WORKING PAPER

A DELPHI PANEL-DERIVED SCENARIO ON
ROAD TRANSPORT INFORMATICS EVOLUTION

Ove Sviden

April 1987
WP-87-32

IIASA
International Institute
for Applied Systems Analysis

A DELPHI PANEL-DERIVED SCENARIO ON ROAD TRANSPORT INFORMATICS EVOLUTION

Ove Svidén

April 1987
WP-87-32

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

ABSTRACT

Modern information and microelectronic technology can be used to improve road traffic. The aim of this study is to create scenarios on how new information systems for improved road traffic can evolve. What are the driving forces? Who can act? Who can benefit? What are the social impacts?

Through the use of a Delphi panel of professionals, researchers and informed generalists, we have gathered impulses for the scenarios on how information technology, communication means and control systems can reshape future road traffic. The issue studied is how this "Road Transport Informatics" (RTI) will evolve.

A short history of road information systems is given and the problem formulation and methodology is discussed. A summary of panelists' responses on events, impacts, actors and barriers follows. Our summaries and conclusions on a possible RTI evolution are presented as scenario scenes for 1990, 1995, 2000, 2010, 2020 and 2040.

FOREWORD

The technological life-cycle is an organizing principle common to several of the investigations within the Technology-Economy-Society Program at IIASA. That is why the development of methodological approaches to life-cycle analysis is very useful for further applied research.

In order to classify and characterize the different phases of the life cycle, we need methods to identify transitional periods. Ove Svidén has developed a Delphi-based scenario method together with Professors Sten Wandel and Lars Sjöstedt in the TES/New Logistics Technologies Project at IIASA.

The method has been tested by Ove Svidén in a case study concerning the introduction of Road Transport Informatics (RTI). Results in the form of market diffusion curves for potential new RTI systems and scenario scenes analyzing the impacts on future road traffic, environment and society are included. Both method and results from the year-long case study at IIASA are presented in this report. We are grateful that the Swedish Road Administration provided us with a generous grant for the whole study.

Professor Robert U. Ayres
Deputy Program Leader
Technology—Economy—Society

PREFACE

The first ideas for the ARISE Project came to me while working in the aerospace industry. Why not put the same kinds of sensors, computers and general purpose displays used in aircraft to use in automobiles to increase safety and improve their performance in traffic?

Lars-Erik Sjöberg quickly realized that these ideas offered important opportunities for the Swedish National Road Administration. He organized SNRA support for the ARISE Project and promoted it as a possible international study. With IIASA as a base, we rapidly succeeded in establishing a broad contact network of researchers, experts and professionals in the field.

At IIASA, Professors Sten Wandel and Lars Sjöstedt helped develop an appropriate study method. Dr. Paul Weaver helped analyze the results. Linda Cechura typed and edited the manuscript.

This study would not have been possible without the generous support of our anonymous Delphi panelists, who shared their expert knowledge, assessments and ideas with us. To them and to the colleagues named above I am truly grateful for their contributions.

Laxenburg, April 1987
Ove Svidén

TABLE OF CONTENTS

(This document has been edited as a scientific report. For those mainly interested in the RTI issue, we recommend reading it from the back, that is, starting with the scenarios and then looking into Chapters Three to Six to read about the panel's support for the scenarios.)

TABLE OF CONTENTS (cont.)

LIST OF ABBREVIATIONS AND DEFINITIONS

AHC	Automatic Highway Chauffeuring
AI	Artificial Intelligence
ALI	Autofahrer Leitungs Information, a route guidance system in the Federal Republic of Germany
ALI-SCOUT	A route guidance system developed by Bosch-Blaupunkt and Siemens
ARI	Autofahrer Rundfunk Information (drivers radio information)
ARISE	Automobile Road Information System Evolution
AVN	Autonomous Vehicle Navigation
AUTOGUIDE	A route guidance system developed by TRRL
BRD	Bundesrepublic Deutschland (Federal Republic of Germany)
CA	Collision Avoidance
CB	Citizens' Band Radio
CACS	A route guidance system tested in Tokyo in 1977
CARIN	A route guidance system developed by Philips (NL)
DRIVE	Dedicated Road Safety Systems and Intelligent Vehicles in Europe, an EC exercise.
ETAK	An autonomous navigation system developed by ETAK, Inc. (US)
Gasistor	A clean engine concept yet to be invented
HELP	Heavy Vehicle Electronic License Plate System/Project
IIASA	International Institute for Applied Systems Analysis
IIRG	Integrated and Interactive Route Guidance System
IIIRG	Third Generation IRG
IRG	Interactive Route Guidance

IT industry	Information and Telecommunications industry
IQR	Interquartile Range (A statistical measure of spread $Q_3 - Q_1$)
LEV	Levitation (MAGLEV = Magnetic levitation for fast trains)
M	Median value (50th percentile)
OECD	Organization for Economic Cooperation and Development (of industrialized countries)
PROMETHEUS	Program for a European Traffic with Highest Efficiency and Unprecedented Safety
Q_1	First quartile value (25th percentile)
Q_3	Third quartile value (75th percentile)
R & D	Research and Development
RDS	Radio Data System
RSI	Road Service Information
RTI	Road Transport Informatics (information, communication and control systems)
SDK	Speed and Distance Keeping
$\sum$	Sigma = Summation
SNRA	Swedish National Road Administration
TRRL	Transport and Road Research Laboratory (UK)
UCAD	User Cost and Automatic Debiting

EXECUTIVE SUMMARY

By the use of a Delphi panel of professionals, researchers and informed generalists we have gathered impulses for a scenario on how information technology, communication means and control systems (Road Transport Informatics or RTI) can reshape future road traffic.

From the first of two rounds, we got overwhelming support for the idea that modern information technology is now mature enough to make major impacts on a number of present road transport problems (navigation, traffic flow, congestion, road capacity, transport economy and safety). The first round also gave us new ideas about the scope of the issue and a way to structure it in seven broad categories. In the first round responses from 54 panelists were documented in a 50 page draft summary.

The second round questionnaire was mailed to the first round respondents at the end of January 1987 and resulted in 31 responses in March. These contained quantitative estimates on significant events, expected performance and cost of future RTI systems together with formulations of possible barriers that can delay, stop or hinder the introduction of any of the suggested RTI systems.

The results from both rounds above are summarized in this report, which indicates what factors, forces and actors can be important for a future RTI development. The panelists give indications of what they expect from this development and its impacts. Time estimates given are condensed into median values and quartile values in order to give an indication of the spread in responses. The quantities given represent indications from informed generalists on complicated technical solutions, mostly not yet developed. Therefore the results must be generalized with caution.

A core scenario has been created which represents the author's best effort of synthesizing the responses into a consensus path of development. The scenario scenes for a number of selected years are products of a synthesis, based on the estimated evolution of the separate RTI systems. A discussion of alternate scenarios is included.

The core scenario is not based on specific technical solutions, but represents an "information service pull" rather than a "technology push" scenario. Our Delphi method reveals some of the expectations from RTI development rather than the preferred technology. The scenario method used was chosen to highlight the systems problems and possibilities in a broad issue such as the Road Transport Informatics Evolution.

An attempt to summarize the first and second round responses gives the following results:

1. Road transport mobility is believed to have a vital and growing role in most societies.

2. Today's road transport problems can act as driving forces. Solutions must be sought for the following problem areas:

   - Economy (road capacity, availability, efficiency, costs for roadside equipment and extra costs for vehicles)
   - Traffic and congestion growth
   - Environment (air pollution, noise, land use)
   - Safety (risks, consequences, suffering)
   - Comfort (monotonous highway driving vs. uncertainty and traffic stress)

3. There is a strong consensus among the panelists that Road Transport Informatics (RTI, i.e., information, communication, control and automation technology/systems) is capable of alleviating some of the above problems and making road transport better in many ways.

4. Drastic improvements are possible for road traffic and can be achieved if qualified technology and intelligent systems are introduced in careful, selected steps.

5. There seem to be no direct cause-and-effect links between "Driving Forces, Technologies, Information Services, Events and Social Impacts". The multitude of factors and forces involved makes many systems solutions possible. The benefits of one subsystem may be marginal in themselves, but if introduced as part of an integrated solution, that subsystem may yield larger benefits.

6. There were only a few weak warnings from our panel of possible negative aspects, risks or pitfalls from introducing RTI. Most panelists agree that something has to be done about the problems and think RTI offers the best possibilities.

7. Centralized and automated identification of different sorts is perceived as a threat to personal freedom. Citizen sensitivity to identification systems can pose a major barrier for convenient and effective solutions.

8. The responses indicate that driving forces exist for developing automation and system integration to high levels, provided these solutions prove capable of drastically reducing accidents, environmental pollution and traffic congestion while simultaneously increasing driver comfort and transport economy.

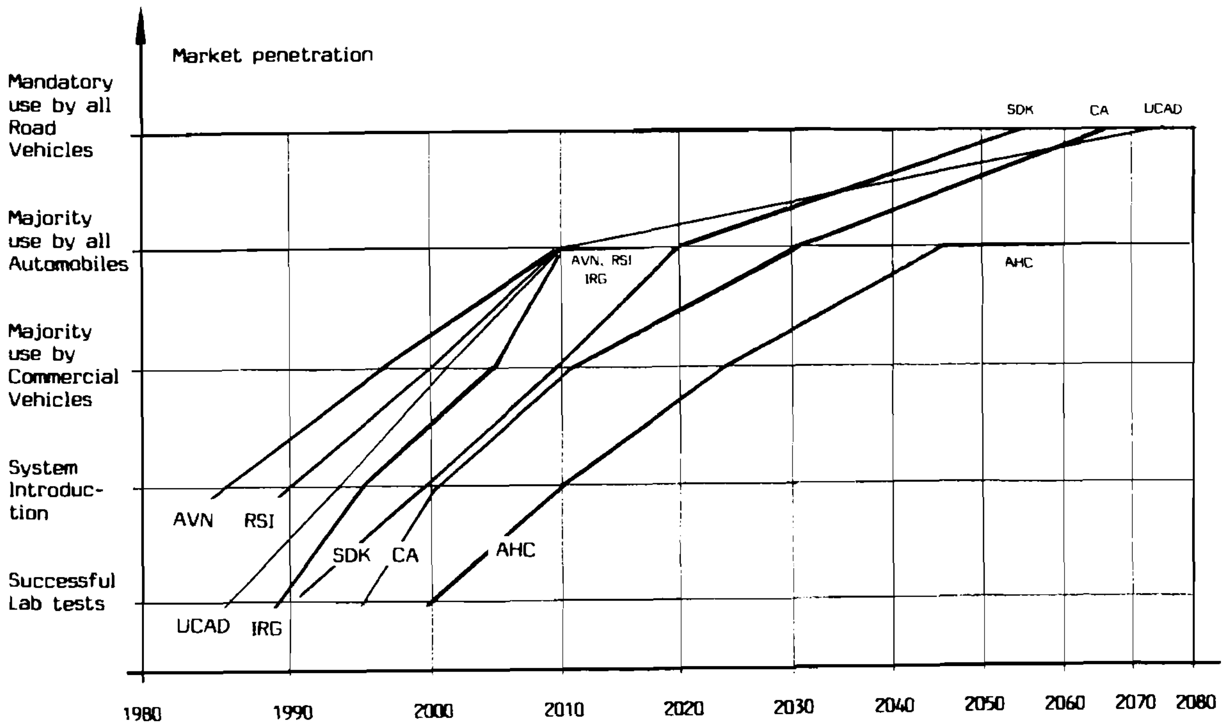
Our system conclusions from the first round and from state-of-the-art reports are that a number of RTI categories can be used as a basis for assessing events. The following RTI categories seem feasible for reasons of technical complexity, cost/benefit, the need for integrating the vehicle and roadside equipment and/or the need to have all vehicles equipped to a common standard.

1. Autonomous Vehicle Navigation (AVN)
2. Road Service Information (RSI) on facilities along roads, road conditions, local weather, traffic congestion and accidents
3. User Cost and Automatic Debiting (UCAD)
4. Interactive Route Guidance (IRG) for navigation and traffic flow improvements
5. Speed and Distance Keeping (SDK) for safe, rapid driving in platoons with short distances between vehicles
6. Collision Avoidance (CA) for safer driving in lanes
7. Automatic Highway Chauffeuring (AHC)

The implementation of items from the RTI categories, when developed into systems, can start at different times, proceed at different rates, and reach different levels of market penetration. A possible future market penetration of RTI systems is thought to pass the following significant levels:

1. Successful laboratory tests / pilot tests
2. Commercial system introduction
3. Majority use by commercial vehicles and cars in business use
4. Majority use by all automobiles (i.e., commercial vehicles, cars in private and business use)
5. Mandatory use of the system in all road vehicles

In a diagram with a time axis and a market penetration axis we can present the panelists' time estimates on events as a curve for each RTI system. The RTI implementation can thus be summarized in the core scenario as shown below. By using the median values we present a scenario, giving the best consensus estimate from panelists on what can happen and when.



Some characteristics of the core scenario are:

- The market penetration curves are based on panelist median estimates on when different RTI events can occur.
- Note the convergence of AVN, RTI, UCAD and IRG curves as a majority use on all automobiles by 2010. This can be a starting point for synergistic system solutions.
- Systems for automated driving, SDK, CA and AHC will come later than the information-oriented systems.
- A mandatory use of RTI can come late or not at all.

The impacts of an estimated RTI implementation can be summarized in the following way:

- All seven RTI systems can improve convenience, comfort and the drivers' feelings of security.

- The vehicle purchase price will, according to estimates, increase by 1% if a UCAD system is added, by 25% if an automatic chauffeuring system is added and by 5-10% each if an RSI, IRG, SDK or and CA system is added.

- Lane capacity can be increased some 10% by using either the AHC or SDK systems.

- Traffic safety is expected to improve by 30% if CA systems are used, and some 42% if all RTI systems are implemented.

- RTI systems are expected to have only small impacts on emissions.

- The two most important actors can, according to the panel's responses, be the IT industry and road administrations.

- Strong action is also expected from the trucking industry, company car owners and professional drivers. This supports our assumption that the commercial fleet market will be interested in RTI development before the private car owners are.

- Cost is assumed to be the main barrier for RTI. If initial investment costs and/or systems operating costs are too high, a mass market for RTI systems will not develop.

A DELPHI PANEL-DERIVED SCENARIO ON ROAD TRANSPORT INFORMATICS EVOLUTION

Ove Svidén

Department of Management and Economics
Institute of Technology
Linköping University
S-581 83 Linköping, Sweden

1. BACKGROUND

1.1. A History of Road Information Systems

In the beginning of this century a mechanical device called "Jones's Live-Map" was marketed as a "phonograph of the road" (6). It gave information to car occupants via a disk attached to the vehicle's odometer. The inventor of the device claimed that it would replace maps and guidebooks.

At the New York Exhibition in 1939 a model was shown of road vehicles driving automatically in smoothly moving platoons. Twenty years later, General Motors demonstrated automated driving of vehicles on a test track. The vision of Automatic Car Controls for Electronic Highways was proven to be technically possible (7).

The car radio for entertainment has been developed during the last four decades to include tape cassettes, Hi-Fidelity and stereo. It is now a mass product beginning to be used for traffic information for drivers. Local radio stations can give detailed information to drivers on weather, congestion and traffic accidents.

During the last decade, commercial vehicles and cars in business use are often equipped with expensive communication equipment such as mobile radios and/or mobile telephones. A qualified bi-directional communication with vehicles in a commercial fleet can be cost-beneficial.

During the 1970's a number of system concepts were tested in the world. In the USA, ERGS, an Electronic Route Guidance System, was developed by the Federal Highway Administration. In the Federal Republic of Germany, ALI (Autofahrer Leitungs Information) was tested. In Japan the CACS project was developed and tested for over a year in Tokyo.

By 1985, the COST 30 (8) study on information technologies for road traffic performed by the European Commission presented some 30 different systems on navigation, communication, route guidance, road information and automatic identification. Most systems developed during the 1970's were based on transistor technology. Systems usually proved to be technically feasible, but with a too high cost/benefit ratio.

1.2. Some Recent System Developments

The microcomputer represents a breakthrough for improving road information systems. Microchip computers are being used in cars today for ignition control, anti-lock brakes and for smart radios switching automatically to local broadcasting with traffic information.

With general purpose microcomputers and microchip sensors, a new range of possibilities has come into existence. Data link systems, navigation systems and display systems which until now have only been used in modern aircraft, have now become feasible for road vehicles. The rapid decrease in the price of microelectronics opens the doors to private car use of qualified systems.

During the 1980's a number of studies and programs were started to investigate the possibilities mentioned above. A weigh-in-motion system, automatic vehicle classification and automatic vehicle identification development program was started in the USA. It is named HELP, an acronym for Heavy Vehicle Electronic License Plate (9).

Systems for autonomous navigation were developed by industry storing maps on mass memories. Philips presented a system called CARIN using road maps stored on Compact Discs and synthetic speech for guiding drivers (10). In 1986 ETAK, Inc. started to market a navigation and dispatch system (11).

Bosch/Blaupunkt and Siemens are developing a route guidance system using infrared beacons and a two-way data link with vehicles. A major test of this ALI-SCOUT will take place in Berlin during 1988 (12). A similar interactive system, called AUTOGUIDE by its developer TRRL is suggested for London (6). In March 1987 announcement was made of tests in Tokyo for a route guidance system.

At the end of 1985 the European Commission started a planning exercise called DRIVE (Dedicated Road Safety Systems and Intelligent Vehicles in Europe), which was designed for finding a basis for a road information project within the EC (13). Two West European programs on road transport informatics were started within the EUREKA framework: PROMETHEUS and EUROPOLIS. PROMETHEUS is an automobile industry initiated seven-year program for European traffic with highest efficiency and unprecedented safety as its goals. EUROPOLIS has its base in the IT industry and urban traffic management.

1.3. The ARISE Project

The foundation for the ARISE Project was laid in the Future of the Automobile Program, which started in 1980. Its study "Automobile Usage in a Future Information Society" (4), included analyses and scenarios on future information technology for road traffic. The first ARISE study was undertaken for the Swedish National Road

Administration (SNRA) in the Spring of 1984. The first short report (14) described a potential for benefits to society by a data link between computers at the roadside and computers on board vehicles. A feasibility study (5) including a cost/benefit analysis was launched in 1985 by the Swedish National Road Administration. It was decided that until industry embarked upon the RTI system idea, it should benefit from a long range systems analysis study from an international research platform.

The ARISE Project moved to IIASA in the beginning of 1986. The project started by establishing a contact network with concerned people and specialists in government, industry and research.

In October 1986 it was decided to end the ARISE Project at IIASA by making a Delphi panel-assisted creation of scenarios using the widest knowledge base possible for us – our contact network.

The purpose of this paper is thus not only to sum up the Delphi study or the work at IIASA, but also to report on the ARISE activities so far. The scenarios represent a form for summarizing and presenting the conclusions.

We had originally used the acronym *ARISE* (Automobile Road Information System Evolution) as a name for our work. The word ARISE is attractive and has worked well for marketing purposes. However, the word ***Automobile*** was often taken to mean only "passenger car" and not "road vehicles" as intended. The word ***Information*** is not specific enough to cover the communication and automation aspects. Our marketing name had begun to place unintended limitations on our ideas.

The acronym RTI, Road Transport Informatics, suggested by one of the panelists, expresses better what we are studying. Road transport of goods and passengers is what can be improved by informatics (i.e., by means of information, communication and control technology).

The well formulated responses from the first Delphi round quite forcefully lifted the issue from an exercise in systems engineering to a study of traffic planning issues from a social science perspective.

2. PROBLEM FORMULATION AND METHODOLOGY

2.1. The Aim of the Study

The ARISE activities at IIASA have created a network of researchers and professionals who represent an impressive resource of knowledge and expertise in the field of RTI. There also exists a considerable amount of background material which provides a rather detailed and updated survey of the state of the art.

How could these resources then be used to provide insights into the enormous potential that modern computer and communication technologies offer in the driver-vehicle-road environment system? Scenario writing is a methodology which is particularly well suited in this context for the following reasons:

- The number of conceivable different systems is basically unlimited, and the systems do not lend themselves to any easy or natural structuralization.
- There is a simultaneous change at all levels which makes it impossible to identify a stable system environment against which any technology may be specified, developed and evaluated.
- The stimulus for change is sufficiently great to provoke shifts in traditional organizational patterns, which again makes straightforward analysis of the potential of a single technology extremely shaky.

Our aim is to create new and better scenarios on how new information systems for improved road traffic can evolve. What are the driving forces? Who can act? What are the pitfalls? Failures? Who can benefit? Who can pay the costs? What are the social prerequisites? What are the social impacts? How do different actors, stakeholders and road-users view future evolution? Will truckers use the new functions before they reach the automobile drivers?

It is our hope that the scenario perspectives will be of value for policy making in road traffic and safety management as well as in industrial research and development. The study material may also be used to advantage for lectures, seminars, workshops, role-playing and/or mini-Delphi studies.

2.2. The Issue

The starting point is our conviction that modern information and microelectric technology can be used to improve road traffic radically. By using sensors, data link technology and computing capacity in vehicles, at roadsides and in traffic control centers a new set of road information services can be designed. The following results can be expected:

- Truck and automobile driving can become more comfortable and efficient.
- Traffic flow can become smoother and emissions can be reduced.

- Lane capacity can be increased.
- Road transport economy can be improved; time and fuel can be used less wastefully.
- Road traffic can become dramatically safer.

The evolution of the Road Transport Informatics that will yield the above results is the issue of this study.

2.3. The Delphi Method

A critical issue is how to involve and make best use of the knowledge in the contact network while creating the scenarios. RTI involves the interests of individuals, industries and the society as a whole. Any scenario will therefore implicitly contain a set of values reflecting some trade-off among these interests. If the scenario is to be used in a research context, it is of great concern that this set of values should be explicitly states or at least be made transparent by the procedure through which the scenario is shaped.

A natural way of illuminating the normative elements is to structure the communicative process between IIASA and the researchers in the network in such a way that the transparency criterion is met. This is best done if it is immediately realized that the way the contact network was built implies that any research effort at IIASA carries with it a distinct *action* research element.

The Delphi method is a well-established way to exercise communication with a group of individuals in a network in the disciplined manner which is required in an action research effort. It was therefore decided to produce the scenarios in a carefully planned and monitored process, where a suitably defined group of individuals in the project network act as a Delphi panel.

By making this decision, we have chosen a "procedural paradigm for policy making" as described in a paper by John A. Sutherland (2).

Policies are normative in nature, generally broad, usually long-range formulation-based constraints on action. Sutherland suggests a procedural discipline that does not constrain a priori the substance of the future. Using crude extrapolation, historical projection or analogy-building "we run the risk of restricting the results of our analysis by the instruments of our analysis" (2).

The method suggested by Sutherland:

> is Janus-faced and has one face turned towards imagination, evaluation and axiological inputs while the other face scans the empirical domain for relevant facts, experiences or objective data. . . . Thus, the method appropriate for normative system-building would rest somewhere between the abject intuition of the science fiction writer and that expirist-positivist platform which dominates modern science and knows only facts and figures. (2)

In his paper Sutherland suggests a number of scenario-building steps. Starting with a syncretistic Utopian scenario which explains a consistent set of desired properties, the Delphi method then applied yields feedback. The panelists formulate their expectations (probability and/or desirability) of events and issues in question. The panelists then seek to find out gaps and suggest ideas for reducing the gaps in the scenario model being developed.

The Delphi method used must work first towards forming a consensus even if considerable divergence is expected to begin with. In later stages of this action, research can produce adverse scenarios which in turn can be the target for consensus seeking Delphi rounds.

Sutherland describes a number of steps involving interactions between a surprise-free and a nominative scenario for the development of a network model and a set of policy action proposals. A full use of the method would require somewhere between five and ten Delphi rounds. As our time schedule only allowed for two rounds, Sutherland's scenario-building theory cannot be used *in extenso*. It remains, however, an important source of inspiration.

The necessary simplifications seem acceptable to us, however. The Delphi method does offer room for ample individualization, as long as the systems theoretic framework is clearly identified.

2.4. Conceptual Model

We are using the model in *Figure 1* as a common base for our Delphi scenario creation. In the center is the actual **Road Transport Informatics (RTI)** with its characteristic hardware and software. The RTI will be described in terms of **technical subsystems and their related software.** On the left-hand side of *Figure 1* are the **actors** whose behavior is characterized by their **values,** and on the right-hand side are the **system designers,** who have a set of **technologies** at their disposal.

Using a systems theoretic language, the actors, the system designers and the RTI may be seen as subsystems, characterized by parameter sets of values, technologies, technical subsystems, respectively. The interaction between the three types of subsystems occurs through **events** which modify the RTI and are initiated by the system designers, **services** from the RTI, and finally, the **evaluation** of the overall system which the actors perform according to their values. Their evaluation, which is aimed at identifying and judging driving forces and social impacts, serves as input to the system designers as they work to improve RTI.

Time is a central variable. A complex new road traffic system must be introduced gradually. A system introduced on all new automobiles beginning, for example, in 1987 cannot be an automobile fleet characteristic before the year 2000. Some cars have a life expectancy of as much as 20 years. Customer demand also follows an evolutionary pattern. Developing products and markets for them takes time. Overcoming institutional barriers and setting international standards also takes time.

To describe the above time dimension of RTI, the RTI Evolution, we will use the **event** concept.

In the process of creating a scenario, the **scenario writer may be seen as taking the role of the system designer, while the Delphi panel** takes the role of the actors. The idea is to simulate the system together. The task of the panel is to predict how future actors will play their roles, while the scenario writer processes their evaluations into the desired services from the RTI system, using his imagination and creativity.

In this way, interaction between subsystems running through the loop is replaced by interaction between the scenario writer describing ARISE and the Delphi panel members. Thus, a scenario can emerge through a series of rounds which describe RTI in more and more detail while simultaneously making the appropriate changes.

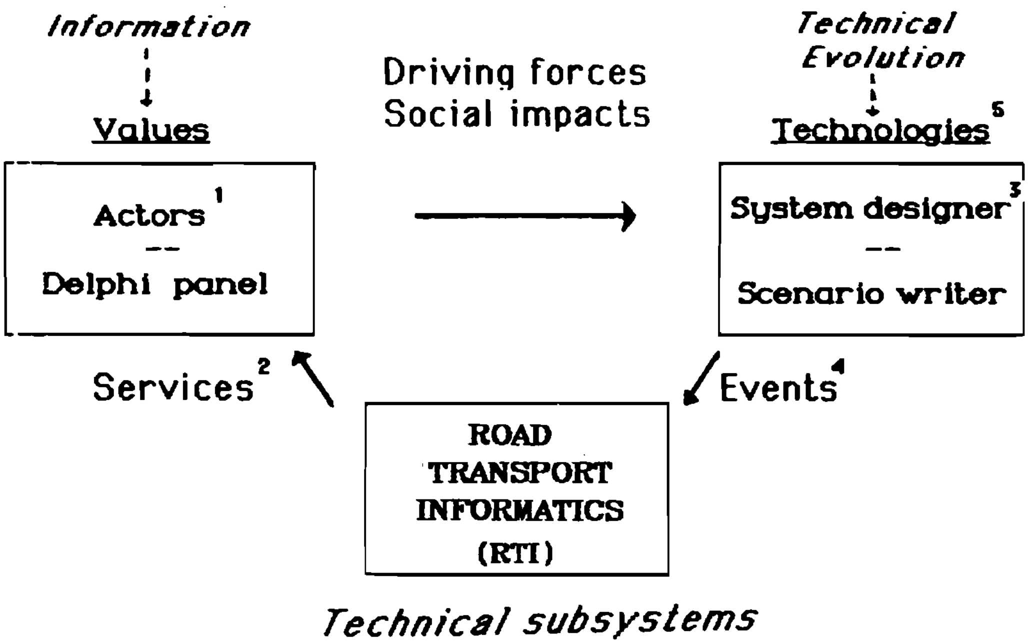


Figure 1. Conceptual model of scenario building as an interaction between three subsystems, where a Delphi panel represents the actors (see definitions in the footnotes below) and the scenario writer takes the role of the designer of the Road Transport Informatics (RTI).

---

1) **Actor** – anyone in a position to influence the evolution of RTI, such as road managers or planners, industry representatives, road users, etc.
2) **Services** – any output from RTI that creates/yields some utility for any of the actors.
3) **System Designer** – Anyone that in his profession or designated role can directly influence the RTI characteristics, such as members of legislatures, industry or road administration engineers, etc.
4) **Event** – any significant step towards introduction/implementation of any element of a road information system, such as legal or policy decisions, investments in systems hardware, etc.
5) **Technologies** – a toolbox of hardware and related software with potential use as components or subsystems in future RTI.

2.5. The Delphi Panel

From the 400 members of the contact network, 120 were asked to participate in our panel. In the same letter they received the material needed for the first round. We got 54 answers in time and asked only these to help us with the second round. We then received 31 responses from the second round.

In the first round we had asked panelists to identify their roles and geographical bases. The panel's composition is shown in the following matrix:

DELPHI PANEL COMPOSITION MATRIX

	Total Number of Invited Panelists	1st Round	2nd Round
Geographical composition			
Western Europe	57	25	13
North America	35	19	13
Japan	15	6	3
Newly Industrialized Countries	8	3	1
Eastern Europe	5	1	1
TOTAL	120	54	31
Position/Role			
Government	35	24	14
Industry	20	11	6
Other (Research, consultant, road-user, organization)	65	19	11
TOTAL	120	54	31

To the above number of panelists we had six late answers to the first round and four to the second. Due to the very limited time available these late answers could not be included in the draft summary or the statistical treatment.

The rapid shrinking of the number of panelists can be explained primarily by the time limitations. We gave the panelists only four weeks including Christmas for the first round and the remaining group only two weeks in mid-February 1987 to answer the second round. Limited to two rounds, we overloaded the panelists with extensive questionaires and requests for detailed quantitative estimates. The large number of panelists and the quality of their answers has, however, given us a better base than anticipated for the scenario creation.

The Delphi method as developed by Olaf Helmer (1) requires that panelists work independently without consulting each other for consensus outside the control of the experiment leader. This is one of the explanations for our efforts to keep the identity of the panelists secret.

In an attempt to avoid overloading the panelists with too much unpaid work, we asked them in both rounds for their expectations , intuitive estimates and educated guesses, on the issues presented. We wanted participants to act out of their personal judgement and experience and not from their positions in various organizations. Thus, in our material there can be ideas and opinions that are based on proprietary information or that indirectly criticize a panelist's own organization. As researchers we cannot know the real quality of an estimate. This is our second argument for not disclosing the names of our panelists. We do not want to be the cause of harm, embarassment or ridicule to the sources of our information.

> There are no hard facts about the future. There are no scientific instruments in existence that can record and register the future. Man himself is the only instument available that can express an image of the future. Man's values, beliefs, ambitions, will power, creativity, ideas, intuition and empathy more than his analytical ability, help him grasp the future.
>
> (*Ref. 3*, p. 686)

In the first round letter we asked each panelist to identify the role from which his response was given. The first round answers gave us a reminder: A well articulated vision about the future is not necessarily related to a position in an organization or a role in society! Therefore, we did not pursue the role playing idea any further in the second round. As true human beings and generalists, most panelists expressed their empathetic capacity by assessing how 17 different actor groups would act or react on the seven RTI categories suggested. Besides that, a number of gaps were found and solutions were formulated for filling them.

2.6. The Delphi Process

The objective of the Delphi method is, according to Helmer (1),

> to obtain the most reliable consensus of opinion of a group of experts. It attempts to achieve this by a series of intensive guestionnaires interspersed with controlled opinion feedback.

The method further dictates that some five questionnairs should be submitted at intervals to a selected group of specialists that are not in contact with each other. Avoiding direct confrontation of the experts with one another, reduces bias coming from a dominant member of the group. An open-ended extra-preliminary round has been recommended (1) to help delineate the subject matter of the inquiry. In our case, a Round 0 was performed in 1986 when the ARISE feasibility study with its intuitive scenario (5) was sent to prospective contacts.

An invitation letter and the Round One questionnaire were mailed to the participants on December 12th, 1986. The questions were very open-ended, asking for new entries which would be considered in the subsequent round.

The responses were requested to be in our hands no later than January 20th, leaving about four weeks, including the Christmas holidays, for panelists to respond.

We grossly underestimated the volume and quality of the responses. To digest the material, to make a synthesis and a second round questionnaire in two weeks time proved to be a most demanding intellectual challenge! In order to make a meaningful quantitative-oriented questionnaire it became necessary to structure the issue very strictly. The seven-category RTI structure (AVN, RSI, UCAD, IRG, SDK, CA and AHC) was conceived over the weekend available and was used as a core for our questionnaire design.

The second round letter and questionnaire was mailed on January 30th. Participants were requested to have their responses in our hands no later than March 2nd, leaving the panelists some two to three weeks to respond. The questions asked were quite "nasty" asking for quantitative estimates along a strict structure, defined for the first time in that letter. We had a few comments on the difficulty. Many objected to the formal structure and gave qualitative comments to most of the quantitative estimates given. We got suggestions for new RTI categories. Some 50% of the first round respondents were not able to or did not want to participate in Round Two.

The two rounds confirmed that the Delphi process represents a "spiralling dialogue" between a "system designer" and a panel giving impulses for the system design. The panelists are both experts with specialized knowledge about the issue studied and can take the role of different actors in society who act for or against the issue.

The panelists can give the issue its social dimension by formulating driving forces and assessing social impacts. The system designer absorbs this information as a "specification on societal values" searching in his "tool box" of technologies for system solutions meeting the demand from society as formulated by the panelists.

The system design is in itself an analytical task and a synthesis. A careful scanning of all data, a frustrating maturation process before new concepts and solutions can be formulated. This is a formulation process in the language domain. Looking back on his crude formulations in Round 0 and Round 1 reminds the system designer of this maturation process. In our case, the formulation process ends with a scenario.

2.7. Scenario Writing

According to the Oxford dictionary, a scenario is "a sketch or outline of the plot of a play, giving particulars of the scenes, situations, etc." We have used this original definition from the theater world to give out scenario a format. Scenes have been constructed for the years 1990, 1995, 2000, 2010, 2020 and 2040. Some science fiction is included as an epilogue. In these scenes we describe traffic, the use of RTI systems and some policy problems of implementation.

The scenario scenes are based on the median values from panelists' estimates on events. These estimates define when different RTI services are expected to be available and to what extent they will be used by various road users, and thus their influence on traffic.

As a part of a Delphi process the scenario scenes are expected to indicate some form of consensus. We have no better consensus than median values on event estimates. These values represent a sort of surprise-free scenario giving us the strongest consensus for what is to be expected in the future for RTI.

Based on individual comments and discussions about actors' impacts and barriers, a number of alternate scenario paths have been suggested for the different RTI systems. These alternatives have not been synthesized into scenario scenes.

The scenario writing task in itself, when based on a wide range of factors over a long time, can best be described by quoting my article "A Scenario Method for Forecasting" (3).

> The tedious maturation process from analysis of such a wide range of data until the formulation of the scenario synthesis, can be described as applied systems analysis. It is a search for elegant systems combinations bridging the factors and the forces involved. An artistic element is needed to synthesize all criterias from technology, economics and politics.
>
> The time dimension arises as a key variable in the synthesis stage. One has to judge the time needed from ideas to innovation, from product introduction to market dominance, from stagnation to phase out.
>
> The scenario scenes represent a method to describe the time needed for the evolution of new solutions, systems and their acceptance and everyday usage. This work is the most frustrating part of scenario writing – relating everything to everything in cross-matrix effort haunts you mentally during days and keeps you awake at nights. The final scenario synthesis can be correspondingly rewarding.

2.8. General Comments

This study has been conducted under time and budget constraints. This limits the quality, reliability and validity of the results in a number of ways. The first limitation is the number of Delphi rounds. A Delphi study with crucial interactions with and feedback from a large panel of experts has to include at least five rounds to get the necessary convergence. We used only two formal rounds. The results from the last one showed both a possibility of convergence and that of a split in the clusters supporting alternate scenarios. This is exactly what was to be expected according to Sutherland (2), and what would form the basis for a questionaire in the next round. A second limitation is the panel composition. We made an open invitation to 120 persons to participate. Interest for the issue and time available is assumed to have been the key factors why so many (60) helped with the first round questionaire. We were astonished to find many creative perspectives on industry from government respondents, and well formulated comments on how society works from the industry side. We have been flattered to see so many constructive contributions from research, industry and government.

We have indications that most first round responses were made from an "informed generalist's" position and as a passenger car driver. We asked for intuitive estimates and educated guesses and got just that. The responses given do not and should not represent policy statements from organizations or their plans for the future. Thus, we conclude that panelists' estimates represent an expectation of what *can* happen, rather that what *will* happen and when. These estimates offer a basis for a scenario rather than a forecast.

A third limitation for this study is that proprietary industry information on technology and its state-of-the-art is not available and explicit. The inventions, R & D efforts and capital in industry will have a major influence on future RTI systems. Our study can only map the prevailing expectations today for possible RTI categories and their assumed implementation. Thus we can only make a "technology pull" scenario. We hope that this can spur industry to produce a "technology push" scenario that is an elegant solution of all the problems and barriers that are raised in our study.

A fourth limitation is the representativeness of second round quantitative estimates. Due to the three limitations mentioned above, we have only used the quantities given as indications. The statistical analysis has included some ranking and presentation of medians and quartile values. The spread of estimates is usually large. The response from a project leader source can differ with a factor of three from the panelist's median value and be outside the interquartile range.

A fifth limiting factor is language. Have we really understood the real meaning behind the statements made by the panelists in the first round? Did we define accurately enough the systems, events and impacts to give panelists a fair chance in the second round to make the good estimates they had the background for? The articulated comments given by many panelists together with their quantitative estimates indicate to us that our qualities were not always sufficiently well defined. Again, this calls for more rounds to be corrected.

Presenting the result is also a linguistic problem. This written report includes a set of tables, graphs, rankings, summarizing comments, scenario scenes and even some science fiction at the end. But this is only an interim result in a long RTI development process with few explicit conclusions and little regard for the pregnant comments of individual panelists. The scenarios may act as a sort of filter. They represent both a summary and a way of formulating conclusions.

A sixth limiting factor is time. Neither the panelists nor the scenario writer have had adequate time for their tasks. Another aspect is how familiar the participants are to working with the time dimension and with estimating times that are decades or centuries ahead. How should an event estimate such as "never" be treated statistically?

We have used time estimates for the ranking of a possible RTI system implementation. Which system will come first? When can a system integration be expected? We have taken never as an indication that something is missing in the RTI categorization as stated and that our suggestion for a system solution will not be implemented in that form. And, it must be remembered that much of the outcome of this study is still hidden behind an unfinished maturation process within a final limitation: the scenario author himself.

3. ROAD TRANSPORT INFORMATICS EVOLUTION

A definition of RTI categories and a presentation of panelists' time estimates on market penetration events.

From our statistical treatment of the 31 responses we present the results as median and quartile values of the year estimates given for different system events.

3.1. Autonomous Vehicle Navigation (AVN):

On board facilities for positioning, stored digital road map, computer and display/or voice synthesis. The driver is informed of his position and relation to the selected address and the road/street geometry in between. This type of system is assumed to give benefits to the users in the form of time savings, fuel economy and convenience. For commercial traffic, delivery vans, business trips, this can bring economic benefits to the user in order of 10% of the transportation costs.

	Q_1	M	Q_3
E1.1 An Autonomous Vehicle Navigation system (ETAK) has been introduced on the market (1986).		1986	
E1.2 Autonomous Vehicle Navigation is used in a majority (50%) of commercial vehicles and business cars.	1995	1997	2005
E1.3 AVN is adopted for use in a majority of all road vehicles.	2005	2010	2020
E1.4 AVN systems become mandatory for all road vehicles using major road networks.	2040	Never	Never

There is clear consensus among panel members on the general acceptance of AVN systems. More than half of the panelists believe AVN systems will be adopted by a majority of commercial users before the turn of the century with general acceptance (by the majority of road-users) shortly thereafter. The median view is for general acceptance by 2010. Mandatory use is not envisaged: 71% estimates that this level will never be reached.

3.2. Road Service Information (RSI):

A better information in road vehicles about facilities along roads, local weather, road surface conditions, traffic, congestion, accidents, road repair and other restrictions can be of great help to drivers. With an update via beacons, cellular radio or broadcasting stations (RDS), digital information can be sent to vehicles from traffic control centers. The on-board computer edits the information so that the driver is shown only the pieces of information that are relevant to his/her situation just then. A general purpose information display presents the results in such a way that is not in conflict with driving.

The benefits of such advanced RTI will be first of all the convenience for the drivers. Some significant improvements in transport economy, traffic flow and safety are anticipated.

	Q_1	M	Q_3
E2.1 RSI systems are commercially introduced.	1990	1990	1993
E2.2 RSI systems are used by a majority of commercial fleet vehicles and business cars.	1995	2000	2000
E2.3 RSI systems are used in a majority of all road vehicles.	2005	2010	2010
E2.4 RSI systems are mandatory in all road vehicles.	2020	Never	Never

Again, there is consensus on the adoption of RSI systems with innovationbroadly coinciding with the market acceptance of AVN. Panelists were unanimous in the belief that RSI would achieve general acceptance (by the majority of road-users) and 50% of the panelists felt that this level of market acceptance would be achieved between the years 2005 and 2010. As with AVN, a majority of panelists saw little prospect of RSI systems being made mandatory.

3.3. User Costs and Automatic Debiting (UCAD):

Today parking fees are accepted almost worldwide. Tollroads and debiting of transports through tunnels, over bridges and by ferries are used in many places. A major road pricing experiment has been performed in Hong Kong.

Pricing of road usage and parking can be an instrument for traffic management. Rather than entering a central business district at peak hours, a detour for through traffic or a park-and-ride alternative can be made economically attractive.

	Q_1	M	Q_3
E3.0 UCAD bridge toll test in San Diego, California.		1986	
E3.1 Systems for automatic debiting of parking fees are introduced and accepted as a convenient alternative to coin meter systems.	1990	1993	1995
E3.2 UCAD is used in a majority of commercial fleet vehicles and business cars.	2000	2001	2020
E3.3 UCAD is preferred to manual systems by a majority of all automobile users.	2000	2010	2020
E3.4 An advanced UCAD, which includes most forms of costs, taxes and insurance related to the actual use of vehicles in traffic, is required by law on all vehicles.	2020	2075	Never

There is a greater divergence among panelists' views on UCAD than on either AVN or RSI. One respondent argues that UCAD could not be phased in gradually, but would have to be made mandatory for all road users right from the start. The majority of panelists believes that automatic debiting will be introduced and will penetrate the market. Some 43% of the panelists believe that UCAD will never be mandatory.

3.4. Interactive Route Guidance (IRG):

IRG systems are based on communication between roadside traffic computer/sensors and on-board computer/sensors/displays. Drivers receive a digital map in "portions" from roadside beacons for their navigation. Vehicles are used as sensors for measuring traffic flow. The roadside traffic computer can give updated traffic information in digital form to be used for route optimization and guidance in vehicles.

The benefits from the interactive route guidance systems in urban areas are smoother traffic flow, reduction in travel time and fuel savings. By addressing both navigation and traffic control problems jointly, IRG systems can offer more benefits to drivers and society than the previously mentioned three systems together. Even non-IRG-equipped vehicles will benefit from a smoother and safer traffic flow.

	Q_1	M	Q_3
E4.0 Interactive Route Guidance (IRG) experiments in Berlin and London have already proven effective.	1988	1989	1990
E4.1 IRG systems are introduced in major urban areas.	1993	1995	2000
E4.2 IRG is used in a majority of commercial vehicles and business cars.	2000	2005	2010
E4.3 IRG systems are now installed in a majority of all road vehicles, and significant traffic improvements can be measured.	2005	2010	2020
E4.4 IRG is required by law on all road vehicles.	2025	Never	Never

The most significant feature of panelists' responses is their consensus in the rapid and widescale market acceptance of IRG. The range of views (reflected in the IQR bands) is very narrow. Demonstration systems are already available and tests on them are planned for Berlin (1987-88) and London. A majority of panelists believes IRG systems will be introduced before the year 2000 and that these systems will be used by a majority of road-users within the next thirty years. Panelists believe that IRG systems will never be required mandatorily since societal benefits do not depend on high levels of acceptance and the necessary threshold level of market acceptance will be achieved volutarily because of the high benefit to cost ratio offered drivers using these systems.

3.5. Speed and Distance-Keeping (SDK):

Cruise control for vehicle speed keeping has already been introduced as a convenience for driving. The next step in convenience should be to let the distance to the vehicle in front of yours, control your speed. With SDK and anti-lock brakes in all vehicles in a platoon, it is possible to decrease the distance between vehicles.

The first benefits of electronically coupled vehicles in a platoon is convenience for the drivers. Secondly, this function can offer increased safety, by decreasing the likelihood of series collisions due to decision lags in individual drivers. As a third benefit, a denser and more stable traffic flow can be obtained that can double the vehicle-per-lane and hour capacity of a highway. The system can be used in residential areas to make "intelligent" limitations on vehicle speeds, which can replace the asphalt speed-reduction bumps used today.

	Q_1	M	Q_3
E5.0 Speed and Distance Keeping (SDK) systems have been tested with satisfactory results on test tracks.	1989	1990	1995
E5.1 SDK systems are introduced on the fast lanes of major motorways.	1995	2000	2010
E5.2 SDK systems are used in a majority of commercial vehicles and business cars.	2005	2010	2030
E5.3 SDK is used in a majority of road vehicles.	2015	2020	2080
E5.4 Only SDK-equipped vehicles are allowed to drive on major road networks.	2025	2055	Never

A significant minority of panelists (19%) believes that this function, which involves automation, will never be introduced. The remaining 79 percent envisage the introduction of SDK systems towards the end of this century or early next (median = 2000). There is a wide spread of views on how quickly such a system would achieve acceptance. Although the median view suggests that a majority of road-users will have adopted the system by 2024, the IQR stretches from 2015 to 2080. Mandatory use of SDK systems is not envisaged by 40 percent of the panelists.

3.6. Collision Avoidance (CA):

Intelligent road vehicles are collision-proof. With advanced sensor systems on board a vehicle it is possible to give drivers warnings in time for them to avoid running off or crossing the edge of a lane/road, or colliding with other vehicles, road users, pedestrians, animals, objects in the road, etc.

It can be assumed that collision avoidance (CA) systems will first attract truckers and drivers of high performance automobiles. CA systems can become attractive to all drivers if they also offer help in staying in the lane, changing lanes and merging.

The most direct benefits from CA systems would be convenience and safety. They will also have positive effects on traffic flow and road capacity. When a platoon of SDK-equipped vehicles follows a CA-equipped vehicle, all drivers will benefit to some extent from the capabilities of the "pilot" vehicle in front.

	Q_1	M	Q_3
E6.0 Collision Avoidance (CA) systems, based on multi-sensor "awareness" (i.e., radar and IR) have been demonstrated.	1990	1995	1998
E6.1 CA systems are introduced commercially.	1995	2000	2005
E6.2 Some sort of CA system is in use in a majority of commercial road vehicles and business cars.	2000	2010	2015
E6.3 CA systems are in use in a majority of all road vehicles.	2015	2030	2060
E6.4 Only CA-equipped vehicles are allowed on motorways and major road networks.	2025	2065	Never

Of the functions involving "automation" there is greatest optimism and consensus among panelists on Collision Avoidance (perhaps because anti-lock brakes are already on the market and a simple CA system would merely involve linking such devices to head-way sensors). Evidently, a majority of panelists believes a CA system would be both cost effective and capable of yielding sufficient societal benefits to warrant mandatory use. As can be seen in Section 5.4, the CA system is the one which is expected to increase safety most effectively.

3.7. Automatic Highway Chauffeuring (AHC)

Automatically controlled trucks operate today for office postal delivery, for transport duties in manufacturing, in automated warehouses and in mines, and are now being tested for buses.

Technically, this system level implies that information from subsystems/levels 1-6 discussed in previous chapters are given as signals to servos that control vehicle steering, braking and accelerating. In addition, there has to be some way to sense the vehicle's position in the lane.

Convenience is the main benefit of Automatic Highway Chauffeuring (AHC). The dull task of tracking the lane and vehicle ahead while driving can be automated. A platoon of heavy trucks can be driven by a driver in the first vehicle, a tactic which can offer economic benefits to the trucking industry.

Businessmen can use their AHC vehicles as office space, relieved of the tedious tracking task. A short nap can be allowed without disasterous consequences.

A key question for AHC is safety. AHC has to be designed to improve safety. (AHC can be compared with the automatic landing systems for aircraft which had a tenfold increase in safe landings as one of their principal design criteria.) If proven unsafe in any way, AHC will be abandoned. However, a good AHC design may become a decisive way to increase road traffic safety.

	Q_1	M	Q_3
E7.0 Automatic Highway Chauffeuring (AHC) has been demonstrated on test tracks for performance, reliability and safety during a 3-year endurance test.	1995	2000	2010
E7.1 AHC lanes are introduced on a motorway network.	2005	2010	2035
E7.2 AHC is in use in a majority of commercial vehicles and high performance "office" type automobiles.	2015	2023	2060
E7.3 AHC is used in a majority of road vehicles for convenience and safety on all motorways and highways.	2030	2045	Never
E7.4 AHC systems are mandatory for driving on major road networks.	2045	Never	Never

Four view points are represented in the above responses:

1. AHC will never be introduced (13%).
2. AHC will be introduced and achieve commercial acceptance (79%).
3. AHC will be introduced and achieve both commercial and general acceptance (68%).
4. AHC will never be made mandatory (54%).

4. IMPACTS

In the Second Round Questionnaire we included a number of questions on expected impacts from different RTI systems. In the text below we highlight the results. In the tables we summarize the panelists' estimates.

4.1. Qualitative Impacts

The responses to the qualitative questions enable us to rank the following qualities in descending order of importance.

1. Convenience in vehicle use.
2. Comfort and well-being.
3. Sense of security.
4. Sense of safety.
5. Marginal utility.

RTI systems are expected to do most to improve the convenience and comfort of driving. Better navigation, weather and traffic information will do much to improve the driver's sense of security. The sense of safety, i.e., perceived safety, is expected to increase as a result of the use of more automated driving.

A collision avoidance system is deemed to be the best solution for increasing the sense of safety. A system for interactive route guidance (IRG) is expected to bring about the largest increases in convenience and comfort in driving. A significant improvement in marginal utility, i.e., the possibility to use in-vehicle time for purposes other than transport, requires a system for automatic chauffeuring. Automatic Debiting is regarded as a minor improvement in convenience.

In the following matrix the panelists' responses are quantified and summarized. A major positive response (++) has been given the weight of +2, a positive (+) = 1 and a negative effect (-) = -1.

	AVN	RSI	UCAD	IRG	SDK	CA	AHC	$\sum$
Convenience in vehicle use	26	30	16	34	23	27	26	182
Comfort and well-being	25	30	3	31	22	27	22	159
Sense of security	25	22	1	24	18	22	13	125
Sense of safety	7	18	-2	14	25	38	21	121
Marginal utility	2	6	0	8	13	9	33	71
$\sum$	85	106	18	111	101	143	115	

4.2. Costs for RTI Systems

Vehicle purchase price is expected to rise on the order of 5% for adding either an AVN or an RSI system, and 10% for either an SDK or a CA system. The panelists expect that an automatic chauffeuring system may add 25% to the cost of the vehicle as a median value.

Increases in fixed annual costs for using the systems are expected to be on the order of 1 – 5%. Operating costs for the systems are expected to be low, and not to increase vehicle operating costs per km more than by one percent. The matrix below summarizes the panelists's responses on expected costs. Their estimates on percentage increase for the parameters above have a large spread. The first quartile (Q_1), median (M), and third quartile (Q_3) values are given in the matrix. Fifty percent of the estimates fall between Q_1 and Q_3.

	AVN	RSI	UCAD	IRG	SDK	CA	AHC
Vehicle purchase price							
Q_1	5	3	1	5	5	7	15
M	5	5	1	7	10	11	25
Q_3	10	5	5	15	15	20	50
Fixed annual costs							
Q_1	0	1	0	1	0	-5	1
M	2	4	1	4	1	2.5	5
Q_3	5	10	10	10	2	7.5	10
Operating cost per km							
Q_1	-1	-5	0	-5	-5	-2.5	-2
M	0	0	0	0	-0.5	1	1
Q_3	2	2	2	5	2	4.5	10

4.3. Travelling Speed and Lane Capacity

Lane capacity can be increased in the order of 10% if using either a speed and distance-keeping system or automatic chauffeuring. Interactive route guidance can improve traffic flow and is expected to improve lane capacity by 5% by panelists.

Systems for RSI and IRG can result in about 5% increase in average speed. AVN, CA and AHC systems may give 2%. (These figures can be related to the possibility of reducing the travelling time by 8 – 12% by helping drivers find better routes according to TRRL, *Reference 1.*

Travel time predictability, i.e., the percentage improvement in the deviation between real travel time and the estimated travel time, is expected to improve by 10% if using an interactive route guidance system.

The panelist's percentage increase estimates are given in the following table as first quartile, median and third quartile values.

	AVN	RSI	UCAD	IRG	SDK	CA	AHC
Lane capacity							
Q_1	0	0	0	0	5	0	2.5
M	0	0.5	0	5	10	2	10
Q_3	1	5	1	6	20	15	50
Average travelling speed							
Q_1	0	1	0	3	-5	0	-7.5
M	2	5	0	5	1	2	2
Q_3	5	5	1	10	5	10	12.5
Travel time predictability							
Q_1	1	3	0	5	0	0	0
M	5	5	0	10	0	0	3.5
Q_3	10	10	0	20	5	5	20

4.4. Safety

The collision avoidance system is the most powerful tool for increasing safety according to panel estimates. Decreases of some 30% in both road traffic deaths and incidents with material damage are expected.

Automatic chauffeuring and functions for speed and distance-keeping are expected to increase safety by some 5 – 10% each. RSI and IRG systems may bring about some 1 – 4% improvements in safety.

As can be seen from the panelists's responses, shown as first quartile, median and third quartile below, there is a large spread in the estimates. The numbers represent percentage increases (+) or decreases (-) in the numbers of traffic deaths and incidents with material damage, respectively.

%	AVN	RSI	UCAD	IRG	SDK	CA	AHC
Number of traffic deaths							
Q_1	-1	-4.5	0	-5	-25	-50	-50
M	0	-1	0	-2	-5	-30	-10
Q_3	0	0	0	0	-1	-3	-1
Number of incidents							
Q_1	-5	-10	-0	-10	-30	-50	-50
M	-0.5	-2	0	-4	-5	-30	-7.5
Q_3	0	0	0	0	-1	+2	+10

4.5. Emissions

The panelists' responses indicate that some small, 0 – 2% improvements in emission levels, are possible as a result of RTI systems. Only small reductions in noise levels are expected according to the qualitative assessment asked for in the second round questionnaire.

The percentage decrease in harmful emissions expected is given in the first quartile, median and third quartile values in the table below.

Percentage	AVN	RSI	UCAD	IRG	SDK	CA	AHC
Emissions							
Q_1	-2	-5	-1	-5	-5	0	-8
M	0	-1	0	-2	-1.5	0	-2
Q_3	0	0	0	-1	0	0	0

5. Actors

An RTI evolution has to be carried out by a will to develop and implement a large amount of new technology both in vehicles and at the roadside. The panel's responses lend support for the following overall ranking (in descending order) of the various actors in regard to their expected support for RTI development.

1. **IT Industry** (computers, electronics and telecommunications)
2. **Road administrations** (road building, maintenance, operations)
3. **Trucking industry** (transport companies, forwarders, truck fleet owners)
4. **Traffic safety administrations**
5. **Company car owners**
6. **Professional drivers** (including truckers, service car operators, business drivers in cars)
7. **Rental car industry**
8. **Automobile manufacturing industry**
9. **Political organizations** at local, national and international levels
10. **Private car drivers**
11. **Bus operators**
12. **Taxi operators**

That the IT industry should have an interest and lend strong support to RTI development could be expected. Note also the strong support expected from professional road users, traffic and road infrastructure organizations and the relatively low profile expected of the automobile manufacturing industry.

The support/interest of actors towards the different RTI categories suggests the following ranking:

1. **RSI** – Road Service Information
2. **IRG** – Interactive Route Guidance
3. **AVN** – Autonomous Vehicle Navigation
4. **SDK** – Speed and Distance-Keeping
5. **CA** – Collision Avoidance
6. **UCAD** – User Cost and Automatic Debiting
7. **AHC** – Automatic Highway Chauffeuring

Information and guidance rank high while automatic debiting of user costs and the automatic highway chauffeuring find little panel support. The above rankings are based on the summary matrix on the next page. It gives a mathematical summary of the panelists' responses. Strong support (++) equals +2; positive and active interest (+) equals +1. For a distinctly negative reaction (-) we assigned the value -1; a strong counteraction (--) received -2.

Note the strong interest from the IT industry in IRG and AVN systems. Professional drivers, taxi drivers and private car drivers are expected to show the strongest interest in RSI systems. Road administrations are expected to be more attracted to UCAD systems than other actors. Taxi operators and unions can be expected to react most strongly *against* automatic chauffeuring systems.

ACTORS SUPPORT								
	AVN	**RSI**	**UCAD**	**IRG**	**SDK**	**CA**	**AHC**	**Σ**
Politicians	16	24	17	25	23	17	6	128
Road administration	17	38	41	38	32	32	22	220
Traffic safety admin.	24	35	14	32	37	26	8	176
Professional drivers	37	43	13	39	17	14	1	164
Car drivers	25	40	-6	23	14	12	4	112
Company car owners	29	33	11	38	18	22	16	167
Rental car owners	27	34	16	24	22	20	12	155
Bus operators	17	28	10	27	18	7	-1	106
Taxi operators	23	41	8	32	-1	-1	-12	90
Trucking industry	37	39	13	36	26	26	22	199
Auto. manufacturing ind.	38	30	3	32	17	21	14	153
Auto service	17	20	7	18	12	7	8	89
Electonics & computer ind.	43	40	40	48	40	38	36	283
Other road users	13	17	3	17	9	0	-8	51
Unions	3	12	-10	6	7	-2	-18	-2
Political parties	8	13	2	15	12	12	4	66
Other. Insurance & traffic managers	5	7	9	9	6	5	1	42
Σ	369	494	192	459	309	256	95	

6. BARRIERS

Most barriers can be overcome by successful ideas. The problem is to find ideas that track on latent social and economic needs.

— A panelist

A nearly endless list of barriers can be thought of for any development such as those discussed in the preceding chapters. Barriers can delay or prevent a development that is planned or has already started. The panelists responses suggest that barriers against RTI development can be ranked in descending order of importance as follows:

1. Initial investment cost and/or system operating costs.
2. Liability and legal issues. (Who will be responsible for a major system breakdown and a resulting crash that could involve hundreds of automatically chauffeured vehicles? What will the legal consequences be if a route guidance system sends drivers into one-way streets from the wrong direction?)
3. System reliability (a high tech requirement on a mass-produced consumer product)
4. Cost to drivers not justifiable. (The benefits from a system may not sufficiently outweigh its purchase price.)
5. Driver opposition regarding civil liberties. (Identification and possibility for "Big Brother" to track the position of individuals)
6. Drivers' psychological opposition (i.e., overcoming resistance of the idea that one's safety is being left up to automated systems)
7. Technical (i.e., how can systems be design that both increase safety and lane capacity?)
8. Drivers' opposition to user charges.
9. Ergonomics. (Systems that are not user friendly will not be used.)

BARRIERS SUMMARY MATRIX*

	AVN	RSI	UCAD	IRG	SDK	CA	AHC	sum
Initial investment and/or system operating costs		2		14		5	6	27
Non-justifiable costs for drivers	10	5		2			3	20
Ergonomics	4	1		1				6
Military/strategic	3	1						4
Technical	1	4		2	1	3	6	17
Problems of mixed operation; Superimposition on existing network systems			2				2	4
Generating threshold demand		2						2
Opposition from vested interests, e.g., labor		1				1	2	4
Driver opposition a) civil liberties			14	1	2			17
Driver opposition b) user charges			7					7
Driver opposition c) psychological					5	4	8	17
Need to establish standards				1				1
System reliability					12	4	8	24
Liability & legal issues				2	6	8	10	26

* Number of respondents who have indicated barriers and for which RTI system these barriers may occur.

6.1 Barriers to Autonomous Vehicle Navigation

Respondents see few barriers apart from cost-effectiveness for drivers. It is costly to achieve the level of accuracy and reliability needed for a system to be useful. The costs would be likely to out weigh the benefits for most private users. Most drivers will not find these systems cost-justifiable and therefore fleet operators will be the main market for some time. The potential for "driver distraction" and "information overload" is also a concern.

6.2 Road Service Information

Setting up base information networks, collecting real-time information, central processing and tranmission are expensive. Credibility depends on information quality, implying either a cost-effectiveness problem *or* a problem of generating the critical threshold user demand for system viability. This is more significant in small countries and less densely trafficked areas. There is the question of ***who*** would set up and run RSI systems. Public investment is unlikely to be forthcoming owing to spending cuts (especially since this would be a new area of spending). In the US particularly, there is a shortage of commercial radio spectra for long distance coded transmission. Line-of-sight infra-red devices might be needed. There is a potential for "driver distraction" and "information overload" as with AVN.

6.3 User Cost and Automatic Debiting

The main barrier to automatic debiting is seen to be "public opposition" which rests on 1) opposition to more widespread user pricing, and 2) the fear of losing one's anonymity. All traditional opponents to "user pricing" will oppose automatic debiting owing to its potential for easing, and therefore making more likely, the levying of charges. The loss of anonymity issue is more directly relevant to automatic debiting and raises "Big Brother", "civil-liberty" concerns which are likely to find powerful support. If automatic debiting is not mandatory, partial take-up would require a "double system" (ie., with manual back-up) which reduces cost-effectiveness. As one panelist points out, there are smart credit card solutions to UCAD and solutions are being worked on in the industry that do not require disclosing one's identity.

6.4 Interactive Route Guidance

Initial investment and operating costs (on the supply side) will be high. Will public funds be forthcoming? Will IRG be cost-effective for society? To work, the system must yield benefits to drivers. There is a potential conflict between guidance to benefit society and guidance to benefit users. Technically, IRG, will face complex dynamic control problems which are still to be overcome. There may be some opposition on "Big-Brother" grounds and some minor liability issues to resolve. Agreement on standards must be reached.

6.5. Speed and Distance Keeping

There are technical barriers to be overcome (eg. problems of obtaining information beyond the vehicle immediately ahead). The main barrier are reliability and the implications of potential system failures, eg. specifying an acceptable failure level, liability issues, need for back-up systems (which would raise costs and make the system harder to justify) and psychological barriers. Conflicts between safety and efficiency objectives are inherent in automated SDK. There is also opposition on "civil liberty" grounds.

6.6. Collision Avoidance

There are limited barriers to simple systems. There are technical problems to be overcome for more sophisticated applications (needing major breakthroughs in image processing and artificial intelligence). The main barrier is reliability and the implications for cost-effectiveness of having back-up systems. There are also large legal barriers concerning liability in the event of system failures. There could be problems maintaining system reliability after installation. Driver acceptability may be a barrier, especially if systems have designated failure levels.

6.7. Automatic Highway Chauffeuring

Major technical and engineering problems are expected (eg., over entraining and detraining) Mixed operation may not be possible. Reliability and implications of system failure are major concerns. Many respondents felt there would be public reluctance to provide the necessary capital investments for a system which would have a design standard below 100% fail-safe level. The liability issue could be an almost insurmountable obstacle. Psychological problems connected with driver acceptance would also present a serious problem. AHC is the RTI system which was received with the greatest amount of scepticism. There is consensus that AHC will have the latest market penetration of any of the systems discussed above.

7. SCENARIOS

7.1. Background Scenario

A Summary of Panel-Supported Basic Assumptions

World population will continue to grow, especially in LDC regions. Large cities and towns will continue to grow at the same time as the population becomes more evenly distributed over large areas. Society will become more dependent on transportation. Urbanization will continue in developing countries with attendant massive traffic problems.

Economic growth will fluctuate between 1-3% per annum as a world average with many large national differences. (We want to avoid becoming involved in speculations about violent political upheavals in the world, however possible they may be.)

The long-term trend of decreasing costs for computer and communication equipment continues to make real-time driver information systems feasible for the general public. Costs for information services will decrease further for many decades.

Demand for mobility will continue to increase. Automobility and efficient goods transport on roads will be a prerequisite for a more widely distributed population and industry. More dispersed living and working patterns will evolve.

Land use will increasingly exercise restraints on new road construction and pressure road planners to make better use of present road infrastructure.

Transport/Traffic Structure. Denser road traffic is to be expected. More traffic congestion is inevitable – "intelligence" in roads will just enable traffic planners to manage it more effectively. The number of cars per family will increase slowly.

Factory production will become more diverse and more closely linked to local needs. Smaller factories will be manned by local workforces.

Inter-city trunk routes will continue to supply the needs for transport of consumer needs and goods, but there will be distribution centers at each end of the routes for transfer to small delivery vans that are more suitable for urban conditions.

Major cities require radial satellites for hyper markets, business centers and industrial areas, Advanced information systems will be essential for the efficient operation and traffic communication and flow.

The use of road transport will increase rapidly in the LCD's and NIC's.

Environmental considerations will play a much more important role in the future. Road traffic must drastically reduce its exhaust gases. Computerization may help bring this about. There will be continued concern about the environmental aspects of road traffic, such as pollution and noise.

Air transport will increase.

Technology. Actual travel information on a systems-wide scale is used to improve current network performance and plans for future growth. Electronics technology development in other fields is applied to road transport. Environmental cconcerns about the impact of automobile use will become stronger. Dense traffic, higher oil prices and environment concerns will lead to requirements for a new and radically cleaner engine and fuel concepts for road vehicles.

Standardization. The implementation of new information systems in transport will require international agreements for obligatory standard components in cars and the transport infrastructure.

Lifestyles. With continued economic growth and increases in real incomes, the nature of demand will shift, work trips will become relatively less important. Only small, slow changes in business travel patterns will come about, in spite of increasing use of information technology and telecommunication.

There will be more work trips per capita due to 1) increased female participation in the work force and 2) an increase in the number of single-parent households and overall decreasing household size, and 3) more elderly people who will enjoy increased mobility in intelligent cars.

There will be longer trips to work as the price of housing in larger cities increases and urban sprawl continues. Inner city shopping will continue to decline with the growth of large suburban shopping centers.

People will have more leisure time and there will be more part-time or short-time employment.

There will be many more drivers on the roads who are over 70 and have diminished sensory abilities.

7.2. A Core Scenario

Our system conclusions from the first round and from state-of-the-art reports are that a number of RTI categories can be used as a basis for assessing events. The following RTI categories seem feasible for reasons of technical complexity, cost/benefit, the need for integrating the vehicle and roadside equipment and/or the need to have all vehicles equipped to a common standard.

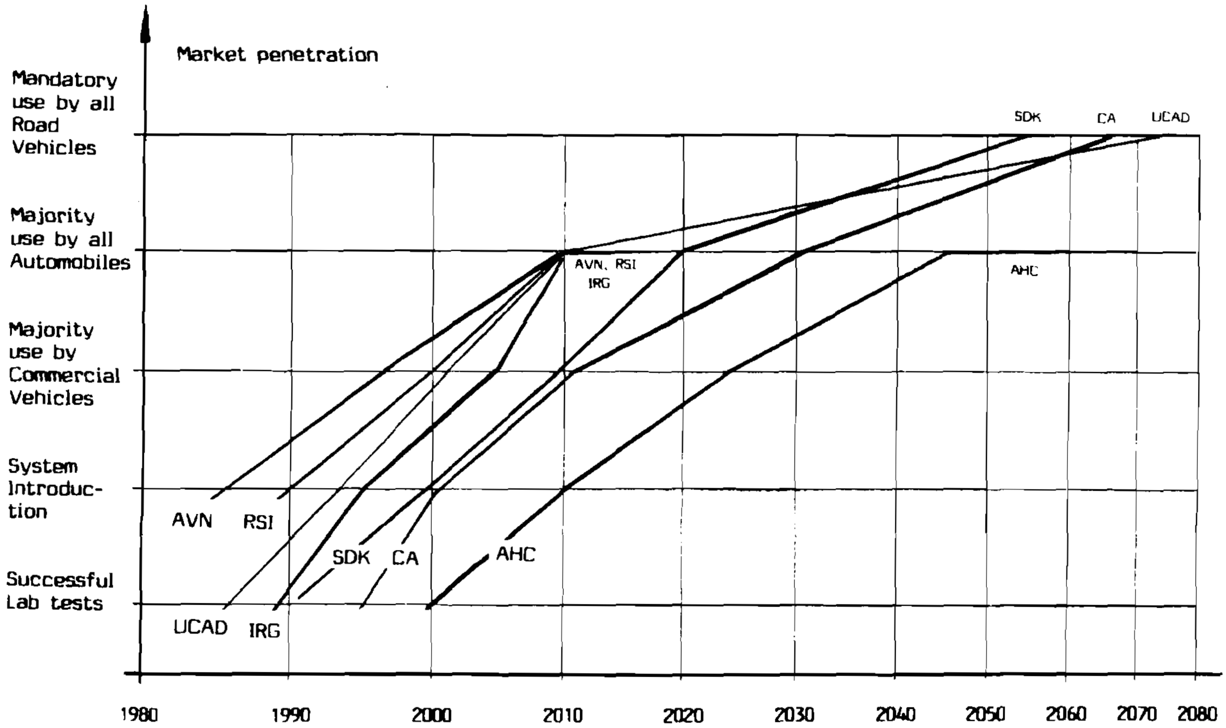
1. Autonomous Vehicle Navigation (AVN)
2. Road Service Information (RSI) on facilities along roads, road conditions, local weather, traffic congestion and accidents
3. User Cost and Automatic Debiting (UCAD)
4. Interactive Route Guidance (IRG) for navigation and traffic flow improvements
5. Speed and Distance Keeping (SDK) for safe, rapid driving in platoons with short distances between vehicles
6. Collision Avoidance (CA) for safer driving in lanes
7. Automatic Highway Chauffeuring (AHC)

The implementation of items from the RTI categories, when developed into systems, can start at different times, proceed at different rates, and reach different levels of market penetration. A possible future market penetration of RTI systems is thought to pass the following significant levels:

1. Successful laboratory test / pilot tests
2. Commercial system introduction
3. Majority use by commercial vehicles and cars in business use
4. Majority use by all automobiles (i.e., commercial vehicles, cars in private and business use)
5. Mandatory use of the system in all road vehicles

In a diagram with a time axis and a market penetration axis we can present the panelists' time estimates on events as a curve for each RTI system. The RTI implementation can thus be summarized in the core scenario seen on the next page. By using the median values we present what can be considered a surprise-free scenario, giving the best consensus estimate from panelists on what will happen and when.

An RTI Core Scenario



- The market penetration curves above are based on panelist median estimates on when different RTI events will occur.
- Note the convergence of ANV, RTI, UCAD and IRG curves as a majority use on all automobiles by 2010. This can be a starting point for synergistic system solutions.
- Systems for automated driving, SDK, CA and AHC will come later than the information-oriented systems.
- A mandatory use of RTI can come late or not at all.

7.3. Scenario Scenes

7.3.1. Scenario Scene 1990

Not very much has changed since 1987.

Traffic. There are more cars on the roads. Traffic growth has been on the order of 5-10% since 1987. However moderate, the increase has created new areas with frequent congestion. The congested areas literally *smell* of exhaust and there is growing concern in urban areas about improving traffic conditions.

RTI. Autonomous vehicle Navigation Systems (AVN), introduced several years ago, are selling as well as CB-radios two decades ago. Trucking companies are rapidly equipping their vehicle fleets with cost/beneficial AVN systems. Rental car industry and company cars used for business follow suite. Systems for Road Service Information (RSI) are introduced on the market. Terminals at service stations can be used for better route planning.

The automobile radio is the carrier technology, making RSI available in vehicles. Local broadcasting, cellular radio systems, radio data systems (RDS), and computer equipped receivers makes it possible to have local information on weather, traffic and hazards warnings edited to drivers' needs. Only the area relevant information is presented to drivers.

Systems for automatic debiting of road/bridge/tunnel tolls and parking are tested in several places in the world.

Interactive Route Guidance (IRG) systems have been demonstrated in Berlin and London. However successful, they have also introduced many new options for navigation, road information services and traffic management algorithms. There is an international drive for early standardization, at the same time that one does not want to jump on conclusions about technology that can be limiting factors for future development. The pilot tests are extended to test the traffic flow improvements shown possible with new optimization algorithms.

Actors. The IT industry is actively pursuing the idea of promoting new intelligent products for installation in trucks, vans and private cars. The automobile is regarded as a huge market for mass-produced electronic products. Autonomous system solutions are being developed, introduced and sold to be used in real traffic as an experimental field.

The automobile industry is actively improving intelligence within vehicles. Clever combustion control reduces emissions. Anti-lock braking systems are being introduced as standard on more and more models. Based on this firm grip of the vehicle-road problem, automobile companies are looking for more challenging system possibilities in the direction of automation of vehicles in traffic.

Governments faced with ever increasing traffic volume, but restricted to building new roads for it, are now looking into smart solutions that can improve traffic safety, road capacity and the environment. Road administrations, road traffic safety administrations, road operators, traffic management organizations and local traffic control and surveillance will play a new role in the future. One thing is becoming more and more apparent now in the Year 1990. The societal benefits of RTI development will be small if the government side does not play a more active role than it has in the past. Standardization and internationally agreed upon technical solution principles are crucial. Capital has to be raised for investment in roadside equipment. Far reaching infrastructural decisions have to be made. Governments and road authorities, both national and international, have to hire qualified people to analyze the options and to specify the way towards a development of intelligent roads beneficial to society.

Early pioneers for RTI systems are the police, fire brigades, highway patrols and rescue vehicles.

7.3.2. Scenario Scene 1995

Traffic. is growing still. The family car has given way to cars owned and used on an individual basis. The number of vehicles, trips, and the length of those trips has increased. People are more and more dependent on individual mobility. This trend is dominant in spite of the good progress being made to expand the services of public transport from city areas out into the peripheral areas (Park-and-Ride schemes).

RTI. Systems for AVN, RSI and UCAD are on the market and used by a significant minority of commercial vehicles. Interactive Route Guidance Systems (IRG) are being installed in some ten OECD cities. Successful lab tests have been conducted for Speed and Distance-Keeping (SDK) and Collision Avoidance (CA) functions.

Computerized route planning for commercial traffic is an established function for many vehicle fleets. Transportation is more effective now. Just-In-Time deliveries have put new requirements on driving, and motivated installing AVN, RSI and UCAD systems on board vehicles.

Route planning at head offices is in fact taking on a traffic management role. With on-line data about road repairs, local weather conditions and accidents, advice/guidance is given to the fleet over the mobile telephone, mobile radio or the mobile data network.

Truckers sometimes feel they are occupying the communications central in a branch office rather than the driver's seat of a truck. The truckers experience of electronics in use is vital for the IT industry. Robust and user-friendly systems are winning over more sophisticated ones. These lessons must be learned before RTI systems enter the private car market.

The most user-friendly system used is still the CB radio. It is a must for "creative trucking". The contact with colleagues and crucial information about what really matters, such as radar controls and possibility to earn extra money, is what makes trucking an interesting profession.

A new category of drivers using the RTI services are the "business-on-the-road" people. They use the time spent in their cars to make telephone calls. They want to find efficient routes to new addresses and how to get there in time.

Truckers and business people in company cars are the second group of consumers of RTI technology, only a short step behind the specialized fleets of emergency vehicles.

By 1995 catalytic converters will have been used for many years. The air quality has improved, but not enough. A new clean engine concept is needed, with radically better emission characteristics to meet the requirements for the next century. A number of alternatives are being studied in a large international R & D program.

A new software industry has come into being and is finding clever ways to improve autonomous navigation systems. The new companies offer tapes and compact discs with unique route guidance for creative trucking and businesses of all sorts.

The market-driven RTI solutions are creating problems for traffic management. The question of authorization of digital maps for route planning is becoming crucial.

A general purpose display and manuevering unit has been requested by truckers which would replace all the dials, nobs and keyboards on each individual piece of RTI in-vehicle equipment. The mobile office equipment in modern trucks must become more user-friendly. It must be possible to operate the equipment and read the messages while driving. The operation of RTI takes too much of the driver's marginal capacity as it is. Concern about safety has motivated funding for the systems research needed.

Actors. After almost a decade of research and development efforts in the RTI field, the interrelation between the IT industry, the automobile industry, road and traffic authorities on different levels has been established. The actors know their roles and what is expected for a balanced development of RTI technologies.

The work on international standards for RTI, UCAD and IRT has been successful. It has given the Western European, North American and Japanese road authorities the respect they needed in industrial circles to achieve effective implementation of more integrated and automated RTI functions.

A need for standardized methods in the presentation and manuevering of RTI systems in vehicles is becoming apparent. An international R & D task force is at work on the problem. Agreement is needed by the Year 2000.

7.3.3. Scenario Scene 2000

Traffic. The number of vehicles has grown markedly since 1987. Traffic has increased drastically, mostly due to private car usage. Commercial vehicles are now operating much more effectively, thanks to RTI. Thus, commercial vehicles represent a smaller part of the total traffic. Public transit never really took off as was assumed in the 1970's. The information society is asking for a more individualistic life style and corresponding transport needs. The decentralization, the spread of living and working is based on the assumption that good individual transport solutions exist.

RTI. AVN is used by a majority of commercial vehicles and business cars and is becoming a status symbol in private cars. RSI and UCAD are used in a majority of trucks for increased transport efficiency and convenience. Interactive Route Guidance systems (IRG) are now requested in all major urban areas in OECD countries. The bottleneck is *not* the introduction of the necessary beacons. A significant minority of commercial vehicles use the system and act as sensors for traffic control optimations. The difficult part is to trim an IRG system to fit into the traffic pattern and driving habits of a particular city. The analysis required is not immediately transferable. There are so many possibilities within the system.

IRG systems now have an established credibility and proven cost-effectiveness for traffic flow improvements and navigation using low price equipment in the vehicles. Many large cities in the developing world are considering leap-frogging the AVN and RSI systems. The IRG systems seem to offer the best options for traffic improvements in the LDC's. The IRG solution addresses one of the biggest problems in the LDC's: urban traffic.

Systems for safe speed and distance-keeping (SDK) and Collision Avoidance systems (CA) are being introduced on the market. The price makes them attractive only for use in commercial vehicles and business cars.

A major Automatic Highway Chauffeuring (AHC) laboratory test has been performed, using modern microelectronics, artificial intelligence and servo technology. It is time for a pilot test of the concept in mixed traffic. Similar to the testing of automatic landing systems for commercial aircraft prior to their introduction, a ten-year test program of AHC as a support system in mixed traffic is needed before it can be commissioned as a truly automatic system.

Driving is still very similar to that of the 1980's for the general public. Traffic is dense and congestion is spreading to new areas and new hours of the day. There is a strong expectation for new RTI technology on such a price bracket that private car owners can use it.

Travelling in commercial vehicles and business cars is like sitting in an office on wheels. In fact, the road vehicle has become a sort of mobile branch office, which in many cases replaces a central business-district office for certain professionals. Tasks such as selling, ordering and marketing have become part of the Truck driver's job. "Creative trucking", which was earlier regarded as a grey sector with black money, has evolved into respected partnership in the transport industry. Truckers now get bonuses for acting on on the spot to include unforeseen transportation opportunities in the major operations to which they have already been assigned.

Driving is more convenient and safer for those who have installed the new standardized display/manuevering units. In the standardized head-up display, drivers get edited and easy-to-read information and with the keys on the steering wheel a driver can select the information he needs and operate all the AVN, RSI, UCAD and IRT systems, as well as the mobile telephone and radio.

Some commercial vehicles have dual navigation systems. AVN is best for good transport management. The IRG system is best for good traffic management, i.e., to avoid congestion, hazardous local weather and bad road conditions.

Actors. The electronics industry is rapidly bringing out new versions of AVN, RSI and UCAD which incorporate the lessons learned from the use of these systems in commercial vehicles. Prices are kept low in hopes of capturing the private car mass market.

The automobile industry is introducing more automation into vehicles. SDK and CA systems are being marketed as useful improvements in themselves, and as a test for the more sophisticated automated highway chauffeuring now deemed feasible.

Governments, road administrations and road operators in general are reacting positively to the above developments, but are acting strongly ***for*** introduction of IRG and UCAD systems. IRG is seen as a principal means of solving increasing traffic problems. UCAD is regarded not only as a traffic management tool but also as a way of financing the infrastructural investments IRG requires.

Strong political pressure is building up among the "Greens". Environmentalist political parties and action groups are demanding more public money be diverted into R & D efforts to develop a clean engine, rather than further refining the RTI systems.

7.3.4. Scenario Scene 2010

Traffic. Really significant changes have taken place. Traffic flow has improved considerably in the past several years, thanks to the integrated RTI systems now in use in the majority of automobiles.

RTI. The RTI solutions first developed for the commercial vehicle market have now reached the stage of integrated low priced system solutions desired and used by most drivers in traffic.

AVN, RSI and UCAD systems are still being sold and used as products in their own right. But more important is the general purpose IRG system which includes AVN, RSI and UCAD as subsystems (actually as chips) in the general purpose display system. This powerful unit with its easy-to-understand, standardized symbols is the crucial element in making driving more comfortable, more convenient and safer. These second generation IRG systems are called IIRG's (Integrated and Interactive Route Guidance systems).

A majority of commercial vehicles is using SDK and CA systems while driving in platoons on highways. The systems have not been commissioned yet for their highest level of performance, automatic vehicle train forming and emergency braking. The systems are being used only for warning and will be tested in mixed traffic for many more years to come. At least, this is the version believed by the authorities. The truth is that drivers are already using SDK and CA systems switched on automatic because this way of driving is so convenient. Rather than being part of a cybernetic inner loop making small adjustments with hands and feet, drivers now tend to take a more relaxed surveillance attitude and use the extra capacity to be more observant of the traffic picture around them.

Automatic Highway Chauffeuring systems are being introduced. This means that separate lanes are being built on a few major motorways and commissioned for testing AHC systems. The crucial difference between autonomous SDK and CA systems and AHC is the dual system principle in AHC. Two completely independent sensor systems, signal paths, computers and servos are needed to provide the reliability and fail-safe operation of AHC required.

Parking. With the integrated IIRG system parking has become much simplified. Well in advance, IIRG informs the driver about empty spaces in a number of parking areas and garages near the destination he has selected. Once there, the car's display shows the driver the parking fee. As soon as the driver selects the PARK mode, a green lamp begins to blink, signalling both the driver and a parking inspector that the on-board IIRG has identified a parking *space*. The driver's identity, however, remains protected.

When visiting a service station on a monthly basis, the driver removes the parking "key" (a smart memory card) in order to pay the amount due. The key's memory with its information about how the parking fees are to be transferred to various recipients is then "cleared", without giving any clue of where and when the car has been parked. The parking key is then re-formatted to receive information on parking fee recipients for the next month.

7.3.5. Scenario Scene 2020

Traffic is dense but flows smoothly. The IIRG systems with their supporting AVN, RSI and UCAD functions make driving easy for a significant majority of road-users. Some of the efficient traffic flow can also be attributed to the SDK systems now being used by a majority of all automobile owners/drivers.

The use of SDK is simple. When driving in a lane the head-up display asks the driver if he wants to lock onto, for example, "Silver tone Volvo XY2 123". If that is the car in front, then the driver need only press the master key on the steering wheel. The distance sensor locks on the responder in the back of the car in front, in our example, the silver-tone Volvo. SDK is not mandatory yet. However, it has become mandatory for all cars to be equipped with SDK-passive responders. It is not allowed to drive in the fast left lanes without an appropriate SDK system with active responders. When driving in the fast lanes, the SDK works in a higher mode. Each car in a platoon gets data link information about speed and distance conditions in the entire platoon. Thus, if the lead car makes a sudden braking manuever, all the cars behind it receive a signal to brake within one-hundredth of a second. An elastic mean of coupling of the vehicles in the platoon has been achieved. Platoon driving with this system has increased comfort, safety and lane capacity considerably in recent years.

A significant number of automobiles are now equipped with Collision Avoidance systems. Beside their automatic engagement in emergency situations, these systems have made driving and changing lanes much easier. The driver can safely remove his hands from the steering wheel for minutes at a time. The CA systems interpret the perspective of the lane markings and transmits its impulses to the steering servo so that the vehicle remains safely in its lane. The driver can choose to remain directly in the middle of the lane or 10, 20, 30 or 70 cm to either side of the lane center, if he so desires by the selection of a trim steering device conveniently located in the armrests.

Changing lanes is facilitated by the SDK and CA systems. The driver indicated his intention to change the lane with the normal blinker lever. The vehicle-to-vehicle data communication works quickly and silently to find or make a slot wide enough for the vehicle to enter the adjacent lane. Once the driver receives a clearance signal, he slips into the new platoon as say, Number 37 in that platoon. He is also informed that his platoon is being led by an AA-ranked Mercedes with AHC, which intends to drive straight through to Paris in the fast lane.

Driving. The IIRG's with artificial intelligence and driver adjusted teaching functions now make driving possible and permissable from age 12 to 100! The smart card with which the driver opens his locked vehicle also informs the vehicle about the driver and his capabilities or handicaps. The electronics adjusts itself to the particular driver's handicap. Higher levels of alcohol in the blood are allowed in drivers whose vehicles are equipped with SDK and CA to AHC AA standards.

7.3.6. Scenario Scene 2040

Highway traffic is dominated by vehicles with well proven RTI technology. A significant minority of all automobiles use automatic chauffeuring systems (AHC). Road transport has been growing for many decades but seems now to have reached a saturation level. Much of this can be attributed to the rapid growth of aviation transport and the high speed levitation trains spanning their transportation networks over the continents.

Safety has been improved by a factor of two since the 1980's. As we have solved most of society's traffic problems with the other RTI systems, the option left for AHC depends on whether it can further improve safety by a factor of 5 to 10.

Now, by the Year 2040, we see other needs for and benefits from an automation of the road transport system not seen previously. On the decentralized society with its widely spread out living and working patterns, people are relying more than ever on roads and automobiles to reach airports, LEV train stations and public transport services around the older cities.

The ecological vehicles of 2040 use clean engine/fuel hybrid systems, gasistors, for power and RTI systems for intelligent social behavior in traffic and for efficient transportation. Convenient road transport is still a key issue for area development and competitiveness for business and industry in any region of the world community.

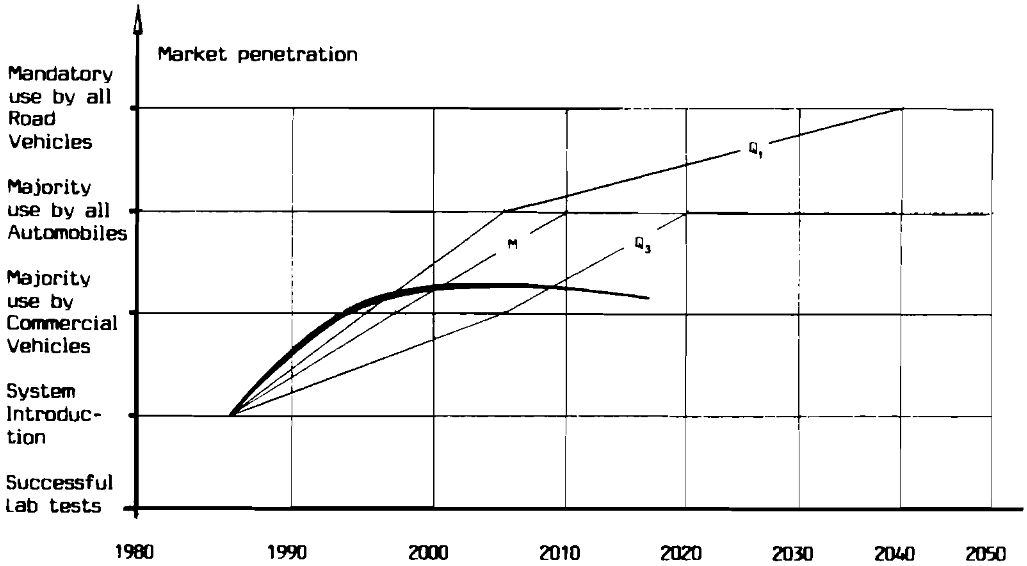
7.4. Alternate Scenarios

> Our imagination is the biggest barrier against RTI evolution. The more we are certain of what the market is, what the future will be like and how the technology must develop, the less likely we are to explore other options and find useful roles for RTI.

The above quotation from one of the panelists challenges us to actively look for alternatives to the "surprise-free" core scenario, which was based on the median estimates from the panelists. What can happen if a certain actor increases or decreases his support for RTI? What can happen if a barrier proves to be a larger stumbling block than was anticipated? What can be the result of new values and life styles regarding the demand for RTI solutions.

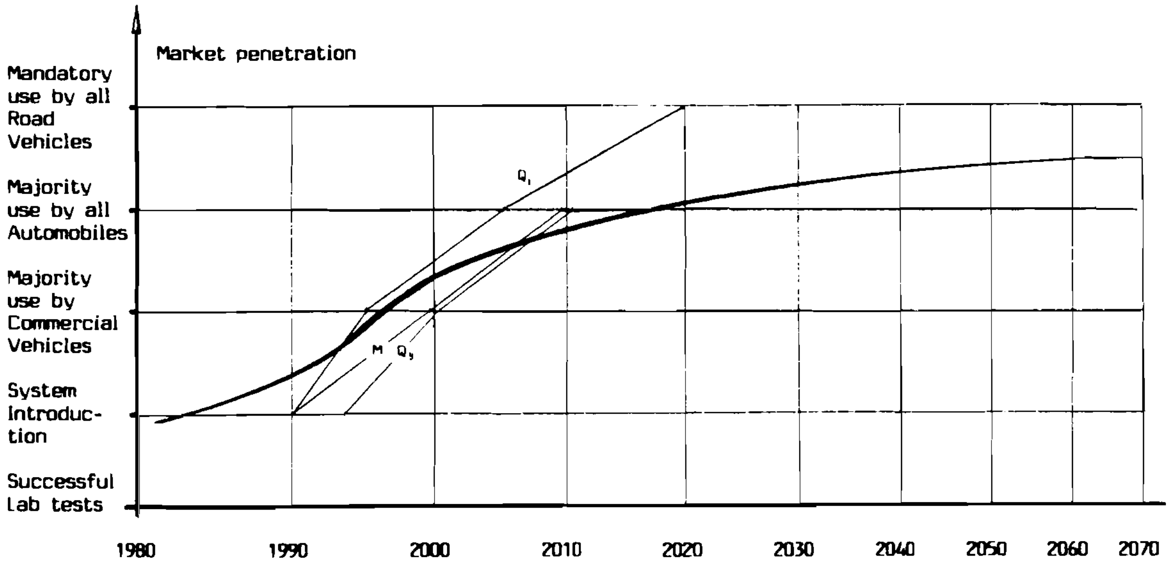
On the following pages a number of scenario alternatives are presented, based on impulses from the panel. In contrast to the core scenario and its scenes, these scenarios do not have any consensus backing. In the diagrams the alternate scenario graph is drawn against the background of three lines representing the first quartile, median and third quartile values of the panelists' estimates, behind our core scenario.

7.4.1. AVN — Autonomous Vehicle Navigation Alternative



- AVN systems can offer substantial benefits to the transport industry.
- Truckers, dispatchers, rental car firms and company car owners could provide the motivation for early market penetration and rapid growth of AVN systems.
- The AVN system offers marginal benefits for the average private car users and, contrary to the panelists' estimates (Q_1, M, Q_3), AVN may level off after saturating the commercial market.

7.4.2. RSI — Road Service Information Alternative



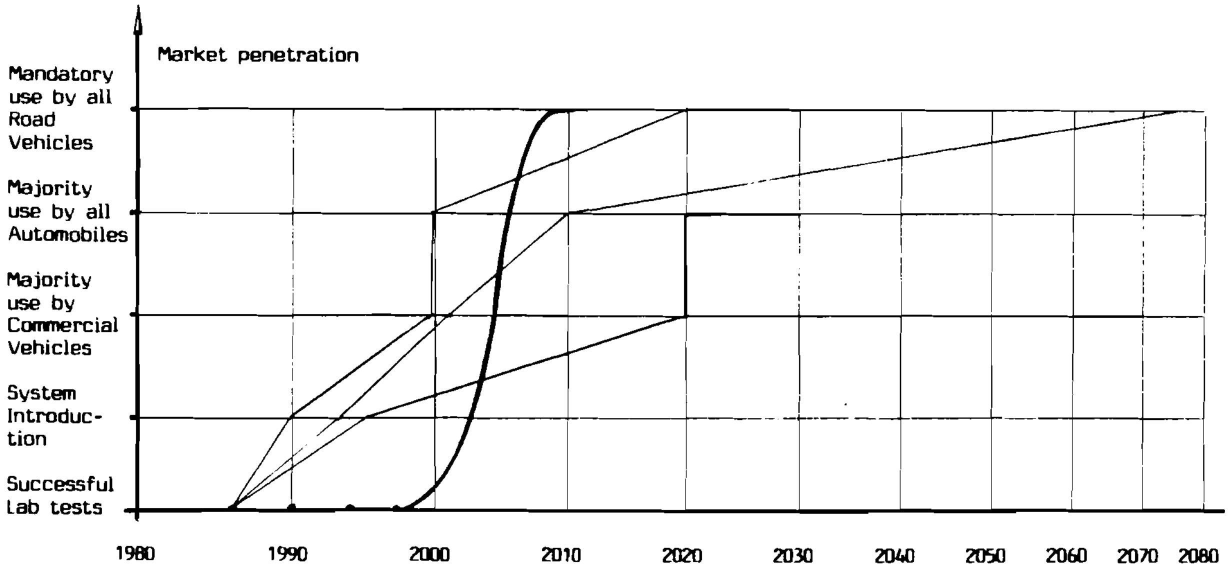
- RSI is an extension of the automobile radio. Traffic information from control centers, highway patrols, air surveillance, weather bureaus is transmitted in a one way data link as voice and data (RDS) to receivers in vehicles.

- Local radio stations with RSI broadcasting (ARI = Driver's Radio Information) represent the introduction of "beacons for improving traffic".

- The market penetration may possibly follow a normal S-shaped curve.

- The emergence of a substantial market for simple low cost automobiles for local use without RTI facilities can also delay an RSI market penetration.

7.4.3. UCAD – User Costs and Automatic Debiting Alternative



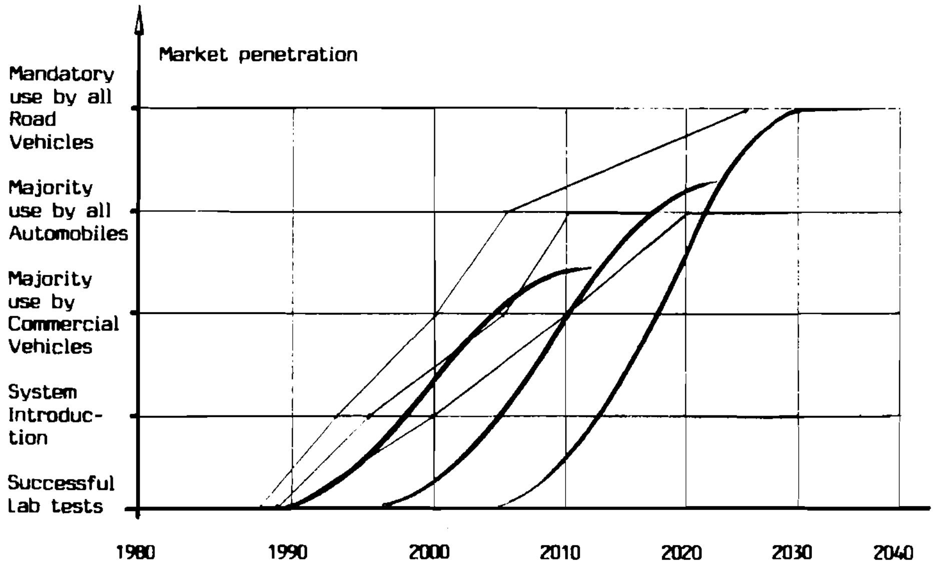
- UCAD systems represent convenience for driving: paying tolls, parking fees and transit charges can be handled without stopping the vehicle to carry out the transaction.

- In the debate climate of the 1980's, it is often assumed UCAD would increase taxes and impose on individual liberties. This widespread "Big Brother syndrome" delays introduction of UCAD.

- A well-designed UCAD system can eventually be introduced as an all-round, usage-oriented allocating system that replaces all forms of parking charges, tolls, insurance fees, purchase taxes, tax deductions and subvention systems.

- A strong, concerted implementation program supported by government actors can make UCAD both a mandatory and convenient system that also finds acceptance among drivers.

7.4.4. IRG — Interactive Route Guidance Alternative



- The IRG system is designed to improve interaction between traffic control and individual drivers. Beacons transmit maps and on-line traffic information to individual vehicles. Vehicles act as on-line sensors of the traffic flow at any moment. IRG solves navigational, RSI and ***traffic*** problems.

- With a well-organized cooperation from the government side (road administrations, traffic management, control centers). IRG implementation can be rapid.

- As a second generation of IRG, IIRG includes in synergy the best elements of AVN, RSI, UCAD and the first-generation IRG's.

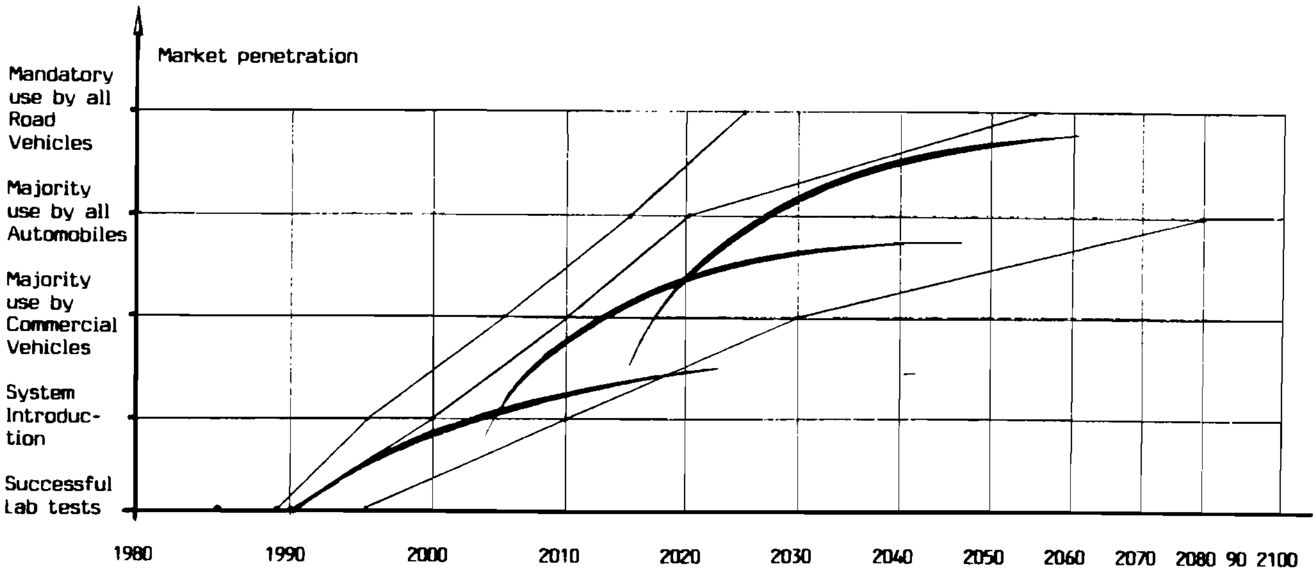
- A general purpose audio-visual display system in vehicles edits and integrates signals from on-board sensors and data links to roadside traffic management systems.

- The IIRG solution can be market implemented seven years after the IRG's.

- After another seven years, IIIRG, a third-generation IRG, is implemented and reaches mandatory status.

- After another fifteen years, 90% of all roadsigns can be scrapped (in 2040).

7.4.5. SDK – Speed and Distance-Keeping Alternative



- AVN, RSI, UCAD and IRG can be considered a group of systems for improved information and roadside-to-vehicle communication.

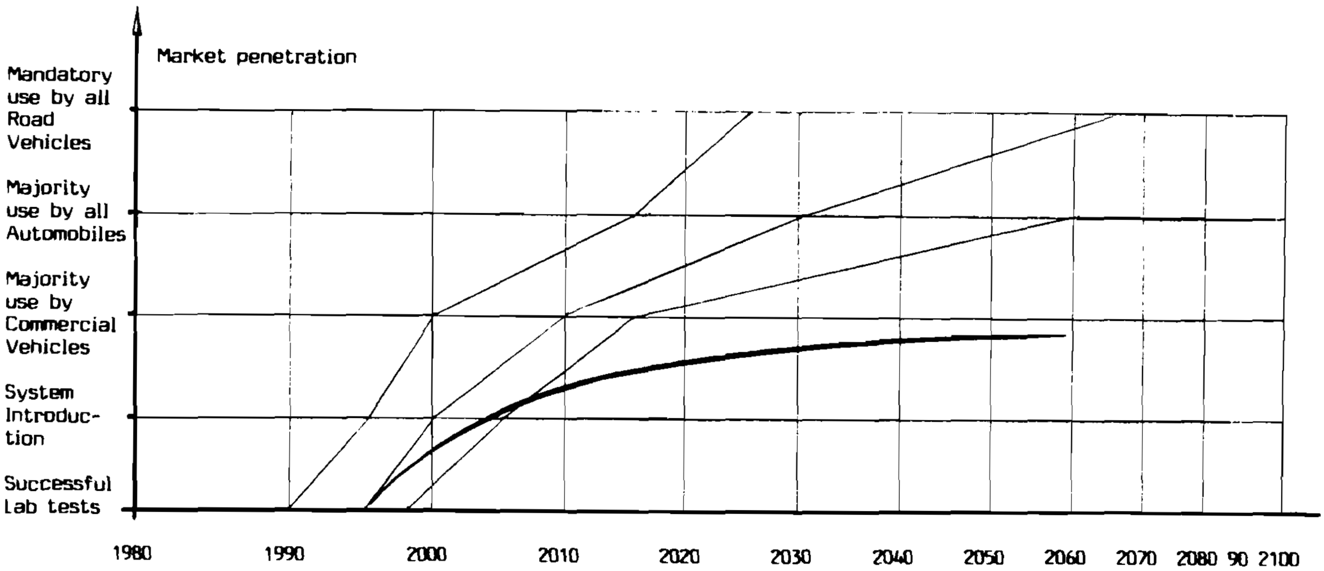
- SDK, CA and AHC then constitute a separate group of systems for automating driving and traffic, which includes vehicle-to-vehicle communication and control technology.

- SDK is a first step towards a one-channel, longitudinal control system for traffic in platoons.

- Using SDK in mixed traffic with only a minority of vehicles properly equipped may create some unforeseen problems with the first SDK versions.

- SDK may have to be implemented in steps.

7.4.6. CA – Collision Avoidance Alternative

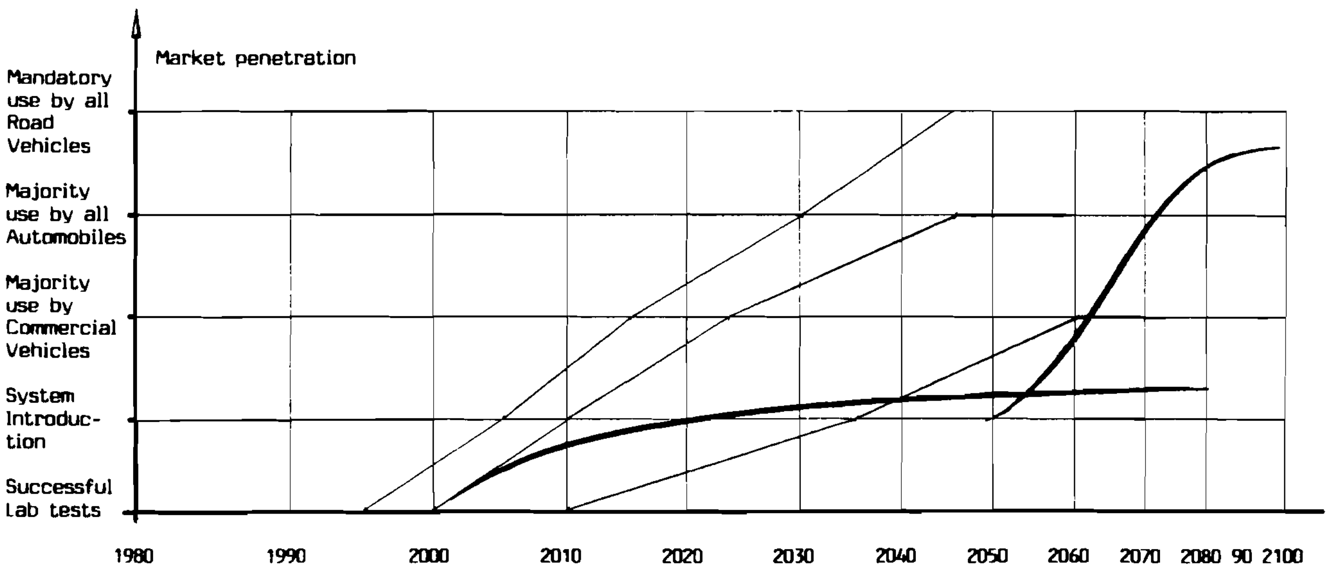


- Systems for automatic collision avoidance and intelligent vehicle behavior in traffic are based on a multitude of sensors, vehicle-to-vehicle communication, large computing capacity (AI) and control technology.

- A number of collision warning systems (radar, IR, sonar) exist as products on the market today. To upgrade these to systems for automatic collision avoidance can be costly and difficult to commission.

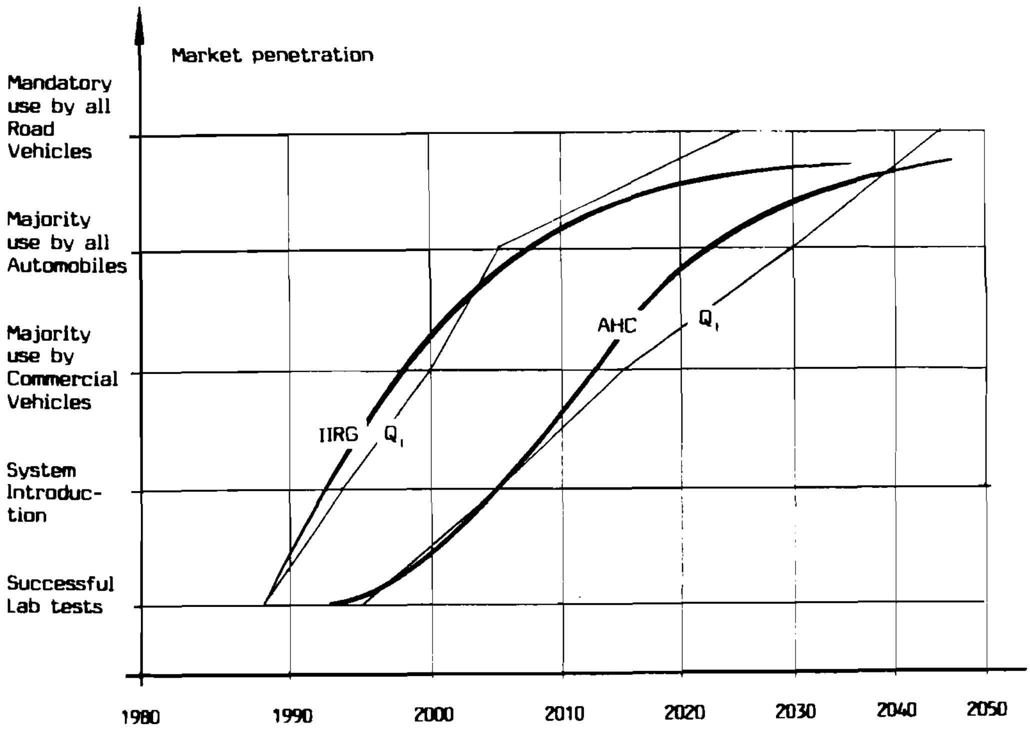
- CA systems may have a limited market for the next decades.

7.4.7. AHC — Automatic Highway Chauffeuring Alternative



- A system for AHC will build on the functions, reliability and experiences from IIIRG, SDK and CA developments.
- Specialized forms of AHC for trucks and buses on separated lanes on freeways, in tunnels, on ramps when docking to a platform can be introduced and used by a significant minority of road transport vehicles.
- In addition some new inventions have to be awaited before AHC really becomes an option for drivers, industry and government.
- Thus, AHC may not achieve market introduction and penetration until the next wave of innovation around 2050.

7.4.8. An RTI Scenario Alternative



- A concerted R & D effort to find integrated system solutions is undertaken jointly by road administrations and the automobile and and IT industries.
- Integrated Interactive Road Guidance Systems (IIRG) are rapidly penetrating the market.
- Only a few years later, safety improving systems for automatic highway chauffeuring (AHC) integrated with new clean fuel/engine systems are implemented.
- The smart ecological vehicles of 2040 are well matched with the intelligent road system. Road Transport Informatics is regarded as a social service.

8. A SCIENCE FICTION EPILOGUE – Some Science Fiction Fragments from Beyond the Year 2087

A History Lesson

Automobility has been marked by four big waves of innovations. The first came in the decades before 1900. The combustion engine replaced the horse. The horseless carriages produced by talented mechanics bacame a mass product.

The second innovation wave came around 1940 and used a number of inventions to make driving easier. Comfortably shielded from the weather, users could enjoy the improved performance of their vehicles. A large road building program paved the way for automobility and the development of the suburbs.

The third wave of innovation came in the 1990's when Road Transport Informatics was introduced. Transport and traffic problems were solved. With the AVN, SDK and CA systems one can say that automobiles became almost as intelligent as horses. They found their way without running into other road users.

During the emission plagued years before the Year 2000 automobility was restricted in urban areas and prohibited in downtown areas. This marked the beginning of stagnating cities. They were literally left at the roadside to decay while businesses, industry, culture and the people moved away. The clean automotive engine finally came – but it was too late to save the cities.

The fourth wave of innovation came around 2050. This was the automation wave. The automatic chauffeuring solution spread to smaller and smaller roads. Personal garages and carports were tied to the system. It became possible to use either one's personal car or any personal rapid transit service needed.

With the PRT road service of today, transurbia represents the dynamic core activity of society and replaced both suburbia and urbia. In the international info-mobility society, high information quality and high automobility are essential for development.

A Family Dialogue:

May I take my own car to Kindergarten today?

Yes, of course, Dear, but don't forget to pick up Liz on the way. I would also appreciate it if you could get us some kiwis from today's harvest of tropical fruit at the airport on your way home.

A Dialogue Between an Inebriated Fellow and the Voice Synthesizer of his Vehicle:

Drive me home . . .hic!

"Yes, Master, driving will be fully automatic. Your condition tells me that you need all the sleep you can get before your important business meeting tomorrow at 9 a.m.,"

thought the vehicle's artificial intelligence, never neglecting to give the traffic situation its full attention even for a nanosecond.

In the Family Car:

Hey, Mom, what's that round thing for?

Where?

There, behind you.

Oh, that. It's just for decoration, I think. What do you think, Grandpa?

Oh no, that's the emergency steering wheel, of course. Didn't you ever learn to steer a car manually at driving school?

No.

What'll you do in an emergency then?

Oh, just press the HELP button, I suppose.

Overheard on a Golf Course:

Oh, automobility is quite a blessing for older and handicapped people like us, isn't it?

Yes, I have heard that in the 20th century only the young and the able could use automobiles. What a cruel time that must have been! Come on, Mary, let's drive over and surprise our classmate John on his 105th birthday.

Outside the Theater:

Here we are – just in time! Let's go in.

Can you park the car here?

No, but I'll ask Saabrina to park herself, of course. O.K. Saabrina?

Yes, Master. Saabrina will park automatically and return to pick you up here three minutes after the final curtain.

REFERENCES

1) Helmer, Olaf, 1983, Looking Forward: A Guide to Futures Research, London: Sage Publications.

2) Sutherland, John W., 1975, "Architecting the Future: A Delphi-Based Paradigm for Normative System-Building" in Harold A. Linstone and Murray Turoff (Eds.), The Delphi Method, London: Addison-Wesley Publishing Co.

3) Svidén, Ove, 1986, "A Scenario Method for Forecasting" in *Futures*, October 1986, pp. 681-91.

4) Svidén, Ove, 1983, "Automobile Usage in a Future Information Society" in *Futures*, December 1983.

5) Svidén, Ove, (Ed.), 1985, ARISE Feasibility Study, Borlänge, Sweden: Swedish National Road Administration.

6) London Department of Transport, 1986, Autoguide.

7) General Motors, 1960, Automatic Car Controls for Electronic Highways, General Motors Corporation Research Laboratory Report: GMR-276, Keith Gardels, (Ed.).

8) Commission of the European Communities, 1981, EUCO-COST 30, European Project on Electronic Traffic Aids on Major Roads (EUR-7154), Brussels.

9) Schmitt, Louis A., 1985, Heavy Vehicle Electronic License Plate (HELP) System, SAE Technical Paper Series: 85-14-56.

10) Benning, Herman J.G.M., 1986, Digital Maps on Compact Discs, SAE Technical Paper Series: 86-01-25.

Honey, Stanley K. and Zavoli, Walter B., 1985, A Novel Approach to Automotive Navigation and Map Display, ETAK, Inc., Menlo Park, California.

12) von Tomkewitsch, Romuald, 1986, "The Traffic Guidance System ALI-SCOUT", Presentation at the CALTRANS Conference, Sacramento, California, 28 Oct. 1986.

13) Commission of the European Communities, 1986, DG XIII – Information Technologies, DRIVE, Planning Exercises, MVA Systematica.

14) Svidén, Ove, 1984, Automobile Road Information System, published by ConNova for the Swedish National Road Administration, March 1984.