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Qualitative analysis of vehicle needs and perceptions towards the adoption of a reconfigurable vehicle

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ABSTRACT

We explore in which extent the notion of a reconfigurable vehicle, presented as an innovation, is an anticipated need given the current patterns of vehicle occupancy. The main goals of this study are: (i) Identify latent needs towards vehicle purchase choices and use; (ii) Characterize the individual perceptions about car use, in general; (iii) Characterize the individual perceptions about the reconfigurable notion of a vehicle, able to be adapted to daily occupancy requirements. The study is based on data from 4 focus groups. To identify that needs data are analyzed through the QFD VOC. Engineering requirements are translated with HOQ. To explore perceptions data are analyzed using a content analysis methodology with MaxQDA10 software©.

Within the context of designing vehicles to comply with European regulations on CO_2 emissions, the results reveal latent needs in human dimensions of the product. The notion of a reconfigurable vehicle was identified as a latent need for different target markets. Stated barriers for the adoption of this particular vehicle do not fully overlap with what individuals ponder when they consider buying a current fuel-based. Educational background was found to contribute for the receptivity of the disruptive proposal.

1. Introduction

In the EU-27, vehicle ownership shows a converging tendency towards 2 passenger vehicles per 5 inhabitants (UNECE, 2013). In Eastern European countries the average number of passengers per vehicle is approximately 1.8 and the average number of passengers per vehicle for the Western European countries is around 1.54 (EEA, 2011). Yet, most vehicles have nominal occupancy for four to five seaters (Gross, Heptonstall, Anable, Greenacre, & E4tech, 2009; Santos, McGuckin, Nakamoto, Gray, & Liss, 2009).

Given the weight ratio (weight of the passengers transported)/(passenger vehicle weight), around 1% of the total energy in gasoline is used in moving the driver—the rest is internal consumption to move the vehicle (Winter & Koger, 2004, pp.217).This pattern of vehicle use behavior partially explains the fact that passenger vehicles are the least fuel-efficient transportation mode, compared to all the other road, waterways and air transportation modes (CEC, 1995, pp.7).

Improving energy efficiency of passenger vehicles, and their eco-effectiveness (Carrillo-Hermosilla, Pablo & Könnölä, 2010), is a primary societal need to reduce both energy demand and CO_2 emissions of passenger vehicles. Minimizing the indicator [(energy use)/(person.km)] is an urgent need for a more sustainable energy use in automobility for personal transportation, i.e., the utilization efficiency is one of the main parameters that determine the energy and emission effectiveness. That reveals the importance of the vehicle occupancy as an indicator concerning the environmental impact of different transportation modes.

Within this framework, this study is part of an ongoing research inquiring new opportunities in vehicle design and development to comply with the need to improve vehicle eco-effectiveness. The main focus of the bigger project is on the adequacy of current passenger vehicle architecture given the patterns of automobiles' occupancy. The project proposes that technological solutions towards vehicle's increased eco-effectiveness shall include a use (occupation and utilization) basis perspective. In a previous study (Carvalho, Baier, Simoes, & Silva, 2012) the authors made a comparative assessment of the fuel savings (and CO_2 emission savings). The scenario took into account the modular concept of a vehicle viz-à-viz a passenger vehicle with an integral architecture with a nominal occupation of 4–5 seats. The recently presented zwei-plus© by VW (Cruz, 2012) is the closest concept of modular vehicle materializing the idea. It intends to remove/add weight that is not needed, therefore adapting the vehicle to the quantity of persons to transport, per utilization. Slowly, we are entering in an era that starts to rethink the passenger vehicles; however, the discussion is at an embryonic, conceptual stage.

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1.1. Motivation

Knowing that the household life cycle (as an objective situational factor) determines the levels of vehicle occupancy and that situational factors are mediated by psychological factors (Anable, Lane, & Kelay, 2006, pp.63), we explore to what extent the notion of a reconfigurable vehicle, presented as an innovation, is an anticipated need given the current patterns of vehicle use.

The reconfigurable vehicle is firstly considered by the authors in a previous study (Carvalho et al., 2012), where a comparative assessment of the fuel savings (and CO_2 emission savings) is made. The reconfigurable concept of a vehicle reacts to the observed low occupation factors in using vehicles with current vehicle's architecture. A vehicle with a reconfigurable architecture is a passenger vehicle that allows reversible and automatic coupling/decoupling rear chunks of the vehicle's body. Is aimed at increasing the energy efficacy of the passenger vehicle on a per use basis (i.e., different load factor needs).

Of particular interest for our research is to:

(i) Identify latent needs on vehicle purchase choices and use;
(ii) Explore technology adoption/non-adoption determinants in relation to occupancy level towards reduced energy consumption and CO_2 emissions.

For that, we:

(i) Characterize preferences and choices of vehicle purchase and vehicle use, in general;
(ii) Identify needs of car purchase and use for current vehicles and for the hypothetical reconfigurable vehicle;
(iii) We communicate an innovation for a different paradigm of a passenger vehicle (innovation construct) and characterize the individuals' perceptions about this hypothetical vehicle, and explore:
  a) What are the main factors determining the adoption of a modular, reconfigurable vehicle (the innovation);
  b) What are the main barriers in determining the non-adoption of such an innovation;
  c) If the barriers mentioned for the modular vehicle are specific to this vehicle or overlap with what individuals consider important when buying any vehicle.

2. Research background

In 1995, the transport sector in the EU was the second-most important sector in terms of CO_2 emissions, accounting for about 25%–30% of total CO_2 emissions (Commission of the European Communities, 1995, pp.6), the main greenhouse gas. CO_2 emissions from passenger cars accounted for about half the CO_2 emissions of the transportation sector (Commission of the European Communities, 1995, pp.2). Road transport accounted for 80% of energy consumed by transport – 30% of final energy demand in Europe (Commission of the European Communities, 1995, pp.3). At the time, foreseeable transport demand was expected to increase; concomitantly, CO_2 emissions from passenger cars were expected to increase as well, keeping pace with the energy consumption, a reality already verified between 1950 and 1981 (Roos & Alan Altshuler, 1984): by about 20% in 2000 and by about 36% in 2010, compared to the 1990 levels (Commission of the European Communities, 1995, pp.2). Between 1995 and 2004: (i) the transport demand increased and the number of passenger-kilometers driven by passenger cars increased by 17,7%; (ii) the mass of new purchased vehicles increased 15%; the power of new purchased vehicles increased by 28% (Commission of the European Communities, 2007, pp.11). The technological achievements in fuel efficiency were offset due to the rebound effects caused by individual's behavior: the fuel efficiency of new purchased vehicles increased by 12.4% and the CO_2 emissions decreased at the same pace, by 12.4% (Commission of the European Communities, 2007, pp.11). Rebound effects counteract the positive effect of increased efficiency through technological development by increased demand (promoted by the lower operation costs) (Berkhout, Muskens & Velthuijsen, 2000; de Haan, Peters & Scholz, 2007; Herring & Roy, 2007; OECD, 1996; Steg & Gifford, 2005). There are also secondary or indirect effects of reducing energy costs through efficiency in the sense that consumers may buy more products and/or choose, larger, more powerful, more feature laden models (Herring & Roy, 2007). The boom of travel behavior studies started in the 1970s (Yue, Lan, Yeh & Li, 2014), possibly related to the energy crisis around that period (Barkenbus, 2010; Roos & Altshuler, 1984). In the 1970s, environmental awareness and concerns increased as well (Kilbourne & Pickett, 2008). Travel behavior is an umbrella theme with multiple dimensions: modal choice, vehicle ownership, vehicle type choice, vehicle use, driving behavior, etc. Some of these dimensions overlap the effects of travel behavior regarding fuel consumption and CO_2 emissions (Clark, 2009; De Witte, Macharis, & Mairesse, 2008). There is a dichotomy between technological options (vehicle type choice and vehicle ownership levels) and use patterns (occupation land use levels).

2.1. Factors affecting vehicle ownership and vehicle use

Passenger vehicles represent high valued products. The meaning of the word *valued* is not restricted to a monetary connotation; it has also symbolic, affective and instrumental connotations. Valued attributes include: flexibility, privacy, security, comfort and amenity (EC, 1995, pp.2), and reliability. To some degree, individuals recognize that “owning and driving a vehicle may give people prestige and distinction” (symbolic motivation) and/or recognize “subjective appraisal service attributes that characterize the vehicle as a transport mode” (instrumental motivation) and/or recognize “enjoyment and pleasure when driving” (affective motivations) (Lois & López-Sáez, 2009). For some segments of the population, there is no other transportation mode competing with the passenger vehicles in every of those dimensions. Other indicators include the perception of enhanced quality of life (Steg & Gifford, 2005).

Vehicle availability (or vehicle ownership (De Witte et al., 2008) is found to be a reliable and strong positive predictor of vehicle use as a travel mode choice. High levels of vehicle ownership predict two levels of vehicle use: higher % of time the vehicle is used and long travelled distances (Klöckner & Friedrichsmeier, 2011). The increasing amount of vehicles per driver in a household increases the probability of travelling by vehicle (De Witte, Hollevoet, Dobruszkes, Hubert, & Macharis, 2013; Klöckner & Friedrichsmeier, 2011; Van Acker & Witlox, 2010). The causality found among vehicle ownership and vehicle use logically explains the causality found among vehicle ownership and emission levels: households with access to two vehicles or more have higher emission levels. Other factors affecting emission levels are associated with: (a) income levels, (b) working status, (c) gender and travel by private vehicles, (d) age, (e) household composition and size (Brand & Preston, 2010); (f) residence urbanity as urban and rural households have different energy consumption patterns. Households living in rural areas are significantly more likely to own a vehicle (Nolan, 2010).

In turn, household size and composition are also found to determine vehicle ownership levels (De Witte et al., 2008). However, whether the causality effect is positive or negative, stronger or weaker is not consensual. Some authors report no significant correlation among vehicle ownership (and vehicle use) with the household size (Yu, Zhang, & Fujiwara, 2011). Others report a negative correlation among household size and vehicle ownership (Delbosc, 2013). This latter result is consistent to a more general finding that households with more members show a higher preference for ownership (and usage) of less energy-intensive end-uses and out-of-home energy consumption tends to decrease steeply (Yu et al., 2011). The non-confirmatory results, of the causal effects among household composition and age structures and vehicle