Disrupting Automotive Logistics
through a Combined Intelligent and Autonomous Transport Solution

Anders Hjalmarsson-Jordania
Assoc. Professor1,2,
Niklas Sundin3,
Martin Romell4,
Johan Isacson5,
Carl-Johan Aldén6

1 RISE Viktoria, Lindholmsgatan 3A, 51833 Gothenburg Sweden anders.hjalmarsson@ri.se
2 University of Borås, Department of Information Technology, 50190 Borås, Sweden
3 Consat Engineering AB, Gothenburg Sweden
4 Volvo Car Group, Gothenburg Sweden
5 Combitech AB, Gothenburg, Sweden
6 SEMCON Sweden AB, Gothenburg Sweden

Abstract
This technical paper addresses a novel and scalable autonomous transport system, applied in the automotive logistics context. Production cars will be utilized as their own means of transportation in the logistic chain, requiring no human driver. The cars will be guided by a novel intelligent transport solution combined with existing on-board Advanced Driver Assistance Systems (ADAS) functionality. This includes using implemented sensors in the production car, fusion of sensor data collected by the car, and connectivity with existing and future mobile networks communication technology. An intelligent off-board traffic control system will manage each production car in the logistic flow and direct the car from point A to point B, as well as manage the interaction between cars in the flow. A prototype of the system has been developed, implemented in a production car and during 2017, being tested in live car-trials in Sweden. In this technical paper, we describe this evolution in vehicle logistics with a focus on its on-board core sub-system and the off-board traffic control system. We pinpoint design features in the system, as well as discuss the capacity for the system to disrupt contemporary models of automotive logistics.

KEYWORDS: Autonomous Transport Solution, Automotive Logistics, Disruptive Digital Innovation

Introduction
The trend is the same over the world. Digitalization and automation are creating an ever-greater mark on increasingly more activities in society. Highly automated manufacturing is nothing new, but the level of automation is now rapidly increasing as described in the concept of Industry 4.0 (Andrews 2017); e.g. in the distribution channel and logistic chain. And the benefits of autonomous driving technology benefits are numerous; there is strong appeal for end-customers in the promise of increased safety, and the convenience and freedom of choice with their now-liberated travel time (Fagnant & Kockelman 2015). Still, how can this technology impact process in areas beyond end-customer applications in factory processes and logistic chains?

This technical paper addresses how to take automated manufacturing to yet another level, through practical application. Using technical expertise and digital technology available today, the project Born to Drive (BtoD)1, has developed and demonstrated an intelligent solution for autonomous transport. Simply put, factory-complete cars are utilized as their own means of transport, without any added hardware, moving driverless from the manufacturing plant along the automotive logistic chain. The solution has been made possible by an innovative on-board autonomous transport application that combines with original on-board car functionality and hardware, guided by an off-board, newly developed Intelligent Traffic Control application.

This technical paper presents the solution and argues for its capability to disrupt automotive logistics. The paper pinpoints design features in the solution, and discusses the capacity for the system to disrupt the logic for how automotive logistics currently operates.

The paper is organised as follows. First, current trends in autonomous transport logistics are reviewed as a backdrop for the technical innovation. BtoD is then described in the broader terms of

1 Born to Drive (www.bortodrive.se) is a research and innovation project funded partly by Sweden’s Innovation Agency Vinnova/FFI (Fordonstrategisk Forskning och Innovation), and partly by participating partners in the project consortia: Volvo Car Group, Combitech, Consat, SEMCON Sweden AB, RISE Viktoria AB, Actia, Swedish Transport Administration and Swedish National Road and Transport Research Institute (VTI). The overall vision of the project is to change the future of logistics.
solution domain and overall concept. Subsequently, the solution is introduced in detail, followed by an overview of the technological solution in terms of an accounting of design choices. The paper concludes with a summary of lessons from the pre-trial tests and the live car trials performed during 2017, all of which is supporting evidence that the concept is substantiated and verified.

**Current Trends in Transport Logistics using Autonomous Technology**

In this chapter, trends and implications are reviewed from using autonomous technology in the automotive logistic chain.

**Autonomous vehicles in logistics: trends and potential**

Heutger & Kückelhaus (2014) provide an in-depth analysis of the implications self-driving vehicles may have on the logistics industry. They argue that there are strong arguments for suggesting that the logistics industry will adopt autonomous technology faster than other industries, the impetus being that different rules may apply when a vehicle is driving in a secure, cloistered zone, compared with vehicles that operate in the open traffic system. Also, liability issues with autonomous transport solutions are lower when it concerns goods instead of people. For these reasons, the authors advocate organisations involved in the logistic chain will adopt autonomous technology faster than e.g. public transit agencies on a large scale.

In the analysis put forward by Heutger & Kückelhaus (Heutger & Kückelhaus 2014) numerous applications of autonomous technology currently deployed for logistics are described. They argue that this provides evidence that 1) driverless vehicles are safe and successful in closed environments, and 2) have the potential to move into other areas within the logistic industry that are not yet targeted with autonomous vehicles. For example, self-driving vehicles today move materials in private warehouses and controlled open-air sites. Beyond warehousing operations, Heutger & Kückelhaus (Heutger & Kückelhaus 2014) expect many more applications in future along the entire supply chain, particularly in outdoor logistics operations, line-haul transportation, and last-mile delivery.

Despite Heutger & Kückelhaus’ (2014) comprehensive analysis of different examples where autonomous vehicle technology is used to change the logistics industry, the concept of the freight-being-moved transporting itself is not covered. Including the mapping of challenges using autonomous drive technology in factory logistics (Karlqvist & Alinde Sundbeck 2016) This is the aim of Born to Drive - to design and test a solution that enables the production-complete car to be transformed into an autonomous transport vehicle during the automotive logistic chain. Consequently, it will be possible to reduce the use of employed drivers to move the car on the outbound yard, reduce the need for trailers to move the cars for loading on ships, trains or long-haul trailers, and move the production-complete vehicle directly to the car dealership for final delivery to the end customer. The domain of the outbound yard has been in focus for the Born to Drive project and will be further explained in the next chapter.

**Born to Drive: Domain and Overall Solution Description**

This chapter introduces the domain for the solution: i.e. outbound logistics (OBL) in the automotive logistic chain. Thereafter the solution is presented, illustrating how the outbound logistics can be impacted by introducing an autonomous transport solution to manage the flow of production-complete cars leaving the manufacturing plant, coordinating their own transport to domestic and international destinations.

**Solution Domain: Outbound Logistics Management**

Outbound logistics (OBL) is the short-term scope for the Born to Drive concept. OBL is an entity in the automotive logistics chain, managing the processes taking place after a production vehicle is cleared for delivery from the production entity to a wide variety of destinations, both domestic and international.

When a vehicle has reached its completion in the factory, it enters a state called Factory Complete (FC). This is a state of the vehicle that implies a number of constraints on what can be added/removed/changed on the car itself. This means that no software can be altered, no sensors can be added, and no changes that leave permanent markings can be made on the car. It implies a state in which the car can be delivered to the customer exactly as it is. However, this also means that whatever software combination that will be used in an autonomous transport solution not intended for customer use must become inoperable after its intended use, as it is not part of the software configuration made available to end-customers.

When a FC-car is handed over to Outbound logistics, the early sequence of activities in the complete logistic chain is currently carried out by factory personnel. Firstly, the vehicle is inspected by human personnel. This occurs as the car is driven off the production line in the factory building and out
onto the OBL-managed yard. Then it is driven to a nearby handover location called Drop Plan (see figure 1).

After the cars are parked in different parking areas within the yard based on dealer destinations, they remain there for varying amounts of time, depending on the carriers’ lead times, financial circumstances, or different agreements with car manufacturer’s global sales groups. Hence, several handover locations for FC-cars exist, depending on their destination within the OBL yard.

These initial movements of the FC-car represent some of the total movements of each car along the automotive logistic chain. In total, each car is moved approximately 25 times from the production line to the dealer; each portion of the journey requires the actions of a driver driving the car, confirming handovers and conducting quality inspections.

![Diagram](https://via.placeholder.com/150)

**Figure 1: Outbound Logistics: Solution Domain in the Born to Drive Project**

**Overall Concept Description: An Autonomous Transport Solution for Outbound Logistics**
The driver that is currently needed for OBL movements is removed in the architecture of the BtoD solution. The vision is that these OBL drivers will be replaced by a novel autonomous transport solution on-board the car. This core will be merged with the on-board Advanced Driver Assistance Systems (ADAS) functionality developed for the end-customer, creating the main functionality in the Born to Drive autonomous transport solution. This solution will remove the need of a driver to 1) move the FC-car from the factory to the handover location drop plan, 2) move cars from the drop plan to other locations within the yard, and 3) in a future possible scenario, also move the car independently from the parking areas to load themselves on trucks, rail or maritime long haul-transport.

The concept includes using available sensors in the production car, fusion of sensor data collected by the car when moving, and connectivity utilizing existing (3G-4G) and future (5G) mobile networks communication technology. An intelligent traffic control system will manage each car in the logistic flow and direct the car with a BtoD-solution enabled from point A to point B, as well as manage the interaction between cars (with or without BtoD-solution enabled) in the flow.

One of the key benefits with the autonomous transport solution is that the role of OBL operative could be transformed from product driver into systems operator, with increased ability and focus on quality assurance and inspection. On average, a car manufacturing plant produces 300 000 vehicles a year, and as each car is moved approximately 25 times from the production line to the dealer, this change in the transport logistics has huge potential for impacting as many as 7.5 million FC-car position changes during the logistics chain. Another key benefit is that using autonomous transport technology will increase the safety of the staff working with OBL, as the BtoD system requires less human agency in the yard. A third benefit, is that without a human driver requiring extra space to account for driving errors, more cars can be located on the yard as self-driving cars can park closer together. In addition to the increased safety and storage capacity, self-parking FC-cars will reduce the incidence of damage to themselves and to other goods, since there would be no need to open and close car doors when parking vehicles.

**Overview of the Technological Innovation**
In this chapter, the technological innovation is highlighted in terms of process and solution design. In order to realize the concept as a prototype solution ready for real-car trials, several creative workshops
were organized in late spring/early fall of 2016, involving engineers and researchers from the participating organisations. Input to these workshops (beyond the concept vision) included constraints and needs provided by the OBL management team at Volvo Car Group Torslanda Manufacturing Plant as well as insights from the theoretically-grounded feasibility study performed in Spring 2016. Based on the domain and theoretically-anchored input, these workshops identified a wide range of potential technologies as possible design directions for the implementation. Gradually, through joint evaluation by the expert team members, a selection of suitable technology components for the BtoD-solution emerged as candidates.

The key components included autonomous parking, collision avoidance and navigation techniques. For collision avoidance, BtoD will be developed based on the active functions already developed in the car. For navigation, both visual positioning, e.g. using Lane Keep Assist (LKA) and Real Time Kinematic (RTK) emerged as candidates for solution implementation. As a next step, three different solution designs where generated, based on the selected technologies. In order to select the most feasible design for the project, three types of categories where used for assessment: commercial KPIs, Coverage, and Technical KPIs, which in turn where operationalized into nine assessment heuristics.

The three solution designs (SD) all shared the use of an intelligent Traffic Control Sub-system to coordinate all vehicles within the outbound logistic area, an integration with the logistic system that organize the operation along the automotive logistic chain. They also all require established communication between the car and the traffic control sub-system via the telematics unit in the car, as well as the use of some of the active safety components in the car, such as the on-board camera for obstacle detection. The difference between the three SDs came to the method of connection to the transition of the car. SD1 relied on transition by routing; SD2 was designed with transition via LKA and traffic sign recognition. Concept SD3 was solely based on camera-based LKA enabling transition. By using the nine assessment criteria, SD1 emerged as the most robust and high-performance design, scoring high on commercial KPIs such as cost and savings for the logistic operations, as well as technical KPIs in terms of robustness, safety and precision.

The chosen design has a driverless transportation solution as key component. The main principle for transition is automatic routing, coordinated by an off-board traffic management system with RTK-GPS mapped areas and low-speed movements. The core technological innovation is the unique combination of existing on-board ADAS-sensors and V2I-connectivity, with novel software functionality creating a new developed intelligent traffic control system – together these components form up to Level 4 driverless autonomous transport movements in FC-cars, directly from the production line without the need for any additional sensors or functionality than what is originally installed in the vehicle. A BtoD-solution enabled car will require EPAS (Electronic Power Assisted Steering), shift by wire, throttle and brake by wire. A car that does not comply with this specification cannot be a BtoD-car, and needs to be driven manually or transported in another fashion.

Based on the selected technical design, the development teams (an on-board development team known as “the car team”, a traffic control team and a communication team) developed the BtoD-solution prototype during Fall 2016 and Spring 2017. The three development teams were composed of systems engineers from industrial partners and supported by researchers involved in the project. In order to systemize the development process, a scrum-structured approach was used by the teams to build the service prototype, including an off-board intelligent Traffic Control Sub-system and the on-board sub-system in the FC-car used for tests and trials. This vehicle was a Volvo XC90 T8 with shift-by-wire and advanced driver assistance systems (ADAS) installed in the FC-cars for use by end-customers.

![Figure 2: Overview of the BtoD-solution](image-url)
On a general level, the developed BtoD-solution is intended to operate according to the following scenario (see figure 2):

The car receives a software download of the BtoD-solution at the end of the production line, giving it a state called “BtoD Mode”. The car is put in BtoD Mode at the end of the production line when achieving FC-car status. A digital transport order, including where on the OBL the car should be parked, is generated from an external Logistic System (1). The Logistic system gives the Traffic Control Sub-system, as part of the BtoD-solution, a destination (normally a parking slot) for that specific vehicle. This order acts as a trigger to the traffic management system to automatically design an optimal transport route for the car using off-board digital intelligence to make transport route decisions. This calculation includes considering both the optimized route for the specific vehicle, and for the complete number of vehicles at the yard. The Traffic Control Sub-system downloads the route to the specific vehicle (2). The BtoD-enabled car moves itself out of the production line/site autonomously. This solution relies primarily on GPS-RTK for positioning and navigation, with dead reckoning of position as fall-back method in the on-board BtoD-solution.

The BtoD-car is positioned using satellite positioning technique and communicates with the traffic control system using mobile communication technology. The car “handshakes” its progress and positioning in real time with the Traffic Control Sub-system, using mobile communication with a MQ Telemetry Transport (MQTT) protocol over 3G, 4G or WiFi (and in the future, 5G). In short, the MQTT-broker manage the message transmission (e.g. keeps track of subscriptions, forwards messages to subscriber clients) between cars and the intelligent traffic control system enabling coordination and assignment of routes and instructions. At optional predefined way-points (e.g. between different segments at the yard), the car stops and awaits the next movement to be automatically initiated by the Traffic Control Sub-system which is coordinating all vehicles on the yard (3).

The on-board solution includes functionality that uses the car’s built-in sensors. It also includes functionality to merge sensor data to support navigation and object detection on the transition route, as well as functionality for making rapid decisions in case objects emerge on its path, using the on-board Autonomous Emergency Brake (AEB) system which becomes activated when the BtoD-solution is enabled. Via the AEB system, the car will stop automatically for any objects in front of the car (e.g. a pedestrian) (4). By arrival at the destination, the vehicle will park itself into its assigned parking slot. The car performs parking autonomously using on-board production ADAS-functionality. The possibility to perform different parking manoeuvres (front, parallel, reverse parking) with the BtoD-solution is dependent on the available sensors in the specific vehicle model (5). The system sends a receipt to the traffic management systems when the parking is completed, which automatically reports to the logistic system that the transport order has been executed (6). The OBL personnel acting as system operators may use complementary optical surveillance (directly from a high-rise traffic control tower and/or a surveillance camera system) to include human agency in this otherwise fully autonomous solution; e.g. operators can observe actions on the yard or verify the parking progress as it displayed through the system.

The OBL personnel are also able to intervene in the operations via the intelligent traffic control sub-system. Selecting of one or all of the BtoD-enabled cars to be halted can be done via the traffic control user interface, and after the issue has been resolved, traffic can be resumed. As the system divides the yard into virtual sectors, areas can be “closed” or in turn, made accessible, for yard operations via the control system. Besides the capability to intervene in the operations, the OBL personnel can also access information about the all vehicles in the system (including cars not equipped with the BtoD-solution). This way information about the vehicles’ status, location, route, fuel and battery levels be retrieved. Via connected car technology, the system can also track and coordinate non-BtoD cars and other vehicles in the area. This technology monitors all movements on the yard, as well as uses this monitoring information during its calculation of the most optimized route for the BtoD-enabled cars transitioning positions in the system.

**Proof-of-Concept: Pre-trial tests and Live Car-Trials**

In Spring 2017, the implemented system prototype was ready for pre-trial tests. In the final month before freezing the prototype, the complete communication link with all hardware and software components on-board and the Traffic Control sub-system were jointly verified. The pre-live car trial tests were performed during several months prior to the live-car tests. When the BtoD-solution prototype 1.0 finally was frozen, over 100 full-scale tests (with complete trial route, Stop and Go sequences, and AEB breaking due to objects on the transition route) had been performed to validate the system. The tests were performed under different weather conditions, ranging from strong sunlight to heavy rain and fog. The pre-live car trials generated several important lessons that with an impact on the completion of the
BtoD solution prototype. Major test outcomes observed where linked to 1) transition route accuracy, 2) object detection capability and 3) car parking precision.

The pre-trial tests provided evidence that the BtoD-solution prototype is capable of navigating itself with high level of accuracy during the transition from point A to point B achieving level 4 autonomous driving. However, when accuracy was limited, this generated an issue-detection problem under a specific set of circumstances. For example, the RTK base station used requires a minimum of 30 degrees of clear space in order to function with an accepted level of operation. Consequently, if an object such as a truck or trailer blocks the air space around the RTK station, the RTK position might be incorrect, which would increase the risk of sensor fusion output being inaccurate. Furthermore, the quality of the route also affects how well the car can follow the route; if the waypoints are not well defined the car might deviate from the route, especially during sharp turns. However, the identified challenges could be mitigated by proper location of hardware and infrastructure, as well as fine-tuning the algorithms in the on-board sub-system and Traffic Control Sub-system.

The BtoD-enabled car showed very high capability, successfully detecting the test dummy which acted as interrupting object on the transition route during the pre-trials test. Early in the pre-trial tests, there were a few occasions when the dummy was not detected; the culprit was that the camera used in development was not initially working well with one of the algorithms in the BtoD-solution. This in turn caused the development team to set the shutter time manually. It also occurred several times that the car failed to detect the test dummy due to improper shutter time setting of the camera, however once discovered this error was corrected. Also in the beginning of the tests, the camera occasionally experienced reconnection issues after a brief interruption, which lead to the camera node going offline and dummy becoming undetectable- but in this case, the supervisor node noticed the node failure and stopped the car immediately. The reconnection problem was later resolved. A third issue identified was that in heavy rains, the windshield wipers have to operate at high speeds to ensure no raindrops block the view of the camera. While rain and active windshield wipers did not contribute to any instances of non-successful detection of objects, this circumstance was nonetheless noted for potential improvements to advance the prototype with an industrialized solution.

In respect to parking precision, the pre-trial tests provided evidence that autonomous parking was successful to a high degree. In the instances that autonomous parking did not perform as expected, the subsequent issue probe produced a number of explanations. The parking yard used for development and pre-trial tests had an ascending slope, that occasionally caused difficulties for the vehicle when completing the last centimetres of parking. Also, strong winds affected the final stages of some instances of autonomous parking, resulting in that the car would roll slightly after it parked and shifted gears into neutral. These problems did not appear when the pre-trials moved to Volvo Car Group’s OBL yard, where the surface is more flat compared to the development area. This issue was also noted to be improved upon in future iterations of the prototype.

The first 2-hour live car-trial was performed in May 2017 and was located at the development and test area within the premises of one of the project partners. The second live-car trial event was located at the Volvo Car Group manufacturing plant in Gothenburg, Sweden, in the operational domain for an industrialized solution targeting outbound logistics. A separate area was made accessible on the OBL yard enabling a similar transition route as defined in the development scenario (see above). Some modifications had to be made, because of different parking-space patterns as well as changing the route from clock-wise to reverse clock-wise compared to the pre-trial tests. The facility at Volvo was used for 4 weeks, to continue pre-testing the prototype and fine tune the functionality on-board as well as onboard; i.e. Traffic Control Sub-system and RTK base station. The following main activities were performed:

- The complete BtoD-system was fine-tuned and made operational (incl RTK base-station and Traffic Control Sub-syste)
- A trial transition route was defined with a set of events to test the BtoD-system capabilities.
- The transition route was tested with the BtoD enabled test car for about 200 times with over 99% success-rate in transition route accuracy and autonomous parking precision.
- The Objection detection functionality was validated for over 100 times with a 100% success-rate

The trial at Volvo Car Group OBL took place in June 2017 and involved 70 participants from the involved project partners, but also representatives from beneficiaries, the project sponsors and invited stakeholders. The aim with the live car-trials was to 1) prove the concept in an operational setting, 2) display the intelligent and autonomous solution as a component of a complete vision about how to use
autonomous transport in automotive logistics, and 3) collect lessons about benefits, challenges and opportunities with the prototype solution.

For the purpose of the trial events, a Traffic Control room was developed at the OBL yard illustrating a future possible work environment for OBL personnel operating the system, which included a user interface for the traffic control system and pre-connection to the legacy logistic system. The trial began in this room by a presentation of the project, the solution and the traffic control system. The participants were invited to go outside, to the outbound logistic yard, to experience the BtoD-solution in action. Figure 3 provides snapshots from the live-car trials at Volvo Car Group. The snapshots cover sequences covering to 1) autonomous driverless parking, 2) driverless route transition, 3) objection detection and AEB, and 4) layout of the prototype Traffic Control Sub-system.

Figure 3: The tests and trials in action

The tests and trial on the Volvo Car OBL yard covered the complete step-by-step sequence as described in figure 2 and the previous chapter (see figure 3 for snapshots from the trials). The trial began with the scenario that a transport order was distributed from the legacy logistic system to the traffic control system, and the distribution of the transport route from the traffic control system to the BtoD-solution enabled car. In this sub-sequence, the demonstration also included a verification of the MQTT-communication link that connects the car with the Traffic Control Sub-system.

The trial then continued with the car moving from the production plant drop plan, to a designated parking lot on the yard, and a sub-sequence in which the car parked itself in the parking lot. The trial included a visualization of autonomous vehicle control through which the car reversed from the parking lot and continued on a second route, from the first parking lot to a second parking lot. During this route, also initiated through a traffic control order, the on-board functionality in the system performed autonomous object detection and autonomous stop was demonstrated using a crash test dummy to simulate an object intruding in the route. After the object detection and AEB, the object was removed, the BtoD-enabled car was reactivated, and the route completed with the car successfully parked on the second parking lot. The system sent a receipt of the successful transition to the traffic control system, which in turn forwarded that the transport order was completed to the legacy logistic system.

As a final activity in each trial event, a focus group was conducted to identify, discuss and collect ideas and feedback from the participants based on their experiences from the trial. The focus group was
organized as joint dialogue facilitated by one of the senior directors participating in the project team. The purpose was to elicit the benefits, challenges and opportunities with the BtoD-solution in the short-term domain, as well as look beyond automotive logistics and see possibilities and barriers in other areas. The focus groups involved 70 participants and took approximately one hour. It was followed by an open-ended questionnaire where participants could give additional comments about the solution and the trial event. The outcome from the focus group will be systematized during Fall 2017 and presented in future publications.

Conclusions, Future Research and Industrialisation

Autonomous driving technology is emerging as a component to shift end-consumer products (Simoudis 2017) as well as critical to re-organizing manufacturing (i.e. Industry 4.0) (Andrews 2017). There exist approximately 213 automotive plants around the world, divided between a number of OEMs. 140 of these are located in Europe. In total, 72 million cars were produced in 2016 globally. The test site for the BtoD-solution prototype is Volvo Car Group, and their automotive plant in Gothenburg, which has a capacity of approximately 300 000 vehicles a year. In total, each car is moved approximately 25 times from the production line to the dealer. Today, each movement requires that human personnel drive an individual car, or the trailers that are used to simultaneously transport multiple vehicles. The technical innovation presented in this technical paper suggest that most of these 25 movements could be performed by the vehicle itself, when enabled by an autonomous transport solution.

This technical paper proposes that removing the need for a dedicated driver or the requirement of driven trailers would disrupt the logic of how automotive logistics is currently organized. The possible positive impact of an industrialization of an autonomous transport system such as the BtoD-solution covers reduction in cost, increased safety throughout the logistic chain, the potential for a more efficient logistic flow, removing the need to open and close car doors, and consequently, the potential to improve quality assurance in the logistics process. An Industry 4.0 system such as the BtoD-solution can also act as a trigger to transform the role of OBL yard handler, from a role that focuses on moving product, to that of a systems operator role focused on quality inspection. One key characteristic of BtoD as autonomous transport solution is that it does not require additional infrastructure or add-on hardware, but rather uses components and programs already installed in the FC-car. This fact is a compelling argument that the BtoD-solution can be developed into a cost-efficient system, with high potential for other positive impacts. A current drawback in this solution, however, is the constraint that it presupposes ADAS functionality in the FC-car, as well as gear shifting by wire, both of which are not yet common standard in the bulk of cars currently produced. However, the projection is that this share will increase rapidly, as AVT technology evolves and new car platforms are introduced. By mid-2020 it is envisioned that a majority of cars being built will naturally fulfill the technological requirements for this solution.

In future papers and outlets, the BtoD-solution will be further explored in terms of impact. While the path ahead for widespread dissemination of the BtoD solution will not be without roadblocks and challenges, with the BtoD solution in control of the vehicle, there is exciting promise in future research applying BtoD in other areas of automotive logistics - from everything to use cases further in the automotive supply chain, to investigating the commercial value and environmental benefits of applications such as valet parking and airport parking.

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