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A mixed-methods approach to derive vehicle concepts for urban mobility

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Abstract

The mobility behaviour of the urban population and the thereby potential shifts in demands create amended requirements for the current available and/or future-conceivable mobility possibilities. Furthermore, developments such as the increasing urbanisation, going along with growing mobility and land use requirements as well as climate protection are placing requirements on the design of future mobility concepts.
At the same time, new transport technologies and vehicle concepts enable novel mobility options and in turn influence demand alongside these developments.
In the context of this initial situation, the paper presents a systematic approach about how future, pioneering user-oriented vehicle concepts for urban mobility can be derived in conjunction with varied requirements and influencing factors.

Keywords: urban mobility; mixed-method approach; user-centerend-design / approach vehicle concepts, city vehicles

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1. Introduction

The current developments in urbanisation are not just particular challenges for megacities in the Asian and Latin American regions. Cities in Europe and Germany are also confronted with an ever increasing growing traffic volume and the associated consequences which they create. Kunzig (2012), Schunder (2016), UNHabitat (2013)
The increasing mobility requirements for the population hereby create a specific conflict of interest with the negative impacts (space requirements, emissions, noise, etc.) for transport and, in particular, for road vehicles. These challenges are currently being addressed by cities, transport operators and transport providers and include, among others, new mobility services such as sharing, multi-modal utilisation of transport resources and "mobility-as-a-service". (compare also with Gebhardt et. al. (2016), Hilger (2017), Loose (2017), Wöhrl (2016))
On the other hand, vehicle manufacturers increasingly rely on new technologies, such as the electrification of the powertrain, the automation of vehicles or the utilisation of information and communication technologies to increase the vehicle technologies. Bozem et. al. (2013), Kienzle et. al. (2017)
A large number of vehicles are simultaneously offered as "small city vehicles", which should contribute to urban mobility for the future. (compare with e.g. Proff et. al. (2017). However, an analysis of data from Germany shows that all vehicle categories can still be found in the urban areas which are also used elsewhere and do not correspond to the typical "city vehicle type". (compare with Figure 1)

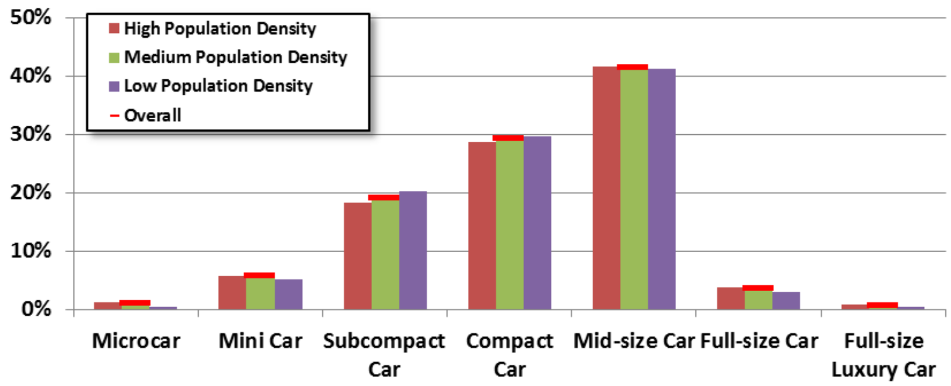


Fig. 1 Proportion of vehicle classes in new registrations for M1 vehicles in Germany 2016 according to population density (Source: Own description according to approval data)

This therefore raises the questions of why these vehicles are being used, which requirements vehicles must fulfil in urban areas and how a mixed-methods approach can be used to derivate vehicle concepts for urban mobility from the user's point of view.
The presented works to give some answers to these questions has been developed and applied in the context of the "Urban Mobility" project from the German Centre for Aerospace (refer to www.urmo.info).

2. Methodological approach for the identification and conception of vehicle in urban areas

In order to take into account the user-specific perspective and requirements in vehicle development, empirical results regarding mobility requirements and user behaviour will be especially integrated. Among other aspects, approaches from Schnieder et. al. (2016), Proff et. al. (2016), Wiedemann (2014) and Wildemann (2004) will be included, summarised and systematically supplemented. (Fig. 2)

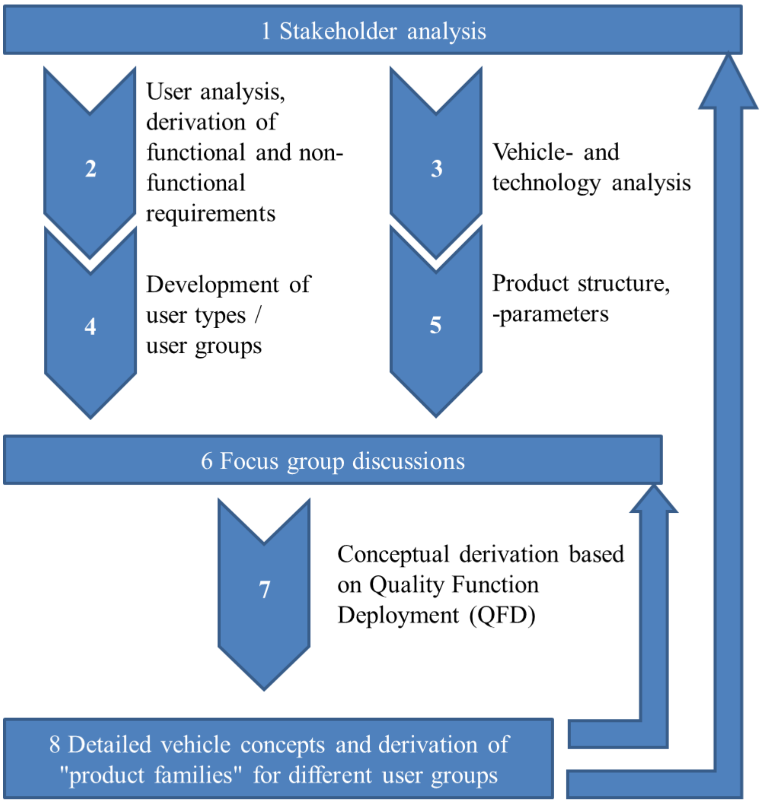


Fig. 2 Procedures for integrating customer-specific requirements in the vehicle concept

Based on the research question "How could future vehicle concepts be designed to meet the needs of urban users and the environment requirements?", the initial basis of the procedural approach is a systematic stakeholder analysis (1) to consider all relevant requirements and interests. (also compare with Niebisch (2013), Grande (2014)) In addition to the major stakeholders of the users, also the cities and municipalities, mobility operators and mobility associations, legislative institutions and the car manufacturers themselves play a decisive role and must be considered with their relevant requirements.

Two parallel investigations will be executed based on this analysis. On the one hand, the "reason for vehicle use in the urban area" will be determined by literature research, expert interviews and quantitative surveys and the necessary functional (and partly non-functional) requirements will be derived (2). The particular utilisation of a quantitative survey enables typical user patterns of people in the urban area to be identified and translated into the description of user types and groups (personas) (4). A persona hereby creates a generalised, comprehensive representation of a user group, including its behaviour, attitudes and motives ("user type"). The advantages of this persona method are, in particular, creating a description of the potential users of the vehicle to be developed, which can then be presented to all project participants (social scientists, engineers, geographers, etc.). (also compare with Graser / Hutzler (2015), Schnieder / Gebhardt (2016))

On the other hand, the available vehicle concepts and technologies will also be simultaneously analysed (3), transferred into a traffic-supporting overarching product structure and identify user-relevant, quantifiable features and parameters (5). (compare with Fig. 3)

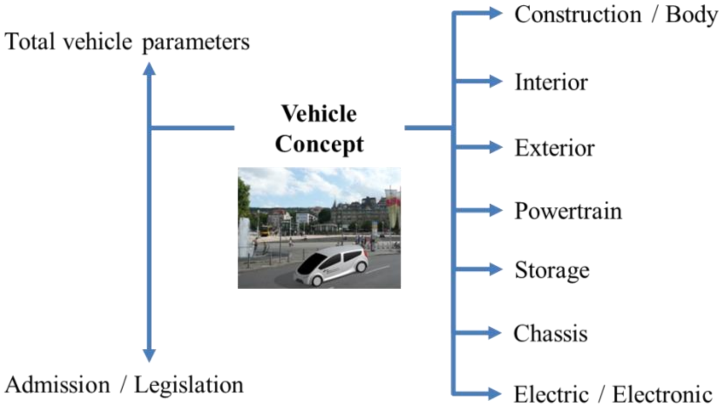


Fig. 3 Structure of the vehicle parameters (illustration of the 1st Level)

In group discussions with selected types of users, requirements were explored and discussed on relevant characteristics of future mobility concepts. In this case, systematic focusing must be implemented on the basis of the multitude of relevant requirements and vehicle parameters. Furthermore, vehicle sketches were developed from these parameters as impulses for the focus group discussions, which will not only reflect the pure vehicles, but also the concrete uses cases in the urban situation.
The amalgamation of the identified customer requirements and vehicle-specific characteristics gained from the different methodological steps (expert interviews, literature research, technology analyses, focus group discussions with selected persona types represents the following step (6).
The derivation of the rough vehicle concept (7) is based on the House of Quality method of the Quality Function Deployment Approach (QFD). (also compare with Bors (1995), Saatweber (2007), Wildemann (2004)) The requirements discussed and supplemented in the focus groups and workshops will be specified in relation to the relevant vehicle parameters.
Finally, the developed knowledge will be utilised specifically to implement a vehicle concept with the aid of simulation-technical design tools (drive train, driving dynamics ...) and geometrical derivations (vehicle architecture and package) for the requirements of users (8) and "product families" with similar requirements and characteristics.
In particular, in the derivation of the vehicle package, the challenges are mainly uncovering and optimally resolving the target conflicts from a customer's point of view e.g. minimal external dimensions for optimal use of the existing parking spaces in comparison to the maximum usable vehicle interior. This however still makes it necessary to reflect the derived results and vehicle concepts and to intensify them further with users and stakeholders as an iterative process.

3. Application of the methodological approach for the derivation of future vehicle concepts in the area of private use

3.1. Stakeholder analysis, user analysis and derivation of functional and no-functional requirements

In the case of the derivation of private vehicle concepts, the functionality and requirements for the use of the passenger car are divided into main categories of Level 1as represented in Fig. 4. These main categories are then detailed and defined again with additional requirements in a 2nd and 3rd Sub-Level so that a systematic requirement analysis and the necessary prioritisation of the relevant requirements can be executed.

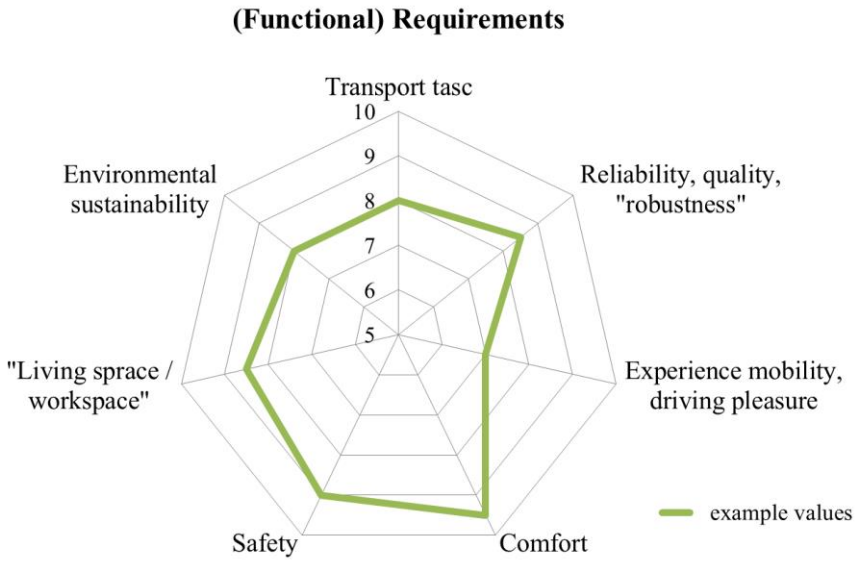


Fig. 4 Compilation of the (functional) requirements for the use of a passenger car in the city (example values), 2nd and 3rd Level not shown

3.2. Focus group discussions

Besides the identification of requirements from literature research and expert interviews, specifications for vehicle concept were explored in the framework of focus group discussions with four different types of users The four types of users were identified on the basis of the quantitative survey on mobility behaviour. They represent four potential actors with typical usage situations in the urban space:

1. The young inter-modal
2. The (all-purpose) car users
3. The urban bike lovers
4. The multi-modal

With the workshop participants analysed vehicle characteristics which have been particularly selected from the range of the transport tasks as well as the environmental sustainability - infrastructure use:

- vehicle interior with seating areas
- luggage storage
- accessing and/or exiting situations
- external dimensions for flowing traffic and parking space requirements in stationary traffic

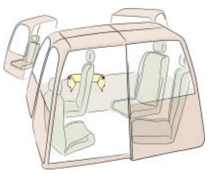
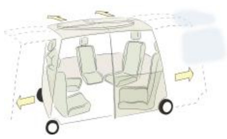
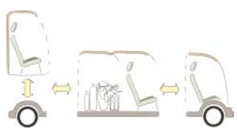
Since the vehicle use and the associated requirements for a vehicle always depends on the urban situation and the use cases, the users motives and preferences as well as the societal, spatial and technological framework, the "everyday contexts of the people” are important. Therefore, everyday situations and the everyday mobility of the users were chosen as the starting point of the discussions. For example, two representations of parking situations were selected: a slightly distorted parking situation and a version with the maximum utilisation of the parking space via the different vehicle variants. (compare with Fig. 5 and 6).
By applying to everyday actions and preferences, behaviours could be understood from user perspective and requirements for vehicles can be derived.

Fig. 5: Design sketch for the visualisation of vehicle characteristics

Fig. 6: Design sketch for the visualisation of vehicle (sizes) classes and the resulting influence on the parking space requirements

By selecting the four very different user types and their mobility behaviour, it was possible to ensure that a very wide range of customer-relevant requirements and concept ideas could be discussed and reflected in the focus groups. (see also tab. 1)

Table 1. Requirements and concept ideas of the different types of users

User Group	**The young inter-modal**	**The (all-purpose) car users**	**The urban bike lovers**	**The multi-modal**
Requirement	**Dimensions:** Adaptable **Capacity:** 2 - 6 persons big luggage space **Parking Space:** Solution: Sharing	**Dimensions:** Adaptable **Capacity:** 2 persons + luggage space or add. persons **Parking Space:** Small	**Dimensions:** Very small **Capacity:** 1 - 2 persons **Parking Space:** Very small	**Dimensions:** Adaptable **Capacity:** 1 – x persons **Parking Space:** Solution: Sharing
Examples of concept ideas				

It has to be seen that the requirements for vehicles in urban areas are very different and thus either a variety of vehicle variants or adaptive concepts are relevant from the user point of view.

However, this variety also presents a specific challenge for the classification and evaluation of the vehicle criteria from the customer's point of view, as this is executed exemplary with additional conjoint analyses or an application of the Kano model. (compare with e.g. Wiedemann (2014))

3.3. Conceptual derivation and detailed vehicle concepts

In order to further derive the rough vehicle concept, the results obtained were processed and correlated with the respective vehicle parameters via the QFD approach and the House of Quality. (compare with Figure 7 and e.g. Saatweber (2007))

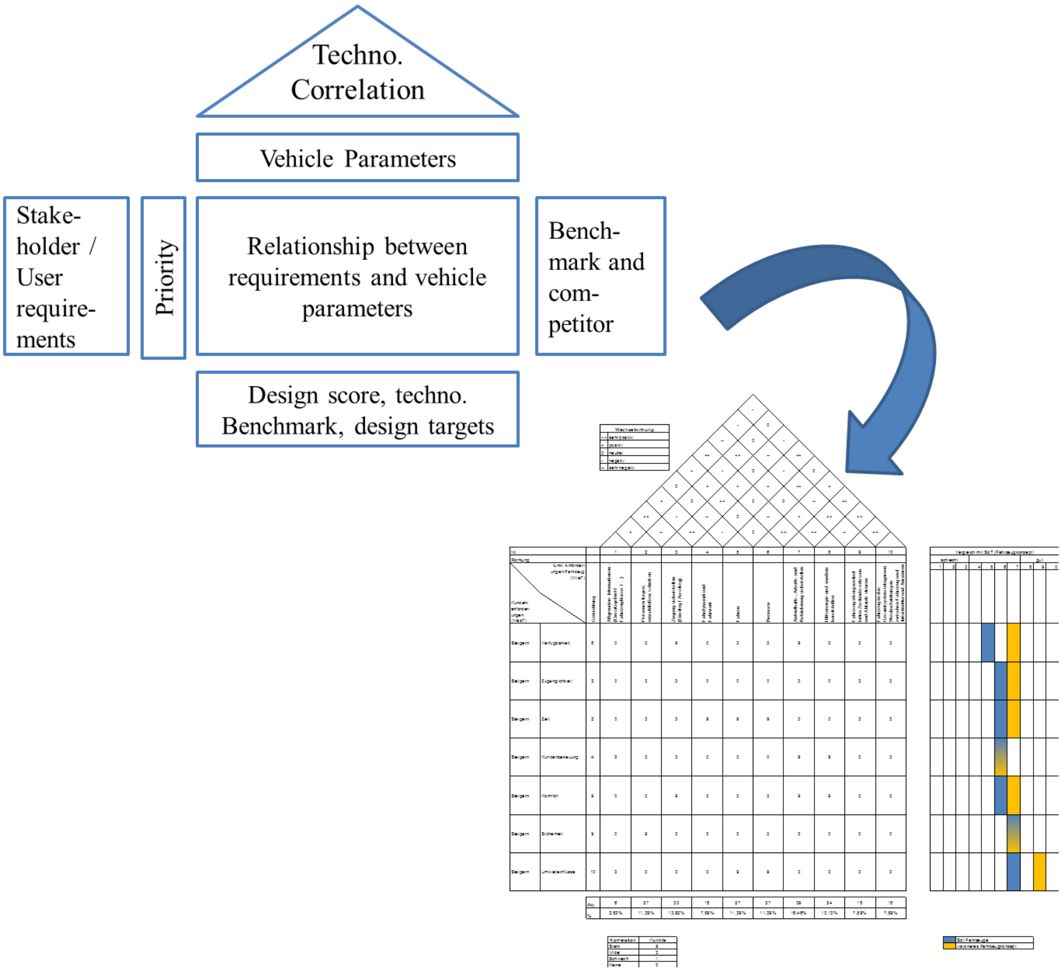


Figure 8: Correlation of requirements and vehicle parameters by the House of Quality of the QFD approach

Especially in the derivation of the vehicle architecture and package, there are major challenges in the prioritization of different requirements, which mutually influence each other. E.g. the exterior dimensions of the vehicle have a direct effect on the necessary parking space (environment / infrastructure). At the same time, the internal dimensions are characterised in particular by the vehicle components (compare with vehicle parameters like powertrain, energy storage, chassis ...) and the internal use of the space by the user (transport tasc with interior). For this reason, it is necessary to be able to derive different vehicle concepts and architectures quickly and efficiently, based on quantifiable criteria and parameters. In particular, this could be achieved by the use of different tools and the derivation of the necessary package. (compare Fig. 8 and also Höfer et. al. (2016) and Münster et. al. (2016))

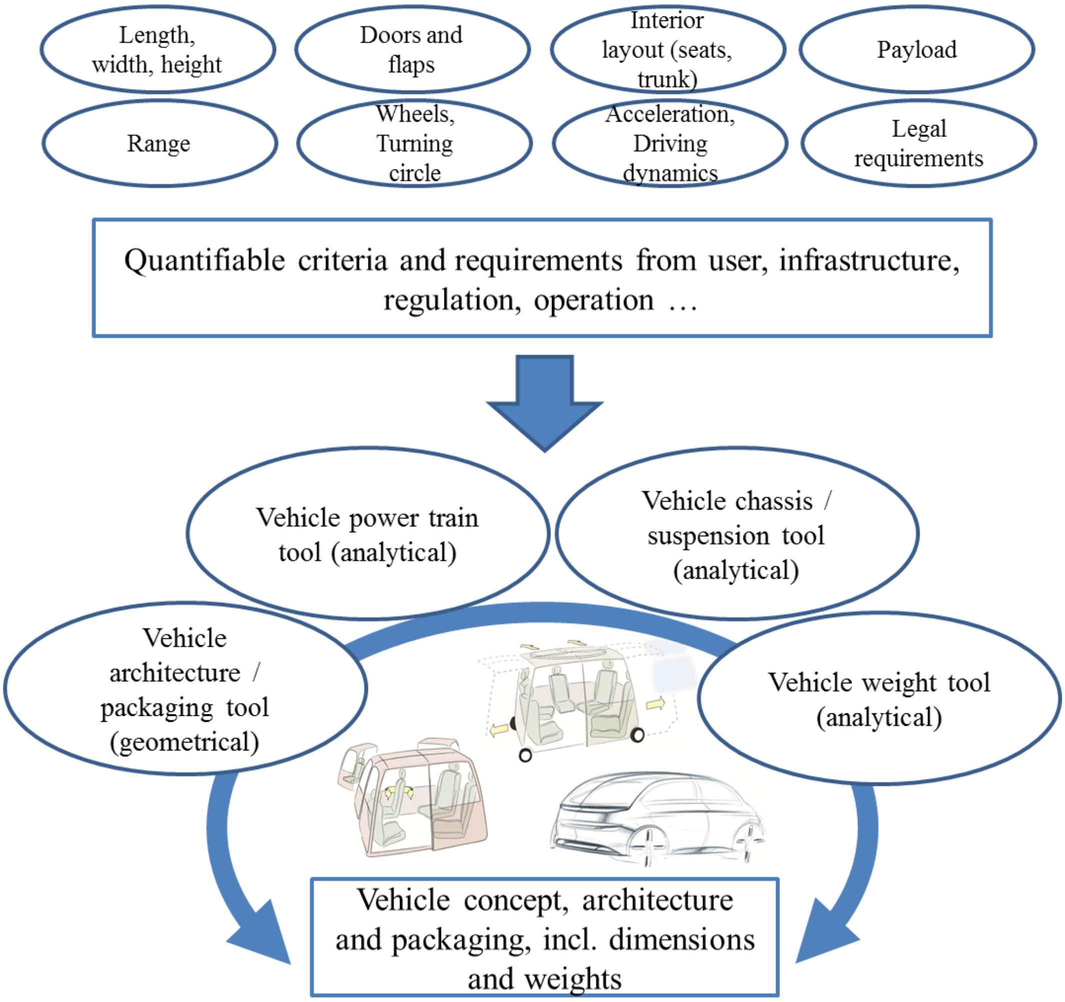


Fig. 8: Quantifiable requirements and necessary tools for the derivation of the user optimized vehicle concept

This objective conflict results in, for example, that scalable and modular vehicle concepts are relevant from the user's point of view, when they can be adjusted to the respective transport tasks.

4. Transfer of the approach to concepts for public transport

In addition to the need for the optimisation and further development of the private MIV in urban areas, urban public transport concepts are of particular relevance in the future. On the basis of this assumption, the methodological approach described above was used and transmitted for the derivation of an innovative bus concept for a needs-oriented operating concept in a virtual laboratory. (also compare with Brost et. al. (2017))
Steps (1) to (5) were executed analogously to the described procedure, whereby specific requirements e.g. from the area of infrastructure use ("bus stops") or barrier free accessibility where also supplemented.
The derivation for possible user groups a was executed via literature research and expert knowledge from the project participants (science, civil society, community, operator). The following 4 groups were selected for user workshops:

1. Senior citizens
2. Mobility-restricted people
3. Regular bus users
4. Regular private car users

In the course of the workshops which were executed, it was particularly shown that the requirements for accessibility, entry and exit, "flow of people on the bus" by means of one or two entrances or exits and the

interaction with the bus driver play an essential role and must therefore be specifically considered for the QFD approach.
The thereby iterative derivation of the innovative bus concept for a needs-driven operating concept was divided into the main vehicle groups, bodywork, interior / exterior and drive / chassis. (compare with Fig. 10 and Müller et. al. (2017))

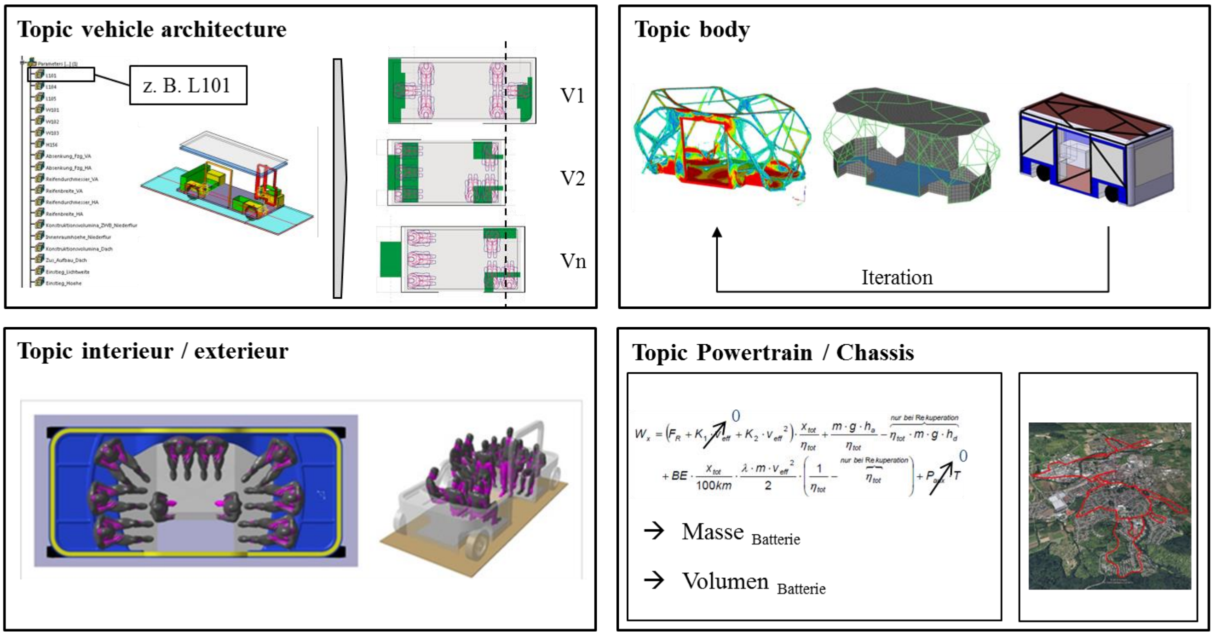


Fig. 10: Subject fields for vehicle development (Müller et. al. (2017)

The derived, innovative vehicle concept is therefore characterised by the following vehicle parameters:

- External dimensions: maximum L*W*H: 5000 mm * 2500 mm * 2200 mm
- 6 seats and minimum 4 standing places
- Pure electrical range defined by real driving cycles and operation application
- Optimisation of the vehicle concept especially in the field of "environmental compatibility", safety, comfort and passenger information

5. Conclusion and outlook

Within the paper, a systematic approach was represented about how future vehicle concepts for urban mobility can be derived in conjunction with a wide range of requirements and influencing factors. This approach is characterised in particular by the strong involvement of the user with the help of the persona method and the use of the QFD approach for the derivation of new vehicle concept.
By utilising the application of the methodology in the area of private car use and the derivation of demand-oriented bus concepts, a systematic addition to the product development process could be presented.
This approach has the advantage that the requirements are integrated from the user's point of view and specific vehicle concepts can be derived for the different urban applications.
In the course of the project, the detailing of the derived vehicle concepts will be executed these concepts will then be reflected with the users and stakeholders.

6. Acknowledgment

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