THE REALITY OF IN VEHICLE TECHNOLOGY EUROPEAN MARKET AND ITS IMPACT ON RESEARCH INVESTIGATIONS

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ABSTRACT: The objective of this paper is to present a methodology to evaluate the availability of in-vehicle technologies (IVT) in the European market. The knowledge that can be gained thanks to this methodology can help to evaluate the impact of the impact of IVT real distribution on the research investigations in the field of road transport. In a first part, this paper explains the methodology developed in the context of FP7 project INTERACTION to assess the IVT penetration in Europe. In a second step, it gives the results of this methodology for year 2007. In a third step, it presents the possible consequences of this distribution on the research investigations. Finally, this paper concludes with some actions that would strengthen the results of the methodology.

1 INTRODUCTION

With the development of communication and information technologies and their deployment in the field of road transport, In-Vehicle Information Systems (IVIS) and Advanced Driver Assistance Systems (ADAS) are becoming tangible features of car driving. According to Stevens [1], IVIS provide the driver with various functions and services, while ADAS provide more direct driver support. IVIS may deliver information related to the trip management (e.g. navigation, traffic or weather information) but also completely unrelated to the driving activity (e.g. phone calls, e-mails…). ADAS take into account immediate driving environment or vehicle dynamics to support the driving task. ADAS may assist the drivers in vehicle stabilization (e.g. Anti-lock-brake (ABS), Electronic Stability Program (EPS)) or by providing specific information, warnings or actions on the level of vehicle manoeuvring, being relevant for immediate driver situation (e.g. Intelligent Speed Adaptation (ISA), Adaptive Cruise Control (ACC), Lane Departure Warning System (LDWS) or Collision avoidance system (CAS)). Despite the interest of these devices, the current economical situation tends not to favour the spreading of expensive high technology systems.

This raises the issue of the representativity of drivers that use the In-Vehicle technologies (IVT) that are tested during research investigations. Indeed, in order to be able to make general statements from the conclusions of these investigations, it is necessary to have a good knowledge of the IVT diffusion. In this paper, we present a methodology developed in the European project INTERACTION. The objective of this methodology is to gain a better knowledge of the European market in terms of diffusion of IVT. In a first paragraph, we explain in detail this methodology. Then, according to the methodology, we present the diffusion of IVT on the European market for year 2007. In a last

part, we identify the outcomes of this diffusion on the research investigations.

2 A METHODOLOGY TO DETERMINE IVT DIFFUSION

INTERACTION is a FP7 European project that aims to study drivers' similarities and differences in their interactions with in-vehicle technologies. This project focuses on in-vehicle technologies that are widely spread and adopted by European drivers. The first task of this project was to define, from all available IVT, which were the most relevant technologies for the project. For this purpose, a specific selection process was defined. Indeed, in order to identify INTERACTION IVT, two main criteria were used: the level of availability of the IVT on the European market and the stakes associated to each IVT in terms of Human/Machine interaction. This paragraph presents in detail the methodology developed during INTERACTION project to obtain the criteria about the level of availability of the IVT. This methodology consists in 6 consecutive steps.

In order to be able to obtain knowledge about IVT availability on the European market for a given year, we have to consider the technologies that are available on the car makes that are the most sold in Europe. Thus, the first step of the methodology is to analyse the number of new passenger car registrations in Europe during a full year. This data are available from the AAA-ACEA [2]. The objective of this analysis consists in evaluating, from the general number of new car registrations, which car makes are the most representative of the European market. In order to get a correct idea of the car makes that are widely spread in Europe for this year, it is not sufficient to study this information only at the general European level. Indeed, as several European countries have local car makers, it is important to take into account the local specificities that may appear in specific area of Europe. So the number of new passenger car registrations have to be studied both in general for Europe and in detail for each European country. This analysis permit to reduce the scope of the study and to focus only on a selection of representative car makes.

From the selected car makes, it is then possible to describe all in-vehicle technologies that can be found and to build a list. This list of technologies permits to define a typology of in-vehicle functions. This typology considers the IVT according to their assistance objectives. Indeed, in order to be able to compare IVT between different car makes, it is necessary to refer to the assistance function the technology is supposed to provide. Indeed, the practical and technical implementation of one function by one OEM (Original Equipment Manufacturer) or supplier, including displays and controls that constitute the interface between the system and the driver, can be very different. For example, on two different car makes, two very different systems, with different displays and controls, can provide the driver with the same assistance as they are two different function implementations. Thus, these two systems have to be grouped in the same IVT category.

The next step of the methodology consists in evaluating, for each IVT of the typology, how it is available on the different selected car makes. However, when looking into details, the availability of the functions depends, for each car make, on the specific car model and category. For example, the IVT available in a Peugeot car is different from one model to another one, i.e. from a 206 to a 308,

but it is also different from a category to another one, i.e. from a 206 “sport” to a 206 “comfort”. Thus, in order to be able to achieve this step and to gain a correct picture of function availability per car make, it is necessary, for each car make, to study all possible car models and to evaluate the availability of the selected functions depending on the models and the category. To define the existing car categories and their associated IVT, data are available, for each car model, on the car manufacturer websites and on various internet forum or websites specialised in the field of automotive. This data indicate if IVT come as a standard function, can be installed as an optional function or is unavailable. This information makes it possible to build tables to present the level of availability of IVT for each car model and category.

However, in order to present availability information for the different selected car makes, it is still necessary to compile data in order to make a synthesis of the IVT availability. Thus, the next step of the methodology consists in grouping the models into families that are representatives in terms of IVT equipment. These families, also established according to the characteristics, usage and size of the models, are the following: Compact car, Mid size car, Sedan car, Luxury car. Compact cars refer to small and economical cars, rather designed to perform trips inside city, or as a secondary vehicle. Mid size cars refer to intermediate cars often referred to as “family car”. Sedan cars refer to cars that offer more comfort and more room that mid size cars. These cars are designed to perform long road travels. Luxury cars are high end vehicles with last generation equipments, best performance, construction precision, extreme comfort, design ingenuity, technological innovation, or features that convey brand image.

From this last classification, it is possible to analyse the availability of the functions according to the car families, but it is still necessary to determine which car families are the most representative in Europe in term of new car registration. Thus, a last step is necessary to determine the car families that are the most representative in Europe. This information is available from the AAA-ACEA with the number of registration according to makes and models of vehicles. Here again, it is important to study the market share of car models in each European country in order to evaluate possible local specificities.

Finally the last step consists in merging all the information in order to obtain the IVT that are available on the European market.

3 RESULTS: DIFFUSION OF IVT ON THE EUROPEAN MARKET

This paragraph presents the results obtained in the frame of INTERACTION project, for year 2007, from the methodology described above.

3.1 Major car makes in Europe in 2007

We collected the car new registration data for each existing car make in Europe for year 2007. These data consider Europe as the 27 member countries of the European Union, and the 4 countries of the European Free Trade Association (EFTA). We analysed these data in order to obtain a relevant selection for INTERACTION project. Indeed, we studied the data that indicate the general numbers of car new registration in Europe and each partner made a local

analysis for their country in order to evaluate local specificities. Finally, we chose to take into consideration the car makes with more than 4% market share and we added to this list Volvo, Seat and Skoda as they have very important market share respectively in Finland, Spain & Portugal, and Austria & the Czech Republic. This addition was done to take into account the local specificities of these INTERACTION partners' countries. These results are illustrated by the following table.

Table.1. INTERACTION Selection of most representative car makes in Europe 2007

Group	Make	Total volume	Market share (%)
BMW	BMW	705 661	4,4%
DAIMLER	MERCEDES	731 338	4,6%
FIAT	FIAT	978 446	6,1%
FORD	FORD	1 302 700	8,1%
	VOLVO	265 966	1,7%
GM	OPEL	1 343 885	8,4%
JAPAN	TOYOTA	945 492	5,9%
PSA	CITROEN	943 301	5,9%
	PEUGEOT	1 106 650	6,9%
RENAULT	RENAULT	1 209 661	7,6%
VOLKSWAGEN	AUDI	661 676	4,1%
	SEAT	386 565	2,4%
	SKODA	482 355	3,0%
	VOLKSWAGEN	1 632 352	10,2%

With this selection rule, almost 80% of the European market is covered, which is representative enough for our study.

3.2 Typology of in-vehicle functions

The next step was to define a typology of the in-vehicle functions representative of the European Market. In the selected car makes, it is possible to list up to 32 IVT providing various functions of assistance. These IVT can be classified according to 7 relevant categories according to their assistance objectives:

- Brake assist: systems that help the drivers to handle emergency situations,
- Longitudinal control: systems that provide the driver with speed regulation assistance,
- Lateral control: systems that provide the driver with trajectory regulation assistance,
- Trip information: systems that provide the driver with information related to their trip,

- Driver perception support: systems that provide the driver with a better perception of their surroundings,
- Miscellaneous informative functions: systems that provide the driver with more driving confidence,

The following table shows the typology of the functions available on the car makes selection according to the categories defined above.

Table.2. INTERACTION In vehicle functions typology

Brake assist	Longitudinal control	Lateral control	Trip information	Driver perception support	Misc. Informative functions	Infotainment
Anti-lock Braking System (ABS) Emergency Brake Assist (EBA) Electronic Brake Force Distribution (EBD) Hill hold control (HHC)	Cruise Control Speed Limiter Adaptive Cruise Control (ACC) Distance Alert / Collision warning Anti-slip regulation (ASR)	Electronic Stability Program (ESP) Continuous Damping Control (CDC) Power-steering Variable power-steering Active Front Steering (AFS) Body levelling Lane Departure warning system (LDWS)	Trip computer Navigation system	Automatic rain sensing / wipers Automatic headlights Adaptive Front Lighting System (AFLS) Parking aid Blind spot assist Head-Up display (HUD) Night Vision Side View Camera	Low tyre-pressure warning system IDIS System (information broadcast manager) Driver alert control (fatigue warning system) Heater / Air Vent / Air conditioned	Phone Radio/CD

3.3 Availability of the in-vehicle functions according to car makes and categories

The next step was to define how these IVT are available on the representative car makes. This is done through the study of IVT availability on each car model and category. This information permitted us to build a table that presents the IVT availability in details. Indeed, the full table presents, in lines, the car models and categories for each car make and, in column, all the IVT listed in the typology. On this table, an “s” indicates a standard function; an “o” indicates an optional function; and a blank cell indicates an unavailable function. The full result is a table made of around 500 lines and 40 columns and cannot be inserted in this paper. The picture below represents, as an illustration, some IVT availability for Peugeot cars, according to the model and category.

				BRAKE ASSIST					LATERAL CC				
				Anti-lock bracking system	Emergency brake assist (EBA)	Electronic BrakeForce Distribu	Traction Control		Electronic Stability Progra	Continuous Damping Control	Anti-slip regulation (ASR)	Power-steering	Power-steering variable
PSA	PEUGEOT	107	Trendy	s		s						s	s
PSA	PEUGEOT	1007	Trendy	s	s	s	o		o	o	o	s	s
PSA	PEUGEOT	1007	Sporty	s	s	s			s	s	s	s	s
PSA	PEUGEOT	1007	Sporty Pack	s	s	s			s	s	s	s	s
PSA	PEUGEOT	206	Génération	s	s	s			o	o	o	s	
PSA	PEUGEOT	206	Urban	s	s	s			o	o	o	s	
PSA	PEUGEOT	206	Trendy	s	s	s			o	o	o	s	
PSA	PEUGEOT	207	Urban	s	s	s	o		o	o	o	s	
PSA	PEUGEOT	207	Trendy	s	s	s	o		o	o	o	s	s
PSA	PEUGEOT	207	Premium	s	s	s	o		o	o	o	s	s
PSA	PEUGEOT	207	Premium pack	s	s	s	o		o	o	o	s	s
PSA	PEUGEOT	207	feline	s	s	s			s	s	s	s	s
PSA	PEUGEOT	308	Confort	s	s	s						s	s
PSA	PEUGEOT	308	Premium	s	s	s						s	s
PSA	PEUGEOT	308	feline	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	407	Confort	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	407	Premium	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	407	Premium pack	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	407	feline	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	607	Premium	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	607	feline	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	807	Premium	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	807	Navteq on board	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	807	Premium pack	s	s	s	s		s	s	s	s	s
PSA	PEUGEOT	4007	confort pack	s		s	s		s	s	s	s	
PSA	PEUGEOT	4007	Premium	s		s	s		s	s	s	s	
PSA	PEUGEOT	4007	feline	s		s	s		s	s	s	s	

Fig.1. Illustration of IVT availability according to make and category for Peugeot cars

3.4 Availability of the in-vehicle functions according to car family

The following step aims to make a synthesis of the IVT availability by grouping the car models into families that are representatives in terms of IVT equipment. The following table represents, as an illustration, the IVT availability for the compact car family. In this table the availability of the functions is represented with a 5 dot system. The colour of the dots indicates the availability of the function according to the following rules:

- 5 green dots indicate that the function is standard on all the models of the make,
- 5 blue dots indicate that the function is optional on all the models of the make,
- 5 red dots indicate that the function is unavailable on all the models of the make,
- All colour combinations are possible, i.e. 3 green dots and 2 blue dots indicate that for this make, the function is standard 60% of the time and

optional 40% of the time,

- In case of 50/50% distribution, only 4 dots are used.
- In case of 33/33/33% distribution, only 3 dots are used.

		MERCEDES	FIAT	FORD	VOLVO	OPEL	TOYOTA	CITROEN	PEUGEOT	RENAULT	AUDI	BMW	SEAT	VOLKSWAGEN	SKODA
Brake assist	Anti-lock braking system (ABS)										/	/			
	Emergency brake assist (EBA)										/	/			
	Electronic BrakeForce Distribution (EBD)										/	/			
	Hill hold control (HHC)										/	/			
Longitudinal Control	Cruise Control										/	/			
	Speed limiter										/	/			
	Adaptive Cruise Control (ACC)										/	/			
	Distance Alert / Collision warning										/	/			
	Anti-slip regulation (ASR)										/	/			
Lateral control	Electronic Stability Programme (ESP)										/	/			
	Continuous Damping Control (CDC)										/	/			
	Power-steering										/	/			
	Power-steering variable										/	/			
	Active front steering (AFS)										/	/			
	Body levelling										/	/			
	Lane Departure warning system (LDWS)										/	/			
Trip Information	Trip computer										/	/			
	Navigation system										/	/			
Driver perception support	Automatic rain sensing/wipers										/	/			
	Automatic headlights										/	/			
	the Adaptive Front Lighting System (AFLS)										/	/			
	Parking aid										/	/			
	Blind spot assist										/	/			
	Head-up display (HUD)										/	/			
	Night vision										/	/			
	Side view camera										/	/			
Miscellaneous informative functions	Low tyre-pressure warning system										/	/			
	IDIS System										/	/			
	Driver alert control										/	/			
	Heater / Air Vent / Air conditioned										/	/			
Infotainment	Cell Phone										/	/			
	Stereo radio										/	/			

Fig.2. IVT availability on compact cars

Three other tables like this one were built for the three other car families: mid-size cars, sedan cars and luxury cars. These tables are not presented in this paper, but are available in the project deliverable [3] that presents the results of this work.

3.5 Distribution of car families in Europe

Then it is necessary to determine the car families that are the most representative in Europe. The following table presents the results for Europe in

general as it presents the sales for 2007 in the 27 member countries of the European Union, and the 4 countries of the European Free Trade Association.

Table.3. Car sales by family in Europe 2007

Position	Make	Model	Family	First vehicle registration number	Market share %	Cumulative market share %
1	Peugeot	207	Compact car	437505	2,96%	2,96%
2	Volkswagen	Golf	Mid-size	435055	2,94%	5.9%
3	Ford	Focus	Mid-size	406557	2,75%	8.75%
4	Opel	Corsa	Compact car	402172	2,72%	11.37%
5	Opel	Astra	Mid-size	402044	2,72%	14.09%
6	Renault	Clio 3	Compact car	382041	2,59%	16.68%
7	Fiat	Grande Punto	Compact car	377989	2,56%	19.24%
8	Ford	Fiesta	Compact car	355933	2,41%	21.65%
9	Volkswagen	Passat	Luxury car	300566	2,03%	23.68%
10	BMW	Série 3	Sedan car	295312	2,00%	25.68%
Total	/	/	/	14 775 253	/	/

Other tables like this one were built for several European countries in order to evaluate possible local specificities. The conclusion from these tables is that the cars that were the most sold in 2007 in Europe were compact cars and mid size cars.

3.6 IVT availability in Europe

As a general result the last step consists in producing a synthesis table from the function availability analysis and the European country sales analysis. In this table, score 1 indicates that the function is not available on the car models that are the most sold in Europe. In the contrary, score 5 indicates that the function is systematically available on the car models that are the most sold in Europe.

Table.4. IVT availability in Europe in 2007

Function family	Function name	Level of availability on the European market
Brake assist	Anti-lock braking system (ABS)	5
	Emergency brake assist (EBA)	4
	Electronic Brake Force Distribution (EBD)	5
	Hill hold control (HHC)	2
Longitudinal Control	Cruise Control	4
	Speed limiter	3
	Adaptive Cruise Control (ACC)	2
	Distance Alert / Collision warning	1
	Anti-slip regulation (ASR)	3
Lateral control	Electronic Stability Programme (ESP)	4
	Continuous Damping Control (CDC)	4
	Power-steering	5
	Power-steering variable	4
	Active front steering (AFS)	1
	Body levelling	1
	Lane Departure warning system (LDWS)	1
Trip Information	Trip computer	5
	Navigation system	1
Driver perception support	Automatic rain sensing	3
	Automatic headlights	3
	Adaptive Front Lighting System (AFLS)	2
	Parking aid	2
	Blind spot assist	1
	Head-up display (HUD)	1
	Night vision	1
	Intersection camera	1
Miscellaneous informative functions	Low tyre-pressure warning system	2
	IDIS System	1
	Driver alert control	1
	Heater / Air Vent / Air conditioned	5
Infotainment	Cell Phone	1

The scores of this table were taken into account, alongside with the stakes in terms of Human/Machine interactions of each IVT, to select the IVT to study during the lifetime of the INTERACTION project.

4 IMPACT ON IVT RESEARCH INVESTIGATION

The distribution of IVT in Europe obtained with the INTERACTION methodology has 3 major impacts on research activities. First, it has to be taken into account for the generalisation phase of the research results on IVT impacts on drivers behaviour and road safety, then it can highlights possible lack of knowledge on specific systems that are the most widespread and finally, it opens interesting perspectives in terms of research on the determining factors of IVT adoption. In this paragraph, we will present in detail these impacts.

Different research investigations, led at the European level or at national level

aim to study the impact of specific IVIS or ADAS on drivers behaviour. These investigations can be conducted through various experimental approaches (FOT, experimental approach on instrumented vehicle or on driving simulator, questionnaires survey…). Many studies focus on systems designed to provide advanced support for longitudinal or lateral control, like ACC or LDWS. The results presented in this paper show that the distribution of these systems remains limited. This is an important fact that has to be taken into account in order to make a correct generalisation of the research results. In another hand, it is highly probable that these systems become, in a near future, common products inside vehicles, which justify the fact research efforts are focused on these topics.

A second impact of these results is to identify possible lack of knowledge about specific IVT. Indeed, some systems are widely spread but only few researches have been conducted so far to determine their effect on driving activity and driver behaviour in general. For example, this is the case of the cruise control, the speed limiter or the ABS, three systems that only provide basic support for longitudinal control, and also of the ESP that only provides basic support for lateral control. INTERACTION literature review highlighted the fact that only few studies have been done so far on these systems, which are nowadays well spread on all makes of cars.

As a third impact, these results highlight possible new research stakes. Indeed, it would be interesting to understand the mechanisms that rule the IVT adoption. Indeed, even though the price is a major issue, it would be interesting to determine why drivers do not tend to buy high end IVT. Thus, research efforts could be used to define how IVT should be designed in order to provide driver with high added value functionalities and to favour their adoption.

However, in order to give full legitimacy to these results and associated effects on research investigation, the methodology might be strengthened.

5 DISCUSSION

Concerning the results of the methodology, it is reasonable to assume that the 2008 crisis had an impact on car and IVT diffusion. Thus, it would be interesting to provide tendencies of IVT diffusion during this time frame. When looking at new car registrations for the period, we can notice that the numbers have not decreased so much. Indeed, there are local specificities that might be explained by government subventions for car renewal. However, these cars are still preferentially in the compact and mid-size family. This may be an indicator that high-end IVT did not diffuse much more on this period. However, it would be necessary to perform the complete methodology in order to be able to confirm this hypothesis.

Even though the methodology presented above gives very interesting results, one must keep in mind that it was designed in the frame of a specific research project. It is probable that this methodology would have to be modified in order to become fully generic and to give results that are not guided by the objectives of a research.

Indeed, a few limits have already been identified for this approach. One of these limits is the accuracy of data collection. It is very hard to make perfectly sure of the exact IVT equipment of each car model and car category. For example, we noticed that car makers sell in a given country a car category with given IVT equipment but that in another country, the same car category is not exactly equipped with the same IVT. Indeed, car makers tend to adapt the IVT equipment to their local market. This is the reason why it would be very useful to have access to more accurate data. For example, this could be done with detailed information coming directly from car makers that would integrate all local specificities.

Another limit of this approach is that it doesn't take into account the market shares of nomadic devices, like personal navigation devices (PND). It would be very interesting to enrich the availability data obtained through the methodology presented above with data coming from the analysis of nomadic devices diffusion in Europe. Indeed, if some specific IVT are rarely available as a standard or optional system inside vehicles, it is possible that drivers buy them as a nomadic device.

A third limit is the difficulty to update the information about IVT diffusion. Indeed, the methodology application is very time consuming as it makes it necessary to collect information on all car models, car categories and associated IVT equipment. It would be very difficult to perform this job every year. However, such results would be very interesting as it would take into account all the new car models, new car categories and new IVT.

A possible solution to address these 3 issues would be to create a "European observatory of IVT diffusion" that would be connected to all European car makers in order to easily get accurate information and that would also study diffusion of nomadic devices. Such an observatory could provide researchers with up to date information about IVT penetration in the European market.

6 CONCLUSION

The methodology developed in the scope of INTERACTION project was useful to determine the distribution of technologies on the European market. The main result is that the most sophisticated ADAS and IVIS are only available as standard on the most luxurious vehicles and as an optional extra for intermediate car families. The number of European drivers having access to these IVT remains still limited. This fact has to be considered when researchers want to generalize the results they obtained on the impact of these systems on driver's behaviour by deducing associated impacts on road traffic and road safety. On the contrary, some IVT such as in-vehicle stabilization functions (ABS or ESP) or cruise control functions are already well spread and knowledge is lacking on the real impacts of these systems on road traffic and road safety. Furthermore, it would be interesting to understand the determining factors of the IVT adoption by European drivers and the mechanisms of their diffusion in Europe for anticipating which IVT will be used in a near future. However, even if the methodology described in this paper gives interesting results, it could be improved in order to give more accurate and up to date results and could be used as a framework for a future "European observatory of IVT diffusion" that

would provide the research community with strong outcomes about IVT penetration.

7 ACKNOWLEDGMENTS

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7 / 2007-2013) under grant agreement n° 218560.

8 REFERENCES

[1] Stevens A., 2007. A practical human factors perspective on driver information and assistance systems, ITS Europe Congress, Aalborg, 11p.

[2] Automotive Auxiliary Association, online in February 2009 at the following url: http://www.acea.be/index.php/news/news_detail/new_vehicle_registrations_by_manufacturer/. Accessed April 2009

[3] Bonnard, A., Karmann, N., Lancelle, V. and Brusque, C. (2009). Terminology definition and selection of In-Vehicle Technologies to investigate. Report FP7 Project INTERACTION, 63 p.