

# The Car of the Future: Electric, Connected and Autonomous

## The Impact of Vehicle Electrification and Connectivity on Electrical System Design

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### Industry in Flux

Just over 100 years ago, Henry Ford disrupted the auto industry of the time with the introduction of the mass-production moving assembly line. To say that the auto industry is again in flux is almost cliché.

Several technology and business transformation trends are in play, signaling substantial long-term changes. Although still in early stages, their confluence is already having a profound effect on automotive companies and the future of the mobility landscape as a whole.

### Electrification

Many consumers recognize the value of electric vehicles in reducing environmental impact. A [survey from AAA](#) shows that 20% of drivers want an electric vehicle and will likely choose an EV for their next vehicle, up from 15% percent in 2017. However, limited travel range of today's electric vehicle and their high purchase cost—even when considering tax relief (which eventually be [phased out](#))—erect tall barriers on the road to broad adoption. Today, less than 5% of vehicles sold in the US use electric propulsion.

While US buyers remains somewhat tepid about electric vehicles, China's electric car market is booming, growing twice as fast as the US. Aiming to [meet air quality standards by 2035](#), China is driving large-scale transition to EVs through market initiatives, charging infrastructure and strict policies. By 2022, the combined sales of EVs and internal combustion vehicles in China will represent over half of global car sales volume. The Chinese auto market represents an enormous market opportunity for American and European OEMs that are investing heavily to seize the opportunity, and so do many startups. [Angellist](#) lists nearly 600 electric vehicles startup companies in the US, with an average evaluation of \$4.2 million.

But competing with dozens of indigenous Chinese OEMs and suppliers and gaining market share, especially in the non-luxury vehicles segment, is not going to be easy for foreign manufacturers.

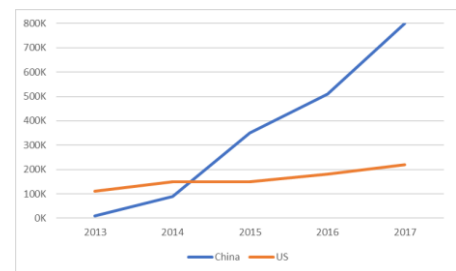


Figure 1. Electric Vehicle Sales (in Thousand Units).

Source: China Association of Automobile Manufacturers and US Dept. of Transportation, as reported by Forbes.

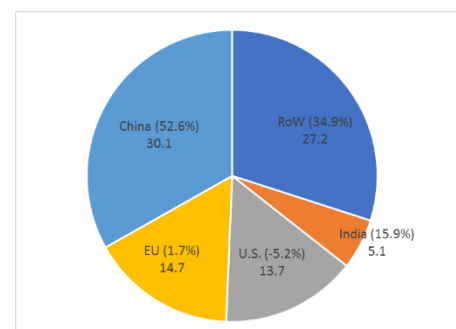


Figure 2. China's Global Car Sales Growth By 2022 (in Thousand Units). (Number in parentheses - % change from 2016 to 2022).

Source: McKinsey.

## Autonomous Driving

The race to achieve [fully automated driving](#) is heating up rapidly, although all contenders are still far from the finish line. Despite many uncertainties concerning technology maturity, regulatory requirements and market adoption, practically all automakers and major suppliers, as well as scores of small upstart companies, want to take part in this race.

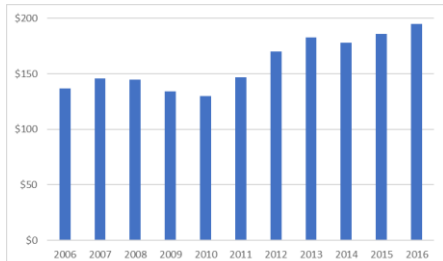


Figure 3. Total OEM Investments (US\$ billions) (Includes capital spending, R&D, M&A)  
Source: Capital IQ.

The path to building affordable and safe fully-automated vehicles and to gaining both regulatory approval and mass-market adoption is going to be long, and the timing and magnitude of realizing returns on hefty investments in developing autonomous systems are uncertain.

Nevertheless, the upside of market leadership in this space is lucrative enough. The ability to capitalize on the early waves of commercialization and consumer adoption and the accompanying boost to the brand continue to drive massive investments in R&D by both automotive companies and outside investors. From 2011 to 2016, R&D investment in

the automotive sector increased by 33%. Furthermore, typically fiercely-competitive, OEMs are seeking [new partnerships](#) and collaborations to leverage this industry-wide momentum.

## Connectivity

Internet-connected infotainment systems are platforms for delivering an increasingly rich set of content and services to drivers and passengers. While OEMs have been offering connectivity, telematic services and infotainment systems for many years, [monetizing](#) these services continue to be weak.

But this is about to change.

Today's consumers demand connectivity, sophisticated mobile apps and rich online content. An [Autotrader study](#) shows that connectivity is becoming an important factor in car buying decision. According to this study, 48% of car buyers prioritize in-vehicle technology over more traditional considerations such as brand name, body style and performance.

In the past, OEMs offered sophisticated head units and brand-name high-end audio systems, but these were mostly available in high-end models, assuming luxury car buyers will be willing to pay a premium for high-tech features and expensive annuity-based services, a model that has seen only moderate success.

Today, as the Autotrader study shows, 56% of car shoppers, especially the under-35 demographic, know exactly what in-vehicle technology they like and are less willing to compromise on the features they want. Realizing this demographic shift, OEMs are moving to better align the value proposition to demographics by adding connectivity and in-vehicle features across their portfolio, including their non-premium brands.

## Smart Mobility

In-vehicle systems, car connectivity and electrification pave the way for innovation in smart mobility. Optimized traffic management, all-electronic parking and tolling and alternative models for vehicle ownership and usage, such as car sharing and e-hailing, are still in early stages, but users in urban areas (again, primarily the millennial population) are quick to experiment with and adopt new ideas and are shaping the evolution of new services and business models.

The inflection points in many of the emerging smart mobility initiatives rely on external factors, such as advances in autonomous driving, infrastructure development, retail systems and numerous other factors, and, with theme, pressing new questions and concerns about operational safety, data security and consumer privacy. While new business innovation may take some time to evolve and mature, the general trajectory is clear and promising, and companies are investing heavily to establish a leadership position and capture early beachheads.

## Globalization and Personalization

Globalization and changing demographics are forcing OEMs to innovate differently. In-vehicle software-defined systems allow automakers to offer a wide range of features to better meet market demand and cater to the ever-changing tastes and whims of customers across different geographies and age groups and help create and bolster brand differentiation.

The ability to tailor functionality seemingly effortlessly to markets and demographics at minimal manufacturing cost is tempting for marketers and design engineers alike. Driven to outdo the competition, automakers rush to implement new performance, comfort and safety features. Some creative marketers and industrial designers envision a configurable and customizable dashboard that ditches most hard buttons in favor of an iPad-like console and augmented reality-enhanced information—an idea many engineers eschew.

But one thing is abundantly clear: electronics and software are defining the competitive battleground of the future.

## A Century-Old Status Quo is Challenged

The convergence of electric propulsion technologies, advanced control systems and pervasive connectivity is enabling a wave of exciting creativity and innovation not only in core vehicle functionality and operational safety, but also, as importantly, in novel business models and customer engagements that are shaping the future of personal mobility, public transit and commercial transportation.

Software-based functionality and low-cost off-the-shelf sensor electronic lower the barrier to entry, creating opportunities for new entrants that move the competitive battlefield to grounds unfamiliar to traditional automakers. In particular, artificial intelligence (AI), machine learning, signal processes and similar highly-specialized fields are at the forefront of technology development for advanced driver assistance systems (ADAS) and automated vehicles.

We are in the beginning of a radical mobility revolution that will continue for the foreseeable future. We are going at a breakneck speed on a road awash with uncertainties and unknowns. Winners are those that to recognize challenges and innovate and adapt quickly.

For new entrants, this is vast landscape of opportunities to leapfrog traditional automotive companies and establish a foothold in a traditionally highly impervious industry. Everything is up for grabs: technology innovation, disruptive customer-centered business models and even challenging the deeply-ingrained retail practices, the way [Tesla did it](#). Upstart companies are forcing traditional OEMs and suppliers to push the envelope and adopt innovation in areas where, in the past, they did not envisage and, at times, refused to consider. A good example is [Tesla's remote software updates](#). Despite popular belief, Tesla did not invent this technology, which has been widely used in the telecommunication industry. Auto OEMs rejected the idea because of concerns that remote updates will reduce dealership visits and hurt service revenues.

Dozens of new entrants are driving innovation and are challenging traditional OEMs and suppliers to keep up. According to [McKinsey](#), the majority of investment activity has targeted companies located in the United States, more than half of which are in the San Francisco Bay Area and not in Detroit.

This report also ranks Israel and Singapore third and fourth (after the US and China) in terms of the number of emerging mobility technology companies and disclosed investments. These countries are outperforming India, Germany, Japan and South Korea in terms of innovation momentum, a fact that is especially telling since these countries do not have traditional car manufacturing industry.

### Suppliers Are No Longer Just Suppliers

Rapidly emerging vehicular technologies are shaping the future of the automotive value chain. Once mostly indistinguishable in a pool of dozens of similar companies in the supply chain, new suppliers are in control of the hottest technologies. They are taking a central role in the automotive value chain and are restructuring to move up the value chain. They are changing the rules of the game to move up the value chain, causing disintermediation and disrupting the status quo.

One of the more profound changes is taking place in the semiconductor sector.

"We are evolving into a provider of services for road users. To come up with new concepts for mobility, we are also reviewing our conception of Bosch."

—Rolf Bulander, Chairman of Bosch Mobility Solutions

According to [Nasdaq](#), in 2017, the automotive sector represented only 9% of the overall semiconductor market, far behind the telecommunication and computer industries which, together, made up nearly 60% of the market. However, the report also noted that automotive is the fastest growing sector and was expected to grow 22% in 2017 followed by 16% growth in 2018.

New entrants are not just suppliers of core mobility technology. The top 5 investment areas according to the

report are: ride-sharing solutions, autonomous operation, user interface technologies, sensors and semiconductors, and cybersecurity.

### **New Automakers Rising**

Tesla is well-recognized as the auto company that managed to challenge and disrupt the hegemony of traditional automakers and is making rapid progress towards bringing autonomous vehicles to market. Tesla succeeded where others before it had failed and showed that traditional OEMs are not invincible, but other companies attempting to emulate Tesla in the US and other mature markets may not be as successful.

In emerging markets, especially in China, the number of OEMs is growing rapidly. Free of the legacy of the past 100 years, Chinese OEMs are laying the foundation for expansion by acquiring global brands and targeting autonomous and electric vehicle technologies. There are over 100 passenger car brands available in China from local automakers and joint ventures with global OEMs and suppliers. Although the ambitions of these manufacturers are mostly regional, they represent a real threat to global OEMs coveting the lucrative China market, which is growing by an average of 7% year over year and is expected to reach an annual sales volume of 25 million vehicles by 2020.

### **Complexity Outpacing Capabilities**

Automobiles have always been an assemblage of mechanical, electrical, hydraulic and pneumatic subsystems. These systems were unsophisticated, and their integration was sufficiently straightforward that they could be designed, prototyped and validated using commonly-used mechanical engineering methods.

Automotive design engineering began experiencing a major shift in the 1980s, as advanced vehicle electronics and embedded control software were introduced into cars to handle increasingly stringent emission regulations.

Modern vehicle control systems are no longer just a limited number of loosely-coupled subsystems with simple interfaces. Nowadays, embedded control and user interface software govern practically all aspects of both vehicle operation and driver experience. They are large-scale software-controlled concurrent and distributed systems with complex system interactions that are difficult to simulate and test thoroughly.

### **Computers on Wheels?**

Software is everywhere. The expression “a modern car is just a computer on wheels” may be a gross generalization and oversimplification that ignores the large number of mechanical parts and subsystems responsible for everything from suspension and steering to passive safety, but the general sentiment is important in itself.

Modern cars are loaded with advanced electronics and complex software systems that control active safety features, steering and braking systems and the car’s infotainment and communication equipment. As importantly, software-based systems and interfaces define the user experience of the drivers and other car occupants.

## Weighty Innovation

Vehicle electrification and connectivity are responsible for the richness and robustness of safety features, infotainment systems and overall driving and ride experience. They are also responsible for some side effects that perhaps weren't anticipated fully.

One of the more significant side effects is the increase in vehicle weight. An electric car is about 30% heavier (and 70% more expensive) than a compatible internal combustion vehicle. Although at some point in the future ADAS and automated driving will reduce the need for heavy passive safety features and the use of light materials and additive manufacturing methods will contribute to further weight reduction, today, EV manufacturers must seek to design tradeoffs between the innovation and the additional weight tax and its impact on vehicle travel range.

## Traditional Methods and Tools are Strained

As automakers focus on designing complex electronic systems and control software, it is becoming clear that legacy engineering systems and methods are no longer adequate. Design engineering and test environments continue to rely on decades-old product engineering and supply chain methods, processes and tools that, by and large, have not kept up sufficiently with new engineering disciplines and the growing complexity of systems development.

Disparate mechanical (mCAD) and electrical (eCAD) design tools and a myriad of software configuration tools built around open-source tools such as Bugzilla, Eclipse and Emacs, are no longer able to support the intricate dependencies across electrical, mechanical and software designs. Often propped up by spreadsheets, XML file interchanges and email communication, this fragmented engineering environment does not provide the level of transparency, traceability and quality management needed to manage changes and updates throughout the design lifecycle.

## Change is Inevitable

"We see more change in the next five years than there's been in the last 50."

—Dan Ammann, President of General Motors (and several others...)

The impact of the transformation the industry is undergoing is overwhelming, and the cumulative long-term effects of rapid technology innovation, disruptive business models and evolving supply chain ecosystems is probably not fully comprehended yet. Nothing in the traditional automotive business, which has remained relatively unchanged for many decades, is safe anymore. Everything is fair game, and OEMs are at a risk of no longer being the masters of their destiny.

The automotive industry has relied on internal innovation, manufacturing expertise and complex supply chains as barriers against outsiders. These may not always be sufficient going forward.

The imperative to mature and reskill is not limited to the engineering department. New vehicle technologies also impact on downstream activities such as dealership service technicians that must learn to troubleshoot software-based control systems; high voltage

systems in hybrid and plug-in electric vehicles are a particular challenge for both service technicians and first responders.

## Software and Electronics Development as a Strategic Capability

Developing software for the earlier generations of software-control modules, which started as early as the late 1980s, wasn't a very onerous task. OEMs and suppliers managed through the process with small teams using rudimentary software engineering environments supplemented by ad hoc use of multiple spreadsheets and lengthy email threads.

But software has grown in both volume and complexity and evolved from controlling electromechanical subsystem to becoming the key differentiator for the customer experience. By some measures, software is now the dominant component in vehicles and its importance continues to increase.

Developing reliable automotive software has become burdensome for OEMs, as is evident by the increasing number of software-related vehicle recalls. [J.D. Power's SafetyIQ](#) reported that the number of technical service bulletins (TSBs) pertaining to software issues increased from an average of 58 recall incidents per year between 2006 and 2010 to an average of 160 recalls per year from 2011 through 2015.

"80% of Product Innovation and Differentiation now electrical, electronics, and software."  
—Seigmar Hassis, Daimler R&D CIO

## Shortage of Talent

During the depths of the Great Recession of 2007-2009, American auto industry employment fell by nearly a quarter of a million positions. Today, the auto industry is in full recovery mode and unit sales are fast approaching pre-recession levels.

But the ability to sustain and accelerate this growth is being threatened by shortage of viable workforce and skills gaps in R&D, engineering and manufacturing. Talent recruiting and retention is a particular issue for companies that must branch out from their traditional core competencies and develop expertise in new technologies.

"The rise of the electric vehicle over the next 10 years will create demand for different kinds of engineering skill sets compared to the traditional skills seen within the automotive sector."  
—Les Hewlett, Director Automotive, Matchtech

Fierce competition, rush to market, one-upmanship culture and workforce shortage are most pronounced in electronic and software design to the point that [allegations and lawsuits](#) about talent poaching and IP infringements are becoming frequent in already talent-strapped areas such as Silicon Valley.

## A New Era of PLM

Automakers use product development methods that have been honed for decades. They have optimized supply chain operations and lean practices perhaps more than any other industry, and, over time, became accustomed to a certain cadence of product development, manufacturing and product introduction.

## The Integrated Electromechanical Design Imperative

The fragmented IT architecture and inflexibility of legacy product lifecycle management (PLM) systems make it hard to scale across the enterprise—hence the widespread use of spreadsheets and accompanying lengthy email threads and contentious meetings to connect disparate processes and plug information gaps.

Automakers must adopt a systems engineering orientation that unifies the lifecycle management of mechanical, electrical and software disciplines to allow design decisions, tradeoff analyses and engineering optimizations to flow seamlessly across domain boundaries.

The electrical, mechanical and software design processes should be connected, integrated and collaborative. Electrical and electronic design teams need to work seamlessly with their mechanical and software engineering counterparts from the start of the development process in order to accelerate design and integration testing, and identify conflicts early, when changes are easier and less costly to implement. For instance, cross-domain conflicts such as weight reduction, thermal management and EMI shielding should be identified and rectified during design and early validation, lest they become too difficult and costly to rectify.

An integrated approach requires tight integration—of both process flow and data exchange—between mCAD, eCAD and software development tools for an optimized workflow and to reduce wasteful and error-prone data duplication and manual data exchanges.

The integrated design environment and workflow will not only improve efficiency and reduce the negative impact of late discovery, but is also likely to promote cultural changes, encouraging design engineers to collaborate, employ organizational best practices, and, indeed, be more productive and innovative.

## The Digital Thread

Today, more than ever, product lifecycle management software fulfils a critical role as the main repository of product information that connects users to critical information and supports collaboration across all disciplines within the extended enterprise, from design to manufacturing and to in-service, using shared models within a single product development environment.

PLM is emerging, again, as the product innovation platform to model and manage all logical connections between requirements, design information, simulation results, test data and other product lifecycle artifacts. The product innovation platform provides through-life management of product configurations, designs and processes.

PLM orchestrates requirements, design and verification activities among the different engineering disciplines of automotive design and manufacturing. It allows stakeholders to navigate through and understand the relationships between design activities and representations from multiple disciplines. It encourages parallel development and synchronization between different design and testing activities that operate in different



cadences: electronics, printed circuit board and wiring harnesses, software and mechanical design.

A common PLM platform enables uniform access to authoring tools and exchanges information with enterprise systems, automates manual processes and provides migration and translation from legacy systems. With integrations for enterprise software systems such as PDM, ALM, CAD and ERP, this next generation platform connects all users into a single set of information and processes.

PLM, as an innovation platform, must remain open and able to integrate multiple objects, data types and processes in a way that curates rich multidisciplinary context and enables frontloading key decisions requires extending the semantic model of PLM software.

Still, while companies should show low tolerance for data silos and must work to establish processes that leverage a common platform, eradicating fragmentation completely is probably unattainable. In part because of the broad set of methods and tools used by the engineering team, and in part due to new value chain participants in product lifecycle management process and practices. Some, notions, such as the Internet of Things are truly newcomers, whereas others, for example service lifecycle management (SLM), are not necessarily new, but are finally claiming their rightful role in the product value chain and demand to be incorporated into early product lifecycle decisions.

## Prepare for the Future

The auto industry's century-old push to gain efficiencies, accelerate output, reduce waste and recoup working capital through lean techniques means it's always looking for better ways and new technologies that can fine-tune their already well-established supply chains. However, in the past, the strong bias towards inside innovation limited its options and slowed down responsiveness.

On the other hand, electronics manufacturers—the new kings of automotive supply chain—are accustomed to rapid innovation cycles and dealing with unexcepted market changes and demand fluctuations. They have long-standing close relationships with suppliers and make frequent use of outsourced contract manufacturers to meet demand variation and short lifecycles.

These companies are moving to the forefront of automotive innovation.

Automakers and Tier One suppliers are facing disruption and value chain disintermediation caused by these new entrants. As the suppliers of the platform and market channels OEMs still control the narrative and the cadence of innovation, but the barriers to entry continue to plummet as innovation's center of gravity is moving from complex, highly engineered mechanical systems and passive safety features to simpler yet powerful hardware controlled by sophisticated electronics and software.

"There has never been a more exciting time to be in automotive."

—Rebecca Fifelski, Executive Director, Global Engineering Operations, Visteon

## Manage Uncertainty

"Yes, there's a lot at stake. Yes, there is a lot of uncertainty. But this is not a time for the conservative or the cautious."

—Carlos Ghosn, chairman and CEO Renault, Nissan and Mitsubishi Motors

Growing and protecting market share will require automotive companies to anticipate market trends faster and to exploit new mobility business models more efficiently. They must be able to embrace disruption and be able to adopt new business and technology innovation to address rapidly changing consumer preferences across demographics and regions, especially in light of increasing urbanization.

## Leverage Partnerships and Ecosystems

The automotive industry's attention is evolving decisively from propulsion to mobility. This transition is not even and will take decades to take shape. While the outcome of this transformation isn't necessarily clear, successful mobility companies will leverage partnerships and open, scalable ecosystems across and beyond the industry boundaries we recognize today.

Although electronics and software are becoming the foundation for market differentiation and competitiveness, driving OEMs and suppliers to keep their cards very close to the vest and keep key technologies in house, they should consider developing select "vertical partnerships" with preferred suppliers, allowing them cut R&D costs while developing and implementing new features faster.

## Transform the Organization

As the entire automotive industry is undergoing transformational changes, product organizations must also transform and modernize century-old thinking to be better equipped to address the new challenges in product development.

Some methods and practices that have been for decades may not suffice anymore. And some of these have been in place for so long that organizations will find it difficult to wean from and evolve swiftly to tackle the challenges of 21<sup>st</sup> century automotive manufacturing.

Automakers need to invest in realizing integrated processes and tools environment that allow, and, in fact, encourage the mechanical, electrical and software domains to intelligently collaborate to ensure first-pass success, while reducing cost and time to market.

Automakers should focus on enhancing product lifecycle thinking, enabling a digital thread of information and decision-making processes that allow all stakeholder gain accurate and unbiased insight and drive better product design, supply chain and customer-facing decisions.

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