

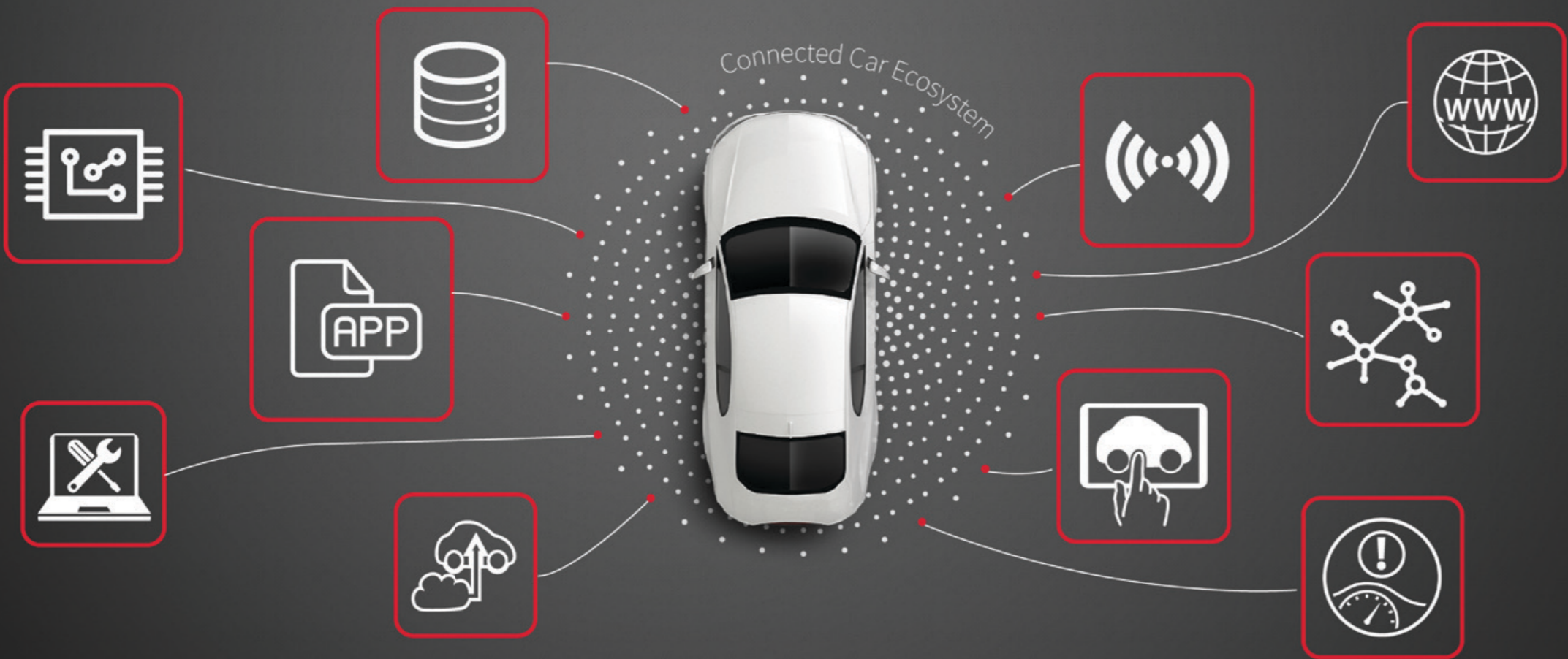
AUTOMATED DRIVING

CONNECTED AND AUTOMATED VEHICLES

NEW DEGREES OF FREEDOM FOR IMPROVING THE POWERTRAIN

In addition to traditional, human-centered vehicles, highly automated and connected vehicle concepts will hit the market in the next 10-15 years. In the fully automated stage (SAE level 5), the driver—or better, the vehicle user—will be out of the control loop. This new experience in mobility goes hand in hand with evolving user expectations and buying criteria. Anticipating this trend, OEMs have the opportunity to create a new vehicle and powertrain portfolio organized according to individual mobility scenarios (e.g. shared city mobility). This allows OEMs not only to develop new vehicle concepts, a fresh brand image and exciting user journeys, but also to optimize powertrains in terms of cost and fuel consumption. FEV and FEV Consulting are highly involved in these areas in terms of market studies, research and tailor-made developments. Against this backdrop, the experts have conducted a field study in which future mobility concepts have been evaluated, focusing on cost and fuel consumption optimization potential to improve the powertrains.

» ON THE JOURNEY TO AUTOMATED DRIVING, MAJOR CHALLENGES SUCH AS REDUCTION OF VALIDATION AND HARDWARE COSTS, EFFICIENT REDUNDANCY CONCEPTS, REGULATORY ISSUES AND CYBER SECURITY, AND EFFICIENT TESTING PROCEDURES NEED TO BE MASTERED



New Mobility Concepts

Based on automation and connectivity technology, new mobility concepts and usage patterns will enter the market in the next 10-15 years. Driverless transportation offerings are facing prosperous market outlooks in European cities. Today's "car to go" concept will transform into an automated "car to come" approach, with guaranteed door-to-door transportation. A specialized "City Pod" vehicle is purely designed for mobility within a city. It is expected that these vehicles will be powered by an electric drivetrain and, if necessary, equipped with a range extender.

For out-of-city trips, City Pods or Collectivos could bring passengers to a "Vehicle Hub," where passengers (or the entire cabin) are transferred onto a "Motorway Pod," or an "LDPC" (Long Distance People Carrier)—a fully automated, dedicated long-distance vehicle with an optimized vehicle and powertrain design. Micro or mildly hybridized Diesel vehicles are good candidates, due to the given duty cycles.

Individually or privately owned vehicles will co-exist with shared mobility solutions in the future. These individually owned vehicles will cover both short-distance, urban trips with minimum emissions and long-distance, outer-city stretches requiring high reach. A gasoline PHEV concept for All-Rounder vehicles is proposed in this context.

Evolving User Expectations for Individual Transportation Needs

Depending on the mobility scenario, including trip distance and number of passengers, five different transportation concepts have been developed. Five future automated and connected vehicles have been designed for five corresponding baseline vehicles (from inner-city vehicles for one person to long-distance transportation with multiple passengers).

In a user survey, FEV measured the degree of evolving user expectations for all five tuples. A tuple represents one mobility scenario, including a baseline and an adapted, automated future version of the vehicle. For each tuple, the expectation deltas are translated into future powertrain specifications using a modified QFD (Quality Function Deployment) approach. After that, the impact of the differences in specifications was translated into costs and CO₂ emissions.

At the core of the approach is an integrated tool, which includes a modified QFD process and relation matrix to assure correct weighting of the vehicle and powertrain characteristics. The translation into detailed specification changes is supported and validated by expert estimations.

User Expectation Depends on Mobility Scenario

The user survey shows shifts in vehicle user expectations once vehicles become automated and highly connected. Survey participants had to answer questions about how the vehicle requirements and buying criteria of over 20 predefined characteristics change in importance, depending on the tuple characteristic (e.g. City Pod).

The results show that importance decreases significantly for ten requirements. Not surprisingly, they can nearly all be found in the powertrain performance and drivability category. However, what is remarkable is that half of them lose importance for both vehicle concepts (inner-city and outer-city). These requirements include engine power, acceleration from 0 to 100 kph, acceleration reserve, change in acceleration and repeatability of acceleration. These results suggest that vehicle performance and drivability will lose their dominant positions in buyer decision-making when it comes to automated and connected vehicles. Yet, there are significant differences within the individual mobility concepts.

Increased Focus on Comfort, NVH and Acoustics

In contrast to those results, aspects concerning comfort gain strongly in importance. All seven predefined requirements were rated as more important buying criteria for future vehicle concepts. Especially showing a strong increase in importance were the requirements of infotainment, thermal comfort, vehicle space and ergonomics. The survey also shows that purely automated city vehicles are welcomed, but need to fulfill special attributes, such as high launch quality, higher economic friendliness and less performance than their motorway counterparts. In the next step, the translation of user-perceived attributes into specific engine attributes will be described.

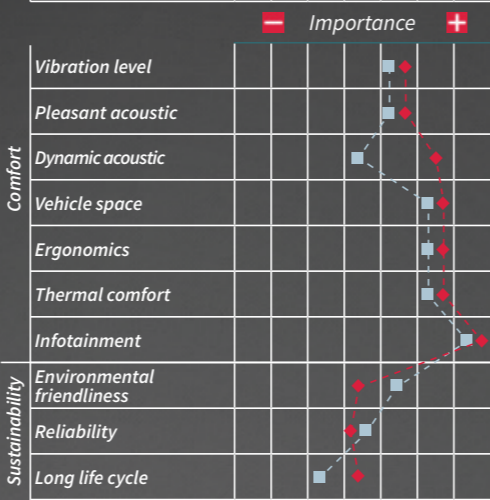
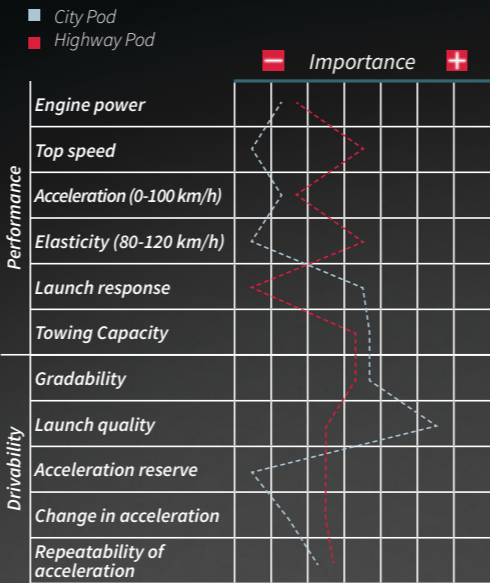
From User Survey to Scenario-based Powertrain Improvement Measures and Specifications

The modified Quality Function Deployment (QFD) specifies possible improvement measures based on the user survey. Each automated vehicle was now precisely specified and quantified. As user demands regarding vehicle performance and acceleration decrease for the City Pod, the cost reduction opportunities for the modified City Pod increase, potentially stemming from less nominal power, less nominal torque, a slightly reduced low-end torque and less responsiveness. Concerning transmission requirements, the gear change quality especially increases in importance, meaning that an interruption of traction should be minimized in order to facilitate a comfortable work and entertainment environment. Regarding NVH (noise, vibration and harshness), nearly all specifications are on the increase. This is mainly the result of higher comfort requirements. Regarding City Pods, working and entertainment during the drive are key user expectations, as is a quiet and smooth mobility experience.

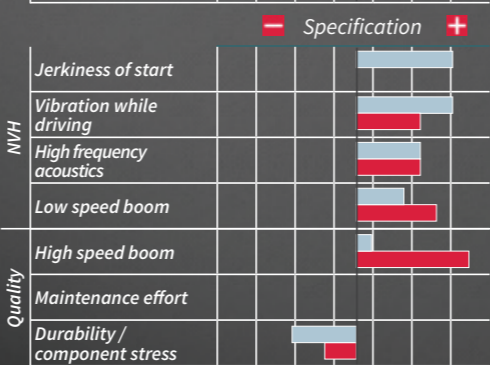
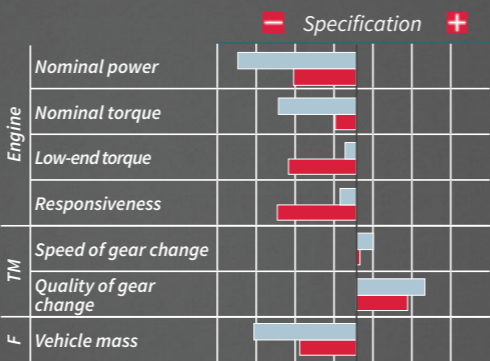
One key finding is the possibility that durability and component stress can be reduced with smoother vehicle operation based on traffic and road prediction. For Motorway Pods, the analysis shows that cost optimization includes a reduction in nominal power, low-end torque and responsiveness compared to their human-driven counterparts. Very interesting from a cost perspective is the fact that the parameters of low-end torque and responsiveness can be reduced even further than the same parameters in the City Pods. The scenario-specific user requirements describe a vehicle design with a defensive driving style and excellent NVH road behavior. This layout creates a friendly work environment inside the Motorway Pod, allowing users to work or hold conference calls. This setting is comparable to today's train rides with the advantage of full privacy and confidentiality.

For both City Pods and Motorway Pods, test results show that the spacious vehicle concept, often referred to as a "third living space," is enthusiastically welcomed on the market. Calculations show that the analyzed tailored powertrain layouts can be designed with lower hardware costs and reduced fuel consumption while still meeting user requirements.

T1: City Pod, optimization from Human driving to Automated Driving
T3: Highway Pod, optimization from Human driving to Automated Driving



User survey results: evolving vehicle requirements



Recommended improvement measures for cost and fuel consumption

Concept	Passengers	Distanz	Baseline Vehicle	Automated & Connected
City-Pod	+1	City	A	EV
Collectivo	+4	City	B	EV
Motorway Pod	+1	Highway	C	Micro / mild hybrid
LDPC ¹	+4	Highway	E	Micro / mild hybrid
All-Rounder	+4	City/Highway	D	PHEV

Comparison of requirements and specifications

Roadmap for Future Mobility

The described FEV Consulting study highlights the significant optimization potential for the powertrains of fully automated vehicles in terms of costs and fuel consumption. Specific cost and fuel consumption savings largely depend on the individual's estimated mobility scenario, baseline vehicle specifications, degree of limitation and operation strategy. The most savings can be achieved with the automated City Pod and the Highway Pod.

It is expected that evolving user expectations will have a significant impact on future OEM portfolio strategies and powertrain development. This could include a reduction in variants, downsizing, and a shifting development focus. Additionally, the question should be posed regarding whether today's one-dimensional vehicle segmentations and portfolio structures (A, B, C, etc.) are suitable for evolving automated and connected mobility patterns. The two-dimensional mobility matrix used

in the consulting study could present an improved alternative. Although the results might suggest a devaluation of the powertrain as a key buying criterion, FEV sees a significant opportunity for OEMs: by organizing vehicle offerings according to mobility scenarios (e.g. automated and shared one-seater City Pods), new market differentiation is possible with specialized powertrain and vehicle concepts. Highly user-centric offerings could, for example, attract buyers with modern and customized brand images. Beneath the image lies a unique and exciting user journey along the entire vehicle life cycle. It embraces highly competitive cost- and fuel-saving performance, a comfortable and spacious cabin, and well-designed apps and interfaces – all based on an automated and connected platform.

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New vehicle segmentation for automated and connected vehicles

1) Long Distance People Carrier