European Commission
Joint Research Centre
INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES

Future of Transport Telematics Technologies

Results of a SMIC inquiry

EUR 17311 EN

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December 1996

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ACKNOWLEDGEMENTS

I thank all the experts for their participation in the SMIC inquiry and for the valuable comments which have helped me in the drafting of this report.

Prof. K. W. Axhausen, *Institut für Strassenbau und Verkeherplanung Leopold Franzens Universität, Austria*
Mr. Jean-Charles Pandazis, *ERTICO, Belgium*
Mr. E. Renstrup, *Denmark*
Dr. Wulf D. Watjen, *CARL BRO CIVIL & TRANSPORTATION, Denmark*
Mr. J. C. Led, *Copenhagen Transport, Denmark*
Mr. Asbjørn Enemark, *TELE DANMARK, Denmark*
Dr. Jan Kildebogaard, *Danish Transport Council, Denmark*
Mr. K. Markworth, *City of Aalborg, Denmark*
Mr. K.J.J. Karessuo, *Finnish National Road Administration, Finland*
Prof. Sulevi Lyly, *Laboratory of Transportation Enginnering Helsinki University of Technology, Finland*
Mr. Risto Kulmala, *FINNRA/Strategic Planning, Finland*
Ing. K. Appel, *TRAFICON Ltd., Finland*
Mr. Jacques Nouvier, *CETE de Lyon, France*
Mr. Bernard Laurens, *CGA, France*
Mr. Alexandre Gold, *CGA - CEGELEC, France*
Dr. Szubert Ludomir, *ECMT/CEMT, France*
Dr. Ing. Dominique Ploix, *F.I.A.-FEDERATION INTERNATIONALE AUTOMOBILE, France*
Mr. Patrick Fournier, *I.S.I.S. Traffic and Transportation Engineering, France*
Mr. Steve Morello, *I.S.I.S.Transport & Circulation Department, France*
Mr. M. Chevreuil, *I.S.I.S., France*
Mr. Yonnel Gardes, *Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les Constructions Publiques (CERTU) Département Systèmes techniques pour la ville Group Transports, France*
Mr. G. Fremont, *COFIROUTE, France*
Mr. B. Beudou, *Départment Informatique et Modernisation, France*
Mrs. Florence Boillot, *INRETS Départment Analyse et Régulation du Trafic (DART), France*
Dr. André Chapon, *INRETS/LESCO Laboratoire Ergonomie Santé Confort, France*

Mrs. Marie Claire de Franclieu, *Ministere de l'Equipment, du Logement et des Transports, France*

Mr. Jean-Pierre Camus, *ASFA (Association Française des Sociétés d'Autoroutes), France*

Mr. Patrick Gendre, *CETE Département Transports, France*

Mr. Peter Sonnabend, *City of Cologne European Projects Office Amt für Statistik und Einwohnerwesen, Germany*

Prof. Dr. Hartmut Keller, *FGV- Technical University Munich, Germany*

Mr. Rainer Koenig, *Frauhofer-Institute for Systems and Innovation Research (ISI), Germany*

Dr. J.M. Sparmann, *Hessiscehs Landesamt für Strassenbau, Germany*

Dipl.Ing. Gerd Riegelhuth, *Hessisches Landesamt für Straßenbau Germany*

Mr. Josef Janko, *HOFFMANN LEICHTER CONSULTING ENGINEERING, Germany*

Dr. Gundlach, *SIEMENS, Germany*

Mr. Heinz Sodeikat, *SIEMENS AG, Germany*

Mr. Lars Källström, *TFK+ VTI Transportforschung GmbH, Germany*

Mr. Frank Behrendt, *HEUSCH/BOESEFELDT GmBH HAMBURG, Germany*

Dr. Ing. Dirk Serwill, *Institut für Stadtbauwesen RWTH Aachen, Germany*

Mr. Dieter Geiger, *SIEMENS A.G. ANLSV, Germany*

Mr. Dimitrios Tsamboulas, *National Technical University of Athens, Greece*

Prof. G. A. Giannopoulos, *Laboratory of Transport Engineering Civil Engineering Department Aristotle's University of Thessaloniki, Greece*

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Prof. Emanuele Angeleri, *Dipartimento di Scienze della Informazione Università degli Studi di Milano, Italy*

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Ing. M. Incardona, *IVECO S.p.A., Italy*

Dr. Massimo Marciani, *T.M.T. PRAGMA srl, Italy*

Dr. Angela Di Febbraro, *DIST - Dipartimento di Informatica Sistemistica e Telematica Facoltà di Ingegneria Università di Genova, Italy*

Dott. Paolo Gay, *Centro Ricerche FIAT, Italy*

Dr. Domenico Inaudi, *Centro Studi sui Sistemi di Trasporto, Italy*

Dott. A. Bartolucci, *Consiglio Nazionale Delle Ricerche (CNR/PFT2), Italy*

Mr. A.E. Kolff, *Europe Combined Terminals B.V., Netherlands*

Dr. Bart Van Arem, *INRO Centre for Infrastructure, Transport and Regional Development TNO Institute for Policy Studies, Netherlands*

Mr. W.F.M. van der Heijden, *TNO - PHYSICS AND ELECTRONICS LABORATORY, Netherlands*

Prof. Dr. J. A. Rothengatter, *Traffic Research Centre - VSC University of Groningen, Netherlands*

Mr. Hugh Gunn, *Hague Consulting Group, Netherlands*

Mr. J. Andela, *TNO Road Vehicle Research Institute, Netherlands*

Mr. P. Lagerweij, *Project AUTOL Ministerie vom Verkeeren Waterstaat, Netherlands*

Mr. J. Escanciano Del Blanco, *Direccion General de Telecommunicaciones Ministerio de Obras Publicas, Transportes y Medio Ambiente Secreteria General de Comunicaciones, Spain*

Prof. Josè Cuena, *Facultad de Informatica Departemento de Inteligencia Artificial Universidad Politechnica de Madrid, Spain*

Dr. Ole Thorson, *INTRA- Ingenieria de Trafico S.L., Spain*

Dr. F. Bernaldo de Quiros Robles, *TEMA Grupo Consultor, S.A., Spain*

Prof. Michael Browne, *Transport Studies Group University of Westminster, United Kingdom*

Dr. M.C. Gurcan, *Imperial College of Science Technlogy and Medicine, United Kingdom*

Mr. Don Golding, *British Telecom Laboratories, United Kingdom*

Mr. Philip R. Oxley, *Cranfield Centre for Logistics and Transportation Cranfield University School of Management, United Kingdom*

Dr. N.B. Hounsell, *Department of Civil Engineering University of Southampton, United Kingdom*

Mr. Peter Murnaghan, *Hampshire County Council, United Kingdom*

Mr. Richard Harris, *Ian Catling Consultancy, United Kingdom*

Mr. Stephen D. Clark, *Institute for Transport Studies The University of Leeds, United Kingdom*

Mr. David Bayliss,	*London Regional Transport, United Kingdom*
Mr. Ian W. Routledge,	*OSCAR FABER, United Kingdom*
Dr. W.J. Gillan,	*United Kingdom*
Mr. Richard Paul Duddles,	*GEC MARCONI, United Kingdom*
Dr. Roger L. Mackett,	*Centre for Transport Studies University College London, United Kingdom*
Eur. Ing. M.J.D. Herbert,	*FORD Motor Company Limited, United Kingdom*
Mr. Steven Brown,	*Hampshire County Council, United Kingdom*
Ms. Colette Nicolle,	*Husat Research Institute Loughborough University of Technology, United Kingdom*
Dr. Ian Catling,	*Ian Catling Consultancy, United Kingdom*
Mr. Frank Montgomery,	*Institute for Transport Studies University of Leeds, United Kingdom*
Mr. John Faulkner,	*Intercity Trucks Limited, United Kingdom*
Mr. Richard J. Brown,	*OSCAR FABER TPA, United Kingdom*
Mr. Nigel K. H. Davies,	*RAC Motoring Services, United Kingdom*
Mr. Ross McMurran,	*Rover Group Advanced Technology Centre Warwick University, United Kingdom*
Eur. Ing. Peter Jetsy,	*School of Computer Studies University of Leeds, United Kingdom*
Mr. C. G. Toomey,	*TCSU - Traffic Control Systems Unit, United Kingdom*
Mr. Bert Morris,	*The Automobile Association, United Kingdom*
Mr. Robin Hewitt,	*The MVA Consultancy, United Kingdom*
Mr. A. McLaughlin,	*The Scottish Office, United Kingdom*
Mr. R.D. Bretherton,	*Transport Research Laboratory, United Kingdom*
Mr. Jonathan Smith,	*Transport Research Laboratory, United Kingdom*
Mr. Robert Meekums,	*Mott MacDonald Transportation and Planning Division, United Kingdom*

A very special thank-you to Prof. Ian Miles from PREST, Manchester University (UK). I also would like to thank Dr. Eamon Cahill, Dr. Jochen Naegele, and Mr. Fabio Leone for the helpful discussions and their critical comments.

The support received from the documentation service of the Institute is acknowledged.

1 INTRODUCTION

The increasing mobility in Europe, of people and goods, results in constantly growing road traffic and its related problems. The resulting unreliability of travel is becoming increasingly difficult to accept especially in urban areas (ECMT, 1995).

Until a few years ago, the principal response to these problems was investment in new road infrastructure. However, economic constraints and the increasing awareness of environmental consequences of traffic, and especially of the congestion problem, indicate that developing networks as rapidly as in the past twenty years, is becoming unsustainable. Optimising the utilisation of the existing networks, improving their safety and enhancing the quality of service provided are now regarded as top priorities before there can be any further extension.

Traffic management is becoming increasingly important. This aims at shifting or modifying traffic flow, in order to optimise the management of road networks as a whole.

Road information technologies, or Advanced Transport Telematics technologies (ATT), are an essential components of multimodal information systems. These will make it possible to compare the different transport options, choose the most advantageous ones, and receive practical information to help complete each stage of a trip under the best conditions. Relevant information needs to be available both before the trip (i.e. in the homes, offices, public places) and during the trip on the road.

Road information services for the public are intended to provide information necessary to:

- prepare a trip, choose the route, and select a time for it;
- carry out the journey, stage by stage, under the best conditions;
- avoid difficult situations, announced in advance or in the course of the trip;

and thus increase comfort and safety, speed and costs.

The development of road information services, is closely linked with the responsibilities of local and national governments in the fields of road network management, regulation concerning motor vehicle safety equipment, environmental protection, and the development of the industries connected with motor vehicles and telecommunications.

The introduction of services to drivers such as assisted route planning, in-vehicle information on traffic conditions, and automatic control by the infrastructure operators in case of difficulties while driving, provide an important response to the transport problem in the cities, even if it is a partial one. The development of such tools is an issue of fundamental importance to future European policy for both transport and industry.

Given this background, it was considered useful to seek to understand and forecast the trends and factors influencing the development of ATT technologies in Europe.

The study is based on an assessment of the possible evolution of some ATT technologies in European medium size cities in the year 2015, through the use of a forecasting technique, the SMIC (Cross Impact Systems and Matrices) method. This method is one of the prospective methodologies based on cross impact matrix analysis which takes form through mailed inquiry to experts of a specific field.

The results of this assessment are presented in the form of expectations and perspectives of experts' knowledge on the future of ATT technologies.

2 CROSS-IMPACT METHODS

A technique method of forecasting closely related to both the Delphi method and the use of scenarios is that of cross-impact matrices. A number of papers have appeared since the 70s reporting applications of this methodology. A cross-impact matrix describes two types of data for a set of possible future developments. The first type estimates the probability that each development will occur within some specified time period in the future. The second estimates that the probability of occurrence of any one of the potential developments would have an effect on the likelihood of occurrence of each of the others. In general, the data for such a matrix can be obtained using either subjective assessment procedures or a method such as the Delphi approach (i.e. experts judgement) (Makridakis, Wheelwright et al. 1983).

Although the Delphi method enables a fairly good synthesis of opinions to be obtained from which a convergent result can be determined, its drawback is that it does not normally allow the interaction among events to be considered.

Several methods of cross-impact analysis have been developed in the 70s. Cross-impact methods are a family of techniques which attempt to evaluate changes in the probability of occurrence of a given set of events, following a previous occurrence of some events. The method starts with a list of events, and their associated probabilities; the basic hypothesis of the method is that the individual probabilities only incompletely account for interactions. Taking the interdependencies into account the method allows one to move from a system of unprocessed initial probabilities to a set of net probabilities (i.e. corrected probabilities (Godet 1993).

The aim of the cross-impact analysis is to refine the probabilities relating to the occurrence of individual future developments to the point that these probabilities can be used either as the basis for planning or as the basis for developing scenarios that subsequently can be used in planning.

2.1 The SMIC method

The SMIC (Cross Impact Systems and Matrices), was developed in France in 1974. The SMIC method invites the experts to answer a grid of all questions *P(i), P(i/j)* and *P(i/not j)* and seeks to develop information as coherent[1] as possible to the initial set of data by minimisation of a bounded quadratic form[2]. In so doing however, data with different degrees of reliability are processed identically (Godet 1993).

The method usually takes form of a mailed inquiry, so to eliminate the elements, like Delphi, of subjectivity present in face-to-face interviews. The experts are asked to estimate the simple probability of a hypothesis occurring, on a scale where:

- '1= event almost impossible, to 5= event almost certain'.

They are also asked to estimate in the form of conditional probabilities the likelihood of a hypothesis coming true as a function of the other hypotheses. Experts use a scale where:

- '1= event almost impossible, to 5= event almost certain' and where the value 6 corresponds to the independence of the two hypotheses considered.

As a result of this, experts have to revise their assessment several times and, to some extent, they must reveal the implicit thinking of their reasoning.

The SMIC method, starting from the information supplied by the experts, allows a choice to be made from among the 2^n possible scenarios and to select those which are worth to a more detailed study, allowing their probability of occurrence.

The experts are asked to give information on:

- the list of N hypotheses considered fundamental to the objective of the study
  H = (H1, H2, H3...Hn);
- the probability of an implementation at a given time horizon
  P(i) probability of hypothesis Hi;
- the conditional probabilities of hypotheses (paired)
  P(i/j) probability of i if j occurs

[1] for 'coherent information' we intend that they should be reliable in terms of obeying to the classical rules governing probabilities.
[2] For further details see (Godet, 1993)pp. 138-166.

P(i/not j) probability of i if j does not occur.

In practice, the opinions supplied in response to some specific questions regarding non-independent hypotheses are not coherent with respect to the conventional constraint bounding probabilities.

These unprocessed opinions must be corrected in such a way that the final results validate the following conditions:

(a) 0 • P() • 1

(b) P(i/j). P(j) = P(i/j). P(i) = P(i.j)

(c) P(i/j). P(j) + P(i/not j). P(not j) = P(i)

The principle of the SMIC method is to adjust the experts' unprocessed opinions in such a way to obtain coherent final results, which remain as close as possible to the initial estimates.

The SMIC method runs with the support of a dedicated software. The SMIC programme gives for each expert, the probability sequence (• 1, • 2...• r) of the r scenarios which provide the highest value of the most probable scenario Max (Max •k). It is possible to obtain a cardinal sequence of possible scenarios, which enables to define the domain of the possible outcomes retaining only those which have a non-zero probability.

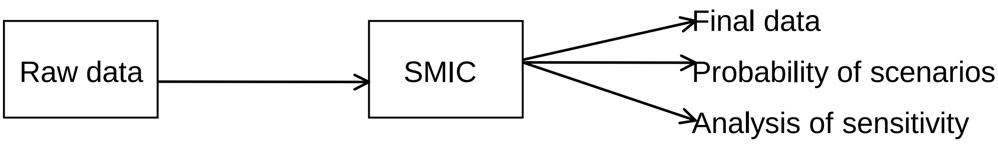

Figure 1: *Results of the SMIC programme* (Godet 1993).

It is possible to distinguish within the domain of the possible outcomes, as indicated in Figure 1, which are the most probable scenarios. The rest of the method consists of a sensitivity analysis to identify the driver or dominant variables and the dependent variables.

3 STRUCTURE OF THE SMIC INQUIRY

The aim of the SMIC inquiry has been to forecast the future of ATT technologies and their impact on congestion levels and traffic volume of passenger vehicles on a period up to 2015 in European medium size cities.

The selection of the events to be included in the SMIC inquiry as been done on the basis of the results of the first round of a Delphi study conducted in parallel[3]. The selection of the technologies forecast in the Delphi study, stems from the DRIVE/ATT Programme of the Directorate General XIII of the European Commission. Amongst others, one goal of the SMIC assessment has been to validate the information, which stem from the results of the Delphi study, on the future evolution of ATT technologies by the time horizon considered.

The SMIC method and its dedicated software, allows only six events in the representation of the system under study. This could be considered as a drawback, because it is difficult to represent complex systems only with a limited number of events. On the other hand, with six events the experts have to fill in twelve matrices for the cross impact analysis, for a total of 66 possible answers. Anything larger would be unmanageable from the participants point of view.

The questionnaire was based on the assumption of a medium size city and on a scenario (Annexes). The scenario was defined to allow for better comparison of the responses which were based on a common framework. The main points of the scenario were:

- Little change in the underlying social processes that lead to people demanding personal geographical mobility.
- Continued growth in aggregate personal disposable income.
- Continued increase in the level of car ownership, with no major transformation of the historical relationship between this and personal disposable income.

[3] For further information and results see (Scapolo, 1996).

- Growing concern with environmental and other impacts of transport systems in urban areas and elsewhere. Increased awareness of both health problems and greenhouse gas emissions.
- Low emphasis on further road network building.
- Continued investment to increase transport efficiency through a better use of the existing infrastructure.
- Growing emphasis on market-based solutions and market instruments (e.g. road pricing) as a means of shaping transport systems.
- Continued investment in research, development and application of technologies (vehicle and infrastructure) which are intended to alleviate problems such as congestion, pollution, hazards.

The questionnaire was divided into two stages. In the first stage, experts were asked to provide the simple probability of occurrence of the single events listed by the year 2015. They had to answer through of a probability scale from 1 to 5. The meaning of the probability scale has been the following:

1 = event almost impossible (0 - 10%)
2 = event unlikely (11 - 30%)
3 = event equally likely or unlikely (31 - 50%)
4 = event likely (51 - 70%)
5 = event almost certain (71 - 90%)

In the second stage of the questionnaire experts had to indicate the conditional probability of the six events. They had to fill in two matrices for each event respectively, where the first matrix was referring to the probability that each of the other five events listed will be implemented given that event (E_n) turn out to be true. The second matrix experts had to indicate the probability that each of the other five events listed will be implemented given that event (E_n) does not turn out to be true. They had to answer through a probability scale from 1 to 6, which meaning has been the same of the one used for the single probability, but where the meaning of value 6 was that the two events considered were independent.

3.1 Characteristics of the Respondents

The SMIC questionnaire was sent to 126 European transport experts. The criteria for the selection of the expert panel were based on the following:

- participants to latest international conferences on Advanced Transport Telematics Technologies;
- experts co-nominated by others;
- experts selected from national research centres and academia on transport, (also with the support of Internet);
- personal contacts which included participants of a Delphi inquiry on the same subject conducted in parallel.

Despite efforts to ensure a balanced sample across European countries, it was possible to identify the same number of experts across the different countries. The distribution of experts by nationality is indicated in Table 1.

Table 1: *Selection of experts by nationality (IPTSinq, 1996)*

COUNTRY	Nº of Experts	% of Experts by country
Austria	1	0.79%
Belgium	3	2.38%
Denmark	6	4.76%
Finland	4	3.17%
France	21	16.67%
Germany	13	10.32%
Greece	5	3.97%
Italy	12	9.52%
Netherlands	10	7.94%
Spain	7	5.56%
Sweden	2	1.59%
Switzerland	1	0.79%
United Kingdom	41	32.54%
Total:	126	100%

On a total of 126 sent, 69 experts replied to the questionnaire. The answer rate was of 54.76%. Figure 2 indicates the answer rate by country involved in the inquiry.

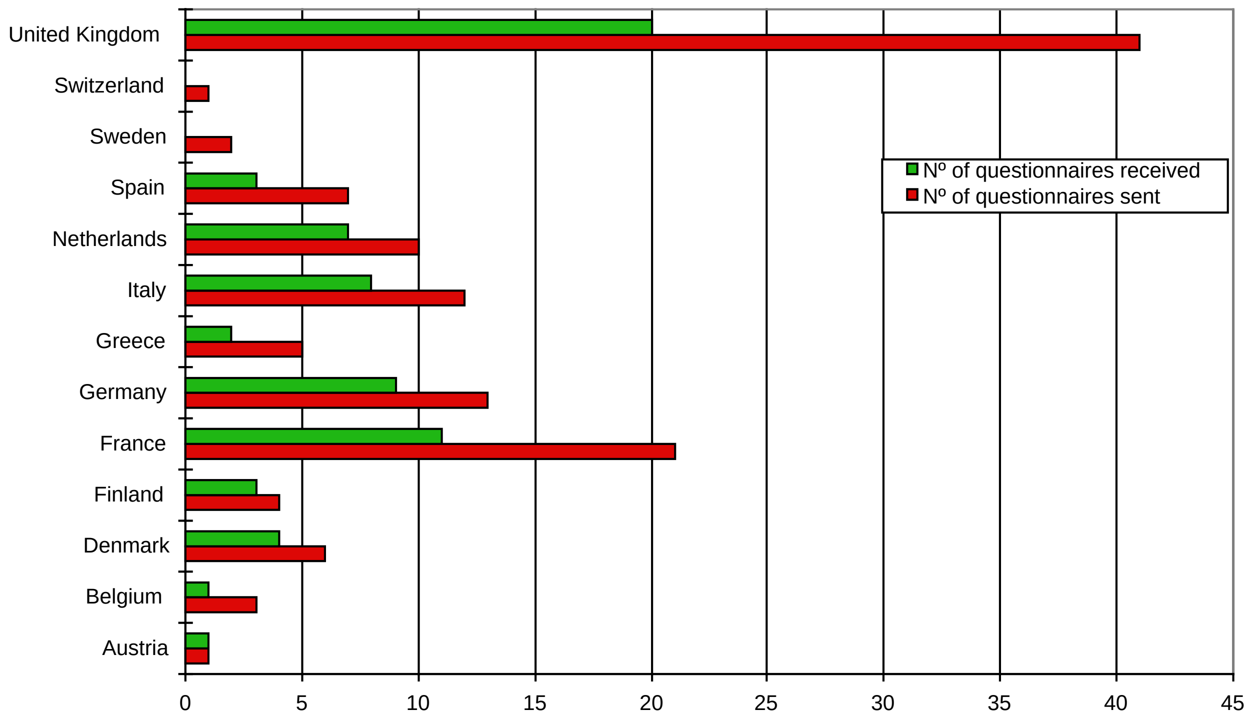

Figure 2: *Answer rate by country (IPTSinq, 1996)*

The main activity of the respondents is indicated in Figure 3. Of the respondents the 32% were consultants in the field of transport, 27% stem from academic activities, 13% from industry, 15% were experts working in transport management and 13% other sectors related to transport activities, such as Government's research laboratories. There are not enough information available to establish that the respondents formed a biased group.

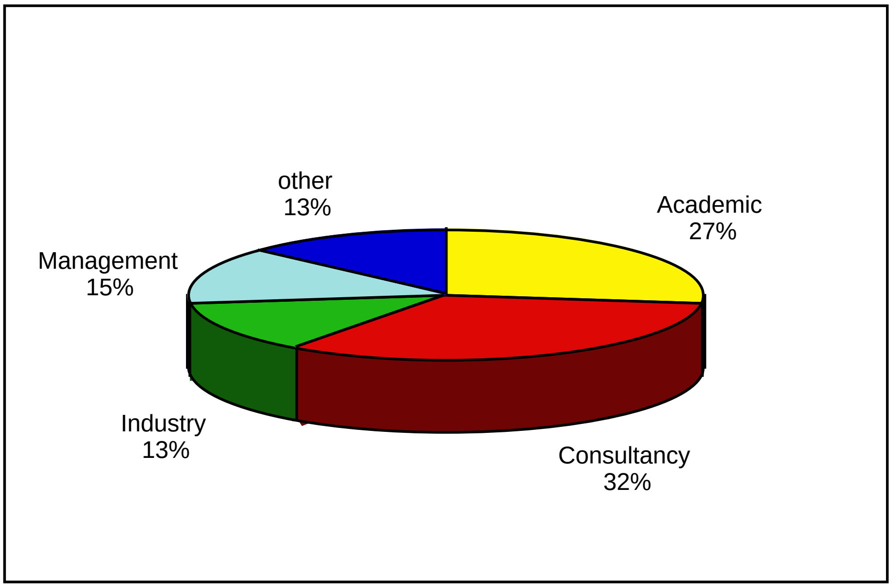

Figure 3: *Main activity of the respondents (IPTSinq, 1996)*

In this specific implementation of the SMIC method it has been asked to experts to rate their degree of expertise on the entire questionnaire. As indicated in Figure 4, 64% of the respondents considered themselves expert and/or knowledgeable on most of the topics, while only 2% define their degree of expertise as casually acquaintance.

Figure 4: *Degree of expertise of respondents (IPTSinq, 1996)*

Experts were asked to describe their familiarity with the majority of the topics they had answered, and they were also asked to rate their familiarity with the remainder of the topics. Table 2, describes the ratings returned by the experts. Each expert will have a combination rating, such as ‘expert on most topics’ and ‘knowledgeable on few topics’, as indicated in the shaded cell in the table below.

Table 2: *Combination rating of expertise ‘on most topics’ and ‘on few topics’ (IPTSinq, 1996)*

		ON MOST TOPICS				
		Unfamiliar	**Casually Acquainted**	**Familiar**	**Knowledgeable**	**Expert**
ON FEW TOPICS	**Unfamiliar**	-	-	1	-	1
	Casually Acquainted	-	-	2	1	-
	Familiar	-	1	2	7	2
	Knowledgeable	-	-	11	6	**6**
	Expert	-	-	2	7	5

The five descriptions offered on the degree of expertise were:

UNFAMILIAR with the topics.

CASUALLY ACQUAINTED if you have read or heard about the topics in the media or other popular presentations.

FAMILIAR with the topics if you know most of the arguments advanced for and against some of the issues surrounding them, you have read about them, and have formed some opinion about them.

KNOWLEDGEABLE in the topics

(a) if you were an expert in them some time ago but feel somewhat rusty now;

(b) if you are in the process of becoming an expert, but still have some way to go to achieve mastery of the topics; or

(c) if you work in a neighbouring field and occasionally draw upon or contribute to the development of this topics.

EXPERT if you consider yourself to belong to that community of people who currently dedicate themselves to the topics and

(a) if you are concerned with markets, commercial matters or needs in the area, you will be recognised outside your organisation as having strong grasp of future market and business trends or of regulatory and other aspects; or

(b) if you are in the technical field you are likely to have presented, written up and/or published the results of your work or may hold patents for its application.

These definitions were previously been used in UK Foresight Programme (Loveridge, Georghiou et al. 1995).

4 RESULTS OF THE INQUIRY

The SMIC inquiry was executed through one round of mailed questionnaires.

The six events considered for this specific implementation of the SMIC method are listed in Table 3.

Of the six events considered it is possible to distinguish two different groups:

a) events involving technologies to improve transport drawbacks (E1, E2, E3, E4)

b) events involving traffic problems, transport drawbacks or consequences (E5, E6).

Table 3: *List of the events (IPTSinq, 1996)*

E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems
E_3	51 - 70% of European medium size cities use transponder-based systems and Automatic Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings
E_4	51 - 70% of European medium size cities use Public Transport information systems, proving real-time information on park-and-ride, trip costs, timetables and duration for different modes
E_5	Congestion levels associated with a given volume of traffic substantially increase in European medium size cities
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities

It is possible to summarise the results in two parts. The first part will describe the single probability of occurrence of the six events considered and the second part will describe the conditional probability of the six events considered up to 2015.

4.1 Prospect for the year 2015: single probability of the forecasted events

The first category of results which stem from the assessment of the SMIC method is related to the single probability of occurrence of the six forecasted events included in the questionnaire. In fact, as described in Section 3.1, each expert had to assess the single probability of occurrence of the six events considered separately. Figure 5 shows the outcomes of the statistical distribution of the responses by the year 2015 in European medium size cities.

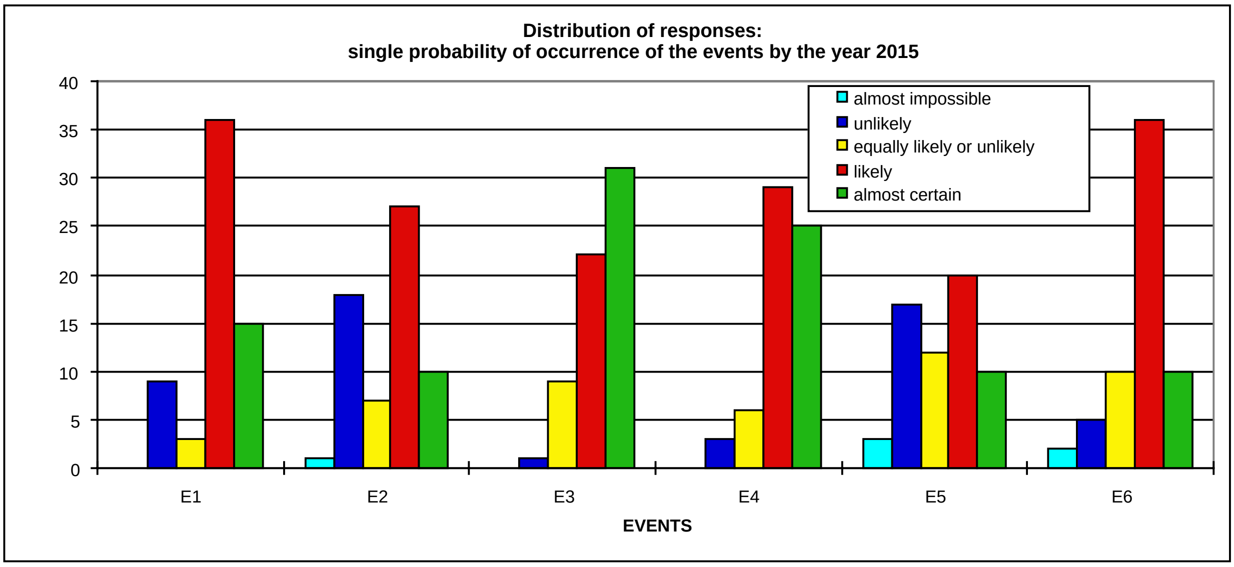

Figure 5: *Statistical distribution of responses of the single probability of occurrence of the forecasted six events by the year 2015 (IPTSinq, 1996)*

Table 4, describes the assessment of the occurrence of the six forecasted events expressed in percentage by the year 2015.

Table 4: *Experts opinions on the occurrence of the six events in percentage (IPTSinq, 1996)*

	almost impossible	**unlikely**	**equally likely or unlikely**	**likely**	**almost certain**
E_1	0.00%	14.29%	4.76%	57.14%	23.81%
E_2	1.59%	28.57%	11.11%	42.86%	15.87%
E_3	0.00%	1.59%	14.29%	34.92%	49.21%
E_4	0.00%	4.76%	9.52%	46.03%	39.68%
E_5	4.84%	27.42%	19.35%	32.26%	16.13%
E_6	3.17%	7.94%	15.87%	57.14%	15.87%

It can be noted that the experts for events E1, E2, E3, E4 and E6 reached the consensus on the probability of occurrence of the listed events. For event E1, *(51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as* *congestion level and incidents warnings)* experts largely supported the view in considering that it will be 'likely'[4] that from 51 to 70% of European medium size cities are going to use this ATT system by the year 2015. For event E2, *(31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems)* experts considered likely that by year 2015 from 31 to 50% of European cities will have their vehicles equipped with devices able to updating road maps for the use of route guidance systems. For event E3 it is possible to note a positive consensus, in fact 50% of the experts forecasted that it is going to be almost certain that from 50 to 70% of European medium size cities will use transponder-based systems and Automotive Vehicle Location (AVL) systems to give priority to Public transport through adjustment of traffic signal timings. Another 45% of the experts questioned, forecasted that it will be likely that this systems is going to be used by the year 2015 in 50 to 70% of European cities.

The forecasted probability of occurrence of the event E4 *(51 - 70% of European medium size cities use Public Transport information systems, proving real-time information on park-and-ride, trip costs, timetables and duration for different modes)* has been of 46% likely and 40% almost certain.

The events E5 and E6 were referring to transport problems respectively to congestion levels and to levels of traffic volume of passengers vehicles. In relation to the event E6, 57.14% of experts reached a clear consensus in saying that it will be likely that by the year 2015 the volume of traffic of passenger vehicles will substantially increase in European medium size cities.

For event E5 *(Congestion levels associated with a given volume of traffic substantially increase in European medium size cities),* experts have not reached a clear consensus. In fact, 27.42% of the experts questioned forecasted that it will be unlikely that this event will occur, and the 32.26% forecasted that it will be likely that this event occur in the year 2015. On the basis of the comments received from the experts, it is possible to say that the formulation of the event was not easy to understand due to its relation with traffic volume.

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[4] according to the scale given, which has been already described in Section 3 of this Paper.

4.2 Prospect for the year 2015: conditional probability of the forecasted events

The second category of results which stem from the assessment of the SMIC method are related to the conditional probabilities of occurrence of the six forecasted events included in the questionnaire. In fact, as described in Section 3.1, each experts in this stage had to assess first the probability of occurrence of P(i/j) probability of i if j occurs, and then the probability of occurrence of P(i/not j) probability of i if j does not occur the six events considered.

For each respondent two matrices were available, which data were put in the computer in order to allow the dedicated software to run. For each expert consulted, the software calculated a list of 2^n scenarios (i.e. in our case 2^6 scenarios, for a total of 64 scenarios for each expert consulted), ranged in decreasing order of probability. The data have to be introduced by randomly selected groups of not more than ten experts each group. Since the population of valid responses for the conditional probabilities was composed of a total of 59 experts, six groups were entered. For each expert and for each group of experts, the software gives a list of 2^n scenarios in decreasing order of probability of occurrence and a sensitivity analysis. The software provides, also, a synthesis of the calculations for the ten experts of each group. In the end, the final results are represented by the summary of all the calculations from all groups of experts, as indicated in Figure 6, and a sensitivity analysis for all groups of experts.

The version of the software used for this assessment and its manual are not very user-friendly. The novice user could sometimes have difficulties in understanding how to input data, and in understanding the calculations which stem from it. The language of the software used is French.

III SYNTHESE GENERALE (ET CALCULS POUR L'ENSEMBLE DES GROUPES)

A/ TABLEAU DES MOYENNES PAR GROUPE ET MOYENNE GENERALE

n°	groupe Ind	1	2	3	4	5	Moy.gen.
64	0	0.221	0.327	0.314	0.227	0.317	0.281
1	111111	0.115	0.064	0.101	0.142	0.110	0.106
49	111100	0.107	0.095	0.054	0.030	0.050	0.067
17	111101	0.084	0.058	0.101	0.058	0.027	0.066
3	101111	0.065	0.046	0.062	0.072	0.025	0.054
48	10	0.043	0.026	0.019	0.036	0.026	0.030
33	111110	0.019	0.034	0.042	0.018	0.014	0.026
4	1111	0.032	0.022	0.015	0.014	0.032	0.023
5	110111	0.007	0.022	0.051	0.023	0.012	0.023
2	11111	0.024	0.026	0.022	0.028	0.012	0.022
16	11	0.036	0.018	0.018	0.013	0.022	0.021
9	111011	0.026	0.017	0.028	0.023	0.006	0.020
19	101101	0.011	0.028	0.007	0.009	0.025	0.016
13	110011	0.014	0.021	0.011	0.017	0.009	0.014
35	101110	0.007	0.013	0.017	0.023	0.010	0.014
21	110101	0.009	0.019	0.005	0.017	0.013	0.012
29	110001	0.007	0.010	0.010	0.017	0.018	0.012
12	1011	0.012	0.012	0.010	0.011	0.012	0.011
14	10011	0.018	0.013	0.011	0.013	0.002	0.011
52	1100	0.010	0.011	0.024	0.004	0.006	0.011
53	110100	0.003	0.008	0.006	0.015	0.022	0.011
36	1110	0.008	0.003	0.011	0.017	0.013	0.010
11	101011	0.000	0.016	0.014	0.001	0.020	0.010
18	11101	0.002	0.006	0.005	0.007	0.028	0.010
51	101100	0.012	0.017	0.003	0.010	0.005	0.009
50	11100	0.020	0.006	0.003	0.010	0.006	0.009
62	10000	0.012	0.006	0.004	0.008	0.013	0.008
37	110110	0.003	0.013	0.009	0.009	0.006	0.008
7	100111	0.008	0.001	0.004	0.017	0.010	0.008
34	11110	0.006	0.012	0.001	0.015	0.006	0.008
25	111001	0.003	0.005	0.010	0.009	0.010	0.007
44	1010	0.002	0.002	0.002	0.014	0.013	0.007
31	100001	0.003	0.001	0.003	0.016	0.007	0.006
63	100000	0.001	0.000	0.000	0.023	0.005	0.006
15	100011	0.009	0.002	0.004	0.008	0.003	0.005
23	100101	0.001	0.004	0.005	0.003	0.012	0.005
38	10110	0.009	0.004	0.004	0.004	0.004	0.005
46	10010	0.005	0.007	0.000	0.003	0.010	0.005
56	100	0.004	0.010	0.005	0.002	0.004	0.005
28	1001	0.002	0.001	0.003	0.006	0.009	0.004
32	1	0.000	0.009	0.002	0.008	0.004	0.004
10	11011	0.002	0.007	0.000	0.007	0.005	0.004
55	100100	0.008	0.001	0.009	0.000	0.003	0.004
61	110000	0.005	0.001	0.000	0.015	0.000	0.004
20	1101	0.013	0.002	0.002	0.001	0.002	0.004
30	10001	0.002	0.008	0.002	0.000	0.005	0.004
45	110010	0.000	0.001	0.008	0.000	0.009	0.004
39	100110	0.000	0.000	0.003	0.003	0.012	0.004
40	110	0.000	0.002	0.002	0.000	0.013	0.003
54	10100	0.001	0.003	0.004	0.007	0.001	0.003
42	11010	0.006	0.000	0.001	0.002	0.008	0.003
8	111	0.007	0.002	0.003	0.002	0.002	0.003
22	10101	0.004	0.002	0.001	0.007	0.000	0.003
41	111010	0.000	0.002	0.004	0.004	0.004	0.003
58	11000	0.003	0.002	0.000	0.002	0.006	0.003
27	101001	0.000	0.003	0.001	0.000	0.010	0.003
43	101010	0.005	0.003	0.000	0.003	0.000	0.002
47	100010	0.003	0.000	0.000	0.000	0.008	0.002

60	1000	0.000	0.004	0.000	0.004	0.002	0.002
59	101000	0.005	0.000	0.000	0.003	0.000	0.002
24	101	0.000	0.000	0.001	0.002	0.004	0.001
26	11001	0.003	0.000	0.001	0.000	0.002	0.001
57	111000	0.001	0.001	0.003	0.000	0.000	0.001
6	10111	0.000	0.001	0.000	0.002	0.001	0.001

Figure 6: *Most likely scenarios in decreasing order of probability (IPTSinq, 1996)*

For the analysis only those scenarios which have at least a probability of occurrence not below 2% will be considered. In our specific case the scenarios considered in decreasing order of probability are. For each state S_k, there is an associated probability •k with ∑•k = 1:

S[5]$_{64}$ (000000) where •[6]$_{64}$ = 0.281

S_1 (111111) where $•_1$ = 0.106

S_{49} (111100) where $•_{49}$ = 0.067

S_{17} (111101) where $•_{17}$ = 0.066

S_3 (101111) where $•_3$ = 0.054

S_{48} (000010) where $•_{48}$ = 0.030

S_{33} (111110) where $•_{33}$ = 0.026

S_4 (001111) where $•_4$ = 0.023

S_5 (110111) where $•_5$ = 0.023

S_2 (011111) where $•_2$ = 0.022

S_{16} (000011) where $•_{16}$ = 0.021

S_9 (111011) where $•_9$ = 0.020

5 S= scenario

6 •= probability of occurrence of the scenario

It should be noted that amongst the selected scenarios which have a probability of occurrence at least of 2%, there are three pairs of scenarios which are exactly contrary (i.e. 64 (000000) and 1 (111111), 49 (111100) and 16 (000011), 17 (111101) and 48 (000010) . Figure 7, is the graphical representation of the probability of occurrence of the scenarios selected.

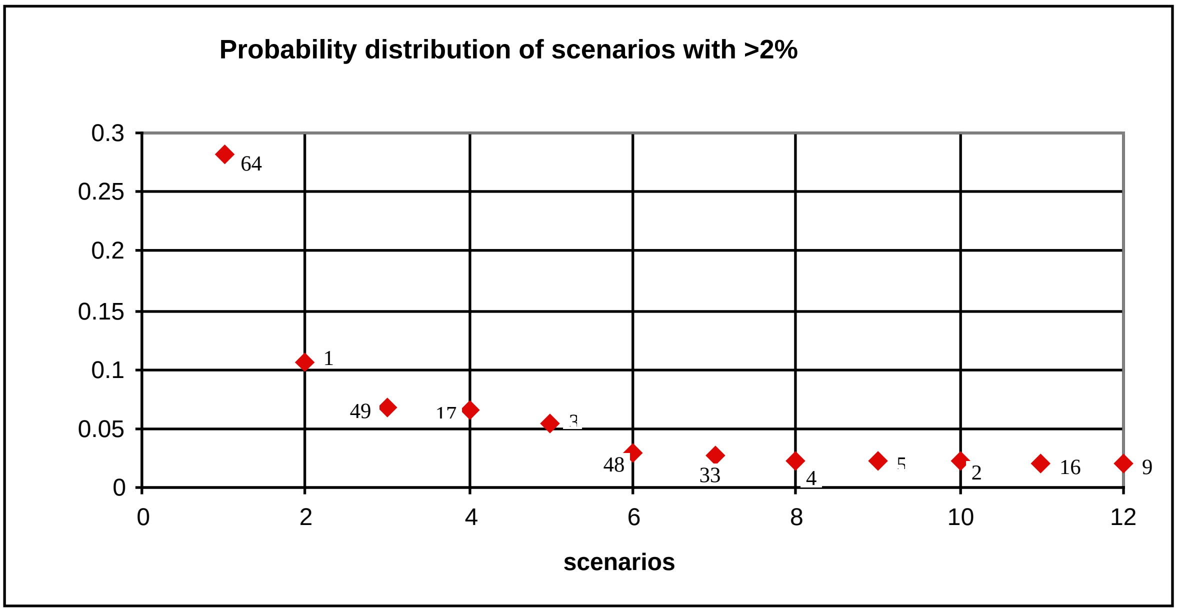

Figure 7: *Probability distribution of scenario with >2% (IPTSinq, 1996)*

It is interesting to note that there is a sharp decrease in the probability of occurrence from the first to the second scenario (i.e. S_{64} = 0.281 and S_1 = 0.106 the probability of occurrence is divided by almost 2, whereas afterwards the decrease in the probability tails off rapidly).

Figure 8, describes the cumulative probability of scenario occurrence for all the scenarios outlined from the SMIC software.

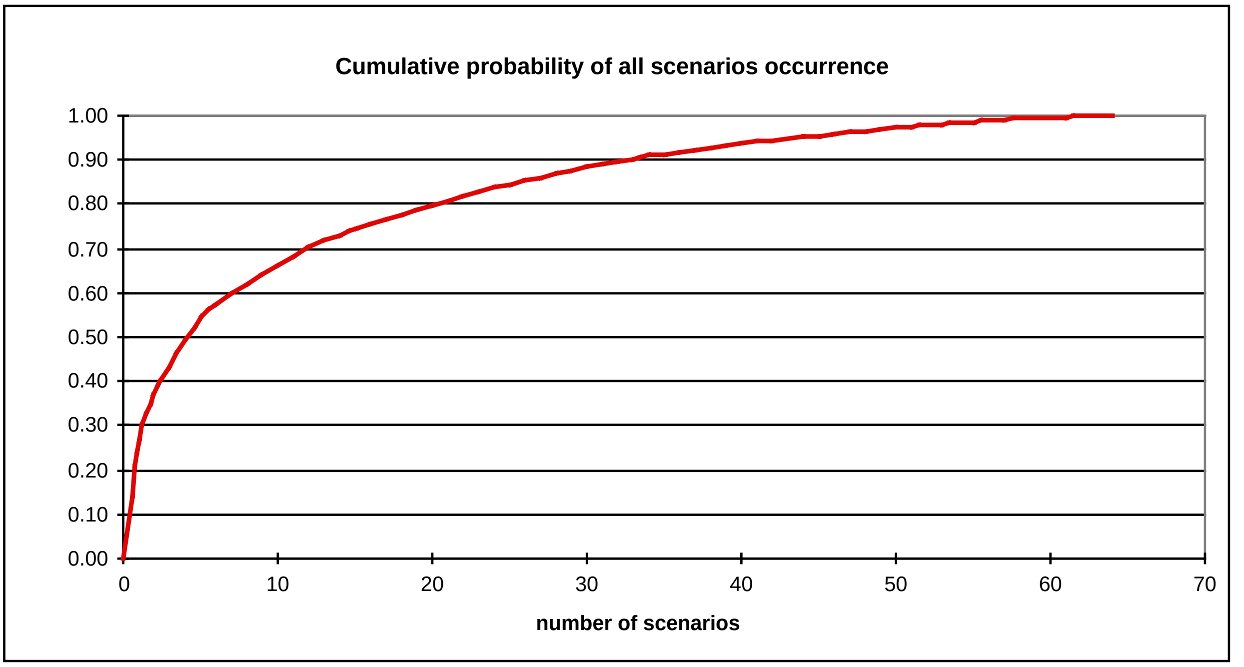

Figure 8: *Cumulative probability of all scenario occurrence (IPTSinq, 1996)*

A general comment received from one of the experts states that it was very difficult to answer to the conditional probabilities, because the formulation of the events was considerably restricting the reply. This was due to the fact that already in the formulation of the events for which the conditional probabilities were being asked it was stated, for example 31 - 50% of European medium size cities would adopt a certain technology in the year 2015. This specific way of formulating the events excluded information in the replies about the ranges from 0 - 30% and from 51 - 100% of European medium size cities, which could be seen as a drawback especially because the final information is on a range of European medium size cities and not specifically on the technology forecasted. On the other hand, this specific way of formulating the events could allow to validate the information obtained through the Delphi study, while keeping the scope of the inquiry to manageable proportion.

4.2.1 Analysis of scenarios

The selection of the scenarios which have a probability of occurrence of at least 2% are worthy to be analysed in more details. Then the fact that the results have in their most probable final scenarios three pairs of scenarios which are exactly contrary could be considered as inconsistent results.

- S_{64} (000000) with $\bullet_{64}$ = 0.281. The probability that none of the events take place is the highest one. None of the ATT technologies selected are going to diffuse in the ranges described and by the time horizon specified, but there will not be an increase (or there will a stabilisation) of congestion levels and of levels of traffic volume of passenger vehicles, which could be considered optimistic without any change in current mobility patterns. This scenario could assume that the trends will be a continuation of current trends of last thirty years which were basically based on building new road infrastructure to meet road traffic growth.
- S_{1} (111111) with $\bullet_{1}$ = 0.106. It is possible to define this scenario as the conflict scenario where all events come true. All ATT technologies will diffuse by the time horizon considered and with the ranges specified. However, the development of technologies is not going to have any effect on congestion and traffic volume which increase anyway.
- S_{49} (111100) with $\bullet_{49}$ = 0.067. All technologies will diffuse in the specified ranges, and have beneficial effects on congestion and on traffic volume. This scenario could be considered as an optimistic scenarios. In fact, it describes a harmonised development of ATT technologies within the ranges considered. Moreover, the ATT technologies which will develop refer both to an improvement of Public Transport and to an improvement of private vehicles. This scenario assumes to some extent that there will be efforts in policies and investments to favour the decrease of congestion and traffic volume, so to improve environmental drawbacks caused by traffic in cities. It would be possible to define this scenario as the one of ‘accelerated change’.
- S_{17} (111101) with $\bullet_{17}$ = 0.066. This scenario is different with respect to the previous one, only for its forecast referred to traffic volume levels. All technologies will develop within the time horizon considered and at the specified ranges. The technologies will have a beneficial effect on congestion despite a continued increase in traffic volume. This scenario implies a clear independence between the development of ATT technologies and traffic volume in European cities. Even if the impact of ATT technologies are beneficial for the level of congestion, there will not be a decrease in the level of traffic volume of passenger vehicles. The

ATT technologies considered not enough to produce a shift in mobility patterns towards a more intense use of Public Transport.

- S_3 (101111) with $•_3$ = 0.054. All technologies will diffuse in the specified ranges expect E2. Experts do not here believe that 31 - 50% of European medium size cities are going to adopt in-vehicles devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems. There will also be an increase in congestion levels and traffic volume of passenger vehicles, experts are clearly no optimistic about the consequences of ATT technologies on transport drawbacks.
- S_{48} (000010) with $•_{48}$ = 0.030. This scenario is a pessimistic one related to the development of ATT technologies in the ranges specified. Nevertheless, there will be an increase in the level of congestion but a decrease or stabilisation in the level of traffic volume of passenger vehicles. It is possible to define this scenario as the scenario of 'uncontrolled growth'.
- S_{33} (111110) with $•_{33}$ = 0.026. All forecasted ATT technologies will develop within the time horizon considered and in the specified ranges. The level of congestion will increase in the future, this would mean that the use of ATT technologies is not going to have an impact towards the decrease of congestion levels. However, the volume of traffic of passenger vehicles is not going to increase further, even if this result could be interpret as an independent relationship between traffic volume and the selected ATT technologies.
- S_4 (001111) with $•_4$ = 0.023; S_5 (110111) with $•_5$ = 0.023; S_2 (011111) with $•_2$ = 0.022; and S_9 (111011) with $•_9$ = 0.020. This four scenarios have in common a positive result in respect to the technological side even if not for all the questioned technologies. Then, they have in common the same result on transport consequences (i.e. congestion and traffic volume) which will increase by the time horizon considered by the forecast.
- S_{16} (000011) with $•_{16}$ = 0.021. This scenario is the opposite of scenario S_{49}. This scenario shows that the ATT technologies considered are not going to develop within the time horizon considered and within the ranges specified. On the contrary, congestion and traffic volume will increase. It is possible to define this

scenario as the one which shows that there is an independence of urban transport systems from ATT technologies. However, it is also possible that the technologies are not going to be adopted in the specified ranges due to factors which could restrict their development, such as either social acceptance, level of investment necessary to develop the technologies in the specified ranges, the development is likely to prove difficult or risky for technological reasons, and or the availability and establishment of European standards for the technology is not developed yet.

The results that should be considered worthy to look at and compare them are those ones which are positive towards the ATT technologies and those which are negative. Amongst the scenarios considered (i.e. those which have a probability of occurrence at least of 2%) a total of 0.381 are positive towards the technologies, and a total of 0.332 are negative towards the ATT technologies forecasted. It is possible to say that the experts are split into two different group those who believe that the technologies are going to diffuse, and those who believe that these specified technologies are not going to develop within the selected ranges. This result is significant, because when experts had to assess the single probability of the forecasted events they largely agreed, but when the scenarios were computed the opinion of the population questioned appears sharply divided. Moreover, experts had to deal with a quite uncertain context, where they had to take into consideration a specified range of European medium size cities, with a specified time horizon, thus experts rely on their beliefs and intuition, which could explain the fact that extreme scenarios coexist in the very first ranks.

4.2.2 Strategic sensitivity analysis

It is necessary for policy makers to be aware of the possible states or scenarios for the evolution of the system under study in order to determine their strategy. In addition, the choice of actions available is conditioned by a previous examination of the direct and indirect effects that each decision could have upon the whole system.

Sensitivity analysis consists of measuring the variation $\bullet Pj$ of the probability Pj of the event j following a variation $\bullet Pi$ of the probability Pi of the event i. Constructing an elasticity matrix allows the driver or dominant events and the dominated events to be deduced. Starting from the final results, we then calculate the elasticity e_{ij} (Godet 1993).

Table 5, summarises the results for the sensitivity analysis. The calculations have been performed with a step function *•Pi* = 0.1 for all *i*.

Table 5: *Results of strategic sensitivity analysis (IPTSinq, 1996)*

	E1	E2	E3	E4	E5	E6	
E1	1.000	0.095	0.057	0.083	-0.021	0.050	0.306
E2	0.061	1.000	0.010	0.035	-0.051	-0.008	0.165
E3	0.057	0.048	1.000	0.113	0.011	0.043	0.272
E4	0.097	0.085	0.122	1.000	-0.005	0.020	0.329
E5	-0.066	-0.077	-0.040	-0.064	1.000	0.011	0.258
E6	0.031	0.005	0.019	-0.002	0.051	1.000	0.109
	0.312	0.309	0.250	0.297	0.141	0.132	

Reading the marginal row totals it is possible to note that the impact of some events is greater that others; in this respect E1 and E4 with:

$\sum_j |e_{4j}| = 0.329$ and $\sum_j |e_{1j}| = 0.306$

The use of automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, and the use of Public Transport information systems time information on park-and-ride, trip costs, timetables and duration for different modes are determinant ATT technologies for the future situation of urban transport in European medium size cities.

Reading the column totals, it possible to note that certain events are more dominated than others. In this respect, E1 and E2 with:

$\sum_j |e_{1i}| = 0.312$ and $\sum_j |e_{2i}| = 0.309$

In relation to e_1, it possible to explain this result with e_{51} = -0.066, which means that, if the probability of e_5 increases of 10%, then the probability of e_1 decreases by 6.6%. In other words, the increase of congestion levels associated with a given volume of traffic reduces the probability that the 51 -70% of European medium size cities will adopt successfully automated systems to monitor the level of traffic on real-time.

In relation to e_2, this result could be explained by e_{52} = -0.077, which means that if the probability of e_5 increases by 10%, then the probability of e_2 decreases by 7.7%. In other words, the increase of congestion levels reduce the probability that 31 -50% of European medium size cities will adopt successfully in vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.

The event E_1 is both a determinant as well as an influential variable. The adoption by a proportion of European medium size cities of automated systems to monitor traffic in real-time and which are able to provide real-time on-board journey information, as well as congestion levels and incidents warnings, is the most sensitive technology from the point of view of the likely development and implications of the use of transport telematics in European medium size cities in the year 2015.

It is possible to note that, if the probability of e_5 increases of 10%, this would affect all the forecasted technologies. In other words, an increase of 10% of the probability of e_5, will decrease the probability that European medium size cities are going to adopt successfully the selected ATT technologies.

Finally, the results show that an increase of traffic volume of passenger vehicles has not a great impact on the system of events.

5 CONCLUSIONS

The conclusions to this paper are be based on the comments and opinions of the transport experts, which responded to this inquiry on the future of ATT technologies in European medium size cities in the year 2015. They are be based on the specific assessment of the methodology used and on its outcomes.

Experts found it difficult to identify the conditional probabilities of the forecasted events, especially when they had to establish the conditional probability of an event involving one technology with one traffic problem. Moreover, the formulation of the events including ranges related to the adoption of one technology by European medium size cities caused some problems due to too many uncertainties to take into consideration.

One comment received from one expert states that, the conditional probability questions were complicated, because in addition to the usual uncertainties involved when future trends are forecasted, some of the events questioned (e.g. traffic growth) depended to a greater extent to other factors than those listed. Then, in relation to technologies, some of the relationship between technologies are dependent on the kind of system employed. For example, in-vehicle navigation systems (E1), could be by semi-autonomous system, which could be largely independent of the technologies to monitor congestion in real-time. Thus, sometimes it would be possible to give sets of both dependent or independent answers.

Furthermore, one expert found that the use of Bayes law to assess conditional probabilities for this specific inquiry, could lead to incoherent tables because the dependency between the events listed is not of a statistical nature in the classical sense. It may be more relevant to list the possible dependency or causal links between the forecasted events (i.e. list factors having possibly an effect on the forecasted topics).

There have been comments on the content of the events, especially the event involving the growth of traffic volume of passenger vehicles, which has been considered not detailed enough. The accuracy of conditional probabilities related to the event of possible increase of traffic volume has considered biased by one expert questioned; due to the evolution of traffic volume of passenger vehicles, which has as its base of reference the level of congestion. Therefore, if in the base of reference the level of congestion is high, the traffic volume of passenger vehicles can hardly progress, thus if the adoption of ATT systems reduce the level of congestion, it is not consequential logic that there will not be an increase of traffic volume, which could be either induced or generated traffic caused by increased capacity (or optimisation) of the transport network. If, in the base of reference the level of congestion is low, it will be even more likely that the level of traffic volume of passenger vehicles could increase, independently from the adoption of ATT systems.

In general, experts believe that there will be a push towards innovation in traffic management area, which would push towards spread installation of ATT systems in urban areas. However, the future development of ATT technologies does not entirely depend on the current levels of traffic volume, other interests such as industry ones are involved, which could play a major role in the development of ATT technologies. Experts agreed that the ATT technologies which could have an effect on traffic volume are the ones related with charges to the user (i.e. automated congestion pricing when entering a zone of the city). The ATT systems may encourage a degree of modal shift towards public transport and a better management of traffic flows, but without financial constraints these effects might be of relatively minor impact.

Finally, there have been comments related with the issue of future development of ATT technologies in European cities, and their impact on transport and mobility patterns. There is a common agreement amongst experts that, transport telematics by itself cannot solve the problem of transport management in urban areas only because these systems are using Information Technology (IT). Then, in relation to the baseline scenario (see Annexes) included in the inquiry, one comment received states that, there are of course different futures which could fit inside the baseline scenario and which could lead to different situations in the year 2015. For example, the adoption by European medium size cities of ATT systems are not an advocacy for building more roads. The limits of ATT systems depend also on the existence of a coherent network of infrastructures. If there are no real alternative routes available, there is not a real need to divert traffic. These limits are a warning about the necessity of physical infrastructure which could make transport telematics technologies useful for an efficient traffic management. Another point that has been considered is the implementation of ATT systems to give priority to Public Transport in urban areas. The improvement of Public Transport management, such as more services to the Public Transport passengers, and the promotion of Public Transport is very important for the future of European medium size cities. Therefore, the likelihood that ATT systems to facilitate the priority of public vehicles could have a market is quite high, especially if levels of congestion and levels of traffic volume of passenger vehicles in European cities are going to increase in the near future.

References:

ECMT- The European Conference of Ministers of Transport (1995). *Road Transport Informatics - Institutional and Legal Issues*. Paris, OECD.

Godet, M. (1993). *From anticipation to action - A handbook of strategic prospective*. Paris, UNESCO.

Loveridge, D., L. Georghiou, et al. (1995). *United Kingdom Technology Foresight Programme - Delphi Survey*. Manchester, PREST - The University of Manchester.

Makridakis, S., S. Wheelwright, et al. (1983). *Forecasting: methods and applications*. New York, John Wiley & Sons.

Scapolo, F. (1996). *Future of Transport Telematics Technologies* - *Results of a Delphi inquiry*, European Commission - Joint Research Centre - Institute for Prospective Technological Studies (IPTS).

Annexes

Definition of a European medium size city:

For the purpose of our study, we would like you to answer in terms of medium-sized cities. By this we understand cities that fall in the broad range of 500.000 to 5 million inhabitants. We assume the definition of built-up area and correspondent rules of delimitation to define the size of European medium size cities. The notion of built-up area is based on the boundaries of the constructed zone of a certain urban area.

We will be particularly interested in the transport network of the city centre or centres.

We would like to underline that the cities we are taking into account, are capital cities of some smaller European countries, and major metropolitan centres of other European countries, but are considered medium sized cities at a European level.
The distribution of cities across Europe is the following:

Of a total of 60 cities:

Austria	1	Vienna
Benelux	4	Brussels, Antwerp, Amsterdam, Rotterdam
Denmark	1	Copenhagen
Finland	1	Helsinki
France	5	Lille, Lyon, Marseilles, Bordeaux, Toulouse
Germany	14	Berlin, Düsseldorf, Köln, Hamburg, Munich, Frankfurt, Stuttgart, Dresden, Bremen, Hannover, Nuremberg, Bielefeld, Leipzig, Mannheim
Greece	2	Athens, Thessaloniki
Italy	10	Milan, Naples, Rome, Turin, Florence, Genoa, Palermo, Bari, Catania, Bologna
Ireland	1	Dublin
Norway	1	Oslo
Portugal	2	Lisbon, Porto
Spain	8	Madrid, Barcelona, Valencia, Seville, Bilbao, Malaga, Gijon, Zaragoza
Sweden	1	Stockholm
Switzerland	1	Zurich
UK	8	Birmingham, Manchester, York, Glasgow, Liverpool, Nottingham, Newcastle, Sheffield

SCENARIO:

We are asking you in this SMIC (Cross Impact Systems and Matrices) questionnaire to provide us with your views about the likely development and implications of the use of transport telematics in medium-sized European cities in the year 2015. However, experience has taught us that the answers, which experts give to such questions, are very conditional on their assumptions about the overall scenarios within which the specific matters at hand are located. Similarly, it can be very difficult to compare, contrast and synthesise expert views when the respondents to such a questionnaire are implicitly utilising very different scenarios. For this reason we are requesting you to assume that the following baseline scenario will in fact prove to be the case. If you have severe reservations about this, we would of course like to know.

The economic, social and political trends over the last 20 years have favoured the use of personal transport so encouraging the use of cars. Public transport use and the quality of Public transport systems have developed unevenly, with relatively slow growth and often stagnation - even decline.

The main features of the baseline scenario are:

- Little change in the underlying social processes that lead to people demanding personal geographical mobility.
- Continued growth in aggregate personal disposable income.
- Continued increase in the level of car ownership, with no major transformation of the historical relationship between this and personal disposable income.
- Growing concern with environmental and other impacts of transport systems in urban areas and elsewhere. Increased awareness of both health problems and greenhouse gas emissions.
- Low emphasis on further road network building.
- Continued investment to increase transport efficiency through a better use of the existing infrastructure.
- Growing emphasis on market-based solutions and market instruments (e.g. road pricing) as a means of shaping transport systems.

- Continued investment in research, development and application of technologies (vehicle and infrastructure) which are intended to alleviate problems such as congestion, pollution, hazards.

On the basis of the results of a first round of a Delphi study which is taking place in parallel, we have selected some transport telematics technologies still in a pilot stage in Europe, which experts believe to have a widespread use by the year 2015. The purpose of this study is to understand if, there are interrelationships between these technologies (amongst them) and with the levels of congestion and traffic volume.

The SMIC questionnaires

STAGE ONE:

In the ***first stage***, we would like to obtain your views about the simple probability of occurrence of the single events by the year 2015. We would like you to provide your answer on the probability of occurrence of the listed events, on a scale from **1** to **5**, as indicated below.
Please, indicate this by checking one of the available boxes, as shown below.

Example of answer:

- Event (E_n)

Unlikely ← → Likely

1	2	3	4	5
			X	

Meaning of the probability scale:

1= event almost impossible (0 - 10%)
2= event unlikely (11 - 30%)
3= event equally likely or unlikely (31 - 50%)
4= event likely (51 - 70%)
5= event almost certain (71 - 90%)

Meaning of answer: All other things being equal, I estimate that is *likely* that event (E_n) will occur by the year 2015.

In the year 2015

Event E_1: 51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.

Unlikely ← → Likely

1	2	3	4	5

Event E_2: 31 - 50% of European medium size cities use in-vehicles devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.

Unlikely ← → Likely

1	2	3	4	5

Event E_3: 51 - 70% of European medium size cities use transponder-based systems and Automatic Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.

Unlikely ← → Likely

1	2	3	4	5

Event E_4: 51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.

Unlikely ← → Likely

1	2	3	4	5

Event E_5: Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.

Unlikely ← → Likely

1	2	3	4	5

Event E_6: Traffic volume of passenger vehicles will substantially increase in European medium size cities.

Unlikely ← → Likely

1	2	3	4	5

STAGE TWO

In the ***second stage*** we would like you to indicate the conditional probability of the six events. For each event, you are kindly invited to fill **two** tables in which you should estimate:

in the **first table** what is *the probability that each of the other five events (listed) will be implemented given that event (E_n) does turn out to be true;*

and

in the **second table** what is *the probability that each of the other five events (listed) will be implemented given that event does not turn out to be true.*

We would like you to provide us your view on the likelihood of the occurrence of an event (E_n), on a scale from 1 to 6, as indicated below.

Please, indicate this by checking the available boxes, as shown below.

Example of answer

- Event (E_n) is true

	1	2	3	4	5	6 (Independent)
E (a)	X					
E (b)				X		
E (c)			X			
E (d)			X			
E (e)						X

Meaning of the probability scale:

1= event almost impossible (0 - 10%)

2= event unlikely (11 - 30%)

3= event equally likely or unlikely (31 - 50%)

4= event likely (51 - 70%)

5= event almost certain (71 - 90%)

6= the two events under consideration are independent

Meaning of answer:

If event (E_n) come out to be true, event (E_a) will be almost impossible; it is likely that event (E_b) will happen; events (E_c) and (E_d) are equally likely to come true; and there will be no connection between event (E_e) and event (E_n).

Please, note that if you think there is no relation between two events that you are considering, you can check column **6**.

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_1 **51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings** is true:

		1	2	3	4	5	6	
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.							Independent
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.							
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.							
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.							
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.							

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_1 **51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings** is not true:

		1	2	3	4	5	6	
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.							Independent
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.							
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.							
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.							
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.							

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_2 **31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems** is true:

		1	2	3	4	5	6 (Independent)
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_2 **31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems** is not true:

		1	2	3	4	5	6 (Independent)
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_3 **51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings** is true:

		1	2	3	4	5	6 (Independent)
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E_4	51 -70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_3 **51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings** is not true:

		1	2	3	4	5	6 (Independent)
E1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						
E6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_4 **51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes** is true:

		1	2	3	4	5	6	
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.							Independent
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.							
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.							
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.							
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.							

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_4 **51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes** is not true:

		1	2	3	4	5	6	
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.							Independent
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.							
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.							
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.							
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.							

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event
E_5 **Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities** is true:

		1	2	3	4	5	6
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

Independent

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event
E_5 **Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities** is not true:

		1	2	3	4	5	6
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_6	Traffic volume of passenger vehicles will substantially increase in European medium size cities.						

Independent

In the year 2015

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_6 **Traffic volume of passenger vehicles will substantially increase in European medium size cities** is true:

		1	2	3	4	5	6 (Independent)
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						

What is the probability in your view, that each of the following events will be turn out to be true, assuming that event E_6 **Traffic volume of passenger vehicles will substantially increase in European medium size cities** is not true:

		1	2	3	4	5	6 (Independent)
E_1	51 - 70% of European medium size cities use automated systems to monitor traffic in real-time which are able to provide real-time on-board journey information, as well as congestion level and incidents warnings.						
E_2	31 - 50% of European medium size cities use in-vehicle devices which can provide continuous dynamic updating of digital road maps for the use of route guidance systems.						
E_3	51 - 70% of European medium size cities use transponder-based systems and Automated Vehicle Location (AVL) systems to give priority to Public Transport through adjustment of traffic signal timings.						
E_4	51 - 70% of European medium size cities use Public Transport information systems, providing real-time information on park-and-ride, trip costs, timetables and duration for different modes.						
E_5	Congestion levels associated with a given volume of traffic will substantially increase in European medium size cities.						