatory control level of vehicles is minimized to hazardous situations such as bad weather. Longitudinal driver support is provided by an integrated system based on ACC and ISA. Real-time information on speed limits is provided by the traffic control centre. To obtain information on obstacles like vehicles or animals the integrated ACC-ISA system uses advanced sensors. The system is always assisting and only mandatory in situations of nasty weather or if a vehicle approaches an intersection that is marked as unsafe. Speed and distance parameters are controlled by the traffic management centre. In all other situations the driver is permitted to witch it off.

Besides longitudinal systems also lateral systems (m2) are an important technology in car driving concept II. An important system on the underlying road network is Lane Keeping. It is developed to prevent collisions due to overtaking. The system uses sensors that are installed at infrastructure. In case of hazardous situations (for example by overtaking when vehicle is approaching on side lane), the system intervenes by warning signals and issues the vehicle to keep lane.

This system is clearly designed to increase safety of using the underlying road networks. The effect of safety is regarded as very good. Besides the safety level the comfort level increases too. This concept is not expected to have significant effect on accessibility (see e.g. Golias *et al*., 2002).

Car driving in activity areas (Car Driving concept III)

Car driving concept III is based on single users (u1), light vehicles (v1), activity areas (i1) and single road traffic support (ts1). The rationale in this alternative is that the regional government's investments are particularly focussed on traffic safety within these activity areas. The information technology (ds1) in car driving scenario III focuses on dynamic route navigation. It suggests alternative routes in case of traffic jams or accidents. With respect to parking, the occupation of all parking lots and major parking areas is screened real-time and 'translated' into information on parking options. Longitudinal systems are used separately from lateral systems (m3).

Table 7. Construction elements for car driving concept III

Morphological elements	*Trends*	*Estimation of expected effects*
ds1: road and traffic information	Car driving investments (CDI)	Safety: ++
m3: long.& lat	Evolving concepts (EC)	Accessibility: +
ts1: single road	Assisting (A)	Environment: no score
u1: single	Co-operative (C-O)	Comfort: +
v1: light	Semi-Integrated (Int)	
i1: activity areas	Open (Contr)	

Scale: – – – very bad, – – bad, – mediocre, –/+neutral, reasonable +, good ++, very good +++

Longitudinal systems are Stop & Go, and detection systems. The detection system uses sensors to avoid pedestrians in front, side to (lateral system) or end to vehicles.

A second safety system that is part of this policy strategy is intersection collision avoidance. This system monitors dangerous intersections and warns or informs the drivers of vehicles entering or approaching the hazardous zone. These systems are based on obstacle detection sensors used to avoid encounters with other vehicles and vulnerable road users (i.e. pedestrians). The employ detection functions as a roadside-to-vehicle or even as a vehicle-to-vehicle communication system (Ertico, 2002). Support of information on destinations and travel and support on information on vehicles at intersections is facilitated by a traffic control centre.

Finally the investment strategy contains information on road speeds by introducing Intelligent Speed Adaptation (ISA) within all activity areas. The system is assisting and meant to help (and not to control) the driver.

Public transport concept I: Automated buses

Public transport concept I encompasses heavy vehicles (v2), collective use (u2) and is used on the underlying road network (i2). The scale of the concept is similar to what currently is used for light rail and bus systems using dedicated infrastructure. An important reason to invest in a road-based ITS system over a conventional system like light rail, is the relative low costs in infrastructure construction (Miller *et al.*, 2002). Further, the infrastructure can be developed faster and has lower exploitation costs and is more flexible in usage and expansion in network. A second important reason is that automated transportation is more cost-efficient since high costs on personnel are saved. This means that transport services can be provided cheaper and more frequently[13].

Important feature of the buses is the automation technology. The buses are fully automated (m3) and controlled through a combination of a board computer system with pre-installed data on maps, GPS, sensor technology for longitudinal control and obstacle detection and an advanced lane keeping system for lateral control. The infrastructure is dedicated and only available for vehicles that use the appropriate technology.

The management of the system is supported by a regional traffic centre. This centre functions as a control room, where information is selected, vehicles are being identified and from which, in case of emergency, technicians are sent. Systems like AVL and Short Distance Radio (SDR) are used to give priority to the buses that approach traffic lights. SDR saves time and therefore improves reliability of the transport services. Another feature of the management system is that the infrastructure might also be used relatively easy by other transport services. In a well managed slot system, taxi's can buy slots to use the infrastructure. Besides taxis, the dedicated lanes could also be used by emergency services like police, fire fighting and ambulances.

Table 8. Construction elements for car driving concept III

Morphological elements	*Trends*	*Estimation of expected effects*
ds3: road and traffic information/ additional services information	Public Transport Investments (PTI)	Safety: +/-
m3: long.& lat	New concept (EC)	Accessibility: +(+[14]) modal shift
ts2: network	Automated (A)	Environment: ++
u2: collective	Co-operative (C-O)	Comfort: +++
v2: heavy	Full Integration (Int)	
i2: underlying road network	Controlled (C)	

Scale: – – – very bad, – – bad, – mediocre, –/+neutral, reasonable +, good ++, very good +++

Passengers that travel by this bus system enjoy the benefits of a dynamic information system on travel and additional services (e.g. mode changing) (ds3). Extensive use is made from an improved version of what is currently developed as a Personal Intelligent Travel Assistant (PITA). This device is personally distributed and serves both as an electronic payment device and keeps track of all information that is relevant to the control centres and the passenger. All scheduled travel information is loaded in the memory of PITA. If a person is for instance travelling from station X to station Y, and a malfunction occurs, this person can power up his PITA, using his chip-card, which will calculate and show the alternative route to Y.

Current case studies on systems similar to public transport concept show that it could have a positive effect on accessibility, environment and the travel comfort level (see e.g. Miller *et al*. 2002).

Public transport concept II: Intra-urban travel

Table 9 presents the key elements for this scenario. It is built on the combination of collective use (u2) of light vehicles (v2) within activity areas (i2). Public transport scenario II offers automated individual passenger transport services within activity areas. The technology is less controlled due to lower speed and corresponding safety measures.

This second public transport system covers intra-urban dedicated infrastructure that transport small groups of travellers from the cities main train stations or P&R facilities to various activity centres within the city area. It could also be implemented on intra-urban roads that connect densely used activity areas that generate large flows of passengers. Examples of such areas are large office locations, universities, medical centres and shopping malls. The infrastructure is dedicated to support both lateral and longitudinal control (m3). Detection systems are fully integrated sensing all static and moving objects. The provision of information in this concept is similar to that of public transport concept I.

The effect of this system on safety is neutral. Its purpose is not to increase safety, but to offer a more reliable and comfortable means of (connecting) transport. People use dynamic information, and experience a quiet and smooth travel mode.

The estimated effects on safety, accessibility, environment and comfort are based on a case study of a system that resembled that characteristics of public transport concept II (see Argiolu, 2002).

Table 9. Construction elements for car driving concept III

Morphological elements	*Trends*	*Estimation of expected effects*
ds3: road and traffic information/ additional services information	Public Transport Investments (CDI)	Safety: +/-
m3: long.& lat	New concept (EC)	Accessibility: +(+) modal shift
ts2: network	Automated (A)	Environment: ++
u2: collective	Co-operative (C-O)	Comfort: ++
v2: light	Full Integration (Int)	
i2: activity area	Controlled (C)	

Scale: – – – very bad, – – bad, – mediocre, –/+neutral, reasonable +, good ++, very good +++

7. Conclusion and discussion

In this paper we discussed the variety of possible future ITS concepts for regional passenger transport given the scientific challenge to improve our knowledge on the possible impacts of ITS on choice behaviour regarding office locations. In order to do this we have used a morphological analysis. Moreover, we have distinguished two alternatives for transport policy priorities and five trends that are related to ITS technology using vehicles. This has resulted in five different concepts, each discriminative in geographical nature.

The last section of this paper functions as a seed for further deepening of the concepts. In this paper we have raised a corner of the veil. In the near future we go in more detail. For instance, we need more information on the architecture of the concepts to define the effects more accurately.

Secondly, and this especially applies for the concepts that involves car driving, we need expert opinion on future development of ADAS. Our quest to reduce these uncertainties and perhaps to confirm our ideas have resulted in the start of a Delphi project called FADAS, in which six researchers, including all the authors of this papers, participate.

Thirdly, the concepts need to be translated from paper to images in maps. Therefore, we need more ideas on how the indicated concepts might be transferred into physical reality. To perform such a transfer, we will work together with transport policy makers in our study area.

Finally, we will test our concepts on location preferences in the KAN-region using a survey. This survey research is planned for the second half of 2004. Obviously, while preparing, conducting and analysing the results of the survey, we will face new challenges. Evidently, we will report on this in the future.

Acknowledgements

The research project that is described in this paper is carried out as part of the NWO-CONNEKT Research program “Behavioural Analysis and Modelling for the Design and Implementation of Advanced Driver Assistance Systems” (BAMADAS). Our project is sponsored by the Cornelis Lely Foundation.

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Appendix

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[1] BAMADAS is an acronym for Behavioural Analysis and Modelling for the Design and Implementation of Advanced Driver Assistance Systems. The program started in 2002. BAMADAS consists of five PhD projects and one post-doc project. The subprojects focus on implementation issues of ADAS studies at the levels of respectively driver behaviour (2 projects), traffic performance, infrastructure design, spatial implications, and legislation and tort reliability. This paper describes part of the project that tends to describe spatial implications (www.bamadas.tbm.tudelft.nl).

[2] For a more specific and complete overview on the nature of different ITS applications see for example publications by Ertico (e.g. 2002) and publications of Bishop (e.g. 2000).

[3] The urban region in our case is the Knooppunt Arnhem Nijmegen (KAN)-region in the far eastern part of Netherlands. The KAN-region has 670.000 inhabitants approximately. The region is mainly build up from two cities (Arnhem and Nijmegen) with 160.000 inhabitants each and at a mutual distance of about 15 km. Another 350.000 people live across dozens of sprawled towns and villages between and directly adjacent to both cities.

[4] This paper does not deal with truck drivers or other professional drivers.

[5] The table that includes all possible strings is not included in this paper. After doing the cross-consistency test 169 pairs of strings were not considered as being logical. Hence, 216 – 169 pairs leaves us with 47 possible outcomes.

[6] The urban region in our case is the Knooppunt Arnhem Nijmegen (KAN)-region in the far eastern part of Netherlands (see note 3).

[7] Another 'third' option could be better management of multimodal transport by for example investing in transfer points to change modes and control centres to provide real-time information. However, our morphological field includes the value of light and heavy vehicle. The multimodal option would include none and is not used in this paper.

[8] Our definition of dedicated infrastructure is infrastructure that is designed for one type of technology. Vehicles that are not equipped with the proper technology are not able and allowed to use it. Technology supportive infrastructure is infrastructure that supports a technology that can be used by vehicles. An example of technology

supportive infrastructure is intersection collision avoidance. Infrastructure senses other vehicles and sends information to vehicles that approach an intersection.

[9] Although we deal with integration in two different ways (heavy versus light vehicles) we recognize that technology development is a complex development field in which manufacturers of vehicles benefit from achievements that are made in the wider spectrum of research.

[10] The scenarios were rated using a Multi Criteria Analysis including full user costs, driver safety, driver comfort, network efficiency/travel time reduction, public expenditure, third party safety effects, environmental effects, socio/political acceptance and technical feasibility (for more details see ADVISORS, deliverable 7.1).

[11] The expected effects only account for the specific road level the concept would apply on. In this case the concept would be developed on motorways. To give more precise figures on effects on road level and network throughput, more transport modelling is needed. This also accounts for the effects that are described in table 6-9.

[12] Compared to our normal follow up distance of 1,2 seconds.

[13] 80% of a public transport company costs that exploits bus trips are based on personnel (see Argiolu, 2002). One can imagine what savings an automated bus system could have. It could for example lead to cheaper transport or additional investments in travel facilities or a more frequent trip schedule.

[14] Due to the modal shift, we expect that the increased use of public transport concept I and II would also benefit accessibility of roads for cars.