CHALLENGES IN VEHICLE DEVELOPMENT

Due to the transformation phase in which the automotive industry currently finds itself, OEMs and suppliers are facing legal requirements and tasks they have never had to master before. They have to strike the optimal balance between available technology and applicable regulations and, at the same time, predict what characteristics will motivate prospective customers to purchase their product. Moreover, since comparative tests have a significant impact on purchasing decisions, the developments of other OEMs have to be kept in sight as well.

A key step in coping with the growing variety of versions is the introduction of a common, scalable vehicle platform, which makes it possible to standardize large parts of the production [1]. Especially in high-volume segments, manufacturing is significantly simplified by components of identical design and by standardized production processes. The scalability of the platform enables short response times to new vehicle trends because additional vehicle variants can be developed with a relatively small investment of effort. However, when planning the platform, the fact that vehicles are typically subjected to a facelift within two to four years must be considered right from the beginning. In this context, other components are frequently installed which lead to new demands being made on the platform – such as a higher axle load due to an updated engine.

Consequently, before starting the development, numerous basic decisions have to be made for the vehicle, for instance regarding weight distribution or emissions, **FIGURE 1**.

These decisions are defined in the form of so-called “target values” – in some cases together with a development partner. Calibration and testing of the vehicle attributes have to take place at an early stage of the development process and thus ensure timely identification of potential complications.

In addition to and irrespective of the vehicle-specific characteristics, global issues such as energy prices or availability and environmental compatibility of the required raw materials must be taken into account. Potential government subsidies or incentives are relevant as

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Virtual Vehicle Development as the Basis of Modern Vehicle Architectures

When OEMs launch new vehicles, they have to carefully consider what measures are necessary to offer their customers competitive and attractive products that also embody the key characteristics of the brand. One of the greatest challenges in this context is the need to define all vehicle attributes a long time before the vehicle is ready for market launch. Supporting this process calls for new solutions such as virtual vehicle development, as IPG Automotive demonstrates.

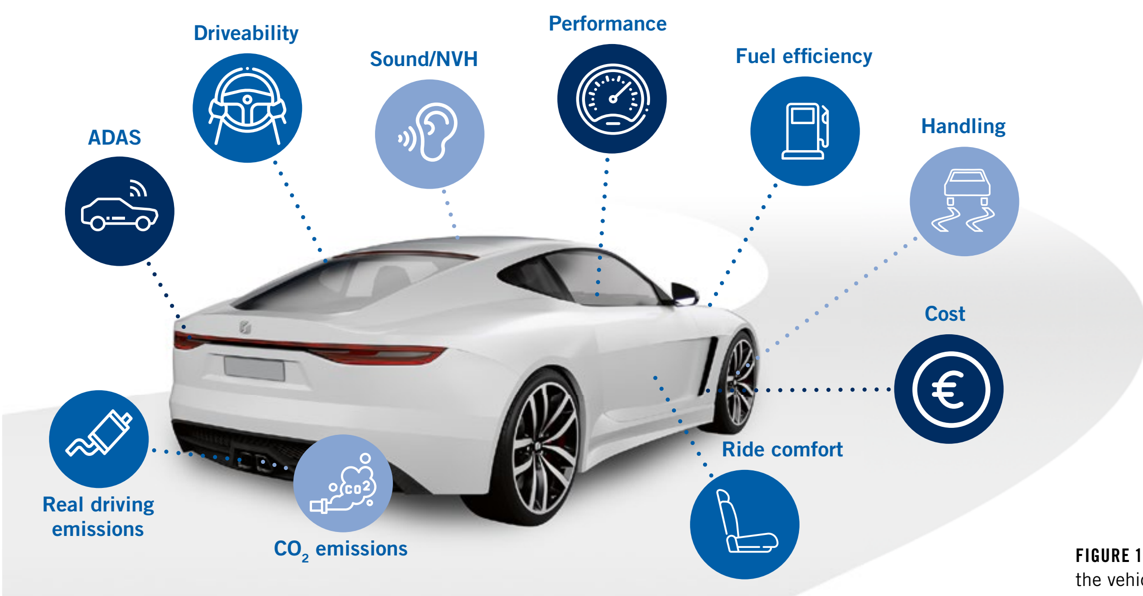


FIGURE 1 Overview of some of the vehicle attributes to be defined (© IPG Automotive)

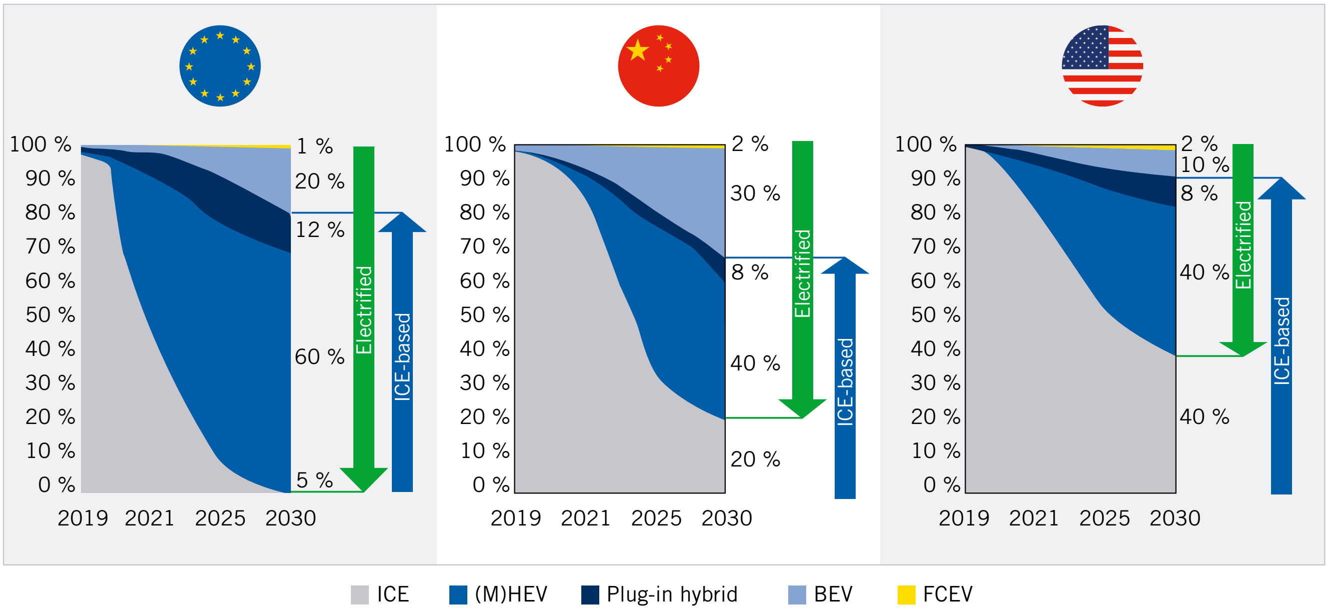


FIGURE 2 The diversity of the powertrain according to IPG Automotive forecast (© IPG Automotive)

well because they can decisively affect the purchasing behavior of customers. Understanding the variety of market demands is more important than ever before and necessary during the entire development process.

For all of these challenges, credible findings in the concept design phase of the vehicle are indispensable. Consequently, the ability to evaluate concepts on the full-vehicle level at an early stage of the development process is important. This can be accomplished with virtual vehicle development, which will be addressed in greater detail following the fields of application and their special aspects.

POWERTRAIN VARIANTS

Since the markets of the world are highly differentiated, localization and legislation pose a wide variety of challenges during the planning process of the vehicle architecture. Whereas in Europe there is a growing trend toward abandoning diesel engines, and CO_2 reduction is one of the key topics, environmental aspects still tend to be of secondary importance in other parts of the world. A look at the forecasts shows that the diversity of powertrains, and thus the development complexity, will massively rise in the coming years. The future belongs to increased electrification – from mild hybrids and full hybrids ((M)HEV) through plug-in hybrids to battery-electric (BEV) and fuel cell vehicles (FCEV), **FIGURE 2**.

This is not the only challenge facing OEMs: In the field of electric mobility development, new players using all-new approaches and development methods have entered the market. Furthermore, vehicle engineering is making great strides in moving away from mechanical toward electrical engineering and software development.

The architecture of the powertrain is particularly important in the area of electrified drive systems. It has a major impact on handling characteristics and performance – for example due to the positioning of the electric motors and the battery. Due to the large number of diverse powertrain concepts, planning and development using conventional methods is time-consuming and complex.

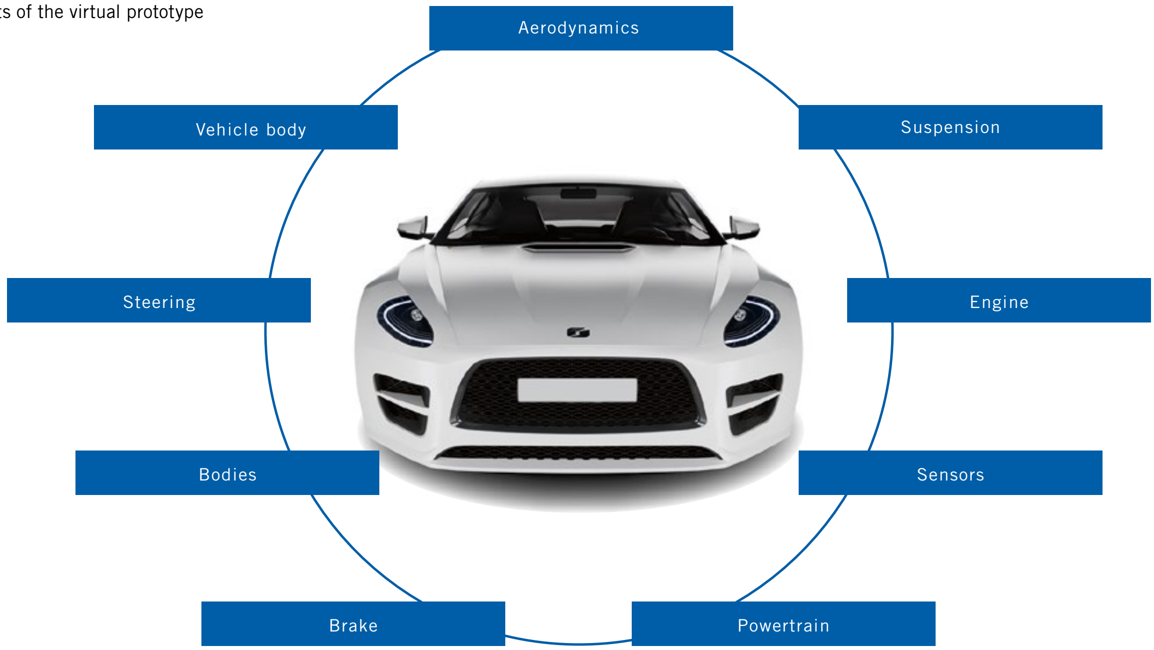
Another challenge is the achievable range of electric vehicles, which is a crucial purchasing criterion. In this context, driving cycles such as the WLTP, which superseded the NEDC in 2017, tend to be of secondary importance to customers due to their frequently unrealistic results. The range achievable in real-word operation [2], in contrast, is a factor that truly affects purchasing decisions. Range, however, results in a conflict for developers dealing with today's battery technology and its low energy density: the larger the range, the higher the vehicle's weight due to the battery cell. Higher weight in turn reduces efficiency.

Virtual vehicle development offers the opportunity to rise to these challenges and to cost-efficiently exploit the enormous potential of powertrain development – for instance by simulating scalable battery layouts.

ASSISTANCE FUNCTIONS AND AUTOMATED DRIVING

Other central topics OEMs are working on are advanced driver assistance functions, automated driving and the required sensors. The objective is to achieve the best possible recognition of the vehicle's surroundings by means of the smallest possible number of installed components. To assure error-free functionality, all sensors, actuators and software functions in the vehicle have to interact smoothly. Due to the complexity and error-proneness this entails, the ability to test – for instance whether or not the planned sensors optimally capture the environment or if the sensor configuration/positioning has to be changed – by means of virtual vehicle development already during the concept phase is indispensable. To avoid latencies in signal transmission

FIGURE 3 Components of the virtual prototype (© IPG Automotive)



between the individual ECUs, there is a trend toward central electronic control units, particularly in the area of automated driving [3].

By means of a virtual ECU (vECU) it can be assured that the extensive functions of a complex real ECU deliver the desired performance in the full vehicle – at any time in the development process. Systems such as adaptive cruise control or lane keeping assist can thus be evaluated and optimized in the vehicle without the vehicle having to exist in reality or the supplier having provided hardware for installation in a physical prototype. Communications tests can be carried out with both Model-in-the-Loop (MiL) and Software-in-the-Loop (SiL). In this way, a simulation environment such as CarMaker from IPG Automotive can decisively help to master the challenges in the areas of advanced driver assistance systems and automated driving.

The target value definition for Euro NCAP tests is a case in point. For this purpose, it must be possible to find out in an early development phase if the planned functions in interaction with the remainder of the vehicle data, such as masses, lead to the desired outcome – that means the achievement of the maximum score in the case of Euro NCAP, for example in an emergency braking situation.

VIRTUAL VEHICLE DEVELOPMENT

As described in the chapters above, OEMs and suppliers have to make a large number of decisions in a very early development phase extending across numerous domains such as mechanical systems, electronic systems and software. One reason for this is the shift in vehicle functions from a component-based toward a system-based method of operation.

Thus, a system-based view is indispensable in vehicle development: According to the automotive systems engineering approach [4], this means a look at the overall system in the full-vehicle context in realistic test cases. The test cases should correspond to the situations the future driver will personally experience. Testing on total system levels must become a value-generating element within the development process. This enables complex decisions to be made at an early stage. Processes, methods and tools are needed for this that can satisfy these requirements.

Virtual vehicle development makes it possible to conduct systematic tests in the decisive vehicle architecture phase on the full-vehicle level and to obtain reliable and robust results. It enables a concept evaluation in a safe, deterministic and highly reproducible environment. Thus, conclusions about the system behavior can already be obtained in the concept phase and any potentially needed concept changes be derived.

A modern opportunity for this is provided by the open integration and test platform CarMaker that was developed in order to reduce the costs and complexity of automotive development. It enables efficiency increases and helps OEMs and suppliers to act today in order to face the exacting demands of future markets and legislation with greater aplomb. The virtual integration of the systems under test into the virtual prototype during a very early development phase provides the foundation for this, **FIGURE 3**. Respective interfaces make it possible to integrate models from diverse simulation tools (re-use of legacy) [5]. Thus, existing models in which a lot of knowledge has previously been invested can easily be re-used in order to include them in the investigation of the overall system.

The full parameterization enables the simulation of all influences of the vehicle systems amongst each other and the precise modeling of the physical vehicle's handling in the virtual world.

Consequently, CarMaker can be used throughout the entire development process. In the HiL phase, software models can be replaced by the now available hardware and existing scenarios and test cases (consumption analyses, Euro NCAP etc.) can be reused in any development

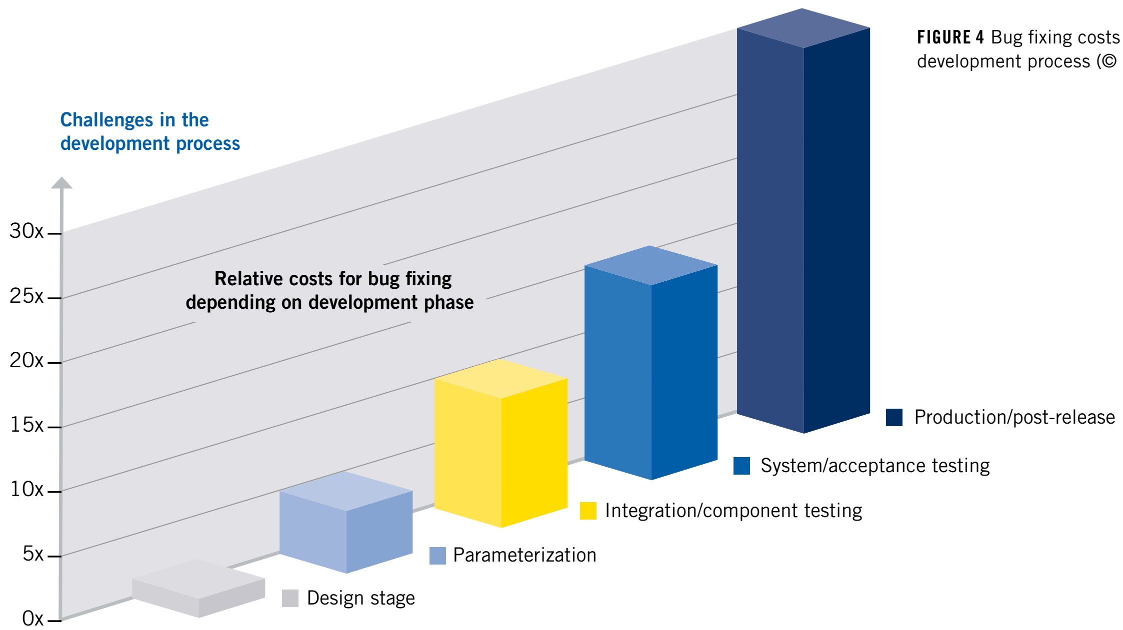


FIGURE 4 Bug fixing costs in the course of the development process (© IPG Automotive)

phase. This avoids a tool disruption that would severely impair development efficiency. For example, a test case that has just been built on the computer can be carried over into the physical vehicle immediately afterwards and personally experienced in a driving situation by means of the vehicle-in-the-loop method. As a result, decisions can be made in more solid ways and at earlier stages in the development process, and the systems can be developed, tested and brought to market faster [6]. The approach leads to shorter development cycles and higher quality. By extensively using MiL and SiL, potential design issues can be identified as early as possible in the development process and costly design changes avoided, **FIGURE 4**.

SUMMARY

Virtual vehicle development provides a solid basis for systematically and efficiently supporting the entire development process. It enables shifting from a component-based view toward a system-based view.

For OEMs and suppliers, the utilization of a simulation environment such as CarMaker translates into reduced development effort, faster and more agile response to new trends, lower costs and shorter time to market.

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