# Hype Cycle for Connected, Electric and Autonomous Vehicles, 2021

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Initiatives: Manufacturing Digital Transformation and Innovation

Connected, electric and autonomous vehicles are leading to a change in how consumers use and experience their vehicles, which is opening up new business model opportunities for automakers, suppliers and tech companies. This Hype Cycle addresses technologies that CIOs need to track for the future.

## Analysis

### What You Need to Know

The large number of technologies in the automotive industry that are in or near the Trough of Disillusionment is indicative of big changes ahead. Autonomous Vehicles are inching toward the Slope of Enlightenment, and we may soon see some breakthroughs. Other technologies, like 5G and Digital Personalization are getting a lot of hype, but haven't actually delivered much. And joining the cycle are many technologies that aim to change the cabin experience and use things like blockchain and artificial intelligence (AI) to offer unique experiences and connect with outside ecosystems.

### The Hype Cycle

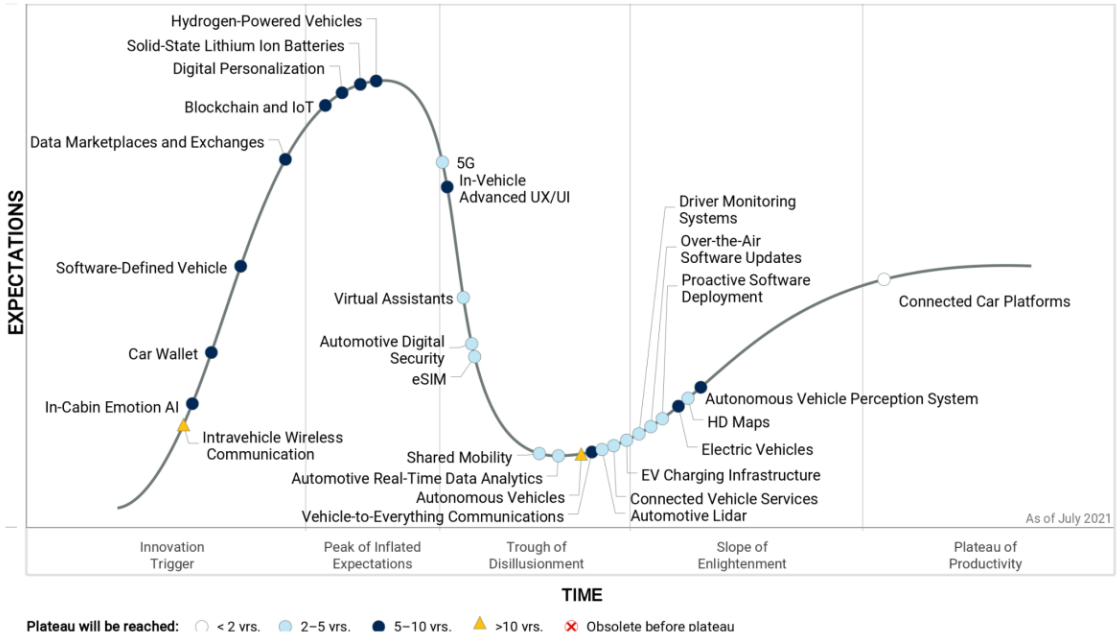
This Hype Cycle is dedicated to the primary technologies that are affecting the automobile, including connectivity, autonomy and electrification. This year, we have moved some business model profiles related to mobility to the Transportation Hype Cycle and have added a few new technologies that had previously been on the Automotive Technologies Hype Cycle. The result is a more robust Hype Cycle that tracks the important core technologies that will impact the automotive industry directly.

In 2021, a prevalent theme is the shift toward digitalization on a number of fronts. CEOs of several major automakers have stated that they see their future as being more related to selling digital services than just the original sale of the vehicle. Although not stated directly, these statements mean that software development and the ability to deliver over-the-air updates, along with real-time data analysis, will become increasingly important. These technologies, along with the connected car platforms that integrate all these capabilities, are all making progress toward maturity.

Electric vehicles and the charging infrastructure that supports them are equally important. Despite huge financial commitments, challenges remain for market adoption. These challenges are reflected in their slow progress out of the Trough.

One of the most hyped technologies on this Hype Cycle is Autonomous Vehicles, and progress is happening, even as consolidation continues. At the Peak of Inflated Expectations is 5G, a technology that may hold a lot of promise for vehicles, but likely will take years to have any real impact. The In-Vehicle Advanced User Experience and Interface (UX/UI) continues to drive hopes for an improved customer experience, with some technologies, from responsive voice interactions to augmented reality (AR) and easy-to-use gesture control, driving closer to what is available in consumer electronics.

Figure 1. Hype Cycle for Connected, Electric and Autonomous Vehicles, 2021




Source: Gartner (July 2021)

Downloadable graphic: Hype Cycle for Connected, Electric and Autonomous Vehicles, 2021

## The Priority Matrix

Virtual Assistants and Connected Car Platforms are coming close to mainstream in a short period of time. These technologies are key enablers of many of the technologies, as they tie together things performed in the cloud with the broad array of new capabilities that occur in the car.

Underpinning many, if not all the major changes in the industry, are Over-the-Air Software Updates. These abilities are progressing and should be maturing by mid decade.

Even technologies that may not have a transformational effect will change the experience in the car over the next few years, particularly Car Wallets and Driver Monitoring Systems.

Table 1: Priority Matrix for Connected, Electric and Autonomous Vehicles, 2021

(Enlarged table in Appendix)

| Benefit | Years to Mainstream Adoption | | | |
|---|---|---|---|---|
| | Less Than 2 Years | 2 - 5 Years | 5 - 10 Years | More Than 10 Years |
| Transformational | Connected Car Platforms | Automotive Digital Security<br>eSIM<br>Virtual Assistants | Autonomous Vehicle Perception System<br>Blockchain and IoT<br>Electric Vehicles<br>Software-Defined Vehicle<br>Vehicle-to-Everything Communications | Autonomous Vehicles |
| High | | 5G<br>Automotive Lidar<br>Automotive Real-Time Data Analytics<br>Connected Vehicle Services<br>HD Maps<br>Over-the-Air Software Updates<br>Proactive Software Deployment | Data Marketplaces and Exchanges<br>Digital Personalization<br>In-Cabin Emotion AI<br>In-Vehicle Advanced UX/UI<br>Solid-State Lithium Ion Batteries | |
| Moderate | | Driver Monitoring Systems<br>EV Charging Infrastructure<br>Shared Mobility | Car Wallet<br>Hydrogen-Powered Vehicles | Intravehicle Wireless Communication |
| Low | | | | |

Source: Gartner (July 2021)

## Off the Hype Cycle

This Hype Cycle has gone through significant changes, having added numerous technologies and dropped others because of the expansion of the Hype Cycle for Transportation and Smart Mobility, 2021 and the discontinuation of the Hype Cycle for Automotive Technologies, 2020.

Off the cycle: Flying Autonomous Vehicles; Micromobility; Mobility-as-a-Service

These technologies fit more into transportation than with automotive technology, as they include flying personal vehicles, scooters and general transportation platforms.

## On the Rise

### Intravehicle Wireless Communication

**Analysis By:** Pedro Pacheco, Michael Ramsey

**Benefit Rating:** Moderate

**Market Penetration:** Less than 1% of target audience

**Maturity:** Embryonic

#### Definition

Intravehicle wireless communication is the use of wireless technologies to exchange data and commands within a car. Specifically, this technology is intended to replace cabling to carry information. It is not related to Wi-Fi for passenger use; rather, it is for the vehicle to control components without wiring.

#### Why This Is Important

Intravehicle wireless networks can lower manufacturing costs by reducing wire harness complexity — something that attracts the attention of OEMs and other companies. In addition, wire harness reduction reduces vehicle weight, which improves driving range — a clear plus for electric vehicles. Moreover, the steep increase in technology embedded in the vehicle provides an additional incentive for wireless networks to prevent further increase in wire harness complexity.

#### Business Impact

The automotive sector experiences strong pressure to increase automation content in order to slash costs. The wire harness is one of the most complex parts of vehicle assembly, so the introduction of wireless connections would enable a direct cost reduction. Furthermore, reduction of in-vehicle cabling would also enable weight reduction, decreasing reliance on more expensive solutions such as lightweight materials.

#### Drivers

- The arrival and growth of new OEMs in the area of electric vehicles (EVs) has been a contributing element. These players face a strong pressure to increase the level of factory automation for cost reasons; hence, competitors are starting to react similarly. This focus on cost generates a need to simplify the vehicle wire harness. At the same time, this trend is slowly generating a drive to harmonize the vehicle communication network, something that is also supported by the move to a centralized high-performance compute vehicle architecture.
- The growth of EVs on the market generates a great need for weight reduction in order to maximize driving range — the main purchase obstacle for EVs. Therefore, technology enabling weight reduction is and will be even more valued going forward.
- Several tech vendors in the area of consumer electronics and smart homes have developed high-quality wireless technology for infotainment and are now trying to expand into the automotive sector.

### Obstacles

- There isn't currently any approved standard or protocol for intravehicle wireless communication, as no consortium has yet made significant progress in this area. This absence increases the adoption cost and inherent adoption risk, which makes OEMs question whether the upsides of this technology are outstripped by the downsides.
- While adopting a wireless network for entertainment applications may be relatively easy, going beyond that presents many more obstacles. However, investing in a intravehicle wireless network will only offer a good ROI once a substantial part of the wire harness can be replaced by wireless.
- Using wireless communication for more critical applications — such as safety and essential vehicle operations — still raises reliability concerns because of signal interference risk vehicles are exposed to. This, in turn, creates a problem of trust in the technology among OEMs and customers.

### User Recommendations

- **For OEMs:** Start incorporating this technology into your roadmaps and analyzing vendor proposals by beginning with infotainment applications and progressively moving into more critical areas. In the meantime, you must form alliances with other OEMs and tech vendors in order to arrive at a standardization of intravehicle wireless communication networks.

- **For tech vendors:** Propose the technology to OEMs (if you already have expertise in robust short-range wireless communication networks) by reassuring OEMs about the reliability of your solution in the realm of automotive applications. Present a quantifiable ROI that considers the advantages this solution brings in terms of vehicle design and manufacturing.

### In-Cabin Emotion AI

**Analysis By:** Pedro Pacheco

**Benefit Rating:** High

**Market Penetration:** Less than 1% of target audience

**Maturity:** Embryonic

#### Definition

This technology collects information on occupants' state of being through several different sensors, like AI computer vision, infrared camera, natural language processing, electroencephalogram (EEG) scan and heart rate measurement. The assessment of each occupant's state of being allows the vehicle to adapt different features and processes to improve onboard experience, improve driver alertness and even assess the occupant's health.

#### Why This Is Important

The increase in the number of cabin sensors to assess occupants' condition will open up new opportunities for emotion AI. For instance, the EU mandates that new car models starting from 2022 be equipped with a driver-monitoring system, which most often uses a camera to monitor the driver. This means OEMs need to invest only in software to add emotion AI capabilities. There is also a growing number of cars using AI voice assistants, which can incorporate emotion AI through speech recognition.

#### Business Impact

The concept of emotion AI, when fully applied, will enable OEMs to develop cars that are much better at delivering experiences to occupants' expectations. Moreover, emotion AI will be an enabler toward improving the vehicle's human-machine interface (HMI), allowing drivers to control more complex features. Finally, emotion AI can also improve people's safety, health and well-being. It will enable onboard sensors to detect driver drowsiness and to assess the health condition of occupants.

### Drivers

- Emotion AI has found good traction in areas of application like marketing and call centers. This has allowed the technology to further mature toward an automotive application.
- The number of cabin sensors for several other applications is increasing — as the EU's driver-monitoring-system regulation shows. This makes it less costly to implement emotion AI in a vehicle since the necessary sensors will already be there.
- Vehicles will display a growing technological complexity that offers a wealth of features and functionalities to occupants. Traditional HMIs — heavily based on large screens and touch — won't be sufficient to help users deal with all the complexity. This is where emotion AI can open up new opportunities by improving the communication between humans and machines.
- Emotion AI offers opportunities in improving driver attentiveness and in assessing occupant health condition — these are the main levers to drive adoption.

### Obstacles

- Consumers have growing concerns about privacy. As such, several may raise concerns when they are told that a machine is reading their emotions.
- Different individuals express emotions differently. This makes it harder for emotion AI to produce correct judgments every time.
- Despite strong interest from some OEMs, the technology still needs several years to achieve sufficient maturity toward market launch.

### User Recommendations

For OEMs:

- Invest in emotion AI now. A vehicle model life cycle lasts six years, which will be less than the time it takes for a commercially viable automotive application to be ready. Engage a technology vendor now to quickly move into a proof of concept.
- Develop a consumer-oriented value proposition for emotion AI, which can get around the issue of consumers thinking their cars are reading their minds.
- Emotion AI can bring many customer benefits. Carefully define all the use cases, and quantify their benefits. This will enable a stronger business case to justify the investment on the technology.

For tech providers or automotive suppliers:

- Take the regulatory framework for driver-monitoring systems as an opportunity to implement emotion AI and, through that, expand the capabilities of your solution.
- Incorporate emotion AI in voice assistants as a way to strengthen the value of this user interface.

### Sample Vendors

Affectiva; Amazon Web Services; audEERING; Eyeris

### Gartner Recommended Reading

AI Multisensory Tech in Automotive HMIs, Part 4: Emotion AI

Competitive Landscape: Emotion AI Technologies, Worldwide

## Car Wallet

**Analysis By:** Michael Ramsey

**Benefit Rating:** Moderate

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Emerging

### Definition

Car wallet is a generic term applied to the ability for a vehicle to make or accept payments. The wallet could have a single or multiple forms of payment and can make or receive payments from a wide variety of users, retailers or service providers. A car wallet could be connected to an individual or even have its own account when multiple drivers are using the vehicle, such as in a shared vehicle circumstance.

### Why This Is Important

An embedded payment system in a vehicle is a progression from existing payment technologies like toll pass devices and facilitates mobile payments for services, such as parking or tolls, or goods like food. The payment capability also makes it possible for the vehicle itself to be paid by users, keeping a digital account in the vehicle. Today, automakers have several avenues to enable making payments through the vehicle, but most are limited in capability and scope.

### Business Impact

Enabling vehicles to pay and be paid is a convenience and safety feature primarily, but it also could lay the groundwork for autonomous vehicles that act like independent entities. While it would not dramatically change the industry, it could be a very useful feature for car owners and users as well as service providers and provide differentiation for automakers. A vehicle with its own account and card could keep a balance and make a payment independent of the user of the vehicle at that moment.

### Drivers

- A single common standard for connecting to vehicles for the purpose of payment would have an enormous impact.
- Any large effort by a government to mandate or influence widespread use of this technology, for instance to collect tolls, pay monthly vehicle-mile-traveled fees or registration, could create a breakthrough effect for this technology that would expand its usage significantly.
- The growth of electric vehicle sales, which will necessitate a move to a vehicle-miles-travel taxation system rather than gas taxes, could expand the viability of car wallets.
- Additionally, the expansion of Google's and Amazon's footprint in vehicle multimedia systems also could significantly increase vehicle payment capability because of those companies' significant ecosystems, though it may not impact the ability to make payments to a vehicle.

### Obstacles

- Tolling systems are designed for a specific purpose and work well, but to expand a payment system to many more users, such as retailers and parking lots, will require a simple API that is flexible.
- Creating a digital wallet for the vehicle has the problem that if there are no vendors that accept this type of payment and it requires a lot of integration to make it work, then there is little incentive for the car companies to put it in the vehicle.
- If it isn't installed in millions of vehicles, then the retailers won't make the effort to connect their systems to it. This is why the best avenue to growth may be through the large tech platforms or through a government mandate, such as a VMT effort.
- The dominance of the existing large credit card/payment providers that already have brand awareness and market presence which may be threatened by the advent of an alternative payment solution.
- Fragmentation in different markets could also limit the appeal and spread of the payment technology.

### User Recommendations

- Explore the different vendors for car payment and determine which has the easiest path to integration with existing point-of-sale systems for retailers.
- Determine whether it makes sense to partner with large tech providers to provide ecosystem access to expand the number of retailers and service providers that already have connections.
- Ensure that the vehicle has the ability to store payment capability, including the necessary security measures.
- Consider working with the existing large credit providers such as Visa and Mastercard to enable closer integration between their technology and the vehicle's technology while leveraging their brand and market presence.

### Sample Vendors

ZF (Car eWallet); Xevo (Market)

### Gartner Recommended Reading

‘Right to Repair’ Initiative Could Have Significant Impacts on the Connected Car Ecosystem

The Future of Data-Driven Transportation Ecosystems

Guide to the Impact of 5G on Connected Vehicles

How to Become the Digital Automaker of the Future

Infographic: Artificial Intelligence Use Case Prism for Automotive Enterprises

## Software-Defined Vehicle

**Analysis By:** Jonathan Davenport

**Benefit Rating:** Transformational

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Emerging

### Definition

Software-defined vehicle functions can be updated, fixed or improved by adding new code. The ability to update code throughout the vehicle decouples hardware and software development life cycles. Service-orientated software is run on three to five high-performance computers with a high-speed communication backbone linking sensors and actuators controlled by domain electronic control units (ECUs). This represents a fundamental shift in vehicle electrical/electronic (E/E) architecture.

### Why This Is Important

Traditional automakers are facing two challenges: delivering profitable connected-vehicle services and responding to the new market entrants who continue to gain ground, both in terms of market share and the levels of technical innovation. In response, automakers are changing their vehicle’s E/E architecture to enable software to be used to deliver new or improved functionality over a vehicle’s life cycle. Revenue will be sought from content sales and features sold on a subscription basis.

### Business Impact

Automakers are focusing on in-house software expertise. For example:

- Volkswagen Group created a software business in 2020 branded CARIAD. It plans to grow its team to 10,000 digital experts to support its ambition to boost the in-house share of car software development from less than 10% in 2019 to at least 60% by 2025.
- Toyota announced the creation of its Woven Planet Group to enable the company to focus on a more agile “software first” development process and software-defined architecture.

### Drivers

- Automakers are moving from specifying software to developing it in-house, disintermediating the IT services and software development companies involved in developing traditional ECUs.
- Service-oriented applications are being developed that allow automakers to standardize software solutions across different vehicle models and brands.
- New electrical and electronic architecture will be needed as the number of ECUs used within a vehicle is dramatically reduced and replaced by high-performance computers and domain controllers.

### Obstacles

- Automotive corporate culture is a major roadblock to digital transformation. Change is hard, because the innovation process is typically a top-down, waterfall approach aimed at incremental improvements.
- Engaging the best talent — especially in the software sector — is a difficult task for legacy car companies, due to limited reward and organizational strategy.
- Automotive executives can see the changes in the market, but are trapped inside the restrictions of their current business and operating models, hence making it hard to adapt to market disruptions.
- Automakers still put more priority on product engineering than software development.

### User Recommendations

Automakers must:

- Build up first-class in-house software expertise by offering talent a remuneration package that matches (or exceeds) those offered by digital giants.
- Embrace agile continuous software deployment by engendering a culture of empowered innovation, making a firm break from traditional waterfall deployment methodologies.
- Outperform the competition by showcasing a customer-first mindset that is prepared to disrupt traditional business models in order to offer excellent in-vehicle experiences/services.
- Specify vehicle hardware with enough performance to enable future application use cases.

Technology service providers should:

- Create strong software-focused partnerships by educating automakers on how to transition from a waterfall development approach to an agile way of working.
- Maximize the value of hardware portfolios by pivoting toward the development of low-cost, reliable sensors and chips, optimized for automotive applications, and divesting noncore assets.

### Sample Vendors

Amazon, Aptiv, BlackBerry, Continental, Daimler Group, Elektrobit, EPAM, NVIDIA, Tesla, Toyota, Volkswagen

### Gartner Recommended Reading

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Market Trends: Software-Defined Vehicles Will Disrupt the Automotive Supply Chain

How to Become the Digital Automaker of the Future

How Technology Providers Can Thrive Against the 'Threat' of the Digital Automaker

Tech Providers 2025: Product Leaders Must Strategize to Win in the Evolving Robotaxi Ecosystem

Market Trends: Monetizing Connected and Autonomous Vehicle Data

### Data Marketplaces and Exchanges

**Analysis By:** Eric Hunter, Jim Hare, Lydia Clougherty Jones

**Benefit Rating:** High

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Emerging

#### Definition

Data marketplaces and exchanges are ecosystems centered around data assets that provide infrastructure, transactional capabilities and services for participants. Marketplaces support data monetization via one-time or recurring subscription transactions while exchanges prioritize sharing of assets over monetization objectives. Both can incorporate public or private-sector participants and commercial or no-cost assets, such as open data.

#### Why This Is Important

Public cloud adoption has largely minimized data gravity as the primary barrier to data marketplaces and exchanges as the balance of data has shifted to CSPs in many organizations. Adoption of data marketplaces and exchanges remain in the early phases, but providers are bringing together stakeholders with mutual interests. Participants are attracted to diverse third-party asset selection, simplified data access/integration, simplified procurement, and reduced operating and transaction costs.

### Business Impact

- Increase the prevalence of third-party data assets for data science models, data enrichment and line of business operational demands (marketing campaigns, etc.).
- Reduce the complexity, time and cost demands for sourcing third-party data assets.
- Increase data monetization opportunities and market reach via marketplaces.
- Data exchanges reduce the barrier to entry for nonmonetized data sharing.
- Expand the visibility, findability, variety and availability of data products.

### Drivers

Marketplaces and exchanges remove barriers to the acquisition of third-party data in support of increasingly data-driven business outcomes and underlying models. They also reduce the exclusivity of specific types of data products through increased competition that will reduce price points for similar data products over the long term. Marketplaces and exchanges continue to increase in adoption through the following drivers:

- Digital business transformation has positioned data products as a key enabler of emerging business outcomes — increasing the demand for third party data, the growing role of business ecosystems, and the growing awareness and need for companies about partnering
- There is increased awareness across both public and private sectors in terms of the value associated with both internal and external data assets and products.
- COVID-19 has driven change across the behavior of many customers, resulting in model accuracy drift for data science models that rely heavily upon first-party customer data for key model features. Third-party data acquired from marketplaces and exchanges has become more attractive as an enabler for remediating these model accuracy issues and in the creation of new model features.
- There is increased adoption of public cloud which has reduced on-premises data gravity limitations that slow the physical movement and integration of data across parties.
- The number of public and private data providers for data marketplaces and exchanges continues to increase — providing both an increased level of specialization and breadth in terms of available third-party data product offerings.

- There is rising awareness of internal and external data sharing benefits through increased virtual work environments, COVID-19-centric use cases and increased enterprise reliance on public cloud.

**Obstacles**

- Data privacy legislation and risks of sharing data impede the pursuit of monetizing and productizing specific types of data, which reduces participation within data marketplaces and exchanges.
- It is a challenge to have mutually acceptable standards for governance of data-sharing scenarios without a balance of common cause and enlightened self-interest.
- Evolving organizational data ethics and sharing standards can prevent the adoption of third party data and/or creation of third-party data products that drive data marketplaces and exchanges.
- Enterprise procurement processes and public cloud account structures provide friction for lines of business user spend within public cloud data marketplace and ecosystems.
- Absent the specialized capabilities for evaluating relevant data products for a given use case, the volume of available marketplace and exchange data product offerings and lacking metadata can overwhelm buyers evaluating the ability of specific data products for new model features.

### User Recommendations

- Promote organizational participation in your marketplace of choice to accelerate the time to business value over the use of independent data asset providers or consumers.
- When seeking to monetize data products, look to marketplaces for the transactional infrastructure to allow internal efforts to focus on building unique and differentiated data products.
- Leverage providers that operate within or are optimized for your cloud providers of choice to reduce data movement complexity and improve integration consistency.
- Evaluate prospective data providers beyond their data product selection and coverage. Examples are integration/access (such as APIs), value-added capabilities and exception alerting.
- Adapt data management policies and standards to account for the realities presented by data marketplaces and exchanges.
- Explore the value of third-party data to increase analytic insights by either adding context as new attributes or through additional data science model features.

### Gartner Recommended Reading

Smart Data Sharing Requires Mapping Use Cases to Architectures and Vendor Solutions

How to Monetize Data Assets With Your Data and Analytics Service Provider

Flip 'Don't Share Data' Mantras — Introducing Gartner's 'Must Share Data Unless' Data Sharing Model

Data Sharing Is a Business Necessity to Accelerate Digital Business

Top Trends in Data and Analytics for 2021: From Big to Small and Wide Data

## At the Peak

### Blockchain and IoT

**Analysis By:** Nick Jones, Avivah Litan, Benoit Lheureux

**Benefit Rating:** Transformational

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

#### Definition

Blockchain and the Internet of Things (IoT) describes blockchain technology used in conjunction with IoT devices or IoT-enabled solutions.

#### Why This Is Important

Blockchain and the IoT can be combined in many ways for purposes such as machine payment, identity management, tokenization of IoT-related assets or services, identity validation, provenance tracking, sensor data authentication, utilization recording or billing, and secure firmware updates. This technology will enable enterprises to create new digital business offerings and ecosystems, and to manage requirements (e.g., proving provenance or compliance) in new ways.

#### Business Impact

Blockchain can provide a decentralized mechanism to secure the results of critical IoT data from hardware, software and systems operations through consensus. Combined with IoT data and processes, blockchain provides an immutable data audit trail. It also supports process automation in situations in which IoT devices create or consume value in a peer-to-peer context — e.g., by making payments, providing services or generating assets, such as solar power.

#### Drivers

Many blockchain platforms and IoT technology vendors have demonstrated integration between IoT and blockchain. In cases where there's a need to do so, it has proved to be feasible. Situations in which IoT and blockchain can be usefully combined include:

- IoT is performing critical functions — tampering with the system or the data it creates and uses could have major financial or safety implications.

- IoT devices need to make or take payments using a cryptocurrency.
- IoT is participating in advanced business models involving distributed applications (aka dapps) and smart contracts.
- IoT devices need to share immutable information with an ecosystem of business partners and other machines — for example, for product provenance and tracking, or supply chain applications.
- IoT needs to provide an immutable audit trail logging its actions, system updates etc.
- The IoT device needs strong proof of identity of itself and of other IoT devices with which it communicates.

**Obstacles**

Challenges include:

- Blockchain and IoT integration is still immature, facing challenges in areas such as scalability.
- Many IoT devices are computationally simple, with limited networking bandwidth. Hence, they are unable to act as primary nodes storing a copy of a blockchain, and as a result, they need to rely on proxies or gateways, which introduce risk and complexity.
- Blockchain is technological overkill when what's required is just immutable data storage without shared ecosystems, business rules or tokenization. In such cases, consider immutable databases or ledgers (e.g., Datomic or Amazon QLDB), or a centralized blockchain ledger.
- Many public blockchain systems evolve with regular forks and updates. This can pose challenges if it implies updates to large numbers of resource-constrained, long-lived IoT devices.
- Most IoT applications and data aren't critical enough to warrant the use of blockchain. Simpler alternatives include encrypted data and signed firmware updates.

**User Recommendations**

CIOs, enterprise architecture and technology innovation leaders should:

- Look for situations in which IoT and blockchain enable new business capabilities and solve real-world problems, and where the technology's immaturity and rate of change aren't impediments.
- Ensure that there are no adequate alternative solutions that are technically simpler, because combining blockchain and IoT is potentially complex. Focus on simple applications such as ensuring provenance, proving identity and securing system updates.
- As is the case with most blockchain applications, private blockchains with known ecosystem members are likely to pose fewer technical and governance challenges.
- Beware of applications involving long-lived IoT devices and data, which will require the ability to periodically deploy blockchain technology updates at scale.

### Sample Vendors

Chronicled; IBM; IOTA Foundation (Tangle); modum.io

### Gartner Recommended Reading

Truth and Transparency in Supply Chain: 3 Case Studies on How Blockchain, AI and IoT Are Shedding Light

Top 10 Strategic Technology Trends for 2020: Practical Blockchain

Integrating Blockchain With IoT Strengthens Trust in Multiparty Processes

Survey Analysis: IoT Adopters Embrace Blockchain

## Digital Personalization

**Analysis By:** Jonathan Davenport

**Benefit Rating:** High

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

### Definition

Connected car technology enables drivers to benefit from personalized experiences. Cloud-based customer profiles will help mobility and transportation companies provide a consistent customer experience across their fleets — an important differentiator supporting long-term customer retention. Personalization will occur inside/outside the vehicle, seamlessly across vehicles and devices, with contextual support and advice (anticipating problems), and with social and functional applications.

### Why This Is Important

Digital personalization moves the industry away from vehicle customization (using preexisting specifications selected at point of purchase) to offering personalized in-vehicle experiences (by fine tuning vehicle functions to match the tastes of specific users). It also moves from connected cars, which allow automakers to understand how the vehicle is being used, to enabling companies to actually gather data about the specific people that are using the vehicle.

### Business Impact

- Automakers will shift their business model to source an increasing proportion of revenue from digital services, built on highly standardized and modular vehicle platforms.
- The automotive industry will maximize customer lifetime value by shifting from a product-centric to a solution-centric mindset.
- Digital services will be an important competitive differentiator and will support long-term customer retention.

### Drivers

- Automakers want to source more digital sales revenue. In the 2021 Gartner CIO Survey, 48% of automotive CIOs expected to deliver 20% or more of their revenue from digital sources by 2022. This is double the percentage of respondents who estimated digital sales revenue as 20% or more of total revenue in 2018. When combined with software-defined vehicles, vehicle functionality will be controlled by identifying the driver and using the cloud-based customer profile to lock or unlock certain vehicle features.
- The volume of connected vehicles is increasing. By the end of 2021, Gartner forecasts there will be 295 million connected vehicles, providing access to a rich set of customer data to gather insights about preferences and, importantly, behavior.
- Cloud-based customer profile technology, underpinning personalized services, is already being adopted. For example, using the BMW ID, individual preferences can be set in any current BMW vehicle quickly and automatically. Likewise, VW and Tesla are also investing in driver profiles.
- Customers want and expect quality, effortless personalized experiences, but shared vehicle platforms and self-driving systems will mean that vehicle performance will no longer be a differentiating factor between automotive OEMs. Therefore, digital personalization will be increasingly important for automaker differentiation.
- Quality in-vehicle experiences will allow automotive companies to differentiate in-vehicle services from those drivers can source from their phones, which has been a challenge to date, with drivers often electing to use smartphone mirroring services like Android Auto.
- Mobility service use cases, such as car sharing, are enabled by digital personalization. For example, when the vehicle is being used by others, different profiles can be assigned to digital keys to enable functions like limiting speed and blocking access to the glovebox.

### Obstacles

- Using cloud-based customer profiles to deliver digital personalization is a nascent concept in the automotive industry today and requires cross-business collaboration to successfully deploy solutions.
- Companies are cautious about how they store and use personal data so that they comply with local regulatory requirements as a result of regulations such as the EU's General Data Protection Regulation (GDPR).

### User Recommendations

- Provide customers with personalized services that deliver value. This value will be exchanged for personal information necessary for service delivery.
- Secure top-level executive sponsorship to devise a clear roadmap for digital personalization implementations, with a clear digital personalization framework and governance.
- Design cloud-based customer profiles that are automatically created and easy for customers to maintain and transfer from vehicle to vehicle.
- Invest in data analytics to draw insights about customer behavior. These insights need to be turned into personalized services.
- Assess where to partner for delivery of personalization systems and where building strong in-house competencies in delivering highly personalized services will be important.
- Address customers' security concerns by ensuring that solutions are in place to protect their personal data. Embed privacy protections in the customer experience to increase trustworthiness and, potentially, digital revenue.

### Sample Vendors

BMW, Eyeware, ForgeRock, Google, Tesla, Volkswagen

### Gartner Recommended Reading

Market Insight: IoT-Based Digital Personalization, Part 1 — Improve Customer Retention

Market Insight: IoT-Based Digital Personalization, Part 2 — Architecture for Automotive Customer Retention

Market Trends: Software-Defined Vehicles Will Disrupt the Automotive Supply Chain

How Total Experience Can Be Applied to Fix Troubled Connected Car Apps

Predicts 2021: Balance Privacy Opportunity and Risk

## Solid-State Lithium Ion Batteries

**Analysis By:** Pedro Pacheco

**Benefit Rating:** High

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Adolescent

### Definition

Solid-state lithium ion (Li-Ion) batteries replace the traditional organic solvent electrolyte with a solid one. Moving to a solid-state electrolyte has several advantages, including increased power density, removing unneeded components, such as separators, and removing safety risks in the conventional battery design. This promises to enable greater driving range and shorter charging time for electric vehicles (EVs).

### Why This Is Important

Moving to a Li-Ion battery with a solid-state electrolyte provides a potential two- to three-times increase in power density, also mitigating the fire and explosive hazards seen in traditional Li-Ion cells — something critical to occupant and public safety. Some companies have claimed a reduction in charge times of 10 to 15 minutes per full charge (from 60 minutes today). These are a major step forward for EVs, heavily mitigating the main consumer purchase objections: range and charging time.

### Business Impact

Several governments — like China and the EU — have put in place aggressive policy to incentivize widespread adoption of zero-emission vehicles, hence making this the top priority for automakers. Solid-state technology will allow OEMs to accelerate EV adoption by addressing consumers' main objections to purchase. As such, this technology is a key enabler to OEMs' compliance in lowering the average $CO_2$ emissions of the vehicles they sell.

**Drivers**

- Regulatory pressure is the main driver. The EU mandates stringent average $CO_2$ targets for the sales of each OEM under the penalty of heavy fines. This is added to generous incentive schemes in several EU countries. China actually preceded the EU in the adoption of sales targets for what they call “new energy vehicles” (pure EVs, plug-in hybrids and fuel cell) as well as incentives to the purchase of these vehicles. Moreover, the new Biden Administration has shown to be clearly pro-EV, and it is expected the U.S. government will soon offer a similar level of regulatory support to EVs. This regulatory pressure is pushing OEMs to put better EVs on the market from a customer standpoint, allowing for a greater driving range and a shorter charging time. This is exactly what solid-state batteries aim to achieve.
- Most of the main OEMs are already investing in solid-state technology, either by developing it in-house — like Toyota — or by investing in startups — like Volkswagen with QuantumScape or General Motors’ investment in SES. Even if OEMs’ investment into solid-state technology is still a fraction of their total EV program budget, the successive announcements of new investments and partnerships generate market frenzy that stimulates further awareness and investment.
- Solid-state technology is known to be intrinsically safer than liquid electrolyte by minimizing the risk of thermal runaway that can lead to fire and even explosion. This will help reduce the inherent liability of OEMs in this kind of occurrence, as well as enabling EVs to raise their credibility among consumers and public opinion.

### Obstacles

- Several companies have promised market launch of this technology in EVs by 2023-2025. However, it remains to be seen whether solid-state batteries can overcome their life span limitations while, at the same time, offering the promised advantages in driving range and charging time.
- Even after market launch, solid-state batteries will command a price premium that will limit them to more premium vehicle segments which are associated with lower volumes. This is something that will be addressed as volumes progressively increase.
- Li-Ion batteries with liquid electrolyte still have some margin for improvement in terms of chemistry and cell configuration. OEMs are starting to launch vehicles with a driving range above 600 to 700 km (373 to 435 miles), which prove already adequate to the needs of most drivers. This factor may delay the market introduction of solid-state batteries as some leading OEMs still see considerable potential in liquid electrolyte configurations.

### User Recommendations

- Ramp up investment in solid state, either by developing the technology internally or partnering with another company. However, for the latter, it's important you have access to proofs of concept that can give you concrete evidence of the solution's strength.
- Continue to invest in liquid technologies which are essential to continue to support EV adoption due to their lower cost than solid state. These still have a considerable roadmap for future development.
- Exercise care in accelerating time to market of solid-state technology — be particularly realistic in terms of production scale-up time. Claiming first-mover advantage is appetizing from a prestige standpoint and as a display for investors. However, make sure the solid-state technology you deploy delivers tangible benefits to customers with limited downsides, also allowing high production volumes competitively.

### Sample Vendors

Toyota; Panasonic; CATL; QuantumScape; SES; Ionic Materials; Sion Power; Bolloré Group; ProLogium Technology; Hydro-Québec

### Gartner Recommended Reading

Emerging Technologies: Venture Capital Growth Insights for Power and Energy Components and Electronics, 2020

Guide to New Business Models in the Electric Vehicle Ecosystem

Cool Vendors in Technology Innovation Through Power and Energy Electronics

## Hydrogen-Powered Vehicles

**Analysis By:** Pedro Pacheco

**Benefit Rating:** Moderate

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

### Definition

Vehicles that use hydrogen as fuel can be powered by internal combustion engines running on hydrogen or fuel cells. A fuel cell is a device that converts chemical potential energy into electrical energy. Fuel cells require hydrogen combined with oxygen (air) and produce water, heat and electricity.

### Why This Is Important

The Paris Agreement will have a dramatic impact in the roll out of zero-carbon vehicles in terms of specific regulatory pressure. Battery electric vehicles (BEVs) still present limitations in terms of charging speed and, in some cases, driving range. These weaknesses give an opportunity to hydrogen vehicles, as refueling takes less than five minutes and their driving range can easily go beyond 600 km (373 miles). In addition, fuel cell vehicles could actually clean the air as they drive.

### Business Impact

The business impact of hydrogen hinges heavily on public incentives and the pace of BEV technology. Hydrogen still has a chance if incentives can enable a price-competitive green hydrogen distribution network before BEVs can address their weaknesses. However, this is a narrow window of opportunity, given there are many more OEMs investing in BEVs than hydrogen. Fuel cell's ability to clean the ambient air could be an opportunity if it's acknowledged from a regulatory standpoint.

### Drivers

- Both the EU and China have put together regulation and incentives promoting hydrogen vehicles, even if those incentives are on par with BEVs. In addition, the EU is also financially supporting the production of green hydrogen — something that will accelerate the creation of a hydrogen distribution network.
- Hydrogen is seen by some governments as a cornerstone of their overall energy strategy. For instance, the EU predicts hydrogen's part of the energy mix will grow from 2% to 13%-14% by 2050. It describes hydrogen as "a technology which can bridge the gap between electricity production from renewable energy and the goal of decarbonizing a large share of the EU's energy consumption by 2050." Looking at the energy ecosystem holistically, hydrogen can be used for renewable energy storage (without the negative environmental impact of batteries), heating and energy to power land, sea and air transportation, as well as industrial processes. Under this holistic perspective, it makes sense that hydrogen is also used to power road vehicles.
- Several OEMs like BMW, General Motors, Honda, Hyundai and Toyota have been very active in promoting hydrogen. This generates interest from other parts of the mobility ecosystem to invest in the technology.

### Obstacles

- Production and distribution of green hydrogen is far from cost-effective.
- Fuel cell vehicles present much lower well-to-wheel efficiency (from fuel production to vehicle use) than BEVs (30%-40% against 80%-90%).
- Incentives and regulation are key to jump-start hydrogen technology — both for vehicles and its supply chain. Their absence makes hydrogen's business case very weak.
- BEV technology is evolving at a very fast pace due to the high number of companies committed to it. For instance, a Mercedes EQS already offers a WLTP driving range of 770 km (478 miles) — more than any production hydrogen car. The rise in charging power and new battery tech, such as solid state, will bring charge time below 15 minutes. Even if a hydrogen car refuels in less than five minutes, in about five years hydrogen will have little edge over BEVs in long-distance driving.
- It is hard for fuel cell's cost reduction roadmap to be more aggressive than BEV's as there are many more companies investing on the latter.

### User Recommendations

- Develop a whole business model rather than just cars or just infrastructure in isolation. Just as Tesla did by setting up their own charging network, gigafactories, and dealer network and online sales, proponents of hydrogen technology must tackle all the hurdles that make the usage of hydrogen vehicles expensive, inconvenient and inefficient. In many cases, this will mean establishing partnerships with a broad number of companies in order to produce a strong impact on the whole energy and transportation ecosystem.
- Focus on the development of hydrogen powertrains mostly for larger vehicles and long-distance applications, given that BEV technology is already quite advanced in terms of short- to mid-distance driving.
- Influence regulations to make sure these recognize and benefit fuel cells' ability to purify the air while in operation.

### Sample Vendors

Ballard; General Motors; Honda; Hyundai; Toyota

### Gartner Recommended Reading

Technology Innovation and Global Regulations Drive New Interest in Alternative Fuel Trucks

## Sliding into the Trough

### 5G

**Analysis By:** Sylvain Fabre

**Benefit Rating:** High

**Market Penetration:** 20% to 50% of target audience

**Maturity:** Early mainstream

#### Definition

5G is the next-generation cellular standard by the 3rd Generation Partnership Project (3GPP). The standard targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps respectively. Latency is as low as 4 milliseconds in a mobile scenario and can be as low as 1 millisecond in ultra-reliable low-latency communication scenarios, and massive scalability. New system architecture includes core slicing as well as wireless edge.

#### Why This Is Important

5G is key for industry digital transformation, with 162 operators rollouts (Source: GSA, April 2021), 20% of mobile networks (up from 9% one year ago). 3GPP 5G standards releases deliver incremental functionality:

- R15: Extreme mobile broadband
- R16: Industrial IoT (massive IoT, slicing and security
- R17: MIMO enhancement of MIMO, Sidelink, DSS, IIoT/URLLC, bands up to 71GHz, nonterrestrial networks and RedCap
- R18: Under definition

#### Business Impact

- Material impact on multiple industries and use cases by enabling digital transformation.

- 5G enables three main technology deployment and business scenarios, which each support distinct new services, and possibly new business models (such as latency as a service), namely enhanced mobile broadband (eMBB) supports high-definition video, mMTC supports large sensor and IoT deployments, and URLLC covers high-availability and very low-latency use cases, such as remote vehicle/drone operations.

**Drivers**

- Increasing device penetration: Gartner estimates that 5G-capable handset penetration will reach 87% in 2023 in Western Europe, similar to North America.
- Operational cost savings for industry use cases.
- Agility — in particular, in oil and gas and manufacturing.
- Requirements from industrial users value 5G lower latency from ultra-reliable and low-latency communications (URLLC) and expect 5G to outperform rivals in this area.
- Demand for massive machine-type communications (mMTC), to support scenarios of very dense deployments up to 5G target of 1 million connected sensors per square kilometer.
- Increased availability of industry-specific spectrum options (e.g., CBRS).
- mMTC addresses the massive scale requirements of IoT.

**Obstacles**

- Availability of spectrum, in particular for industrial private networks, in some countries.
- Security concerns over certain vendors, and when using 5G in critical industrial scenarios.
- Readiness of R16 solutions; availability and pricing of networks and modules.
- Use of higher frequencies and massive capacity requires very dense deployments with higher frequency reuse.
- Uncertainty about use cases and business models that may drive 5G for many CSPs, enterprises, and technology and service providers (TSPs).

- Different dynamics by regions: where in many parts of Africa for example, 5G would not be the next step up from lower bandwidth services, and handset cost may be an inhibitor for lower-income subscribers. Adoption is more aggressive in APAC and NAR, with Europe cautiously enthusiastic — and the developing world lagging.
- Feedback from some industrial clients mentioned that the majority of their use cases could be serviced by a 4G private network, and/or NB-IoT and other LPWA such as LoRa.

### User Recommendations

- Enable a diverse network that can offer adequate and cost-effective alternatives to 5G for many use cases (e.g., LPWA, NB-IoT, LoRa, Wi-SUN).
- Enable 5G for temporary enterprise connectivity, mobile and FWA secondary/tertiary use cases for branch location redundancy, as long as 5G is not the primary link for high-volume or mission-critical sites, unless there are no other options.
- Provide clear SLAs for network performance by testing installation quality for sufficient and consistent signal strength, signal-to-noise ratio, video experience, throughput and coverage for branch locations.
- Ensure backward compatibility to 4G devices and networks, so 5G devices can fallback to 4G infrastructure.
- Focus on architecture readiness — such as SDN, NFV, CSP edge computing and distributed cloud architectures, and end-to-end security — in preparation for 5G.
- Build their ecosystem of partners to target industry verticals more effectively with 5G.

### Sample Vendors

Cisco; Ericsson; Huawei; Mavenir; Nokia; Qualcomm; Samsung; ZTE

### Gartner Recommended Reading

U.S. Telco 5G Plans Take Shape

Emerging Technologies: 5G Technology Spending, 2020 Survey Trends

5G as a Service: Deployment Scenarios of Private Networks in the 5G Era

Market Guide for 5G Network Ecosystem Platform Providers

Creating Your Enterprise 4G and 5G Private Mobile Network Procurement Strategy and RFQ

### In-Vehicle Advanced UX/UI

**Analysis By:** Pedro Pacheco

**Benefit Rating:** High

**Market Penetration:** 20% to 50% of target audience

**Maturity:** Early mainstream

#### Definition

In-vehicle advanced user experience (UX) and user interface (UI) technologies are used to enable interaction between the vehicle and its occupants. Widespread vehicle connectivity use is triggering a growing number of functions and features at the disposal of occupants. This requires more advanced technologies like augmented reality, mixed reality, AI voice assistants and gesture control that enable more efficient and safer exchange of large amounts of information between human and machine.

#### Why This Is Important

A study from the American Automobile Association (AAA) Foundation for Traffic Safety found that when drivers use touchscreen and voice activation technologies, they are visually and mentally distracted for more than 40 seconds, which creates a major risk of accident. Considering the rising number of digital functions on board, this means cars require more advanced UX/UI technologies that enable safer driver operation.

#### Business Impact

- The business impact of advanced UX/UI tech is high because it is needed to achieve a successful implementation of connected and autonomous vehicle functions.
- These solutions turn the car into a place where users conduct several activities, like shopping, payments, work and content consumption.
- Automotive and technology companies can explore new opportunities for monetization by selling new functionalities, content and, even more importantly, enabling new business models.

### Drivers

- Fast growth in the number of connected cars is increasing the number of features and functions that need to be controlled by the driver. However, today's most common vehicle HMIs focus a lot on large displays and touch as a way to exchange information. This can often be distracting and lead to safety issues. As such, this safety gap calls for a more advanced UI that addresses this issue.
- Besides the driver, occupants will also have a growing number of functions and features to control. Similarly, this justifies a more-advanced UI to avoid poor user experience.
- OEMs must also prepare for new UX/UI use cases enabled by autonomous vehicles, where sometimes drivers will have opportunities for entertainment, leisure or work while en route. This further heightens the development of a more-advanced UI that can suit a broader range of situations.
- Given that the current UI focuses heavily on large touchscreens, the need for drivers to process more information enabled via vehicle connectivity will prompt an impending need for adopting new technologies in the midterm.
- These will provide a more-natural human-machine interaction and will reduce driver distraction, which benefits safety. Moreover, many of these technologies will help redefine the onboard experience for autonomous cars, where occupants will have the chance to perform a broader range of activities during trips.

### Obstacles

- OEMs are mostly focused on increasing the number and size of screens onboard. This is a major trend that takes place mainly because it's easier to add more screen area than alternative technologies. As such, this is an intermediate step before OEMs move into more advanced technologies based on a broader range of sensors and interfaces.
- Besides large touchscreens, some other UI technologies are still not mature enough to assume a major role in the vehicle UI.
- Price of alternative technologies is often high, considering they cannot replace large touchscreens but just complement them. Consequently, OEMs often tend to stick to touchscreens rather than going beyond that.

### User Recommendations

- Tackle the safety risk that touchscreens represent for drivers. Consider this as a crucial factor in the sourcing and selection of your UI technology.
- Develop a holistic approach to vehicle UI. Invest in technologies like advanced reality, mixed reality, smell sensors, smell generators and smart surfaces.
- Account for the development of a new UI for infotainment because electric vehicle drivers often have to spend a considerable amount of time waiting for their vehicles to charge.
- Plan your vehicle UI roadmap with a focus toward the increase in amount of time drivers have for leisure and work activities while on route. Especially as vehicle autonomy grows in terms of adoption and sophistication,
- Identify other functions that a UI sensor can bring because this increases ROI. For instance, a driver monitoring system installed in the rearview mirror can also assess for forgotten objects, children or animals in the cabin.

### Sample Vendors

DENSO; HARMAN; Continental; GestureTek; Amazon; Apostera; Tanvas

### Gartner Recommended Reading

AI Multisensory Tech in Automotive HMIs

AI Multisensory Tech in Automotive HMIs, Part 1: Smell

AI Multisensory Tech in Automotive HMIs, Part 2: Visual Immersion

AI Multisensory Tech in Automotive HMIs, Part 3: Smart Surfaces

## Virtual Assistants

**Analysis By:** Van Baker

**Benefit Rating:** Transformational

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Adolescent

### Definition

Virtual assistants (VAs) help users with tasks previously handled by humans. VAs use semantic and deep learning models, natural language processing, prediction models, recommendations and personalization to interact with people via voice or text conversations. Increasingly, they also automate processes and workflows. VAs learn from user behaviors, build data models, and recommend and complete actions to support VA users. VAs can be deployed in simple as well as complex use cases.

### Why This Is Important

Conversational interactions are inherently appealing to both customers and members of the workforce. The ability to converse with applications to retrieve information or accomplish transactions is a natural extension of human-to-human interactions to human-to-machine interactions. A well implemented virtual assistant is always available, cannot be distracted, and can be very efficient in assisting humans in accomplishing tasks and retrieving necessary information.

### Business Impact

VAs, RPA, event brokers and other technologies are automating the enterprise. VAs use contextual multiturn conversations to drive business workflows. Integration with enterprise applications enhances the handling of complex tasks by VAs. Consumer VAs led to enterprise VAs embedded in SaaS platforms. Business channels such as websites, mobile apps and messaging are commonplace. Voice-based VAs are becoming the focus of conversational AI providers. Additionally, use of VAs can expand hours of operation and improve customer response time.

**Drivers**

- Customer expectation for access to customer service anytime, anywhere. This is especially true for online e-commerce businesses that have seen extreme growth in response to the pandemic.
- Consumer expectation for access to product information anytime, anywhere. E-commerce is a 24/7 business and consumers expect to get their answers whenever they engage.
- Employee access to information on a real-time basis via conversational queries, resulting in enhanced productivity because of increased use of business-critical information.
- Increasing demand for technology that is easy to understand and interact with. While this is true for all workers, it is especially needed by remote workers in the enterprise.
- A strong desire by businesses to automate business workflows and processes wherever automation can deliver value to the business.
- The ability to initiate communication with your workforce in response to event triggered conditions or transactions. This facilitates more timely response to changing business conditions by removing the need for workers to initiate transactions.
- The ability of conversational AI platforms to deliver more complex transaction capabilities spanning multiple users and business processes.
- Improved access to the business across multiple channels addressing the preferences of particular customer segments, allowing them to select their channel and modality of choice.
- Improving capability for conversational AI platforms to use natural language generation. This allows the virtual assistants to initiate interaction with customers and employees rather than just reacting to user requests.
- VA tools are becoming available that enable the automatic ingestion of unstructured and structured data to enhance and improve the language models.
- Enabling technologies are making creation of VAs easier such as low-code tools, automated identification of intents and entities, and the use of APIs for complex integrations.

### Obstacles

- Poor or inadequate language models for the use case that is deployed. The virtual assistants need to be able to respond to an extraordinary variety of users' questions. They should also be able to handle off-topic questions to some degree.
- Inadequate conversational AI platforms that do not have the capabilities needed to deliver virtual assistants. Many platforms lack the ability to handle complex transactions, context switching, multi-intent utterances, strong integration, process automation and other functionality needed for virtual assistance level capabilities.
- A design approach that oversimplifies use cases for virtual assistants. Many dialogue designs assume consistency in the way that people ask questions or do transactions that do not exist. This often leads to successful pilot development efforts that fail upon deployment.
- The need for ongoing continual retraining of the language models is often overlooked or ignored leading to poor performance over time.

### User Recommendations

- Assess the continual rapid evolution of the technologies that support the creation and deployment of virtual assistants. These technologies are evolving at a very rapid pace that is not expected to slow in the near term.
- Deliver significant levels of integration and business process automation in conjunction with virtual assistant conversational capability as the platforms in the market are becoming increasingly sophisticated. Many conversation AI platforms include workflow automation capabilities as part of their offering.
- Evaluate that VAs will have voice and text capabilities with voice becoming the dominant modality.
- Define a chatbot strategy at the enterprise level and decouple the technical decisions from it.
- Pick your core services by favoring modular technical solutions that allow the same.

### Gartner Recommended Reading

When Should I Use Embedded Conversational Assistants?

Making Sense of the Chatbot and Conversational AI Platform Market

Craft a Chatbot Initiative Based on Your Business Requirements and Solution Complexity

Roles and Responsibilities for Scaling Chatbot Initiatives

Solution Criteria for Enterprise Conversational AI Platforms

### Automotive Digital Security

**Analysis By:** Michael Ramsey

**Benefit Rating:** Transformational

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Emerging

#### Definition

Automotive digital security is a holistic approach to protecting a vehicle from any type of cyberthreats. Automotive digital security aims to protect all vehicle hardware, software and information related to vehicles, their users and customers.

#### Why This Is Important

As cars become more defined by software, and updated through cellular connections, they become another attack surface for cyber criminals. There are an increasing number of incidents involving theft of vehicles through keyless entry, and some using app-based API attacks. In addition, the R155 cyber regulation, which goes into effect in July 2022, will mandate compliance in 60 countries.

#### Business Impact

Automotive companies are in the process of creating more secure ECUs, TCUs and other data connections into vehicles and spinning up security operations centers to monitor and respond to breaches in the vehicle fleet. Compliance with new regulations will require a more structured response to security. Security breaches could be quite significant, leading to costly plant shutdowns, ransom attacks, intellectual property theft and even physical harm to drivers.

### Drivers

- Regulations, such as the UNECE R155 as well as standards being adopted for security, such as ISO/SAE 21434, will lead to a significant expansion of security in vehicles as well as organizational changes to address security.
- Rising numbers of ransomware attacks in the automotive industry will increase the focus on security and lead to a number of implementations.
- Efforts to consolidate security operations along with efforts to produce revenue or catch other issues in the fleet could help to pave the way for more investments by reducing the burden of the expense.

### Obstacles

- Security efforts can be costly and it is difficult to recover the investment in the expense from consumers, who expect the coverage but don't want to pay for it.
- There are many different potential ways to protect vehicles and none will protect from every different method of attack. Hackers are creating new ways of breaking into vehicles, and networks are being created every day to expose vulnerabilities.
- Cars are adding more and more ways to connect and control them as features, but these same features lead to a greater number of vulnerabilities that could be difficult to address.
- Hackers could attack vehicles to compromise safety by altering braking or steering and could unlock software features that are not available or not paid for on the vehicle.

### User Recommendations

Automotive industry security and risk management leaders must:

- Adopt the frameworks for secure-by-design, monitoring and updating set out in UNECE R155 as well as by third-party cybersecurity groups such as NIST and Auto-ISAC.
- Create a strategy to secure electronic control units (ECU) and the semiconductor chips such as MCUs, application processors and memory chips used in ECUs, data storage, sensors and actuators, in-vehicle network, and the data gateway.
- Monitor vehicles in operation for attacks and plan a way to respond to those attacks with patches.

- Work with legal and public relations to have an action plan in case of a ransomware attack or other attacks and know what your public response will be ahead of time.
- Update vehicles to secure software where new vulnerabilities have been discovered.

#### Sample Vendors

Argus; Approov; Irdeto; Karamba Security; HARMAN; Upstream

#### Gartner Recommended Reading

Innovation Insight for Quantum Computing for the Automotive Industry

How to Protect Connected Vehicle Monetization From Commercial Hackers

### eSIM

**Analysis By:** Pablo Arriandiaga

**Benefit Rating:** Transformational

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Emerging

#### Definition

The embedded SIM (also called eSIM or eUICC) is a programmable subscriber identity module (SIM) that is physically embedded into a mobile device. It is designed to remotely manage multiple CSPs profiles and be compliant with GSMA specifications. An eSIM is provisioned over-the-air (OTA) with operator credentials, giving users the ability to change providers.

#### Why This Is Important

Enterprises, OEMs and communication service providers (CSPs) need common standards for mobile and IoT connectivity that enable them to scale their business while reducing costs. More than 200 mobile network operators (MNOs) worldwide support eSIM. Leading smartphone and laptop manufacturers such as Apple or Samsung support eSIM in their new devices. Adoption is accelerating, mainly in consumer devices, driven by use cases such as wearables, where mobility and life cycle are important.

Business Impact

- **Smartphones, tablets and PCs** — eSIM enables the user to switch between mobile operators without removing the physical SIM from the device.
- **Wearable devices** — eSIM (and an embedded radio module) removes the dependence on smartphones as IoT gateways, making wearable devices always-connected IoT devices.
- **IoT** — eSIM enables industry transformation, standardizing the manufacturing process and simplifying device activation, no matter which country the product is delivered to.

**Drivers**

- Main device manufactures like Apple or Samsung support eSIM both in their latest smartphones and wearables. eSIM shipments for 2020 were 309 million with a 83% year-over-year (YoY) increase as reported by the Trusted Connectivity Alliance.
- In IoT, one of the main drivers is the connected car where Gartner forecasts that by 2023, two-thirds of all new connected vehicles produced will feature an eSIM for cellular connectivity, up from less than 5% in 2021. Regulations, such as eCall in Europe, are also accelerating adoption. In IoT most use cases are using eSIM as insurance to avoid future lock-in. Other industry-verticals such as utilities and logistics are also driving adoption as well, though reported eSIM connections by participants in Gartner's Magic Quadrant for Managed IoT Connectivity Services, Worldwide is really low.
- In IoT, multinationals are looking for more sustainable IoT connectivity platforms to avoid switching them each time they change the IoT connectivity provider so they can integrate the platform with other IoT and internal business systems. This positions eSIM as a key driver for this increasing trend as most enterprises Gartner talks to prefer standardized mechanisms that guarantee future compliance for their devices as the technology evolves.
- In IoT, specialized providers that act as local connectivity IoT hubs for CSPs around the world could accelerate adoption if they are able to add as many local MNOs as possible, including commercial agreements, not just technical integration. One example of this is Eseye with the Anynet Federation. These initiatives apply mainly to multinationals looking for local IoT connectivity in bring-your-own-connectivity scenarios.
- For CSPs, facilitating digital transformation of SIM provisioning with eSIM, creating cost and process efficiencies and ability to drive customer engagement.

### Obstacles

- Complexity for multinationals in IoT of assessing MNOs support by country, including version of the standard supported, and interoperability with other eSIM subscription management platforms.
- Some CSPs have been reluctant to embrace eSIM because the technology reduces the barriers for automakers and telematic service providers to switch mobile operators. Some IoT MVNOs tell Gartner that sometimes even when they sign agreements with an MNO for eSIM, that agreement only applies to that particular client.
- In IoT, due to the lack of scale, pricing is a big problem as eSIM vendors don't see scale so they are not bringing prices down. And CSPs don't see competitive pricing to promote it, apart from their reluctance to open their networks to third parties.
- Immaturity of the standards: Low power standards, such as NB-IoT, struggle to support eSIM provisioning despite being a popular platform for IoT projects.

### User Recommendations

Recommendations will vary, depending on the type of user:

- **Enterprises** — Evaluate the eSIM service CSPs offer acting as prime contractors by assessing MNOs supporting each by country including version of the standard supported, and interoperability with other eSIM subscription management platforms with special focus on NB-IoT support.
- **OEMs** — Promote eSIM in designs where its advantages are attractive(e.g., swapping cellular providers regularly across countries) and with big amounts of data by working with the GSMA and CSPs to present end users with a superior solution and a balanced playing field for new and innovative offers.
- **CSPs** — Leverage the flexibility of eSIM to attract new customers with superior service offerings that also motivate existing users to stay by, for example, eliminating per-device fees and instead bundling in content, wearables and more.

### Gartner Recommended Reading

Magic Quadrant for Managed IoT Connectivity Services, Worldwide

Critical Capabilities for Managed IoT Connectivity Services, Worldwide

Emerging Technology Horizon for Devices

Market Trends: Reinvigorate Wearable Devices by Reinventing NFC and eSIM Technologies

Cellular Data Trading: Why the Automotive Industry Could Be an Early Adopter

### Shared Mobility

**Analysis By:** Michael Ramsey

**Benefit Rating:** Moderate

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Adolescent

#### Definition

Shared mobility encompasses the use of ride-hailing or other on-demand mobility models that manage the pickup and drop-off of customers, primarily through a mobile application. These platforms often offer cars, but could offer bikes, scooters, boats and even helicopters.

#### Why This Is Important

Shared mobility has fundamentally created an entirely new channel and methodology for travel and for the use of transportation assets. By creating an IoT platform that can schedule, book, route and manage payment of travel, consumers have lower-cost options to get around in urban areas, and drivers are more able to use their vehicles to make money. In addition, these same platforms have been leveraged to offer micromobility services, such as floating bikes or e-scooter shares.

#### Business Impact

Shared mobility — primarily through Uber and other ride-hailing platforms — has had a huge impact on transportation, which is likely to continue. Although the model suffered in 2020 after the onset of lockdowns, usage has snapped back. Shared mobility has created new ways of getting around in urban areas, but its impact hasn't been all good. Traffic in city centers has sometimes increased as people have traded walking, riding public transportation and biking for inexpensive ride-hailing.

### Drivers

- The end of the COVID-19 pandemic will have a significant positive impact on shared mobility as people return to work in urban centers and begin to do more entertainment and travel, which helps to increase shared-mobility usage.
- Shared mobility may be positively affected by the rise in electric vehicles as their price drops. In addition, the cost of operating ride-hailing cars should fall as more vehicles use electricity rather than fuel. This also could also reduce pollution concerns in urban centers where the increase in traffic from ride-hailing initially raised concerns.
- The rise of autonomous vehicles (AVs) could also increase shared mobility because the AV is ideally suited to perform mobility services.

### Obstacles

- The economics of shared mobility have always been a problem. Many shared mobility platforms have been unprofitable, and it is difficult to see an easy path toward profitability.
- Changes in culture around working from an office versus at home, as well as the uncertainty around when the pandemic will recede, could impede shared mobility.
- Laws in certain regions that require ride-hailing providers to be considered employees or limit them against taxi operators may change the structure of the primary companies offering services and make it more difficult to expand.

### User Recommendations

- Look for ways to connect these services into a holistic transportation strategy, enabling payment or scheduling options that complement public and private transportation options.
- Be wary of investing in, or connecting with, services that skirt city regulation, because the services could quickly be frozen out for an individual town.
- Create transportation plans as a means to improve traffic congestion, to address pollution concerns and to even provide lower-cost transit.
- Look for ways to use shared mobility to provide transportation options for people who feel uncomfortable in public transportation as a result of the pandemic or who aren't able to use public transport, like the elderly.
- Set up data exchanges for mobility and related ecosystem datasets that can be combined for new services on last-mile logistics, as well as adjacent service potentials in touristic, health and insurance business sectors for CIOs working for industrial and commercial clusters and real estate development.

### Gartner Recommended Reading

Smart City Funding Models: It's Time to Be Creative

Turning Smart Cities Into Intelligent Urban Ecosystems

Market Trends: 5 Smart City IoT Deployment Trends to Drive Innovation Opportunities

3 Ways Transportation CIOs Can Shape a Mobility-as-a-Service Ecosystem Effectively

## Automotive Real-Time Data Analytics

**Analysis By:** Michael Ramsey

**Benefit Rating:** High

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Adolescent

### Definition

Automotive real-time data analytics enables vehicle, driver and passenger services based on live data analytics. The key element is that information is processed for use in real time, rather than a delay of hours, days or weeks. Use cases include predictive route planning, vehicle condition monitoring, predictive collision avoidance, video analysis, predictive cyberattack avoidance, targeted marketing, connected car data management and personalization of consumer services.

### Why This Is Important

Real-time data analytics has the potential to help reduce road traffic volumes and increase safety by providing nearly live feedback to the vehicle or driver. Ultimately, these two use cases can be reduced to making better routing decisions and by determining the state of a driver and intervening with suggestions or actions. Use of AI-based real-time information can be matched with past behavior to make suggestions for services.

### Business Impact

Automotive real-time analytics can help avoid incidents and make vehicles safer. Predictive services will also evolve to provide real-time analysis of vehicle operation. The ability to dynamically synthesize data from multiple areas of a customer's journey, including car usage, trip data and contextual data, will be key in delivering personalized mobility services to consumers, improving customer retention and differentiation in a world where usage-based business models proliferate.

### Drivers

- More connectivity, as well as faster connectivity, is certain to speed up the implementation of real-time data analysis. The growth in capability of cloud-based connected car platforms to receive and send back information will increase the number of use cases.
- 5G may also make some real-time analytics more useful because of greater data volume capture capability.
- More intelligence in the vehicles themselves will lead to better real-time analysis. While most of the real-time analysis today is done in the cloud, high-performance computing in vehicles is likely to expand vehicles' ability to conduct the analysis on their own, without sending information to IoT platforms.

### Obstacles

- Data sources for use-case solutions are typically a combination of structured driver behavioral data or vehicle data comprising of fields (e.g., year, make, model, and warranty parts and claims) and unstructured data sources (e.g., parameters such as odometer reading and braking, but also service protocols, even social media data).
- How best to ingest data in a standardized way to provide unified back-end processing services, correlate data, build the necessary machine learning models and eventually trigger the right action.
- Handling structured and unstructured dynamic data across entire fleets and consumers is a new element for the consumer automotive industry. Apart from technology assessment/deployment, principal issues (e.g., governance and organization, data ownership, and privacy and security) need to be solved before widespread adoption across multiple markets and vehicles.
- The implementation of GDPR and CCPA may affect car makers' ability to implement real-time analytics.

### User Recommendations

- Assess the needs of various services for rate of information update. Some services may require frequent information updates, which could increase data transfer costs and bandwidth issues.
- Ensure there is a mechanism to improve the system through analysis of false positives or suggestions that are ignored by the driver to ensure the artificial intelligence used to analyze live data isn't making useless or annoying suggestions.
- OEMs must continue developing the technology but also look into further developing a governance structure and effective data and information management capabilities. They should also work with cloud providers, such as Amazon Web Services (AWS), Microsoft and Google, to obtain capabilities more quickly.
- OEMs must address organizational changes that reflect the increasing role of data and analytics by installing a chief data officer. It also will be important to design the end-user data agreements appropriately to protect privacy and intellectual property.

### Sample Vendors

Google, Lear, Omnitracs, Waze, HERE

### Gartner Recommended Reading

Best Practices for Making Money From Connected Vehicles, Part 1: Strategy and Organization

Best Practices for Direct Monetization of Connected Vehicles, Part 2

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Guide to Connected Car Profitability

How to Protect Connected Vehicle Monetization From Commercial Hackers

## Autonomous Vehicles

**Analysis By:** Jonathan Davenport

**Benefit Rating:** Transformational

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

### Definition

Autonomous vehicles use various onboard sensing and localization technologies, such as lidar, radar, cameras, GPS and map data, in combination with AI-based decision making, to drive without human intervention. While self-driving passenger cars are getting most of the attention these days, the technology can also be applied to vehicles that transport goods.

### Why This Is Important

Autonomous vehicles have the potential to change transportation economics, cutting operational costs and increasing vehicle utilization. In urban areas, cheap fares and high quality of service may cannibalize private car ownership. Road safety will also be increased as the AI systems will never be distracted, drive drunk or speed. Autonomous features on privately owned vehicles enable productivity and recreational activities to be undertaken, while the vehicle handles the driving operations.

### Business Impact

- Autonomous vehicles have the potential to disrupt established automotive business models.
- Technology companies are building high-performance computers on which to run their self-driving software platforms.
- After the office and home, vehicles will become a living space, like airplanes, where digital content is both created and consumed.
- Over time, staff members currently undertaking driving roles must be retrained and redeployed to other, higher-value-adding roles within the company.

### Drivers

- Some progress is being made toward autonomous vehicle regulations and standards. Automated lane-keeping system (ALKS) technology has been approved by the United Nations Economic Commission for Europe (UNECE). This forms the first binding international regulation for SAE Level 3 vehicle automation, with a maximum operational speed of 37 mph. Likewise, the German government aims to enact laws that enable autonomous vehicles to operate without special permits by 2022. Companies like Intel, Waymo and Aurora are working on the IEEE 2846, which will create a standard that describes the scenarios to be considered when developing autonomous road-safety-related models.
- To take advantage of the new regulatory landscape, automakers are beginning to announce Level 3 solutions. These autonomous vehicles provide drivers with safety and convenience features, reduce vehicle fuel consumption and improve traffic management. Honda is the first company to announce a commercially available Level 3 vehicle, though only 100 will be produced.
- Improvements are also being made to the perception algorithms and broader self-driving systems for Level 4 vehicles that will operate as robotaxis. Fully driverless operations have started, with Waymo operating in Arizona and WeRide operating in California without safety drivers. The flexibility of vehicle operational design domains (ODDs) has been showcased — e.g., Mobileye's perception algorithm required minimal additional training when it tested vehicles in new locations. Mobileye has developed its self-driving software on the roads in Israel, but showcased its autonomous technology in both Munich and Detroit. Likewise, Yandex has made great strides, showcasing how its autonomous vehicles are capable of handling the harsh weather conditions of winters in Moscow.

### Obstacles

- Designing an AI system that is capable of driving a vehicle is hugely complex. As a result, the cost of bringing a commercial autonomous vehicle to market has been greater than companies could have previously envisioned. This has required significant investments to be made in companies. Acquisitions have occurred, and further market consolidation is expected — e.g., Walmart has invested $2.75 billion in Cruise; Cruise acquired Voyage in March 2021; Aurora acquired Uber's ATG in December 2020; Amazon acquired Zoox for $1.2 billion in June 2020; Apple bought self-driving startup Drive.ai in June 2019.
- When autonomous vehicles are commercially deployed, autonomous vehicle developers, not the human occupants, will be liable for the autonomous operations of the vehicle. This raises important issues, should a vehicle be involved in an accident.
- Challenges increasingly include regulatory, legal and societal considerations, such as permits for operation and the effects of human interactions.

### User Recommendations

Governments must:

- Craft national legislation that ensures that autonomous vehicles can safely coexist with an older fleet of nonautonomous vehicles.

Autonomous mobility operators should:

- Support consumer confidence in autonomous vehicle technology by remaining focused on safety to deliver on the vision of an accident-free road environment.

Self-driving system developers should:

- Seek out use cases, such as mining, agriculture or airports, where autonomous vehicles can operate in restricted areas safely without regulatory restrictions. Use these implementations to drive early revenue and gather data and insights to improve the performance of self-driving systems.

Traditional fleet operators looking to adopt autonomous technology into their fleets should:

- Minimize the disruptive impact on driving jobs (bus, taxi and truck drivers) by developing policies and programs to train and migrate these employees to other roles.

### Sample Vendors

Baidu; Cruise; Mobileye; Waymo; Yandex; Zoox

### Gartner Recommended Reading

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Utilize Partnerships to Secure a Winning Position in the Autonomous Driving Ecosystem

Market Insight: Use Situationally Aware Platforms to Enable Safe Autonomous Vehicle Handovers

Tech Providers 2025: Product Leaders Must Strategize to Win in the Evolving Robotaxi Ecosystem

## Vehicle-to-Everything Communications

**Analysis By:** Jonathan Davenport

**Benefit Rating:** Transformational

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Emerging

### Definition

Vehicle-to-everything (V2X) communications support the wireless transmission of data directly between vehicles and other road users or infrastructure. Messages are transmitted over either dedicated short-range communications (DSRC) or cellular (4G or 5G) technology. Vehicles send messages to and receive messages from other vehicles (V2V), external infrastructure (V2I), pedestrians (V2P), cyclists (V2C), the home (V2H) and the power grid (V2G).

### Why This Is Important

Two use case examples:

- V2V safety messages can be sent using low-latency communications. Vehicles communicate with one another over an ad hoc mesh network. Combined with V2P and V2C messages, this will improve driving performance, which will have a tremendous impact on public safety if implemented on a large, interoperable scale.
- V2I functionality could be used for innovative traffic management systems and help improve traffic flow.

### Business Impact

- Automakers can market V2V communication as an additional safety feature, which will provide drivers with supplementary data warning of hazardous road conditions, collisions and changes in traffic patterns.
- For governments, V2I communication could be used for innovative traffic management systems and help improve traffic flow.
- V2G will allow electric vehicles to help balance peak network loads by either ceasing to charge or by selling electricity back to the grid.

**Drivers**

- Automakers that wish to comply with the Euro New Car Assessment Programme (NCAP) 2025 Roadmap will need to implement V2X by 2024. Car manufacturers want to ensure their vehicles score well in Euro NCAP's test program, which is an important data source for consumers.
- For autonomous vehicles, V2V communication technology provides additional safety input that cannot be captured by conventional vehicle sensors, thus allowing the vehicle to adjust its driving strategy and initiate emergency maneuvers to ensure the safety of passengers and other traffic participants.
- While V2X is not essential for autonomous driving, significant benefits will be delivered to autonomous vehicles if they can communicate with the infrastructure around them. Active sensors in autonomous vehicles, such as camera, radar and lidar, can be supplemented with additional insights from V2X, especially non-line-of-sight data points, effectively allowing vision beyond the sensor range and enabling vehicles to see around obstructions.
- V2I communication will help keep vehicles moving, thus minimizing the time spent idling at junctions and traffic signals. Passenger journey times should improve, as should fuel efficiency, which leads to potential environmental benefits.
- Some V2X use cases are already proven. For example, DSRC-based electronic road tolling is a commercially deployed technology for established applications, such as electronic road tolling. Deployments are based on aftermarket, rather than embedded solutions.
- Competition for V2X communication may intensify following Volkswagen's announcement to incorporate DSRC-based technology into mass-market vehicles.
- China will likely establish C-V2X as its technology for V2V, creating an important global shift that may well tip the scale in favor of C-V2X over the long term.
- Governments have allocated (expensive) radio spectrum to V2X applications. That spectrum is currently idle and, if not harnessed, is vulnerable to being diverted to other use cases.

### Obstacles

- V2X is an emerging technology that is being extensively tested, but it is not yet widely deployed.
- DSRC and C-V2X technologies aren't compatible. The future technological evolution of V2X has yet to gain global consensus. Momentum had been building for C-V2X; however, Volkwagon's decision to use DSRC added further confusion to which technology will "win" in Europe.
- V2X technology is most useful when there is a large installed base of vehicles, but rollout of the technology has been slow and limited to disparate geographic regions.
- Automakers continue to lack direction from a regulatory standpoint.
- Direct willingness of consumers to pay for the technology is extremely limited.
- Early cellular-based vehicle-to-network-to-infrastructure solutions are also emerging, which communicate over the standard cellular network — bypassing the need for direct low-latency communications. Audi has started using Green Light Optimized Speed Advisory data, which reports traffic signal status.

### User Recommendations

Automakers and Tier 1s should:

- Lobby governments to push for a regional V2X standard.
- Prepare to utilize different communication technology, depending on regulatory mandates and local market adoption trends.
- Consider how use cases that do not rely on low-latency messages can be delivered using vehicle-to-network-to-everything.

Governments should:

- Help improve road safety by consulting on regulatory mandates that will help drive adoption.
- Seek advice about investment costs for roadside units and highway infrastructure for both DSRC and cellular solutions. Use this research to help guide policy decision making

Communications service providers should:

- Lobby governments and automakers to push for the cellular standard.
- Ideate possible revenue models that could be used to generate income from low-latency-based use cases.
- Ensure that revenue is generated when spectrum assets are used for V2V communications, even when messages do not travel across the cellular network.

### Sample Vendors

Autotalks; Ericsson; HARMAN; !important; Panasonic; Qualcomm; u-blox; Vodafone Group; Volkswagen

### Gartner Recommended Reading

Market Insight: Roadmap for V2X Technologies for Autonomous Driving — When to Invest

Toolkit: Top 10 Trends in Automotive and Smart Mobility for 2020

Market Trends: 5G Opportunities in IoT for Communications Service Providers

The Top 10 Wireless Technologies and Trends That Will Drive Innovation

Market Insight: How Mobile Operators Should Accelerate 5G Impact on Autonomous Vehicle Design

## Automotive Lidar

**Analysis By:** Michael Ramsey

**Benefit Rating:** High

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

### Definition

Lidar (light detection and ranging) is an optical remote-sensing technique for scanning surfaces from a distance with laser light. Lidar systems use an active optical sensor that transmits laser beams, and calculates ranges and the precise position of the target. Measurements are combined into a point cloud dataset, which is registered to a 3D-coordinate system. It is used in autonomous vehicles operating at Level 3 and above, and to generate HD maps.

### Why This Is Important

Lidar is considered one of the core technologies to enable autonomous driving by most players in the industry. While advances are being made by improving the range, frame rate, resolution and cost, the technology still is expensive compared with other safety sensors, including radar and cameras.

### Business Impact

Lidar is one of the key components to enable autonomous driving and to improve advanced driver assistance system (ADAS). Lidar provides superior information to computers and can be used to create maps and identify objects. While there is some debate on whether lidar is an absolute requirement for autonomous vehicle applications, it is used by many companies for advanced safety systems that are not fully autonomous.

### Drivers

- Adoption of lidar technologies for high-volume applications is the single-biggest driver for success as it will lower the cost of production and make it easier for the technology to be adopted by others.
- Lidar VCSEL and SPAD-type lidar used in consumer markets (e.g., in phones and tablets) may help lower the production cost of the most expensive parts of lidar enabling the sensor to spread across automotive applications.
- Several companies have implemented ADASs, which are much higher in volume than full autonomy, but are also simple devices with shorter range. Chinese electric car maker Xpeng Motors plans to debut a lidar on a forthcoming vehicle, for instance.
- Several top players in lidar have gone public in the past year and have brought in new capital that will help with production and may give them money to acquire new technology or competitors.

### Obstacles

- The cost, performance and fragility of lidar in commercial applications remain obstacles. While production-ready lidar have come down in cost by an order of magnitude, they still are expensive compared with cameras and radar.
- New radar and vision technologies may lessen the need to employ laser sensors. While fully autonomous vehicles will likely need lidar, these other sensors may reduce the number required.
- The slow start of production for fully autonomous vehicles could limit the market size for lidar and cause consolidation in the industry, where dozens of companies use lidar technology.

### User Recommendations

- Find lidar solutions that have a clear path to cost reductions, such as those that use technology similar to consumer electronics'.
- Prioritize vendors that offer perception algorithms/software capabilities with the hardware to ease and optimize analysis.
- Evaluate whether other combinations of sensors may achieve similar results if lidar costs remain too high.
- Be wary of company promises of capability. There are usually some flaws in each type of lidar that makes it less than ideal.

### Sample Vendors

AEye; Ibeo Automotive Systems; Innoviz Technologies; Luminar Technologies; Ouster; Quanergy Systems; Valeo; Velodyne Lidar; Waymo

### Gartner Recommended Reading

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Tech CEOs Should Reprioritize Their Strategies as Robotaxi Deployment Expectations Cool

Cool Vendors in Autonomous Vehicle Systems

Cool Vendors in Perception Solutions for Autonomous Vehicles

### Connected Vehicle Services

**Analysis By:** Michael Ramsey

**Benefit Rating:** High

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Early mainstream

#### Definition

In-vehicle services are enabled by a wireless connection from automobiles to the cloud. These services can include wireless internet, theft prevention and recovery, preventive maintenance, retail purchase tie-ins, parking location and payment services, event booking, driver health monitoring, dynamic navigation map updates, advanced driving systems and digital or human concierge services.

#### Why This Is Important

Digital services in the car may be a key differentiator for automakers, and could be a new source of revenue for third-party service providers. Several automakers, including Tesla, BMW and Mercedes, have begun offering capabilities as a service, disconnecting them from the options purchased when the car was new. These services could be enabled at the time of the sale or afterward. There is a significant effort behind digital services in the industry that will lead to recurring revenue.

#### Business Impact

Connected vehicle services are at the heart of a shift in business models in the automotive industry. Digital services or capabilities in cars will shift the focus away from the sale of a vehicle and toward these aftermarket services, which typically are higher margin than the sale of the car itself. In addition, aftermarket digital services enable car makers and other service providers to have a relationship with second and third owners of vehicles.

### Drivers

- A steady increase in the number of connected vehicles is likely the most important influence in the development of in-vehicle services. A constant data connection is the first-level requirement for the services, and the onset of 5G may improve service delivery.
- The creation of an application ecosystem for the vehicle through a common platform, similar to the Apple or Android stores.
- A willingness for car companies to agree on common standards and to allow third-party developers to creatively solve problems or offer services will also lead to improved services development.
- Consumer acceptance for paying for services rather than purchasing capability through options upfront will be important to growing this area.
- New entrants in the space, primarily the EV startups, are likely to offer digital services and upgrades that put pressure on the rest of the industry to adapt.

### Obstacles

- While a digital connection into the vehicle has been in use for some time, the maturity of these digital services is still developing. The business model for providing services always has been challenging because of competing capabilities from smartphones.
- It may take some time to create an ecosystem that enables third parties to easily integrate with these systems.
- Consumers may be angry or unwilling to accept additional fees for capabilities that they feel should be standard on vehicles or could be provided by smartphones.
- Right-to-repair legislation could interfere with automakers' ability to control the types of services delivered to vehicles by opening up service delivery to third parties that are outside automaker control.

### User Recommendations

- Explore new developer interfaces that make it simpler to build applications for in-vehicle services, such as the new HARMAN Ignite developer portal or the forthcoming IVY development tool from AWS-BlackBerry.
- Assess value creation in terms of the entire product, not just the revenue generated from data sales or transactions from the connected services themselves.
- Create cloud-based customer profiles that facilitate delivering services to the vehicle and the consumer.
- Deliver services that are differentiated from smartphone applications and are not considered something that should be standard in a vehicle. Charging for something people expect to be permanent in the car will be unpopular.

### Sample Vendors

Amazon; Google; HERE Technologies; Lear

### Gartner Recommended Reading

Best Practices for Making Money From Connected Vehicles, Part 1: Strategy and Organization

Best Practices for Direct Monetization of Connected Vehicles, Part 2

Guide to Connected Car Profitability

## EV Charging Infrastructure

**Analysis By:** Zarko Sumic

**Benefit Rating:** Moderate

**Market Penetration:** 20% to 50% of target audience

**Maturity:** Adolescent

### Definition

The EV charging infrastructure, or Electric Vehicle Supply Equipment (EVSE), is a component of the overall supply system for the recharging of EVs and plug-in hybrid EVs. Different means of providing electricity to charge EV batteries exist, including slow residential AC charging and fast commercial DC charging. Ownership models include publicly owned municipal or commercial charging points or private ones, including those owned by EV manufacturers and individuals.

### Why This Is Important

Most rechargeable EVs and equipment can be recharged from a domestic wall socket, but publicly accessible charging options are needed.

EV charging infrastructure has multiple implications for utility companies. Depending on the role a utility company wants to have in the electrification of transportation, the business impact can be:

- Minimal — in the case of charging infrastructure that is owned and operated by a third party
- Significant — in the case of a utility company wanting to manage and operate its own EV charging infrastructure

### Business Impact

The major areas of impact will be delivery (charging infrastructure life cycle management) and retail (customer service, metering and billing).

Owners of the distribution network will have to ensure their infrastructure can handle additional load introduced by the EVs. The impact of EV charging on distribution networks can be mitigated with charging control to avoid periods of peak demand. Thus, ownership of the EV charging infrastructure provides network operation benefits in addition to increased energy sales.

### Drivers

According to the International Energy Agency Global EV outlook in 2020, the total number of charging points, or EVSE outlets, exceeded 6.4 million in 2019. In a Stated Policy Scenario (conservative) the number of charging points is expected to reach almost 135 million in 2030, corresponding to 30% average year-over-year growth. The cumulative installed capacity of those chargers will be 0.6TW. In the Sustainable Development Scenario (optimistic) this number will almost double to 240 charging points in 2030, with cumulative installed capacity of 1.1 TW. The energy research and consultancy Wood Mackenzie predicts charging infrastructure investment in the U.S. alone will exceed $18 billion annually by 2030 for equipment, installation, operation and services. China is expected to have three times more energy demand from EVs by then.

In markets where there is strong public and policymaker support for EV, the network operator may explore an option in which EV charging will be treated as an extension of energy delivery infrastructure, with a traditional investment recovery model. In some markets, utilities may approach EV charging as an unregulated business opportunity. In each case, the ability to gather consumption patterns will help utilities mitigate the impact on the distribution grid and may eventually result in additional opportunity for revenue growth as electricity starts to displace gasoline as the preferred transportation fuel. Consequently, oil companies are taking an interest in EV charging networks and entering this market through acquisition of EV charging service providers.

### Obstacles

It’s important to consider electric-grid-related challenges once the number of EVs grows. Recharging a large battery pack places a high load on the electrical grid, but it can be scheduled for periods of reduced load or reduced electricity costs. To schedule the recharging, either the charging station or the vehicle can communicate with the utility via the smart grid communications backbone. Many plug-in vehicles allow the vehicle operator to control recharging through a web interface or smartphone app. Furthermore, in a vehicle-to-grid scenario, the vehicle battery can supply energy to the grid at periods of peak demand.

EV charging service ownership and business models continue to evolve with multiple interesting parties, different and changing value propositions and diverse actors (car manufacturers, utilities, O&G companies, new entrants). Market fragmentation and lack of common unify platform — every provider has its own IT infrastructure and provides a different user experience — slows maturation and adoption of this technology innovation profile.

### User Recommendations

- Make sure that your EV infrastructure strategy aligns with your jurisdiction's regulatory treatment into EV infrastructure investment. The regulatory structure has strong implications for the ownership structure and organizational arrangements of emerging charging infrastructure.
- Invest in electric charging infrastructure if you operate in markets where there is a significant government sponsorship for EV adoption, such as in many European countries. In those markets, utilities (mostly distribution network operators) can recover the investment in EV charging through regulated distribution tariffs
- Leverage EV charging infrastructure to get better insight and some control over EV charging implications on existing distribution grid and improve asset utilization.

### Sample Vendors

ABB; Blink Charging; ChargePoint; Enel X; EVgo; EVBox; GE; innogy; Siemens; Tesla

### Gartner Recommended Reading

Top 10 Trends Driving the Utility Industry in 2021

Guide to New Business Models in the Electric Vehicle Ecosystem

## Climbing the Slope

### Driver Monitoring Systems

**Analysis By:** Jonathan Davenport

**Benefit Rating:** Moderate

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Adolescent

#### Definition

A driver monitoring system (DMS) is an in-vehicle system that employs sensing technologies and analytics to monitor head and body pose, eye state, attention, drowsiness, emotions and impairment. This system can also be used to identify drivers and to monitor other occupants. DMSs are used to prevent accidents caused by fatigue or distraction, and also to ensure effective handovers between the vehicle and the human in Level 3 autonomous driving situations.

#### Why This Is Important

In Europe, automakers applying for type approval from July 2022 will need to have driver drowsiness and attention monitoring/distraction technology. The move to regulate DMS stems from the technology's impact on reducing motor vehicle accidents caused by driver fatigue or distraction. Driver alertness is a crucial factor in a significant proportion of road accidents, according to research studies such as those conducted by The Royal Society for the Prevention of Accidents (RoSPA).

#### Business Impact

- Automakers will produce vehicles that should be involved in fewer accidents.
- Over reliance on Level 2 adaptive cruise control ADAS features will be prevented by ensuring that the driver continues to supervise the operation of the vehicle.
- Smoother vehicle-human handovers will be delivered using DMS technology when the vehicle is operating autonomously.
- DMS camera technology can identify babies left behind in vehicles and, in mobility use cases, left luggage and spills.

#### Drivers

- Euro NCAP is encouraging automakers to include DMS in vehicles now, and the European Commission's new general safety regulations (GSR) will mandate driver drowsiness and attention monitoring/distraction recognition for all new vehicles applying for type approval from July 2022.
- Alerts from the DMS can be used by fleet managers to educate drivers on safe behaviors while behind the wheel. For example, DMSs can identify (and capture evidence of) drivers who light a cigarette while driving or pick up a mobile phone.
- DMS will play an important role in the adoption of Level 3 autonomous vehicles, by verifying that the driver is able to resume manual control if necessary.
- The ability to use a DMS cabin camera for facial recognition enables biometric authentication of drivers. DMS-based driver identification can be used to offer personalized services, such as adjusting seat and mirror positions. The tension of seat belts can also be adjusted based on the size, gender or age of occupants. The feature also has the potential to increase vehicle security and underpin use cases like authentication for in-car payments.
- ADAS features such as lane-keeping solutions can be improved by monitoring head and eye movement to gauge driver intention, for example, if the driver intends to change lanes, even without using an indicator signal.
- Incorporation of in-cabin camera technology enables automakers to offer multimodal user interfaces with gestures or gaze in combination with voice. So, for example, location-specific questions, such as "What is that?" made to a voice-based virtual assistant, can be linked to a driver's gaze to provide contextually aware answers.
- DMS can also be used to monitor the quality of occupant experience (emotion AI) to detect forgotten objects on board and the presence of children or animals left behind in vehicles, which can be dangerous on hot days.

**Obstacles**

- Privacy concerns about being monitored in the vehicle exist, though most solutions only process data at the edge. Some radar-based systems have been developed to overcome this concern.

- DMS can be used to get the driver's attention back on the road when he or she is distracted or to suggest the driver take a break when tired. However, current solutions still mostly rely on the driver to act on the system's warnings, which can impact efficacy.
- The lack of regulatory pressure has historically led to a very low investment from OEMs, similar to what happened with many other safety technologies.
- Some earlier DMSs presented several technical limitations in terms of effectively recognizing driver drowsiness, something that has deterred some OEMs from widening adoption.
- The systems are an added expense and when not mandated it's not clear that consumers want or would be willing to pay more for this feature.

**User Recommendations**

Automotive manufacturers must:

- Deliver a safer and more pleasant driving experience by improving the level of integration between DMS and broader advanced driver assistance systems.
- Leverage a DMS to support a smooth machine-human handover for Level 3 autonomous applications. This will be particularly important when calculating the period of time necessary to perform a handover based on the activity the driver is engaged in.

Mobility fleet operators must:

- Drive customer retention by utilizing the ability to recognize occupants (not just the person who made the booking) and use this to undertake digital personalization of the vehicle's environment.
- Use DMS also to assess the level of cleanliness of the cabin and to detect and inform customers about objects forgotten inside the vehicle.

Insurers and corporate fleet operators must:

- Improve safety by leveraging DMS-based telematics solutions to educate people about safe driving practices and reduce the risk of accidents.

### Sample Vendors

Continental, Cipia, Nauto, Seeing Machines, Smart Eye, Vayyar

### Gartner Recommended Reading

Invest in 3 Critical Semiconductor Enablers for a Successful Driver Monitoring System Product Portfolio

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

AI Multisensory Tech in Automotive HMIs, Part 4: Emotion AI

Market Insight: IoT-Based Digital Personalization, Part 2 — Architecture for Automotive Customer Retention

Market Trends: Machine Vision Will Be the Game Changer Across Markets

## Over-the-Air Software Updates

**Analysis By:** Michael Ramsey

**Benefit Rating:** High

**Market Penetration:** 20% to 50% of target audience

**Maturity:** Adolescent

### Definition

Over-the-air (OTA) software updates refer to methods of using wireless communication to distribute new software or firmware updates and/or configuration settings to automobiles' various computing systems, including infotainment systems and electronic control units. OTA software updates typically leverage dedicated server locations to send and manage the updates to all automobiles in a given region, or by model and year.

### Why This Is Important

OTA updates are already frequent, but primarily for multimedia control unit software, though they still are not used regularly in the automotive industry to make updates beyond that. Automakers are adopting the technology, but have been restrained by the architecture on the vehicles themselves, and software development capabilities. Tesla is the most advanced in its approach, using a continuous deployment method, including regular updates to operational controls and safety-critical functions.

### Business Impact

Automotive CIOs can use OTA software updates to:

- Reduce service and maintenance, and product and warranty costs, including reducing the need for costly vehicle recalls.
- Improve product differentiation and consumer satisfaction during the vehicle ownership phase, and provide new revenue opportunities (e.g., adding new capabilities).
- Evolve business models as vehicles evolve, delivering content and features to vehicles rather than just building a product that depreciates with time.

### Drivers

- Proliferating connectivity in automobiles combined with new electrical and computing architectures is enabling OTA. Prior to a few years ago, embedded connectivity in vehicles was not common and the use of OTAs to deliver repairs or upgrades was even less common. Tesla's success with OTAs has pushed the rest of the industry to speed up.
- The shifting business model priorities at automakers from a vehicle-centric business model to a customer-centric model, where revenue is generated on an ongoing basis rather than from a single sale, will support an even greater adoption.
- OTAs will benefit from wider adoption of embedded 4G connectivity and, eventually, 5G connectivity. OTA offers the ability to repair and upgrade vehicles at a low cost relative to dealership visits and offers high completion rates for recalls. It also creates an aftermarket opportunity to maintain and monetize vehicles over a long period of time. The potential savings to automakers by using OTAs to complete vehicle repairs could be as high as $15 billion annually on a global basis, according to some vendors that have made estimates.

### Obstacles

- The absence of a high-performance computing architecture makes the regular deployment of OTA updates too cumbersome for OEMs.
- The technology is limited by connectivity to vehicles, as well as data security and software validation concerns by the automakers.
- Most automakers are not organized to do regular deployment of new software on a large number of different models as this capability is largely held outside the automaker today. Marrying agile software development with the system engineering approach is challenging for most automakers and suppliers. In addition, there could be resistance from dealers, as OTA updates represent a potential loss of their service business.
- The need to pay for the connection to the vehicle also is a concern. If consumers do not subscribe to a data connection, then the automaker must pay CSPs for that data connection to the vehicle, creating a burden on carmakers.

### User Recommendations

- Stop using a simple ROI equation for introducing OTA as these updates must be done to facilitate and implement many advanced technologies and new business models.
- Ensure that teams are set up to create and test new software on a constant basis by working with engineering and business partners rather than just reacting to whatever problems may exist on vehicles in the fleet.
- Invest in a new system for developing software that puts an emphasis on continuous deployment, rather than multiyear deployment cycles.
- Emphasize cybersecurity by using software that can operate within a network-based security monitoring system. Automakers must determine whether it is more advantageous to build their own OTA infrastructure solution, partner with a provider for a solution or use a hybrid approach.
- Seek vendors that can execute OTA updates securely and efficiently to minimize network demand and limit the cost of downloads.

### Sample Vendors

Airbiquity; Amazon (AWS); Aptiv; Microsoft; Samsung

**Gartner Recommended Reading**

Three Ways Automakers Can Successfully Deliver Over-the-Air Updates

Market Trends: Software-Defined Vehicles Will Disrupt the Automotive Supply Chain

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Market Trends: Software-Defined Vehicles Will Disrupt the Automotive Supply Chain

Guide to Connected Car Profitability

## Proactive Software Deployment

**Analysis By:** Jonathan Davenport

**Benefit Rating:** High

**Market Penetration:** Less than 1% of target audience

**Maturity:** Emerging

### Definition

Proactive software deployment is the ability to create, test and then deliver new software versions frequently when all relevant tests have passed. Proactive software updates are usually delivered using over the air (OTA) software updates. An example would be how car makers deliver bug fixes and new functionality to customers.

### Why This Is Important

Proactive software deployment enables incremental improvements to be made to vehicle firmware and software. These OTA updates enable owners to unlock new functionality and experience improvements over a product's lifetime.

### Business Impact

- The ability to fix issues on vehicles without having to visit a repair shop. For automakers, this has the potential to deliver significant cost savings for warranty and recalls.
- Remote maintenance will reduce breakdowns with associated improvement in customer satisfaction and brand loyalty.
- Developing and deploying new and improved software to vehicles unlocks potential for additional revenue streams. Research shows Tesla's annual software revenue per vehicle in operation, in 2019, was $1,177.

### Drivers

- The technique of proactive software deployment is quite nascent, but competitive pressure from companies like Tesla are driving the market forward. For example, Tesla delivered an OTA update to a Model 3, which improved the car's braking distance by almost 20 feet, after Consumer Reports had previously shown the vehicle's stopping distances were significantly longer than any other contemporary car.
- Most other automakers are already deploying some form of OTAs and are gradually increasing their frequency.
- Future software-defined vehicle architectures, such as Volkswagen's ID family of electric vehicles, support easier updates with fewer control units and modern software technology.
- New market entrants working with a "greenfield" vehicle electronic and electrical (E/E) architecture, following an agile software development process, will deliver proactive software deployment much quicker than traditional OEMs that have to work with a wide range of legacy systems.
- Auto companies building internal software development capabilities and staff, as well as new organizational structures to deploy software on a batched basis, will promote this practice. For example, Volkswagen Group created a software business in 2020 branded CARIAD. According to the company, it plans to grow its team to 10,000 digital experts to support its ambition to boost the in-house share of car software development from less than 10% in 2019 to at least 60% by 2025.

### Obstacles

- Automakers have begun to alter internal processes to shift to regular updates and upgrades, but progress remains fairly slow, because it requires time for organizational changes to stabilize.
- Automakers are set up to produce physical products, not to develop software, which usually requires an agile organization and development process.
- Even if OTA updates are technically possible, it still requires effort and organizational change to generate software versions for a wide range of different models. Each model might have a complex architecture with up to 100 control units that can differ significantly between vehicles in an automaker's fleet.
- The potential negative impacts of making changes to mission-critical safety software applications is something that many in the industry are extremely nervous about.
- Updating vehicles with new functionality is often not possible where embedded ECU compute power is limited and memory has already been consumed by the software at the start of production.

### User Recommendations

CIOs and IT leaders in automotive OEMs need to:

- Excel at in-house software development by bringing together all IT functions into a single team and then focus on recruiting top software engineering talent.
- Work in an agile software development environment by focusing on releasing and delivering products to customers in contrast to the traditional project-oriented workflow.
- Ensure the highest levels of safety by using digital twin technology to test and simulate software across each vehicle model variant prior to deployment.
- Align all participants that are delivering components of a vehicle's software stack by preparing contracts for services in advance, which allows for proactive software deployment.

### Sample Vendors

Aptiv; Daimler; Elektrobit; Tesla; Toyota; Volkswagen

### Gartner Recommended Reading

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Market Trends: Software-Defined Vehicles Will Disrupt the Automotive Supply Chain

Guide to Connected Car Profitability

Three Ways Automakers Can Successfully Deliver Over-the-Air Updates

A Guidance Framework for Continuous Integration: The Continuous Delivery 'Heartbeat'

## Electric Vehicles

**Analysis By:** Zarko Sumic

**Benefit Rating:** Transformational

**Market Penetration:** 5% to 20% of target audience

**Maturity:** Early mainstream

### Definition

Electric vehicles (EVs) use battery-stored electricity to power one or more electric motors or traction motors for propulsion. They are recharged by connecting the vehicle to public or private charging infrastructure. Continued R&D efforts into developing battery technology to achieve longer driving ranges are crucial to making EVs a viable alternative powertrain technology for passenger and commercial vehicles.

### Why This Is Important

Electric transportation offers growth opportunities for utilities in mature energy markets. By controlling/influencing charging via different commercial programs, utilities can use EV batteries as intermittent energy storage to:

- Act as a buffer for daily variations in energy consumption
- Address flexibility needs to counter renewables' intermittency

These can lessen the pressure on utilities' resource and infrastructure capacity and provide additional societal and environmental benefits such as $CO_2$ emission reduction.

### Business Impact

EV will positively impact utility sector revenue as demand increases in more-developed energy markets. Delivery will be affected by a need to strengthen the distribution infrastructure to meet this demand. The retail segment will require deployment of OT solutions (e.g., car identification, smart metering) and IT solutions (e.g., new billing and transaction processing). Some blockchain technologies have been trialed to create an EV charging payment and transaction monitoring platform.

### Drivers

- EVs are an important powertrain technology to address governments' emission mandates for fuel efficiency gains. EVs play a critical role in meeting environmental goals by reducing $CO_2$ emission in the transportation sector. The International Energy Agency (IEA) Sustainable Development Scenario outlines investments in electric vehicles as one of the key contributors to decarbonizing our energy future.
- According to the IEA Global EV Outlook 2020 report, sales of electric cars topped 2.1 million globally in 2019, surpassing 2018 — already a record year. Electric cars, which accounted for 2.6% of global car sales and about 1% of global car stock in 2019, registered a 40% year-over-year increase. IEA estimates that by 2030 the number of EVs will reach almost 250 million. Consequently, EVs are quickly becoming one of the largest flexible loads on the grid in many countries.
- Ambitious policy announcements have been critical to stimulating the EV rollout in major vehicle markets in recent years. Countries leading in electric mobility use a variety of measures, such as:
  - Fuel economy standards coupled with incentives for zero- and low-emissions vehicles
  - Economic instruments that help bridge the cost gap between electric and conventional vehicles
  - Support for the deployment of charging infrastructure
  - Extending policy support to address the strategic importance of the battery technology value chain

### Obstacles

- EV deployment is not simply “plug and play” for electric utilities. Utilities do not have a major impact on EV adoption and tend to take a reactive posture, aiming preemptively to mitigate the negative impact of increased EV adoption on the existing distribution network. To capture digital transformation opportunities EVs can offer, utilities need better visibility of EVs and their charging patterns.
- Most of the utility projects are exploring control charging models (or potentially the future vehicle-to-grid) that leave the companies in control of the charge and discharge process. Although this approach provides the most benefits to utilities and alleviates stress on the infrastructure from the additional load, it is not convenient for customers and may impede adoption.

### User Recommendations

- Modify and develop new IT applications which would address the impact of EV on delivery infrastructure as well as take advantage of growth opportunities created by electrification of the transportation sector.
- Collaborate with automakers and/or utilize an independent service provider to address offboard, energy-charging aspects, including vehicle and user identification, metering and billing.
- Make EV adoption easy and convenient for consumers, and provide adequate charging infrastructure by investing significantly in OT and IT. OT investments will be needed to enable access to vehicle identification and location, telematics, tracking, metering and remote battery status monitoring. IT investments will be needed to support billing, settlement and payment functions.

### Sample Vendors

BMW Group; Ford; General Motors; Mercedes-Benz; Nissan Motor; Rivian; Tesla

### Gartner Recommended Reading

Guide to New Business Models in the Electric Vehicle Ecosystem

Top 10 Trends Driving the Utility Industry in 2021

Market Guide for Distributed Energy Resource Management Systems

What a CIO Needs to Know About the Rise of Electric Vehicles

## HD Maps

**Analysis By:** Jonathan Davenport

**Benefit Rating:** High

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Adolescent

### Definition

High definition (HD) maps are developed as an additional layer on top of traditional navigation maps to provide autonomous vehicles with data to localize themselves, plan maneuvers and improve the driving comfort for passengers. HD maps are designed to be read by a computer. These maps provide a centimeter-level accuracy of 3D road geometry, boundaries and permitted traffic routes, along with semantic information about the environment, such as the position of traffic lights and road signs.

### Why This Is Important

HD maps provide autonomous vehicles with environmental knowledge to help navigate the road infrastructure. Not having an HD map can be likened to how a human driver feels when driving through an unfamiliar city. In this example, humans' stress levels rise, as they don't know which lane to be in, which traffic lights to watch at intersections, what the speed limit is, etc. So, by providing these sorts of data points, the HD map removes a burden from the autonomous vehicle's perception system.

### Business Impact

- HD maps provide an additional data feed to enable the autonomous vehicle to make better informed decisions.
- Vehicle sensor suites can capture data that can be used to triangulate a vehicle's position on an HD map, providing centimeter-level accurate localization.
- HD maps provide driving style data. For example, while it may be safe and within the speed limit to drive around a corner at a certain speed, the HD map can provide reference speed information to ensure passengers feel comfortable.

**Drivers**

- HD maps are becoming easier to incorporate into vehicles. Historically, HD maps required very large onboard storage, with file sizes exceeding 100TB. However, companies such as Mobileye and DeepMap have spearheaded a revolutionary approach that creates lighter weight HD maps that contain the essential information autonomous vehicles need to drive and localize themselves.
- There is also a trend toward simplifying the building (and maintenance) of HD maps, which has been a bottleneck to map expansion in the past. Vendors are creating solutions that enable a road to be driven multiple times with a standard production vehicle fitted with camera, inertial measurement unit (IMU) and GPS technology, as well as lidar and radar, to capture the necessary data points about the road's surroundings (e.g., buildings, street furniture and road curvature). These data points are uploaded to the cloud over the cellular network and kept fresh by the distribution of delta updates over the air.
- In the long run, it is likely that HD maps will be standardized across manufacturers and become a commodity. Activities for standardization are happening now (e.g., in the Navigation Data Standard [NDS] Association), but are not yet complete. There is also the potential of de facto standards emerging from innovators in this field, like Waymo or DeepMap.
- The opportunity for HD maps extends beyond autonomous vehicles. Broader autonomous things (e.g., robots, drones, ships and industrial equipment) will require rich information about their operational design domain (ODD), which extends the reach for map developer's solutions.

### Obstacles

- Traditional mapping companies use surveying vehicles to build a map. This approach is expensive and doesn't scale because roads need to be continually surveyed to maintain accuracy.
- Real-time kinetic (RTK) solutions improve the accuracy of GNSS-based localization by identifying satellite position errors. RTK could cannibalize the localization side of HD maps.
- Elon Musk's comments about how Tesla considered using "high-precision lane line [maps], but decided it wasn't a good idea" has caused a minority in the industry to question the importance of HD maps.
- Though the production of HD maps is becoming more scalable by leveraging fleetwide data collection, maps still require manual annotation, for example, so that the autonomous vehicle knows which set of traffic lights it should be watching.
- Companies that do not have access to large vehicle fleets will be at a disadvantage from the perspective of updating and extending HD maps.

### User Recommendations

Companies developing vehicles capable of operating autonomously should:

- Overcome the challenge of building and maintaining an HD map by collecting camera and other sensor data from third-party vehicle fleets equipped with advanced sensors (e.g., cameras and radar devices).
- Work collaboratively with traditional mapping companies, IT services firms or startups to build and maintain an HD map in the autonomous fleet.
- Adapt to differing regional conditions by developing systems that can comply with different regulations, especially in China, where mapping is strictly regulated.
- Invest in storage and computing resources for automated processing of map input data to streamline and deliver updates over-the-air to vehicles.
- Design safe autonomous vehicles by ensuring they can work in situations in which the HD map is not correct due to changes in the environment (e.g., construction, road maintenance, accidents).

- Set the ODD of vehicles to ensure they only operate in areas with an up-to-date HD map.

### Sample Vendors

Civil Maps; DeepMap; HERE Technologies; Mobileye; MOBILTECH; TomTom

### Gartner Recommended Reading

Cool Vendors in Autonomous Vehicle Systems

Vendor Rating: Intel

Top 10 Strategic Technology Trends for 2020: Autonomous Things

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

## Autonomous Vehicle Perception System

**Analysis By:** Jonathan Davenport

**Benefit Rating:** Transformational

**Market Penetration:** 1% to 5% of target audience

**Maturity:** Adolescent

### Definition

Autonomous vehicle perception systems generate a virtual representation of static obstacles and moving objects to identify free space and plan a vehicle's driving path. Software takes sensor data as an input, fusing camera, radar, lidar and other sensors, based on statistical methods or artificial intelligence, and outputs a representation of the vehicle's surroundings that neural networks can use to control automated vehicles.

### Why This Is Important

Advanced sensor data fusion and perception systems are fundamental to autonomous driving use cases. So all automotive OEMs and autonomous vehicle technology firms working on the perception part of automated vehicles are developing this technology and implementing it in development projects, and some even have limited commercial deployments. Many ADAS solutions, such as Tesla's Autopilot, also use perception systems, as do some aftermarket video telematics solutions like Samsara and Netradyne.

### Business Impact

- The core commercial application is for ADAS use cases, such as supporting automatic emergency braking, automated lane keeping assist and adaptive cruise control safety features.
- The perception algorithm is one of the core elements that will make the autonomous vehicle (Level 3 to Level 5) safe, secure and trusted by consumers.
- All automated vehicles require a perception system, so eventually the technology will become a commodity, with perception systems optimized for specific use cases.

**Drivers**

- The requirement for perception algorithms is broad, underpinning Level 2 automation now and up to Level 5 functionality in the future. As a result, long-term investment in varying system sophistication will be necessary.
- The perception algorithms that underpin the most complex element of a self-driving system have the potential to unlock radical improvements in transportation economics, cutting operational costs and increasing vehicle utilization.
- New regulations mean that, through 2021, the functions for Level 3 and higher automation will begin to be released on a commercially deployed basis for both passenger cars and mobility services use cases, but in very small volumes.
- Perception algorithms are being provided with an ever-richer understanding of the vehicle's environment, thanks to advancements in sensor technology (lidar sensor, camera and imaging radar technology) development.
- Beyond autonomous driving, perception algorithms are being used to localize the vehicle in a specific lane and provide insights about the future driving path to underpin human-machine interface use cases. For example, head-up information can be intelligently overlaid onto the road surface, providing drivers with contextual information projected virtually in front of the vehicle through the windshield or on existing in-vehicle infotainment and digital instrument cluster systems.
- Companies are investing in perception algorithms, because the applicability of the software will not be limited to the automotive industry. The perception system in its final developed stage will provide a generic capability of "things," "vehicles," "sensors" and "machines" to make sense of a complex environment populated by human beings. For example, the technology could easily be adopted in commercial transportation, automated security applications (for example, perimeter security) and robotics, and it may also have military applications.

### Obstacles

- A main challenge that remains is standardization of methods for performance validation of usage/functional safety within International ISO 26262, plus assessment of broader artificial-intelligence-based system failures.
- Build systems and processes to label and manage the huge quantities of situational sensor data (different junctions, road networks and objects) required to train the neural networks.
- The fact that automated vehicles will operate in highly diverse traffic situations and road environmental conditions means the perception system technology must be able to address a long tail of rare incidents.
- The finite number of customer contracts combined with the major cost burden of validating highly automated functions has already resulted in market consolidation.
- Cross-vendor standardization, developed in collaboration with OEMs, will follow based on lessons from ongoing/emerging large pilots, and standardization can also be driven by safety considerations and regulations.

### User Recommendations

- Create a perception system that is adaptable to different sensor feeds, sensor positions and environmental inputs. This is important to enable a single perception algorithm, designed for a certain use case, to be easily deployed on different vehicle models.
- Design in the capability to retrain perception algorithms quickly to enable deployments into different countries (road signs and markings, traffic regulations, or animals), cities or use cases (such as robotaxi, mining or delivery robot).
- Build scalable perception systems with functional software components that are able to cope with ever-increasing volumes of test-use cases.
- Invest in simulation hardware/software/application technologies that help train the deep learning networks for executing safe and secure driving maneuvers that are required for certain parts of the perception systems.
- Enable rapid testing of perception software by ensuring that any alterations to the algorithm can be deployed on test vehicles in an agile manner.

**Gartner Recommended Reading**

Cool Vendors in Perception Solutions for Autonomous Vehicles

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Top 10 Strategic Technology Trends for 2020: Autonomous Things

Market Trends: Monetizing Connected and Autonomous Vehicle Data

Market Insight: Use Situationally Aware Platforms to Enable Safe Autonomous Vehicle Handovers

Cool Vendors in Autonomous Vehicle Systems

Public Opinion Will Be Critical to Successful Autonomous Vehicle Adoption

Market Trends: Establishing Autonomous Vehicle Safety Standards Is Critical for Successful Implementation

Market Insight: Cracking the Semiautonomous Machine-Human Handover Problem

## Entering the Plateau

### Connected Car Platforms

**Analysis By:** Michael Ramsey

**Benefit Rating:** Transformational

**Market Penetration:** More than 50% of target audience

**Maturity:** Early mainstream

#### Definition

Connected car platforms make available a set of cloud-based services and tools that enable the carmakers or technology companies to develop in-vehicle services as well as gain insights into the use of the vehicles. Enabled services include speech recognition, communications, infotainment and payments, telematics and vehicle management services, advanced and contextually enriched navigation, and customer insights for marketing product development and continuous engineering purposes.

#### Why This Is Important

Connected car platforms bring together vehicles operating on the road with automaker or third-party services. These platforms enable connected vehicle data to be turned into new services to consumers, change potential ownership models, lead to cost-saving predictive analytics and more feedback to development engineers. They are the centerpiece of the changing business model in automotive.

#### Business Impact

These platforms manage solutions for connectivity, content, service orchestration and integration/development for connected vehicle services. The operation of a single connected vehicle platform will further enable OEMs in integrating consumers, dealers, repair and service, aftermarket services, as well as building up automotive data marketplaces to sell data to third parties. The technology is one of the core enablers of OEM monetization of the connected vehicle.

#### Drivers

- The expanding number of connected vehicles is the largest-single driver for connected car platforms and their success. Tens of millions of new vehicles are added every year, creating a better environment for platforms to be successful.

- Managing all these connections across different regions also requires some standardization. The expansion of capabilities by hyperscalers is increasing the value of the platforms to executing new business models, such as moving to a more service-based revenue model and lowering the importance of the sale of new vehicles. The hyperscalers include Amazon Web Services (AWS), Microsoft Azure and Google, as well as a large array of specialized platforms that have more refined services aimed at the automobile.
- Mobility service operators or other large fleet owners can effectively create scale for platforms and create the viable use cases for applications and services that are delivered by them.

**Obstacles**

- First-generation platforms are currently evolving, and automakers are switching to cloud-service providers and telematics providers as they seek ways to establish services that stretch beyond individual countries.
- It may be difficult to create a combined global solution and it may not even make sense to do so given the differing regulatory requirements in the U.S., Europe and China.
- The lack of standard data formats and standard programming interfaces limits the ability to create an ecosystem of applications for vehicles.
- These obstacles are made harder to solve by the long development cycles in automobiles and the requirement to maintain functional safety standards.

**User Recommendations**

- Ascertain the capabilities of the emerging suppliers as well as their own capabilities. Is it worth developing things in-house when so much of the capability for these platforms could be managed by out-of-the-box platforms?
- Assess whether you must own the capability and spend the money to develop it, or outsource it to a third party, which could deliver it more quickly, but with less flexibility.

- Evaluate vendor lock-in at an early stage, as the platforms are only maturing and standards for data are yet to be defined. Vendors do increasingly offer fully vertically integrated platforms, such as connectivity and telematics services. It is important to retain flexibility of vendor choice on a connectivity level, independent of AI services or experience-relevant connected vehicle services, in order to further support multiple sourcing strategies.

**Sample Vendors**

Amazon; BrightBox; IBM; Microsoft; Mojio

**Gartner Recommended Reading**

2021 CIO Agenda: An Automotive Perspective

'Right to Repair' Initiative Could Have Significant Impacts on the Connected Car Ecosystem

The Future of Data-Driven Transportation Ecosystems

Guide to the Impact of 5G on Connected Vehicles

How to Become the Digital Automaker of the Future

Infographic: Artificial Intelligence Use-Case Prism for Automotive Enterprises

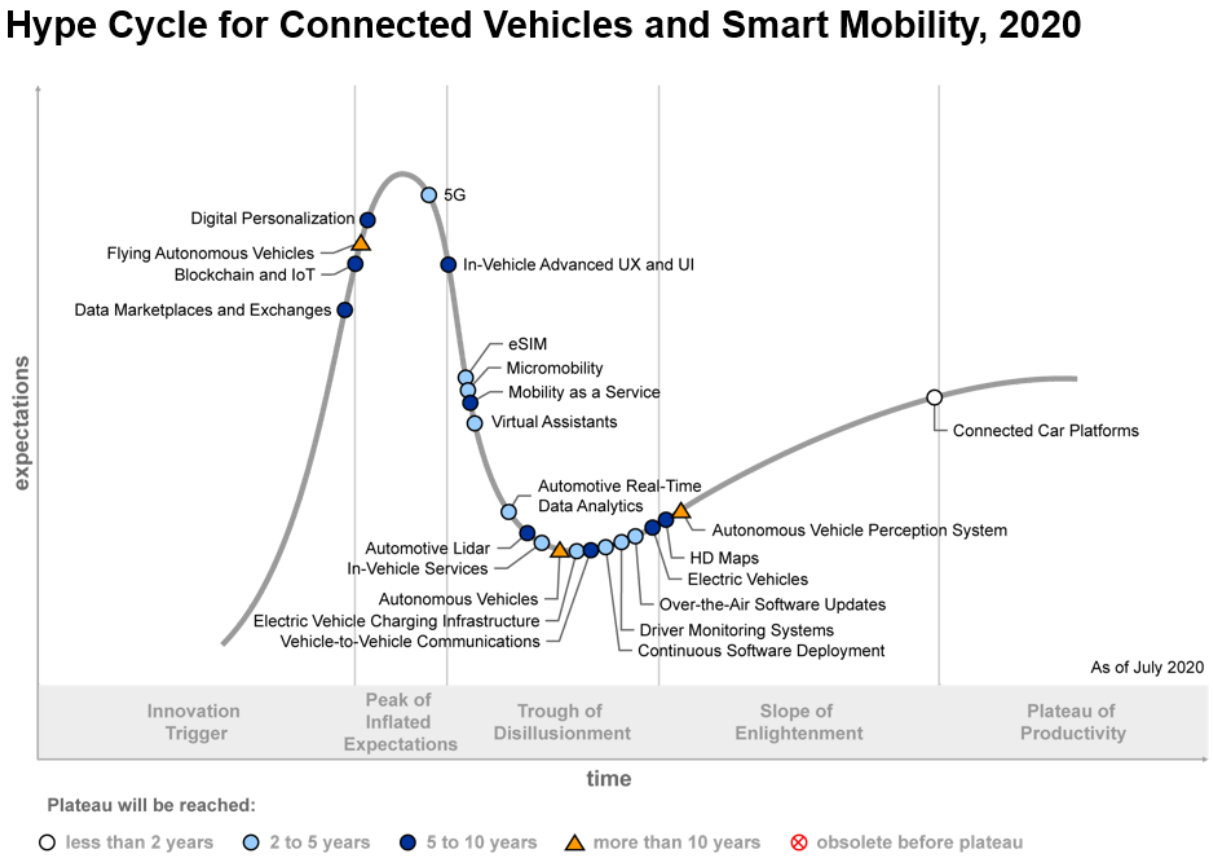
Market Insight: IoT-Based Digital Personalization, Part 1 — Improve Customer Retention

Market Insight: IoT-Based Digital Personalization, Part 2 — Architecture for Automotive Customer Retention

Market Trends: Monetizing Connected and Autonomous Vehicle Data

# Appendixes

## Figure 2. Hype Cycle for Connected Vehicles and Smart Mobility, 2020




Source: Gartner
ID: 450205

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# Hype Cycle Phases, Benefit Ratings and Maturity Levels

## Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

| Phase | Definition |
|---|---|
| *Innovation Trigger* | A breakthrough, public demonstration, product launch or other event generates significant media and industry interest. |
| *Peak of Inflated Expectations* | During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers. |
| *Trough of Disillusionment* | Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales. |
| *Slope of Enlightenment* | Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process. |
| *Plateau of Productivity* | The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase. |
| *Years to Mainstream Adoption* | The time required for the innovation to reach the Plateau of Productivity. |

Source: Gartner (July 2021)

Table 3: Benefit Ratings

| *Benefit Rating* ↓ | *Definition* ↓ |
|---|---|
| *Transformational* | Enables new ways of doing business across industries that will result in major shifts in industry dynamics |
| *High* | Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise |
| *Moderate* | Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise |
| *Low* | Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings |
| | |

Source: Gartner (July 2021)

### Table 4: Maturity Levels

(Enlarged table in Appendix)

| Maturity Levels | Status | Products/Vendors |
|---|---|---|
| *Embryonic* | In labs | None |
| *Emerging* | Commercialization by vendors<br>Pilots and deployments by industry leaders | First generation<br>High price<br>Much customization |
| *Adolescent* | Maturing technology capabilities and process understanding<br>Uptake beyond early adopters | Second generation<br>Less customization |
| *Early mainstream* | Proven technology<br>Vendors, technology and adoption rapidly evolving | Third generation<br>More out-of-box methodologies |
| *Mature mainstream* | Robust technology<br>Not much evolution in vendors or technology | Several dominant vendors |
| *Legacy* | Not appropriate for new developments<br>Cost of migration constrains replacement | Maintenance revenue focus |
| *Obsolete* | Rarely used | Used/resale market only |

Source: Gartner (July 2021)

## Document Revision History

Hype Cycle for Connected Vehicles and Smart Mobility, 2020 - 17 July 2020

Hype Cycle for Connected Vehicles and Smart Mobility, 2019 - 31 July 2019

Hype Cycle for Connected Vehicles and Smart Mobility, 2018 - 18 July 2018

Hype Cycle for Connected Vehicles and Smart Mobility, 2017 - 28 July 2017

Hype Cycle for Connected Vehicles and Smart Mobility, 2015 - 21 July 2015

Hype Cycle for Vehicle-Centric Information and Communication Technology (Vehicle ICT), 2014 - 21 July 2014

Hype Cycle for Vehicle-Centric Information and Communication Technology (Vehicle ICT), 2013 - 31 July 2013

Hype Cycle for Vehicle-Centric Information and Communication Technology (Vehicle ICT), 2012 - 30 July 2012

Hype Cycle for Vehicle-Centric Information and Communication Technologies (Vehicle ICT), 2011 - 27 July 2011

Hype Cycle for Vehicle-Centric Information and Communication Technologies (Vehicle ICT), 2010 - 22 July 2010

Hype Cycle for Vehicle-Centric Information and Communication Technologies (Vehicle ICT), 2009 - 24 July 2009

Hype Cycle for Vehicle-Centric Information and Communication Technologies (Vehicle ICT), 2008 - 1 July 2008

Hype Cycle for Vehicle-Centric Information and Communication Technologies (Vehicle ICT), 2007 - 30 June 2007

Hype Cycle for Automotive Information and Communication Technologies, 2006 - 26 June 2006

## Recommended by the Author

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

Create Your Own Hype Cycle With Gartner's Hype Cycle Builder

2021 CIO Agenda: An Automotive Perspective

'Right to Repair' Initiative Could Have Significant Impacts on the Connected Car Ecosystem

The Future of Data-Driven Transportation Ecosystems

How to Become the Digital Automaker of the Future

Infographic: Artificial Intelligence Use-Case Prism for Automotive Enterprises

Building a Digital Automaker: How to Make New KPIs

Guide to New Business Models in the Electric Vehicle Ecosystem

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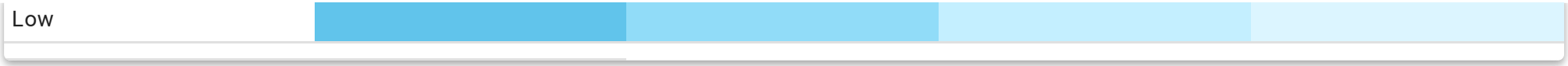
## Table 1: Priority Matrix for Connected, Electric and Autonomous Vehicles, 2021

| Benefit | Years to Mainstream Adoption | | | |
|---|---|---|---|---|
| | Less Than 2 Years | 2 - 5 Years | 5 - 10 Years | More Than 10 Years |
| Transformational | Connected Car Platforms | Automotive Digital Security<br>eSIM<br>Virtual Assistants | Autonomous Vehicle Perception System<br>Blockchain and IoT<br>Electric Vehicles<br>Software-Defined Vehicle<br>Vehicle-to-Everything Communications | Autonomous Vehicles |
| High | | 5G<br>Automotive Lidar<br>Automotive Real-Time Data Analytics<br>Connected Vehicle Services<br>HD Maps<br>Over-the-Air Software Updates<br>Proactive Software Deployment | Data Marketplaces and Exchanges<br>Digital Personalization<br>In-Cabin Emotion AI<br>In-Vehicle Advanced UX/UI<br>Solid-State Lithium Ion Batteries | |
| Moderate | | Driver Monitoring Systems<br>EV Charging Infrastructure<br>Shared Mobility | Car Wallet<br>Hydrogen-Powered Vehicles | Intravehicle Wireless Communication |




Source: Gartner (July 2021)

## Table 2: Hype Cycle Phases

| *Phase* | *Definition* |
|---|---|
| *Innovation Trigger* | A breakthrough, public demonstration, product launch or other event generates significant media and industry interest. |
| *Peak of Inflated Expectations* | During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers. |
| *Trough of Disillusionment* | Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales. |
| *Slope of Enlightenment* | Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process. |
| *Plateau of Productivity* | The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase. |
| *Years to Mainstream Adoption* | The time required for the innovation to reach the Plateau of Productivity. |

| Phase ↓ | Definition ↓ |
| --- | --- |

Source: Gartner (July 2021)

### Table 3: Benefit Ratings

| Benefit Rating ↓ | Definition ↓ |
| --- | --- |
| *Transformational* | Enables new ways of doing business across industries that will result in major shifts in industry dynamics |
| *High* | Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise |
| *Moderate* | Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise |
| *Low* | Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings |

Source: Gartner (July 2021)

## Table 4: Maturity Levels

| *Maturity Levels* ↓ | *Status* ↓ | *Products/Vendors* ↓ |
|---|---|---|
| *Embryonic* | In labs | None |
| *Emerging* | Commercialization by vendors<br>Pilots and deployments by industry leaders | First generation<br>High price<br>Much customization |
| *Adolescent* | Maturing technology capabilities and process understanding<br>Uptake beyond early adopters | Second generation<br>Less customization |
| *Early mainstream* | Proven technology<br>Vendors, technology and adoption rapidly evolving | Third generation<br>More out-of-box methodologies |
| *Mature mainstream* | Robust technology<br>Not much evolution in vendors or technology | Several dominant vendors |
| *Legacy* | Not appropriate for new developments<br>Cost of migration constrains replacement | Maintenance revenue focus |
| *Obsolete* | Rarely used | Used/resale market only |

Source: Gartner (July 2021)