WHITEPAPER / AVP Services

Automated Valet Parking (AVP)

How Connectivity and Smart Infrastructure Shapes AVP — Re-thinking Mobility

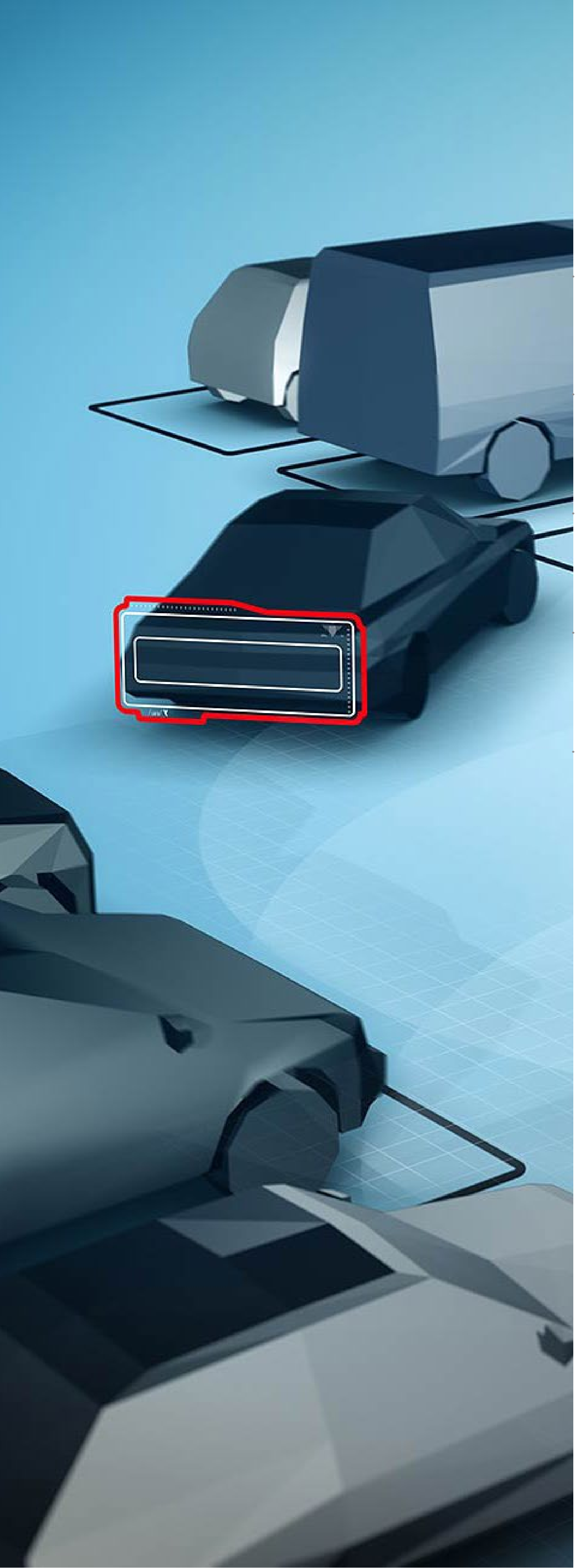

Table of Contents

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1. What is AVP?

Today, the idea of autonomous driving is well established in the automotive and mobility industry and an essential part of the technological roadmap of almost all automakers and their suppliers. Autonomous driving is not a recent idea. It has evolved and manifested in different ways in different industries. In the agriculture industry for instance automation of trucks is now an indispensable factor. Likewise for manufacturing and shop floors, where AGVs (automated guided vehicles) are already state of the art and the usage of automated forklifts is a standard practice. The urge for automation was always motivated by two factors: increase safety and increase efficiency; and therefore enabling new business approaches. Currently autonomous driving is on the verge of a breakthrough, in both the passenger car and the commercial vehicle domain. One may ask, why it took so long. The constraint of driving on public roads and in non-fenced and barely structured spaces has a big impact on a high requirement for safety. This is still a major hurdle to overcome. With new sensor technologies, high performance computing, high-speed and reliable connectivity capabilities the situation is changing.

The Operating Design Domain (ODD) can vary from highway automation to urban "robotaxi", but driving is not always from A to B. Drivers spend large amounts of time searching for parking or relocating their vehicles in the same area [1]. This is the least fun part of driving - highly inefficient, time consuming and stressful. Who has not experienced a long and tedious search for a parking lot in a huge and crowded parking facilities. What if you could drop off your car at the parking garage entrance and the car figures out by itself where to park. Whenever you need the car again you just call it and it will meet you at the pickup zone. This idea gave birth to the notion of Automated Valet parking (AVP), the automated version of valet parking, **(see Figure 1).** One can easily imagine how useful and convenient such a technology is:

- »» Drop off your vehicle at the mall entrance and enjoy shopping without the hassle of finding a parking spot or worrying if it is too narrow for your vehicle
- »» Drop off your car at the airport designated locations and hurry to catch you flight. The car will take care of itself
- »» Pick up your rental car when you arrive or better yet the car will drive automatically and pick you up from where you are waiting

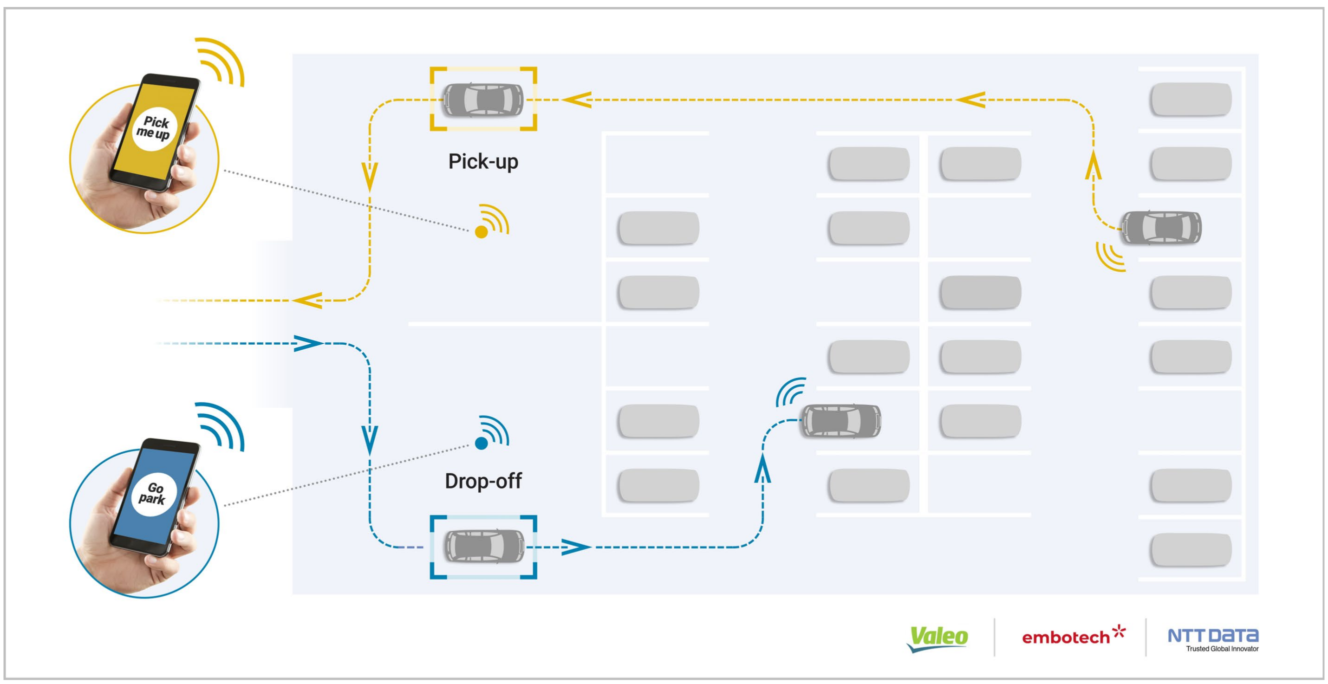
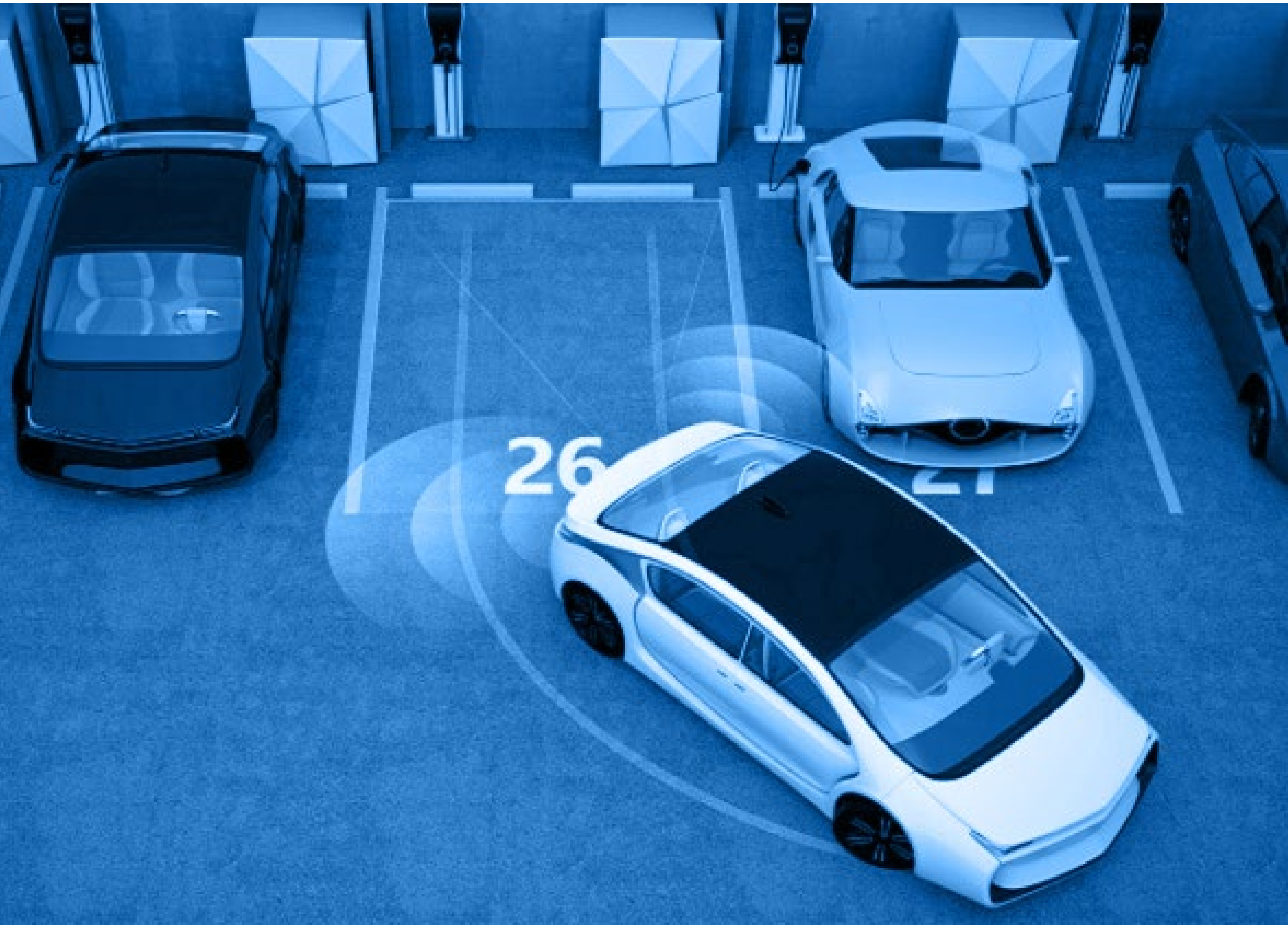


Figure 1
Automated Valet Parking

- Drive home to the suburbs. With one click, the garage door opens and your car finds its way in and closes the door

Aside from the numerous private car use cases one would immediately associate with there is also the industrial application aspect of this technology:

- Freshly produced cars at the end of the production line find their way out to the huge parking lots get charged automatically and loaded onto trains, ships and trucks to be delivered to the customers
- Delivery trucks collect goods from a logistics center and moving from one station to another automatically
- Rental cars returned by customers automatically queue in line to be washed and prepared for the next customer



2. AVP: Technology Overview

To realize such automation there are two opposite approaches: smart vehicle vs smart infrastructure. In the engineering community these approaches are referred as Type 1 and Type 2, respectively **(see Figure 2).**

the interoperability among AVP systems of different brands and different suppliers.

According to experts and developers in the automotive industry, Type 2 is more likely to be introduced first to the market. Even though it appears more simple and

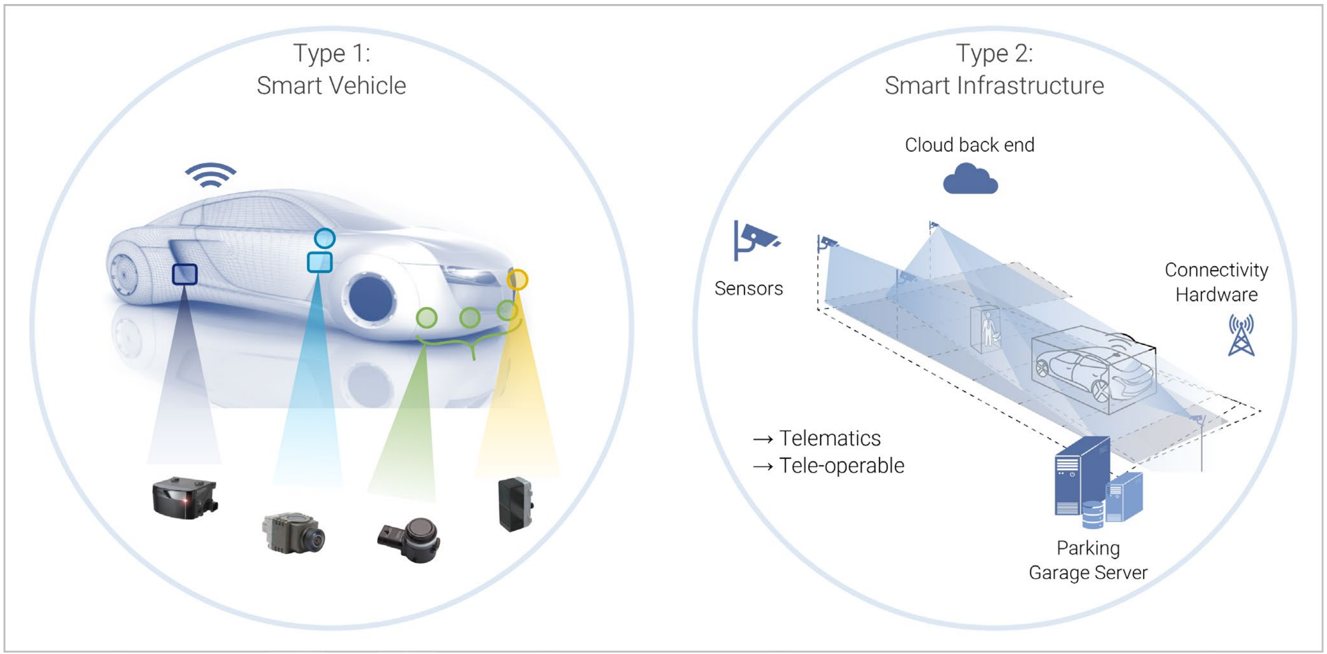


Figure 2
Types of Automated Valet Parking

In Type 1 the vehicle is 100% independent and autonomous. By using its own sensors, e.g. cameras, radars, ultrasonic sensors and its own perception and smart algorithms, the vehicle can recognize its environment, determine its current position, define its options to move and decides by itself where to drive and where and how to park.

In Type 2, it is quite the opposite. Sensors (e.g. cameras, lidars, etc.) are mounted outside the vehicle in the facility infrastructure (e.g. sailing and poles of parking lot). The vehicle recognizes the environment calculates how to move based on an algorithm then send it driving commands. The car just executes and is remotely driven by an external system that is completely responsible for the driving and parking automation.

The two types are now well established definitions in the industry. The International Organization for Standardization is currently working on releasing high-level standards for AVP systems (ISO 23374) [2] to accelerate the market introduction by assuring

straightforward, Type 1 requires sophisticated sensors and algorithms to be embedded in the vehicle. Currently this remains a costly endeavor. Furthermore, safety, regulatory and liability issues are unresolved. With Type 2, costs and complexity are taken out of vehicles and put in the infrastructure. Flexibility increases and costs reduces. One can use different set of sensors and adapt them to the environment. Alternatively deploy state of the art surveillance cameras or other sensors

> **"Beside public parking, AVP with smart infrastructure can be applied today in the industrial field, e.g. in car assembly plants"**

available in the market. Removing the automation software from the vehicle gets rid of the computational power restriction. It centralizes the "perception and thinking" of the AVP system and facilitates the safety and security assessment. Nonetheless, for Type 2 a vehicle-to-infrastructure interface has to be developed to enable the information exchange between the car and the smart infrastructure. In the medium run, such interface have to be standardized and agnostic from any car brand or any infrastructure. This will make sure that every vehicle can communicate with any infrastructure-based AVP system. This interoperability is the subject of the standardization work mentioned above [2]. The interoperability had been successfully demonstrated at the IAA mobility fair in Munich in 2021 by several OEM and suppliers [3], among the latter NTT DATA provided the connectivity with 5G [4].

In the following, we will be solely focusing on Type 2 AVP. **Figure 3** shows a simplified architecture of AVP Type 2. The functional principle is quite simple:

- »» The external sensors (cameras, lidars, etc..) observe the surrounding area and capture the current situation in form of data
- »» The data is sent to the perception software located in the back-end: this is the first path of connectivity: Sensor-to-AVP-System
- »» The perception software "understands" the data by identifying static and dynamic objects, e.g. by labeling the objects detected whether they are driving cars, parking cars, human, poles, and so on and so forth
- »» The velocities of the moving objects are estimated and assigned. The object list is handed over to the vehicle control system
- »» The role of the vehicle control system is to track and control the vehicles that are on the field. It calculates the necessary trajectories, translate them into driving commands and guide the vehicle from their current locations until they reach their assigned parking positions
- »» The control system is the gatekeeper for safety. It detects possible collisions and incidents and mitigate accidents either by calculating alternative routes or engaging the emergency braking system
- »» The driving commands are sent to the respective vehicles — this is the second part of connectivity: AVP-System-to-Vehicle
- »» The vehicles receive the driving commands through the above-mentioned vehicle-to-infrastructure interface. These commands are handed over to the car onboard electronic systems that execute the driving task and send back the actual status via the same interface to the backend.

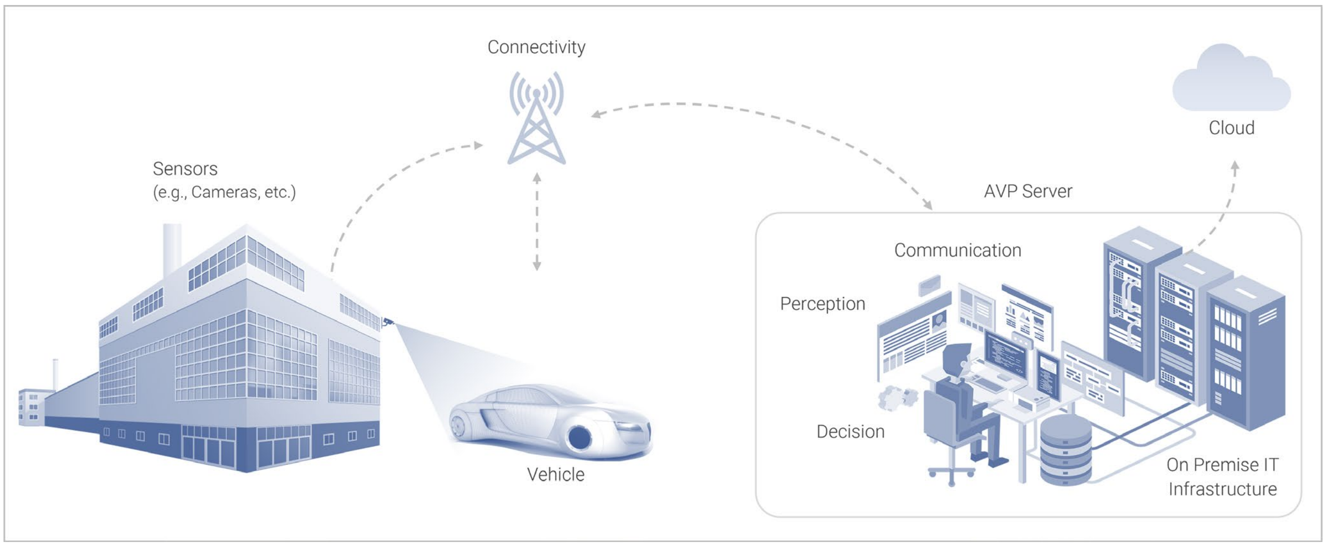


Figure 3
Principle of Infrastructure Based Automated Parking System

The technical requirements to be fulfilled by the car are nowadays almost standards, noticeably:

- »» Automatic transmission
- »» Shift and steer by wire

- Electronic stability program (ESP)
- Start/stop function
- Electric parking brake
- Connectivity interface, e.g. 5G sim Telematics control unit (TCU) — not a standard yet and varies according to the OEM vehicle series — or alternatively LTE (almost 100% standard but the technology will be outdated within the near future)

As mentioned above, the infrastructure-to-vehicle interface has to be implemented in the car. The interface consists of a software module that receives the driving commands from the smart infrastructure and send the actual information of the vehicle back to the AVP-Backend. The exchange of information is done according to a communication protocol. The protocol is currently subject to standardization work [2]. A common standard or common protocol language will allow every vehicle to communicate and understand every infrastructure. This is called interoperability. It is expected that the standardized interface will be implemented within the next two vehicle generations. Until then every car manufacturer has his own proprietary interface, such that an implementation of the technology, for single brand, e.g. in a factory environment (see also below) is possible.

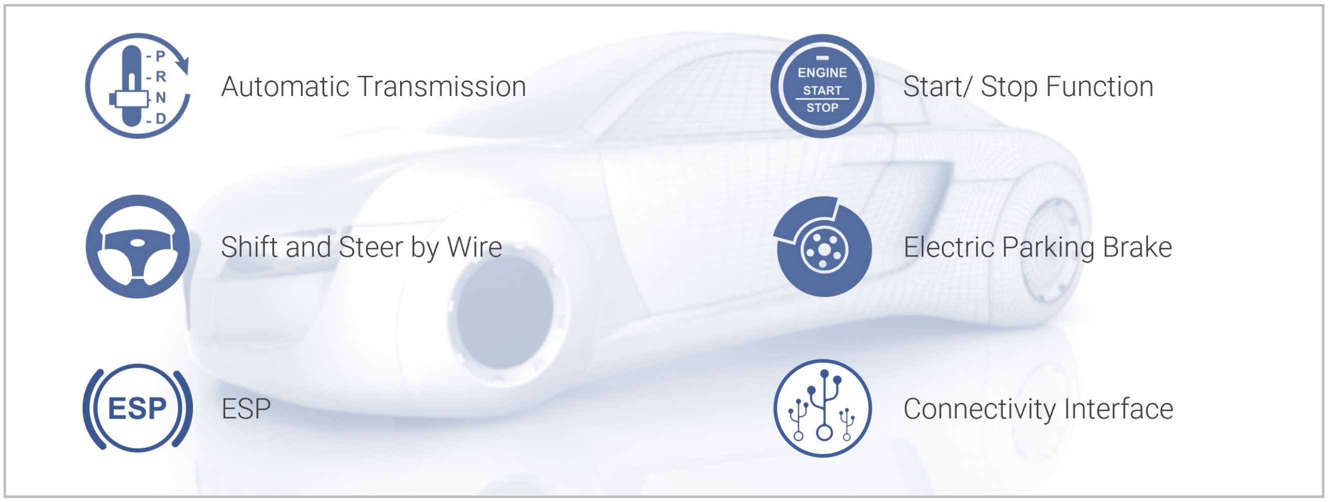


Figure 4
Vehicle Requirements for AVP

3. Use cases for automated parking

Even though the "valet" use case in a parking is the prime example for the Type 2 smart infrastructure based approach, there are more cases or scenarios that are feasible and even more likely to be realized soon. Generally, the market can be categorized in four segments listed from short to long run prospects:

- »» **Auto manufacturing plants:** Vehicles coming off the production lines have to be parked before being delivered to retailers or final customers. This is done manually by jockeys that drive the vehicles back and forth. AVP helps to automate this procedure, increase efficiency and reduce costs. This use case can be implemented within the controlled ecosystem of the auto manufacturer. The technology is deployed in a fenced private area. The controlled vehicles belong to one brand and thus, interoperable interfaces are not required.
- »» **Big Car Retailer:** The respective market segment may appear less large. However, this would be a very important step to deploy the technology outside private, controlled and fenced area in the public space. As long as only one brand of vehicles is considered, interoperability is not required.
- »» **Car logistics yards:** e.g. supply chain logistics, ports, car rental parking, in other words, everywhere vehicles are transported in an industrial field. This implementation will stay within a controlled, private and fenced area but will require full interoperability as transported vehicles can be of different brands and of different technologies
- »» **Public (or valet) parking:** A prime example. AVP technology should work safely and reliably in a public environment. A full interoperability is required. Thus, it is expected that this use case will be the last to be realized.

4. How to achieve scalable deployment of AVP

A vital question remains - How will this technology emerge from bespoken implementation in controlled fenced areas into a scalable consumer business on public space? Besides the technical aspects discussed above we believe that three major factors will enable AVP to conquer public spaces: safety, 5G connectivity and scalable Operations IT-platforms.

> **“Three major factors will enable AVP to conquer public spaces: safety, 5G connectivity and scalable Operations IT-platforms”**

Safety: Wherever machines are interacting with human, safety is of a big concern. This is no different with AVP. A special challenge with Type 2 AVP is that safety must be ensured on a multi-domain complex system. The vehicle itself, the infrastructure sensors, the connectivity, the software managing the systems and the IT backbone have to contribute in a holistic safety approach. A safety framework that combines and harmonizes the requirements of all domains is necessary. This framework will enable AVP operators to assess the safety of their systems according to standards and state of the art technology. Having such a framework will reduce time-to-market and accelerate the implementation and adoption.

5G Connectivity: The connectivity between the sensors and the backend (1st path of connectivity) as well as between the vehicles and the backend (2nd path of connectivity) are crucial for the success and market adoption. High or fluctuating latencies affect the stability and the safety of the system. If the latency is high, the response of the system is low when it comes to a necessary emergency brake to avoid accidents. Thus, the vehicle speed needs to be slower when system latency is high. This might make AVP very slow and inefficient provoking congestions during peak traffic time. 5G technology allows for ultra low latency and thus, for higher vehicle speed and efficient operations. Furthermore, the availability and reliability of the system is key. It is known that 5G provides above 99.99% of network availability and reliability. This will prevent cars from getting stuck or stopping due to unstable connectivity which would disrupt the operations significantly, making a deployment of AVP questionable.

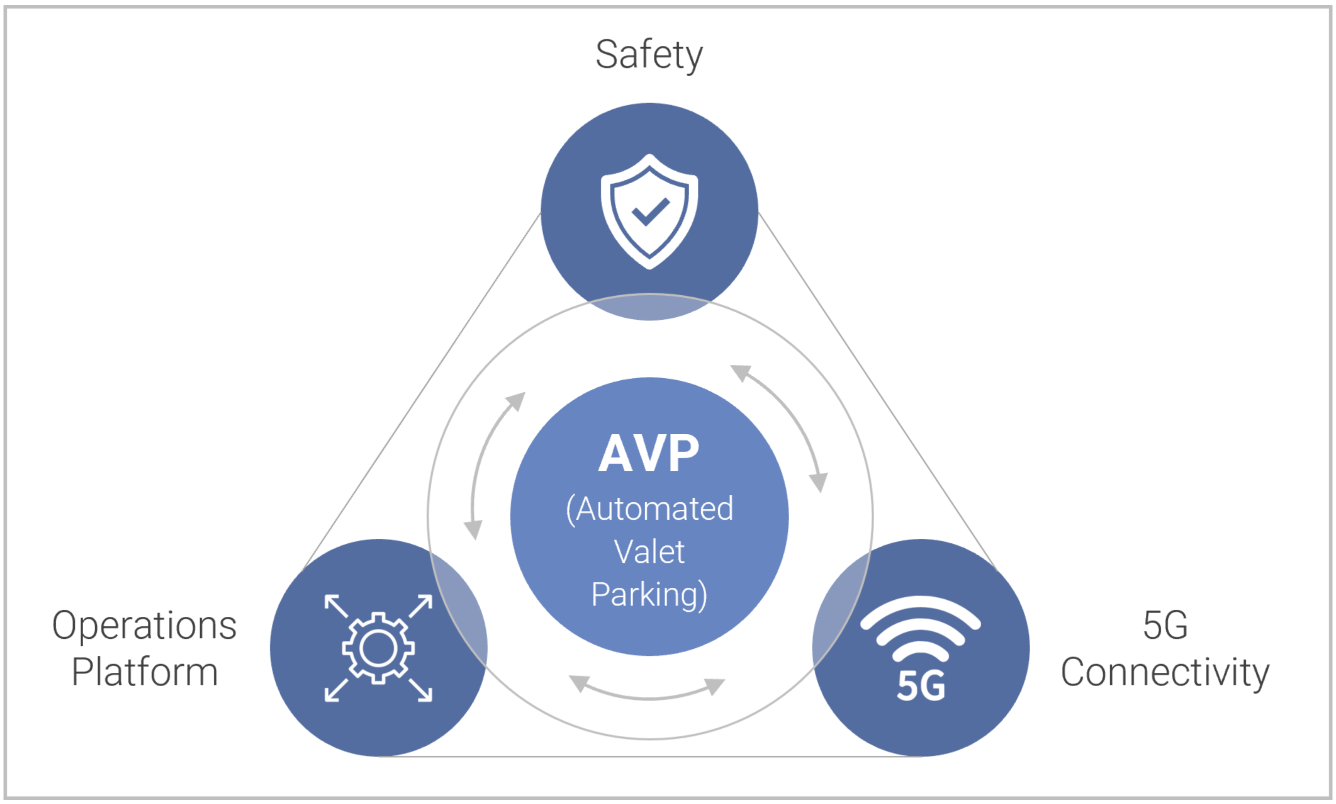


Figure 5
Major Enabler for Scalable AVP Business

Operations platforms: In all market segments automated parking is a 24-7 operation. Only the extensive and continuous use will drive the business case. The management of the vehicles goes beyond driving: e.g. data collection and monitoring, payment transactions for the public parking etc. This would need an appropriate operations (IT) platform that is able to operate different facilities simultaneously, aggregate data and exploit it through analytics. It is expected that the market will be driven by big players that operate multitude of facilities.

VEN.AI

Valeo, Embotech and NTT DATA have joined forces to develop and provide a complete automated parking solutions that addresses the technical and commercial challenges above. A joint venture VEN.AI developed an end-2-end AVP/AVM solution.

Valeo provides the perception part, including sensors, perception and environment model software as well as the infrastructure-to-vehicle Type 2 interface. Embotech provides the vehicle control management algorithms needed to precisely control at real-time multiple vehicles simultaneously while ensuring driving safety. NTT DATA provides the connectivity solution, the IT infrastructure and engages with the clients as a system integrator and operator. The powerful and complete solution of VEN.AI was successfully demonstrated with several clients and presented to the public at the IAA mobility show in Munich, 2021.

Citation:

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4. Valeo, NTT DATA and Embotech collaborate to showcase Automated Valet Parking at IAA
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References — Pictures
Page 1: Imagine Photographer / Royalty Free
Page 3: Automated Valet Parking / Royalty Free
Page 4: Types of Automated Valet Parking / Royalty Free
Page 5: Principle of Infrastructure Based Automated Parking System / Royalty Free
Page 6: Vehicle Requirements for AVP / Royalty Free
Page 9: Major Enabler for Scalable AVP Business / Royalty Free

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