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A SYSTEMIC ANALYSIS OF OLDER DRIVERS REQUIREMENTS TO GATHER KNOWLEDGE TO BE USED BY DESIGN ENGINEERS

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1. Introduction

Mobility needs and safety issues of the ageing population have become an issue of interest for research, industry and governments, especially in the industrialised world. This development is due to the expected increase of percentage of older persons in the population. OECD (Organisation for Economic Co-operation and Development*)* estimates that by 2050 one quarter or more of the whole population of the OECD countries will be aged 65 and older. As the proportion of older people in the population is rising, the proportion of older driving licence holders is increasing at the same time [OECD 2001]. Owning and driving a car can play an important role in providing senior citizens access to social facilities and offer the possibility to live an active and independent life. Beside the need to enable seniors to stay in their home environment one additional key aspect is safe mobility of older persons. Independent out-of-home mobility is an important part of older persons' well-being. Previous research has shown that mobility and the ability to leave the home are among the essential aspects in the quality of life of older persons [Langford et al 2006].

During the last decade, design of cars has mainly focused on safety, fuel consumption and pollution decrease of carbon oxides. The challenge of our very next future is to design cars that not only address those aspects, but also face the specific needs of the older generation that have been driving earlier with a non negligible experience and knowledge. This paper aims at highlighting the results of a functional analysis of older driver's needs in order to be able to make recommendations about design requirements through a multidisciplinary approach.

2. Related Works

Our research work is based upon 3 pillars. We consider multidisciplinary research regarding the older driver, research based on the analysis, identification and utilisation of user-requirements and inclusive design approaches. Beside this we follow a systemic philosophy. The following paragraphs give an overview about the current state-of-the-art of each pillar and discusses their implications for our work. This research work has been started in 2006 with a state-of-the-art survey and a technical analysis and case studies of accidents involving elderly [Flöck 2007].

2.1 Evolution of the research field "older driver"

Research on older drivers is a relatively new topic of interest although some general interest has already been expressed in the 1930s by DaSilva in the area of Psychology. A first important wave of research on older drivers happened by the end of the 1960s, mainly in the US. This wave has been influenced by Thomas W. Planek who published several research articles and books, addressing the effects of ageing on the driving performance. In his understanding an older driver is a person 55 years or older. His main research interest was to identify deficits and impairments of ageing persons and to analyse them in the context of driving [Planek 1973]. In Europe some age-related controls or restrictions concerning driving licensing have been introduced at that time, but the topic didn't yet raise any common interest at governmental and research institutions.

A report published by the OECD in 1985, dealing with the safety situation of older road users and the current situation in research, finally encouraged widespread interest amongst European researchers and governments. The report approached the topic from a generic point of view and discussed the problem of older road users in general, with driving as one aspect. It discussed thus the presence of older persons as unprotected road users due to the fact that they are over-represented in fatal traffic accidents and the use of different travel options [OECD 1985].

Since then interest in the topic constantly raised not only in Europe and North America, but also in Australia and some Asian countries and is nowadays treated by a multitude of scientific fields (e.g Psychology, Ergonomics), technical areas (e.g Independent Living, Transportation) and from various points of view (e.g Political, Insurance Companies). Since the 1990s, one can notice that the issue of "older drivers" is addressed in various conferences and by an increasing number of researchers from different countries. Knowledge about this target user group is thus advancing.

As an important result of the growing research interest we can now prove that although their risk of being injured or killed in accidents is very high, older drivers are not a road hazard, having a higher risk of accidents than younger drivers. Only drivers with a mileage bias under 3000km per year and over the age of 74 are over involved in accidents. In general older drivers seem to be very safe drivers as shown in Figure 1 [Langford et.al 2006].

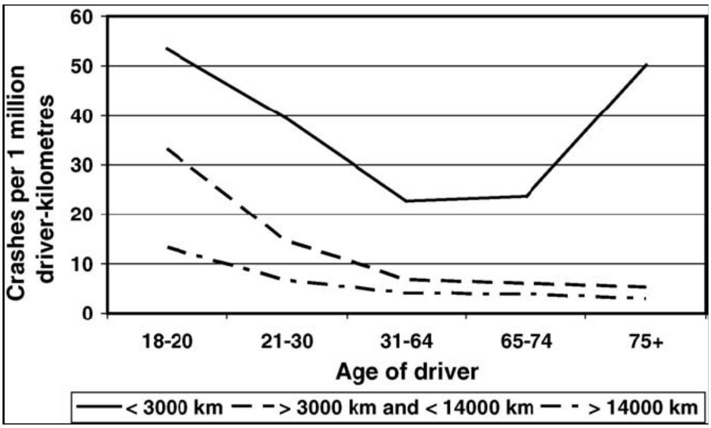

Figure 1. Annual crash involvement for different driver ages

If we imagine this figure for the expected population in 20-30 years, we can expect a rising number of accidents in the age group over 65 as this part of the population will significantly grow. Although the European car industry already shows strong interest in the issue [e.g. Coda & Gadeselli 2003], beeing forced to adapt their products, to be able to keep a stable market position, suitable solutions are still outstanding.

2.2 Inclusive design approaches

Design of everyday products rarely takes into account the specific needs of different age groups and is often not user-friendly. Inclusive design as introduced by Roger Coleman and further developed through the research team around P. John Clarkson, builds upon this need and can be defined as "a methodology aiming at enabling designers to ensure that their products and services address the needs of the widest possible audience" [Keates and Clarkson 2003].

The term "inclusive design" is mainly used in European countries, whereas in the U.S. and Japan researchers mainly talk about "universal design". Experts at the US Centre for Universal Design have introduced 7 principles that they suggest designers to use when designing products [Story 1997].

1. Equitable use - the design is useful and marketable to people with diverse abilities.
2. Flexibility in use - the design accommodates a wide range of individual preferences and abilities.
3. Simple and intuitive use - use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
4. Perceptible information - the design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
5. Tolerance for error - the design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. Low physical effort - the design can be used efficiently and comfortably and with a minimum of fatigue.
7. Size and space for approach and use - appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

We consider the methodology of inclusive design as an important step for automotive design. As demonstrated by FIAT through its successful Autonomy Programme, based on the idea of promoting and facilitating mobility for people with reduced physical capabilities, the consideration of inclusive design elements can help to establish a new market position and design vehicles that are accessible for the whole population [Coda and Gadeselli 2003].

2.3 Research on User Requirements related to "older drivers"

Eurostat[1] anticipates that the number of elderly people aged 65-79 (+ 37.4% until 2030) and very elderly people aged 80+ (+57.1% between 2010 and 2030) will increase significantly after 2010 and until around 2030.

A major part of the population will thus be in an age where certain impairments are increasing. The following have been identified as important for the driving task [Herriots 2005].

Physiological: decreased mobility & strength, hearing loss, reduced muscles
Sensory: more rapid onset of fatigue
Perceptual: visual deterioration
Motor abilities: using technical and functional equipment
Cognitive abilities: reduced ability to process information, slowed reaction time

Research regarding user requirements is a relatively wide field. We distinguish between

- Research to identify user requirements
- Research developing methodologies for the identification of user requirements
- Applied research, developing new products and services, with respect to user requirements

Our approach builds on a combination of these and focuses on user centred methodologies.

2.4 Systemic Approaches

Although systemic research is known in various sciences and application areas, we can characterise it in an overall way. Instead of considering individual objects, the focus lies here on the consideration of the whole system with all it's possible componenents. The aim is to obtain a precise and inclusive holistic view, in order to characterise the system with a maximum of its specifications. We analyse the different entities constituting the system, their interrelations and the exchange of the system with its environment. Our approach is mainly based upon the work of Le Moigne [Le Moigne 1990].

[1] Eurostat is the European portal, offering statistics on a variety of topics and is accessible via ec.europa.eu/eurostat

2.5 Conclusions and consequences

We can thus summarise that research in the respective areas is already on an advanced level itself and that it has led to relevant research results and industry applications. Nevertheless particular research on design requirements of older drivers is still neglected and efforts are mainly based on mono-disciplinary research, not leading to accessible solutions.

We propose a consideration of the presented approaches, using the already existing knowledge and experiences and embed our research in a holistic perspective. This means that at any time we use a systemic view, to gain a complete picture of the research field under consideration of all possible stakeholders, circumstances and influences. The combination of the 3 key pillars, multidisciplinary research on older driver, user-requirements and inclusive design, embedded in a systemic perspective, assures a user-centred approach, helping to develop design elements tailored for our user-group, the older driver and can assure accessible products for the whole population.

3. Objectives

Our analysis is motivated by the need to contrast diverse points of view, in order to obtain new perspectives and research directions, which will lead us to the ability of formulating coherent design requirements. The results will then enable Design Engineers to include the particular needs of the older generation into their design processes and adapt vehicles accordingly. The functional analysis proposed in this paper, is a second step of a research work started in 2006, where we analysed descriptions of accidents caused by drivers of 65 years or older [Flöck 2007]. It will assist us in achieving our aim, the formulation of coherent sets of requiremnts. In addition to the knowledge we gained on interactions within the system, the functional analysis is meant to help us being more concrete about the functionalities of the design solutions, suitable for the older driver. Our final aim is to limit accidents and so help achieving the aim of zero accidents in Europe. By including all experts in the process, engineers will be able to build safer cars serving the whole population and the older drivers in particular.

4. Method

Figure 2 represents the approach we used in an earlier study. The proposed systemic analysis is based upon the content of a database called EDA[2] [Flöck 2007]. We consider a system built out of several items, in order to catch the interaction between them and to make conclusions.

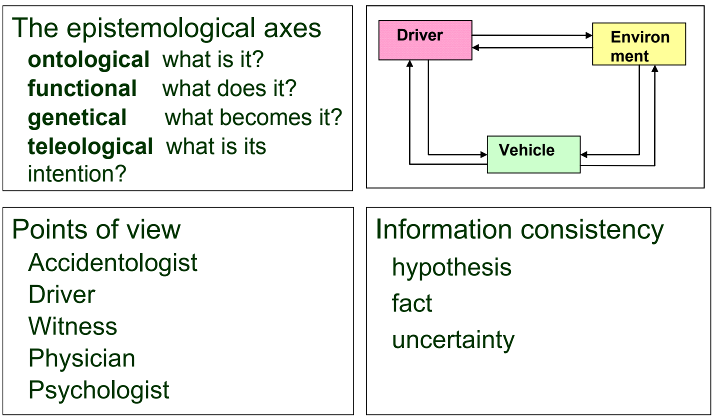

Figure 2. Systemic analysis of car accidents involving older drivers

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[2] EDA = Etude Détaillées d'Accidents (Detailed Accident Descriptions). It is used by the Laboratory for Accidentology and Biomechanics of Renault and PSA who kindly allowed us to use their database for our analysis.

Le Moigne considers the analysis of a system on the 4 epistemological levels [Le Moigne 1990]. The heart of this analysis is the reflection of the analysed elements on the ontological, functional, genetical and teleological level to learn more about their nature. As additional elements we use the different points of view represented in the case studies and the information consistency, which means the analysis of statements, distinguishing between hypothesises, facts and uncertain statements.

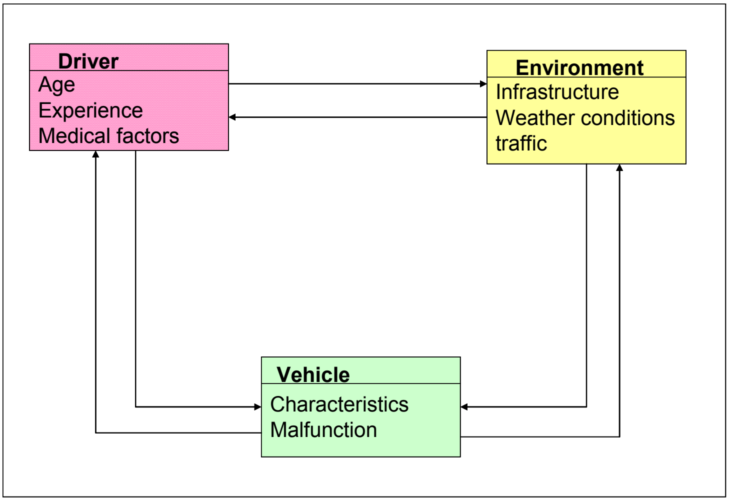

Figure 3. Driver-Vehicle-Environment Model (DVE)

Beside this we take into account the Driver-Vehicle-Environment (DVE) Model for analysis. According to Miller's definition of a living system [Miller 1995], we define the DVE as an open and living system since each component is constantly interacting with its environment by means of information and matter-energy exchanges, which means that we consider not only the driver himself, but the whole interaction between the driver, the vehicle and the environment in which he is acting, to assure consideration of the whole system.

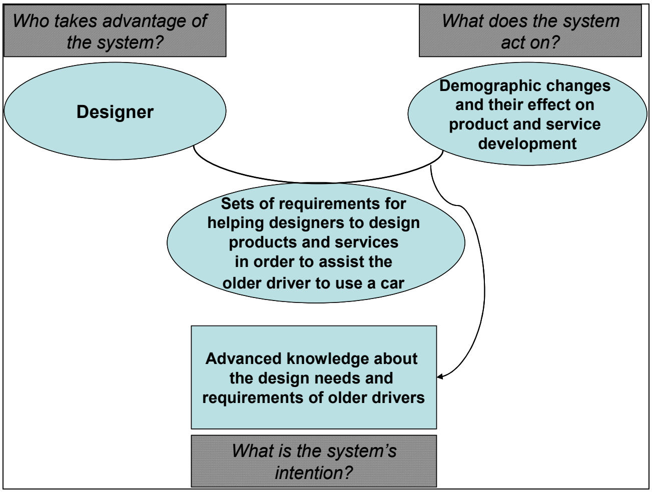

Figure 4. Holistic view on our system

The functional analysis[3] that we present in this paper acts as a support mechanism to the above described study and helps mastering the complexity and interrelations in the field, which will lead to the establishment of sustainable research results.
We use the instrument as a step towards the development of sets of multi-disciplinary design requirements of older drivers, which will be used by car designers for the development of future cars.
Along with the identification of environments that are related to, reacting on and and influencing the system, the functional analysis aims at the formulation of functions, describing the optimum behaviour of the system and its terms of usability. The functional analysis also helps to analyse cost efficiency and resources needed to determine a service or a product. Figure 4 gives a holistic overview of our system that we define as "Sets of requirements for helping designers to design products and services in order to assist the older driver to use a car".

5. Results

5.1 Environments acting in and on the system

We identified the following environments according to our system, which are illustrated in Figure 5.

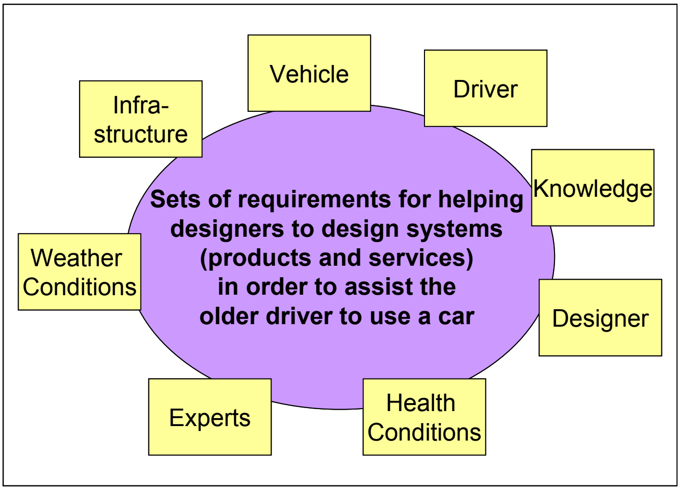

Figure 5. Main environments related to the system

The main environments that have been identified, as having influence on the system and being influenced represent clusters of environments. They are constituted of a set of more specific environments. Examples for environments under "weather conditions" would be, sun, rain and snow.
The reasoning for the clustering is as follows. As the DVE System covers the three main points of view and assures a systemic picture, it is a logical step to consider these 3 elements as big clusters of environments in the functional analysis. One cluster is represented by the "vehicle", which we mainly break down according to primary, secondary and tertiary safety systems and their functionalities. Also the "environment" is considered as one cluster. Here we summarise mainly aspects related to regulations, road infrastructure or other road users.
The driver himself plays a particular role in this case and is also considered as an environment. The older driver is the heart of this functional analysis and all information provided and used is meant to support him. He acts as an expert from his particular point of view and is consulted in the process to assure end-user acceptance and usability of the proposed solutions.

[3] We refer to the APTE® formalism for conducting a Value Analysis

As health conditions and cognitive abilities have major influence on the driving task and changes have a huge influence on the driving skills of older and younger adults (see 2.3), we use a cluster "health conditions", which deals with any kind of cognitive and physical impairments.
Another additional environment considered is the different "experts" (Psychologist, Physician, Accidentologist, etc.), as they provide important knowledge for the identification of the design requirements from their respective disciplines. We see this group as crucial, as our aim is to have a clear picture about the design needs of older drivers and a coherent set of requirements combing various view-points. "Designers" can of course be seen as one element of the experts' cluster, as they can provide their input and point of view during the process. Nevertheless we decided to represent them in a separate group, as they will act as an end-user of the developed solutions and thus intervene at a different level during the process.
A last big cluster is built around the different kinds of "knowledge" and their sources. We consider different sources of information. Mainly we base our research on story telling by the different experts and the analysis of existing databases, like the EDA [Flöck 2007].

5.2 Formulation of functions

Out of 114 transfer functions and 33 constraint functions that have been identified through the establishment of relations between the outlined environments shown in Figure 4, we choose the following key functions to be considered for further analysis. They represent main aspects of the system and will help us to determine additional characteristics of older driver's requirements in a qualitative and quantitative way.

FT1: The system should include the experience gained by **Accidentologists** through the **EDA.**
FT6: The system should enable **embedded system designers** to provide new systems for **car designers.**
FT9: The system should give information to **car designers** about the influence of different **environments** on driving.
FT21: The system should give information to **car designers** about **primary and secondary safety** aspects concerning the **older driver.**
FT25: The system should be able to estimate the influence of **health problems** of older persons on **driving a car.**
FT26: The system should give **inclusive information** about **environmental circumstances** influencing the driving performance of **older drivers.**
FT27: The system should enable **car designers** to consider **typical impairments** of **older drivers** during the design process.
FT49: The system should give **car designers** access to **multi-disciplinary expert knowledge.**
FT114: The system should enable **car designers** to design cars based on the principles of **inclusive design.**
FC25: The system should be able to **limit accidents** of **older drivers** during left turns.
FC29: The system should be described to be usable by **car designers** and therefore include them in the development process**.**

5.3 Analysis of functions

The identified functions are now analysed to obtain more concrete information about interdependencies and to be able to make more concrete statements. We use a methods called TEMI$[4].
As an example we show the analysis for FC26:
Some more conclusions we obtained from the TEMI$ by analysing the functions:
FT9: Driving is a relatively expensive and complex task, which affords knowledge about the different environments and their implications on the driving task.

[4] Analysis according to Time, Energie, Material, Information and Cost

FT25: Physical and psychological impairments have an influence on various situations in every day life and can create high costs. In combination with the already complex driving task, we can conclude that their consideration is important in order to avoid high cost and high risks.
FT29: Car designer should try to include usability aspects from the older user's point of view into the design process. The optimum product would be easy/ intuitive to use, related with low physical efforts and always usable.

FT26	**inclusive information**	**environmental circumstances**	**older drivers**	**Conclusions**
Time	investement of more time		at what age people have impairments influencing the driving task, topic evolution over the time	**Information related to the older driver needs to be as inclusive as possible, to allow conclusions and the formulation of requirements. As a wide range of environmental circumstances plays a role in the driving task, we also need to consider different situations when analysing.**
Energie	work force		older drivers need more energy for driving due to their cognitive and physical impairments	
Material	knowledge	weather, road infrastructure	literature, research studies	
Information	detailed and complete knowledge about a product or service	location, weather, daytime, known or unknown environment	experts like Hakamies-Blomqvist, Monash etc	
Cost	higher		related costs for health sector and insurances	

FC25: Accidents are multi-facetted events, involving according to their severances a multitude of people and disciplines. A limitation of accidents could save money, work force, and lives and therefore we should try to assist the most vulnerable user group of older persons.
FT26: Information related to the older driver needs to be as inclusive as possible, to allow conclusions and the formulation of requirements. As a wide range of environmental circumstances plays a role in the driving task, we also need to consider different situations when analysing their needs.
FC25: Intersections are complex environments that require concentration on multiple tasks. As impairments of older persons can have a bad influence on the perception designers should take this into account when designing new cars and consider assistive technologies.
FT6: As the development of new embedded systems is quite expensive and needs detailed knowledge about requirements and specifications, designers have to be very concrete in their recommendations.
FT1: The EDA gives detailed knowledge about the situation of the accident analysed by an expert group of Accidentologists and Psychologists. This knowledge should be included in the design process and taken as an example for other expert groups as their documentation is inclusive and gives room for interpretation.
FT114: Inclusive design can help to make products more accessible for the whole population. Therefore designers should work according to those principles, in order to maximise usability and to minimise cost.

5.4 Hierarchical order of functions

In a final step of analysis we measure the importance of characteristics identified through the functional analysis, to be able to make more concrete recommendations. Each of the shown categories can imply or implies several functions that are regrouped here. The weighting in terms of percentages can vary according to the end-user. In our example we consider the point of view of a Car Constructor (upper percentage) and the point of view of the older driver (lower percentage) himself. The percentages are based upon the results of a literature review, that we conducted earlier.
This picture shows that different priorities are set in the two groups and that they have different views on the issue. The older driver seems to focus on ergonomic and medical aspects, whereas the car constructors put a lot of weight on economic and marketing issues. On the other hand the analysis shows that industry is already aware of the need to include medical and psychological aspects into the design process, which is a first step towards a common goal.

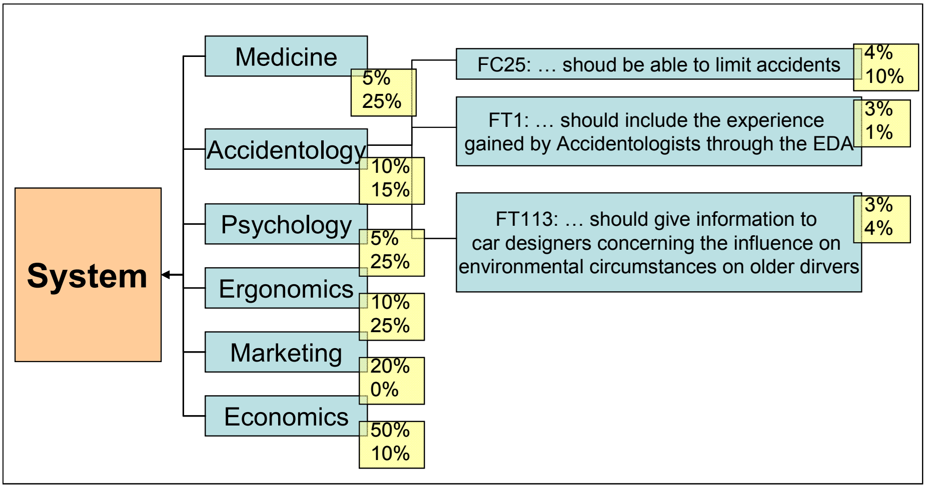

Figure 6. Weighting of functions

6. Conclusion

The functional analysis shows that the design to support older drivers' safe mobility, should take into account the special characteristics of older persons, both in terms of the different facets of the ageing process and in terms of the older persons' mobility needs. In addition, the design should also capture the heterogeneity of the older population. Those categorized as "elderly" vary greatly in terms of their chronological age, functionality, socio-economical status, gender, and travel patterns. The needs and abilities of older drivers need to be considered in vehicle design.

Our analysis has shown us that most functions are based on the assessment of the behaviour of the older driver. We therefore assume that particular attention should be paid to the consideration of the point of view of older drivers themselves. In a user-centred approach for product development and a systemic analysis of the field according to the epistemological approach proposed by Piaget [Piaget 1975] and further extended by Le Moigne [Le Moigne 1990] we take into account these aspects and analyse the system accordingly [Flöck 2007].

We are now able to describe the research field from a systemic point of view enriched by specifications about the functionalities of the products and services to be developed, which makes it possible to identify key elements and to formulate coherent research questions for future studies in the field of older drivers.

The functional analysis allowed us, to gain a better picture about the key elements, stakeholders and decision makers in the research field of older drivers. It gives insights into the complex system, shows interrelations and will help us to advance in the development of coherent research aiming at the multidisciplinary delivery of sets of requirements to be considered by car designers and constructors.

It becomes evident, that the development of design requirements for older drivers is a complex task, which needs to take into account a maximum of influencing factors in order to obtain exploitable results. In a next step we will focus on activities in the field, in order to obtain detailed and comparable results from reality. Knowing that requirements can conflict with each other ; for example, wider opening doors make it easier to get in and out of the vehicle from an Ergonomic perspective, but may make the car body more fragile from an Engineer's point of view, a story telling method will assist us in getting in contact with researchers and practioners from various domains and to contrast those diverse perspectives. The functional analysis enables us to be more concrete in this future step as we have already identified major key aspects relevant for the research field and we will build upon these results, when we give the speech to the different experts.

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