Ph.D. COURSE IN INDUSTRIAL ENGINEERING – XXXIV CYCLE

PhD Thesis: summary

How to improve comfort and reduce discomfort in future vehicles.

A comprehensive study of subjective and objective data

Student: Iolanda Fiorillo (UniSa)

Tutor: prof. Alessandro Naddeo (UniSa)

Scientific Committee: prof. Nicola Cappetti (UniSa), prof. Peter Vink (TUDelft)

Ph.D Course Coordinator: prof. Francesco Donsì (UniSa)

Considering a vehicle as anything that transports a person or things (such as a car, a truck, a plane, a bus), in the near future autonomous driving vehicles, or vehicles with a high level of automation, are predicted. Obviously, with the current innovation in every sector, people expect to travel comfortably, or at least with less level of discomfort. Thus, in the designing phase for every vehicle, the concept of (dis)comfort should be included. Consequently, my question research is: how can we improve comfort and reduce discomfort inside future vehicles?

As is known, the field of Ergonomics (or Human Factor Engineering) in the vehicle products developments considers all aspects (such as exterior design, interior design, instrument panel, seat design) to assure that all-important ergonomic requirements and issues are contemplate at the earliest time and resolved to accommodate the needs of the users, such as drivers and passengers. The vehicle design process begins with a discussion on the vehicle size and types, considering the anthropometric data and the number of occupants the vehicle should accommodate. Furthermore, once defined the layout and the environment, the attention goes on the seat, that plays an important role in the passengers' wellness and come into design aspects like as seat dimensions, materials, foam, structure, etc.

Going through literature studies, it is possible to acquire knowledge in comfort optimization in some vehicle elements. However, some literature gaps need to be filled; for instance, the analysis of interactions between passengers in terms of personal spaces to achieve the highest comfort while travelling. Or the comparison between car and aircraft seats in terms of pressure distribution maps. Hence, this PhD dissertation will consider the distances between seats, body movements, postures, social interactions, and contacts with others. Moreover, overall comfort can be defined as the measurement of "well-being level" perceived by humans when interacting with objects and the environment. This level is hard to detect and measure because it is affected by individual judgements; thus, quantitative and qualitative methods are necessary for the analysis. Therefore, subjective and objective data are compared to achieve statistical results.

Once defined the distinction between comfort and discomfort clearly, this PhD dissertation aims to individuate and analyze the factors linked with perceived (dis)comfort inside future vehicles. The graph in **Figure *1*** shows the conceptual map of this PhD dissertation: the involved factors can be analyzed and measured with subjective and objective data and are influenced by external perceptions (seat, environment, and interaction with people).

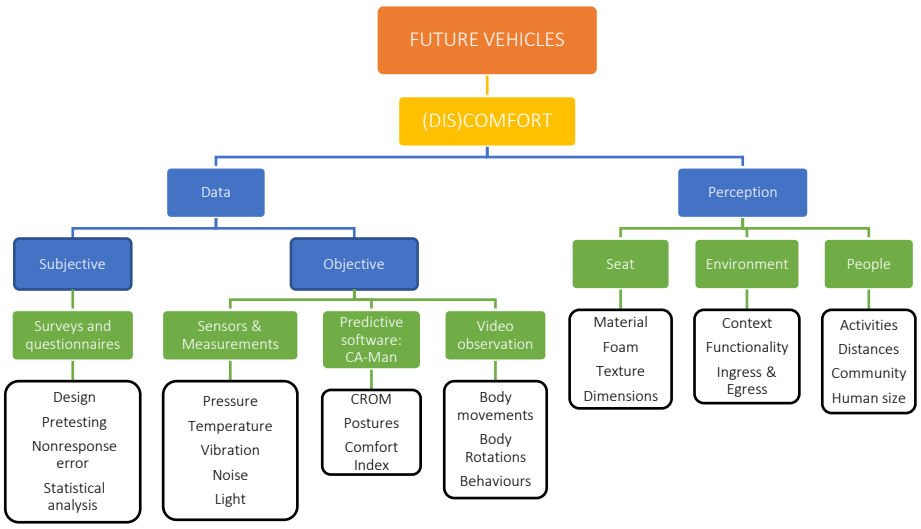

Figure 1 *Conceptual map of this PhD dissertation*

The comprehensive study in this PhD dissertation demonstrated that the analysis should be performed by acquiring subjective and objective data, always considering the external perceptions influences on interactions between humans and objects (mainly the seat), environment or people. So, we need data that can describe the interactions between the human and object/environment/people and detect/evaluate their perceptions. Essentially, we need subjective and objective data in vehicle (dis)comfort assessment to have a complete overview of the case study.

The subjective data gather personal feelings or feedbacks from people to comprehend their perceptions and expectations. The suitable instrument is the survey that from a sample it is possible to infer to the population by inferential statistics. While the survey includes the set of questions and the process of collecting, aggregating, and analyzing the responses, the questionnaire includes any written set of questions. Consequently, the questionnaire represents the constant conversation with people; that is why we can collect subjective data with the survey (see Chapters 4 and 5).

Having only subjective data is not enough in the vehicle (dis)comfort assessment. Consequently, objective data are required for mutual validation with subjective data, explaining the reasons for personal feelings and finding solutions or improvements. In this PhD dissertation, 3 macro-areas for objective data are distinguished: sensors, predictive software (CA-Man) and video/photo observations. One macro-area does not exclude the others so that they can be adopted simultaneously.

Since the seat plays a vital role in vehicle (dis)comfort assessment (Chapter 10), examples reported in this PhD dissertation refer mainly to the interaction between humans and the seat and between seated humans with the surrounding environment or people. For these reasons, among all available sensors' technology, in this PhD dissertation, the focus was on pressure distribution since the high correlation with discomfort perception on the seat. In particular, pressure distribution maps could be useful to create an optimal virtual prototype validated by a physical prototype (Chapter 11). Going from virtual to physical prototype, few interactions and simulations are required to optimize the product comfortably, becoming an advantage for the Time To Market.

Also, the postural analysis in vehicle (dis)comfort assessment can be done through the analysis of video/photo (Chapters 13-16) or through software that can predict the level of (dis)comfort knowing postural angles (Chapter 7). Thus, the software CA-Man could be very useful (Chapters 7-9).

In summary, the vehicle (dis)comfort assessment can be explained through the 5-W, as shown in **Figure *2***.

Future Vehicle (dis)comfort assessment	Who is involved?	Passengers (more related to leisure and relaxation) and drivers (more related to attention and safety)
	What do we need?	Subjective (survey) and objective (sensors, predictive software, video/photo observation) data
	When do we need them?	In all vehicle design phases (concepts, prototype, final product)
	Where do we need them?	In the interaction between human and object/environment/people
	Why do we need them?	To improve comfort and reduce discomfort (as customers expect)

Figure 2 *Future Vehicle (dis)comfort assessment explained with the 5-W*

In the end, my PhD dissertation aims to be a guideline for future vehicle design and development, showing how the external factors influence the (dis)comfort. Through in-depth literature studies, literature gaps were filled with experiments that adopt both subjective and objective data to gain a complete overview of the design process.