New Mobility

The Autonomous Logistics Hub of the Future

Taking the first step into a fully autonomous logistics chain

Porsche Consulting
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Abstract

The logistics industry is currently facing challenges from multiple sides: on the one hand, the demand for logistics is steadily increasing due to e-commerce and globalization, but on the other hand, there is a lack of skilled workers in the form of truck drivers who can handle this demand. In Europe alone, over 380,000 truck driver job postings were unfilled in 2021.[1] This significant shortage is exacerbated by increasing labor expenses, which aggravate the cost pressure already caused by rising fuel prices. Moreover, the climate crisis calls for sustainable processes that can be carried out in a carbon-neutral and resource-conserving manner. Two technological leaps can help to address those challenges. The first—the electrification of trucks, driven by lower Total Cost of Ownership (TCO) and sustainability demands—is already taking place. The subsequent leap—autonomous trucking—is expected to take off in the second half of this decade and is key to solving the massive driver shortage, increasing safety, and enabling further operational savings. This paper examines the autonomous logistics hub of the future, which is a critical link in enabling sustainable, autonomous trucking.

This paper has been developed in close cooperation with Ansorge Logistik, an innovative German logistics service provider that performs warehouse and transport operations for major Fast Moving Consumer Goods (FMCG) and industry customers by operating five logistics hubs in Germany and Italy. To present a comprehensive analysis and validation of the concepts through different angles within this paper, interviews with different technology companies and suppliers, OEMs, and hub operators have been conducted.

The autonomous hub is the first step to enter the world of autonomous logistics.

The key technology enablers for an autonomous logistics hub are already well on their way to commercialization but need to be integrated into an overall concept.

Autonomous operations in logistics hubs can enable cost savings of up to 70 percent, amortizing upfront investments.

The transition towards autonomous freight logistics

Logistics hubs currently play a crucial role in the almost 2000 billion ton-kilometers of on-road goods transport within Europe.[2] Containing warehouses, trucking and shipping services, staff offices and distribution areas, goods are being manufactured, assembled, labelled, sorted, distributed, and thus prepared for national and international transport. In anticipation of a fully autonomous logistics chain, logistics hubs are the crucial interface to enable autonomous hub-to-hub operations.

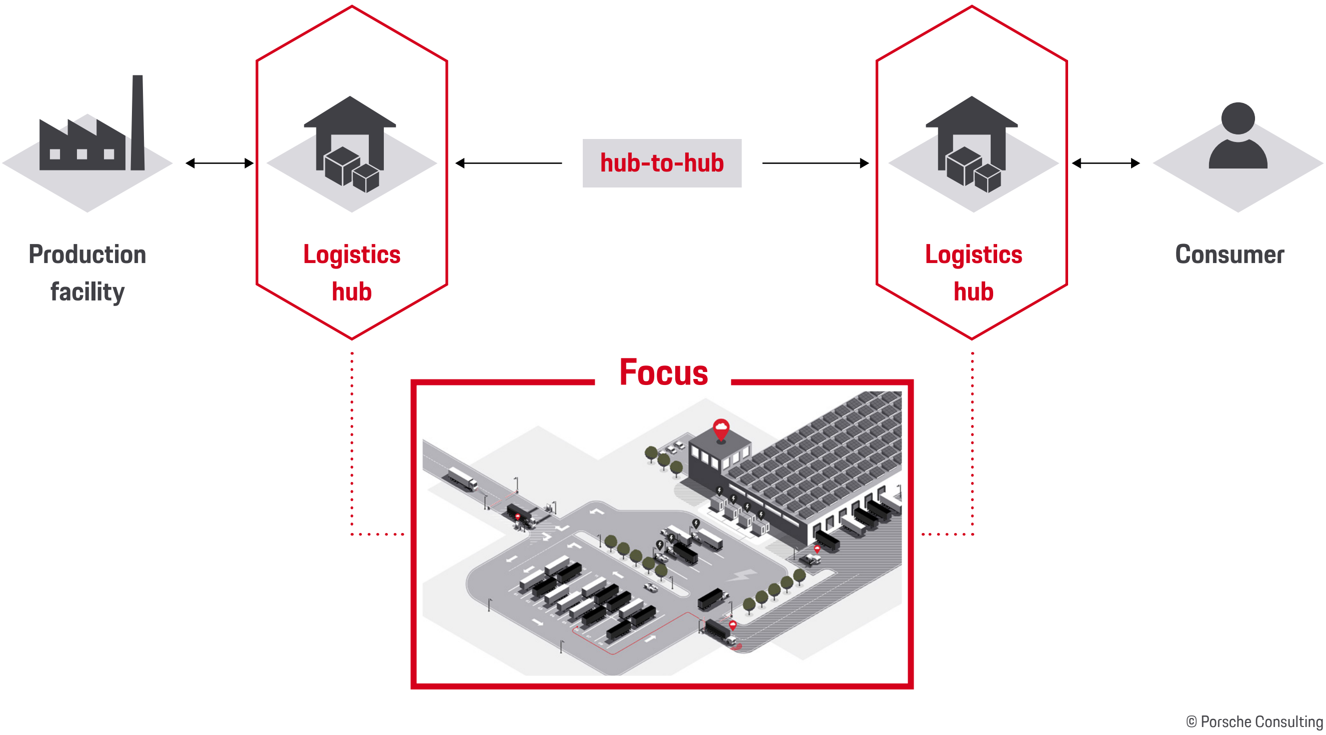


Figure 1. Logistics hub as the crucial interface to the autonomous hub-to-hub operations and link between production and customer

This paper is directed towards incumbent transport and hub operators, truck OEMs as well as new entrants who would like to prepare for the future of autonomous operations and are interested in getting answers to the following questions:

- What are the specifics of an autonomous logistics hub?
- What will operations in the autonomous hub of the future look like?
- Which key technological enablers and systems are required?
- How much investment is needed and what cost savings can be achieved?
- What are the challenges along the way towards implementation?

Before deep-diving into the building blocks and financials of the autonomous hub, a short status update on the technical and legal maturity of autonomous trucking will be given.

Excursus: The status quo of autonomous trucks

Within the Society of Automotive Engineers (SAE) J3016 standard, introduced in 2014, the levels of automation have been defined that apply to both passenger cars as well as commercial vehicles. Within SAE level 2, features such as adaptive cruise control or lane assistants are supported— the drivers are still driving the vehicle even though they are allowed to take their hands off the wheel and feet off the pedals in certain circumstances. This changes with level 3, as the truck will drive on its own in certain driving situations—yet it is legally still required to have a truck driver seated within the vehicle. At level 4, a driver is no longer necessary: the truck will drive autonomously in certain geographical environments, supervised by teleoperators who are able to intervene in operations, e.g., as soon as the truck leaves the highway and is moved to its destination or depot. For defined use cases and operations, level 5 seems achievable.

The current systems used for trucks in Europe support features that correspond to SAE level 2. These systems mainly increase driver comfort and safety. Yet, the actual economic breakthrough can only be achieved as soon as the driver to vehicle ratio drops below the threshold of 1, which will be achieved with SAE level 4. Consequently, there is high attention and a race for development of the self-driving system for level 4, mainly driven by technology companies such as Aurora, Plus, Embark or Waymo. From a legal perspective, enclosed private areas and public areas are differentiated. For automated guided vehicles (AGVs) within enclosed private areas, norms such as the Machinery Directive 2006/42/EC apply,[3] describing safety regulations for autonomous vehicles. Within public areas, all EU members have their own regimes for regulation of autonomous vehicles - in accordance with the Vienna Convention and the Geneva Convection on Road traffic.[4] In 2021, Germany was the first country to introduce the regulatory framework that allows for SAE level 4 and 5.[5] In July 2022, a European-wide harmonized type approval that allows for approval of up to 1,500 vehicles per manufacturer each year was introduced as part of a larger update on the General Safety Regulation (GSR).[6]

Multiple OEMs have already received approval for autonomous on-road operations. Einride and Scania have received special permits from the Swedish Transport Agency, the latter performing route tests with three self-driving trucks on a close to 300 km route between Södertälje and Jönköping. Within the Autonomous Innovation in Terminal Operations (ANITA) project, MAN completed a first journey on public roads in May 2022.[7] While these operations can still be categorized as pilot tests, the first commercial autonomous transports will be conducted by the end of this decade.

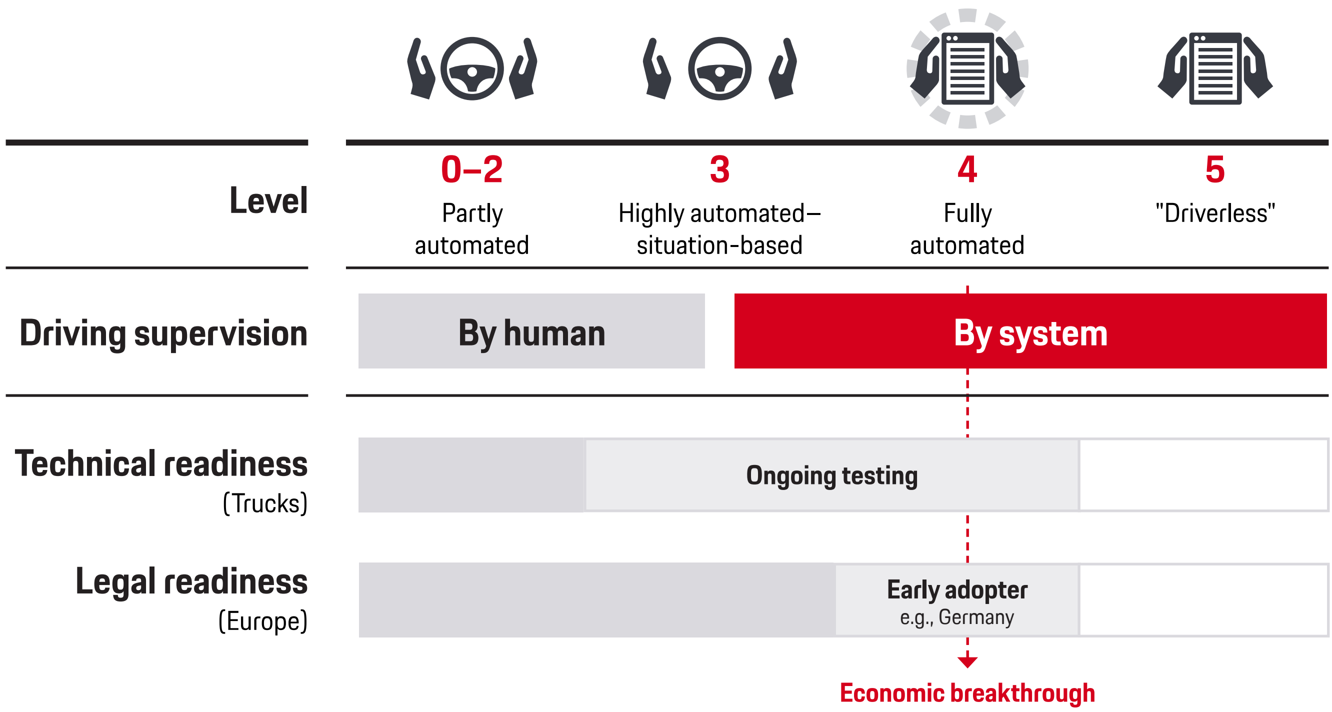


Figure 2. Current legal and technological readiness based on the levels of automation defined in SAE J3016

» You could say that we, rather than developing autonomous trucks, are enabling autonomous transport flows. By the end of this decade, we will have commercial autonomous transport between logistics hubs on major routes.

Dr. Atif Askar
Head of Business Development, Strategy and M&A
TRATON

TRATON

The introduction of autonomous hub-to-hub transport dictates the latest point in time in which relevant logistics hubs need to be future-proof to support autonomous hub-to-hub operations. The target picture of a fully autonomous logistics chain of course envisions both autonomous hub-to-hub operations hand in hand with autonomous operations within the hub. Nevertheless, the introduction of autonomous operations within a logistics hub is compatible with both autonomous and non-autonomous trucks. This will allow hub operators to initiate lighthouse projects and enter into autonomous operations today. But is the autonomes hub a suitable starting point towards a fully autonomous logistics chain, especially comparing it to other use cases? And what are the characteristics of this use case? The next chapters will take a closer look at these questions.

01

The autonomous hub is the first step to enter the world of autonomous logistics.

01 | Autonomous use cases in the logistics chain

Autonomous logistics hubs are the ideal starting point for automation, as they typically involve manual, highly repetitive tasks such as internal shuttle or trailer shunting use cases, are located on private property with fewer legal regulations, and thus operate in an enclosed, less complex environment compared to inter- or intra-city transport use cases. The highest savings potential in operations will be related to hub-to-hub operations, especially for a typical second-party logistics (2PL) player performing transport services or for a third-party logistics (3PL) player offering fulfillment services, including transport and warehouse services. Nevertheless, there is significant savings potential within European logistics hub operations, totaling six billion euros per year.[8] In case of a 3PL, competencies can be initially built up for automation of processes within the hub and later scaled towards on-road operations.

To fully automate the logistics value chain from production facility to end customer, multiple automation use cases exist, which have different characteristics, vehicle, and regulatory requirements and thus have different automation potentials. Some of the most common use cases are listed below.

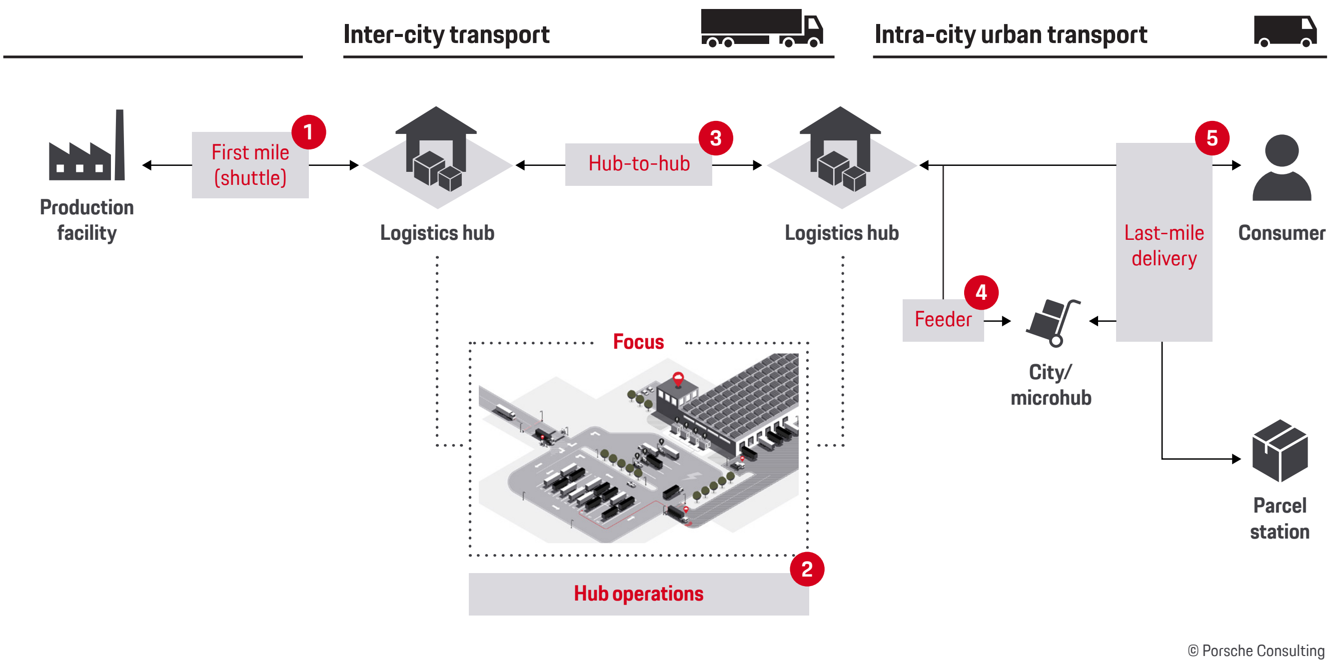


Figure 3. Five use cases with automation potential along an exemplary logistics value chain from production to end customer

Use case 1 | Automated shuttle (first mile)—This use case refers to a high-frequency, lower-distance shuttle used for supply of raw materials or collection of finished goods either at the production facility or at a nearby warehouse operated by a 3PL fulfillment partner. The number of shuttles mainly depends on the size of the production facility, respectively daily production volumes. These movements are usually performed by a yard tractor or conventional tractor, primarily on private grounds with potential intersection on public roads, which might require special permits by local authorities.

Use case 2 | Automated hub operations—Operations on a hub comprise a largely varying number (depending on the hub size and operations) of short-distance yard tractors on private grounds, which are used to shunt trailers, e.g., to enable preloading concepts. A very low vehicle to trailer relationship of close to zero applies, as multiple trailers will be shifted throughout the day. For a large hub, more than 10 vehicles can perform such shunting activities in a three-shift model. This type of operation correlates well with operations on a transshipment hub (road to rail) or harbor. In Europe, these activities are supported by a total of around 25,000 yard trucks, which stay within the logistics hub throughout their whole operational life.[8] And as of now, these trucks are operated by truck drivers with conventional driver's licenses leading to a total operational cost burden of at least six billion euros.[I]

Use case 3 | Automated hub-to-hub transport—This use case describes on-road, mostly long-haul, longer-distance operations (on average 520 km per day) with multi-day trips and thus with less frequent change of trailers, mostly one to two trailers per truck per trip. The number of vehicles depends on the fleet size of the operator. Hub-to-hub operations are mostly performed on dedicated, known routes with a high automation potential, as utilization of vehicles can be increased while decreasing the high share of driver cost of up to ~35 percent.[9] For these type of operations on public roads, high technological maturity is needed to decrease safety concerns. A permit will be required by the authorities.

Use case 4 | Automated feeder—As an important part of intra-city urban transport, this use case refers to a hub-to-spoke transport for a two-step logistics process (i.e., for inner-city parcel delivery with urban distances of up to 100 km and multiple tours per day, e.g., when a sub-contractor is used) and is typically performed by medium- to heavy-duty vehicles (>12t). A comparable use case at a more regional level could be a milk-run tour with distances of up to 300 km per day, mostly performed by heavy-duty trucks (up to 40t). This use case involves a more complex environment due to regional and partly inner-city traffic. Share of driver cost makes up 38 to 43 percent of the total costs—depending on the use case.[9]

Use case 5 | Last-mile delivery—The final delivery to the customer is either performed via a conventional one-step logistics process with a light- to medium-duty vehicle (up to 12t) that performs a single tour with multiple stops (i.e., up to 200 parcels per day in the CEP segment) or from the city/microhub via cargo bikes that perform multiple tours (i.e., up to three to five tours per cargo bike per day) via a two-step logistics process. Typically, this use case faces a very complex environment due to inner-city traffic.

The comparison shows that the autonomous hub is the ideal first use case to enter the world of autonomous operations. But are relevant technologies for autonomous operations within the hub already mature enough? What do operational processes look like? This will be the focus of the next chapter.

[I] assuming 240.000 TCO per truck incl. salary and employer cost

The key technology enablers for an autonomous logistics hub are already well on their way to commercialization but need to be integrated into an overall concept.

02 | The autonomous hub of the future: drivers and technologies

The severe driver shortage issue not only affects on-road transport; there is also a shortage of skilled personnel to perform shunting activities on the hub, especially in multiple shift operations. Teleoperations combined with automated yard tractors that use steer-by-wire technology can mitigate this issue in a twofold manner. Initially, relocating the driver position from the vehicle to the teleoperations center or even to the driver's home office will significantly improve working conditions. With further intelligence of the vehicles, autonomous operations are possible, as one teleoperator can monitor multiple vehicles. This leads to significant operational savings. Other technologies, e.g., automatic coupling technologies of trailers, help to automate the secondary tasks of truck drivers.

COSTS	SHORTAGES	SAFETY
Improving total cost of ownership (TCO)	**Balancing future employee shortages**	**Reducing accidents caused by humans**
>50% of shunting cost can be related to drivers	Gap of >380k truck drivers in Europe	~10k accidents on hubs due to truck movements (GER)

Figure 4. Key facts on the three key drivers for an autonomous hub of the future

Within yard operations, over 50 percent of the total cost can be attributed to truck drivers, while salaries are constantly increasing.[10] This puts additional pressure on the already slim margins of logistics operators.

In addition to increasing cost, there is a severe truck driver shortage issue. The great imbalance between transport demand and truck drivers has been one of the top issues for logistics operators, while developments such as the war in Ukraine and Brexit have continued to worsen the situation. In Europe alone, over 380,000 truck driver job postings have not been filled in 2021. The main reasons are the high skill level required for the job, difficult working conditions, and a general poor image of the profession. The trucking business is heavily male-dominated, as only 3 percent of truck drivers in Europe are female. What complicates the situation further is that 34 percent of European truck drivers are over 55 years old.[1]

The third driver relates to safety issues. Hub operations involve highly repetitive manual tasks that pose significant safety risks for drivers. In Germany alone, around 10,000 accidents per year can be associated to operation of trucks in enclosed areas.[11] In total, truck drivers are on sick leave 25 days every year, of which around 37 percent can be associated with muscle issues or injuries.[12]

> Autonomous logistics hubs have great potential to increase efficiency and safety in our industry and to improve the day-to-day work life for our truck drivers.

Benedikt Roßmann
Authorized Officer
Spedition Ansorge GmbH & Co. KG

The integration of autonomous technologies can help to relieve that burden. In this case, a 3PL provider is depicted that performs both transport and warehouse operations for his customers – that way, there is an incentive for the provider to optimize the operational interfaces. The hub of the future is split into a trailer and inner yard – this separation has multiple advantages. Next to enabling preloading concepts with minimum dwell time, the transport operations and the operations of the warehouse are fully decoupled. While autonomous trucks could move 24/6 or 24/7 (depending on legal driving restrictions), the warehouse and yard operations with yard tractors could only operate in a one or two-shift model. This would not only prohibit unauthorized access during the night at the warehouse, but also improve safety, as shunting activities would mainly be carried out by the hub operator and prohibit blocking of docks in case of a breakdown of 3rd party operated autonomous trucks in the inner yard. In case of frequently returning 3rd party operators, exchange trailers could be an option. Infrequently arriving 3rd parties would have to perform docking throughout the warehouse shift.

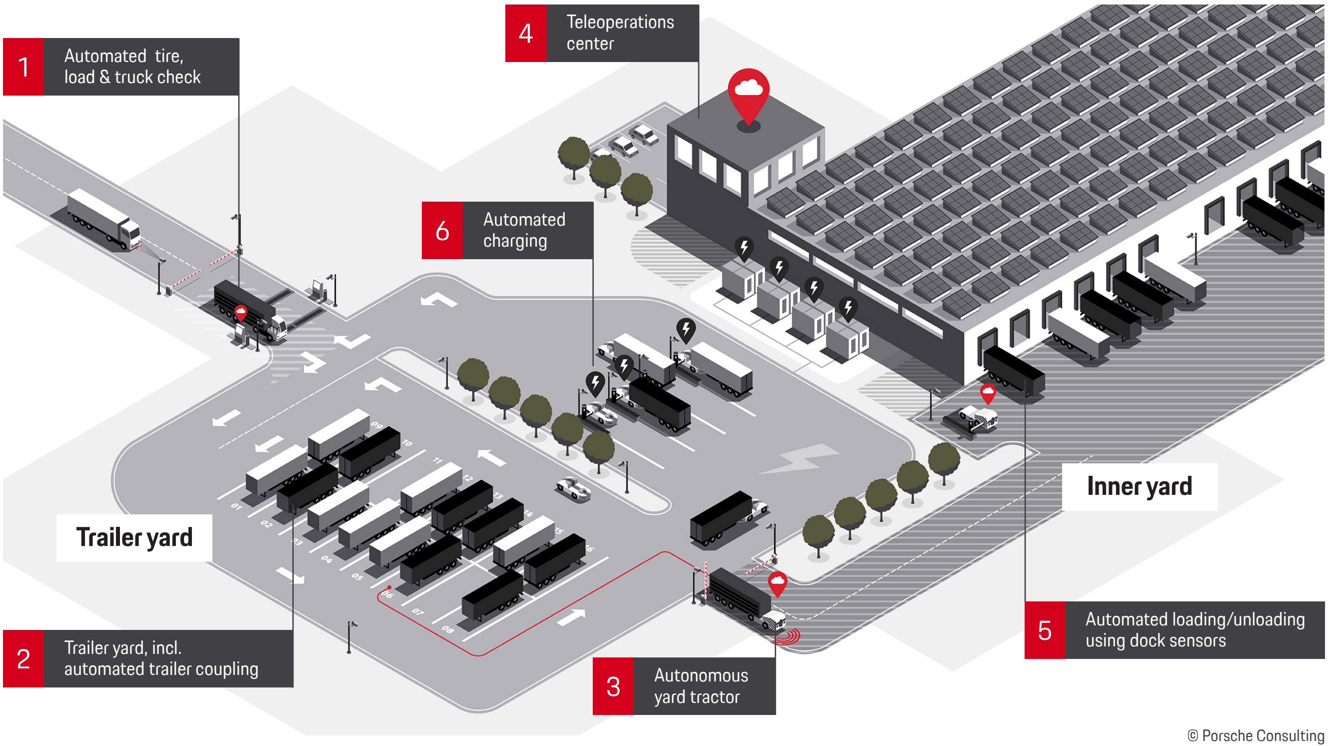


Figure 5. The six key technology enablers of the autonomous hub of the future incl. access, shunting, charging and unloading

To enable these operational processes within the hub, six key technology enablers are required.

Technology enabler 1 | Automated access, tire, load, and truck check—The autonomous hub utilizes automated access management—trucks are registered before freight delivery or if a charging slot has been booked within the hub. In addition to installation of cameras, appropriate freight tags and load checks can ensure and validate digital check-in and -out of trailers. Physical barriers also ensure the operation within an enclosed area—assuring "private" operations from a legal perspective. While automated access solutions with license plate recognition or tire and load check systems are mature and commercially available, the challenge will be to set up the system interfaces—especially to third-party operators.

Technology enabler 2 | Trailer yard, including automated coupling—Within the autonomous hub, a pure tractor / trailer fleet is assumed—which reflects the dominant vehicle combination for inter-city transport within Europe. Within the trailer yard of the autonomous hub, non-autonomous and autonomous tractors can place full trailers in dedicated parking slots and onboard preloaded trailers directly. That way, dwell time in the yard for a particular truck is minimized. Automated coupling technologies, which are already available on the market, ensure automation of secondary activities such as pulling a fifth-wheel lever to open, letting down supporting legs, and plugging in the cables for ABS/EBS, air, and electric coupling of the trailer. Legislation may need to be further adapted so that the teleoperator is able to remotely control the automatic wheel wedges from the teleoperation center. The trailer yard has a dedicated routing system to ensure efficient and safe maneuvering. Supervision via cameras is secured to document damages.

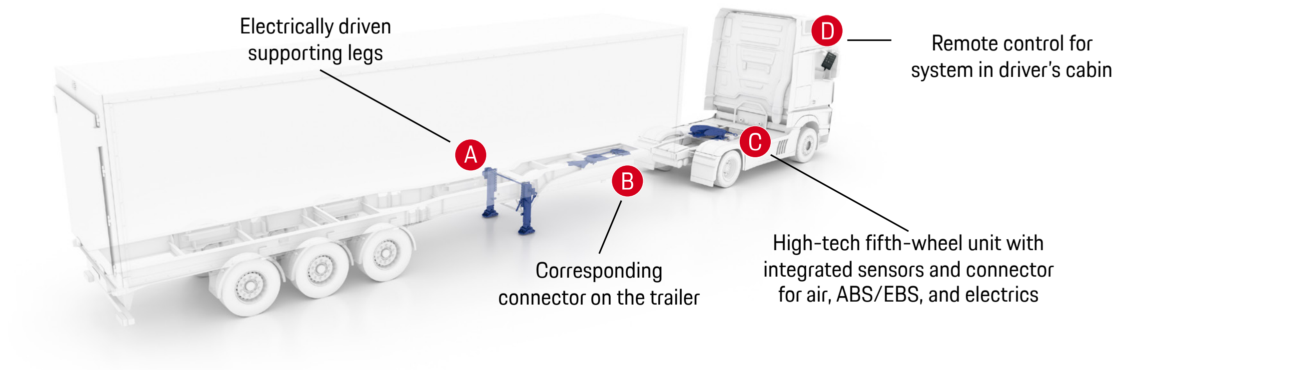


Figure 6. Illustration of four technological components enabling automated trailer coupling. Source: JOST

> Automatic coupling systems are paving the way towards autonomous driving on-yard as well as on-road, as they reduce manual actions to a legal limit, increase safety, and save costs.

Andreas Jakubin
Product Manager
JOST-Werke Deutschland GmbH

Technology enabler 3 | Autonomous yard tractor—Autonomous yard tractors (such as those by Gaussin or Terberg) typically shunt trailers from the trailer yard to the docking area or vice versa. The maneuvering towards the dock is performed by autonomous yard tractors. Hereby, the infrastructure and yard tractor must communicate accordingly, assigning a specific shunting task to a specific yard tractor. With regard to sensor placement and functions for trajectory planning, object recognition, and localization, it is yet to be determined which functions and sensors will be placed in the vehicle and which ones in the infrastructure. The most likely scenario is a mixture of both, depending on the size of the hub and cost development of the sensors. Some leading players have integrated those functions into the vehicle, combining both cameras and 3D lidar sensors for greater robustness in terms of communication loss and cybersecurity. For autonomous operations, these yard tractors are equipped with an AD kit—a virtual driver—that performs and executes motion planning activities (i.e., braking, steering, accelerating). Yet as of now, in the case of a tractor-trailer concept, a 360 degree obstacle detection cannot be fully ensured in all shunting scenarios. These might be resolved by achieving sensor improvements, establishing sensor fusion technologies, or additional sensor placements within the infrastructure.

Technology enabler 4 | Teleoperations center—The teleoperations center mainly conducts or supervises yard shunting activities. As currently stated within German law and the AFGBV[II] amendment that came into force on July 1, 2022, teleoperations is mandatory for operating autonomous vehicles in defined public areas. Start-ups like Fernride are already performing teleoperations—initially on well-defined properties. Teleoperation incorporates the concepts of teledriving, teleassist, and telemonitoring and refers to operation of a system at a distance. Starting with a "safety driver" to be able to shut down the vehicle in case of critical situations such as communication loss, the next step will be to remove the safety driver and solely steer the yard tractors via the teleoperations center. Economic savings will be achieved as the driver to vehicle ratio reaches values below 1—driven by the approach of gradual autonomy implementation, values of 1:10, 1:20, or 1:50 are likely achievable, especially when operational learning is transferred to hub-to-hub use cases.

» Teleoperation will be an essential, legally mandatory component to enable autonomous operations across industries.

Hendrik Kramer
CEO & Co-Founder
Fernride GmbH

FERNRIDE

[II] AFGBV = Autonome-Fahrzeuge-Genehmigungs-und-Betriebs-Verordnung (Ordinance Regulating the Operation of Motor Vehicles with Automated and Autonomous Driving Functions and Amending Road Traffic Regulations)

Technology enabler 5 | Automated loading/unloading using dock sensors—Arriving at the dock, automated wheel wedges prevent the trailer from rolling away while loading or unloading. A drive-through dock design that enables opening the trailer swing doors after docking is a precondition for a fully automated docking process.[13] Depending on the desired degree of automation and products being loaded/unloaded, rolling doors and trailers with automated unloading systems may be used—especially for high-frequency shuttles with a 1-1 vehicle-trailer relationship.

Technology enabler 6 | Automated charging—Automated charging is of course a precondition for conducting autonomous operations. In an autonomous world, nearly non-stop operations are feasible, except for the time in which trucks are being charged. In general, it is expected that charging power used within the hub will also increase to minimize idle times; yet there will be a trade-off with charging power and respective costs—also considering the restraint of available grid capacity at the hub. Ideally, installed solar panels will produce green electricity over the course of the day, which can be stored via local energy storage systems and flexibly provided throughout the day.

> Autonomous megawatt charging is a key enabler for electrification of heavy-duty transport. It minimizes the downtime for charging autonomous vehicles and thus maximizes their utilization.

Dr. Stefan Perras
Head of Pre-Development & Innovation
Siemens AG

SIEMENS

This also opens up room for new business opportunities for 3PLs. If produced energy exceeds the demand of a company's own fleet, charging slots can be offered via selected Electric Mobility Service Providers (eMSPs) or roaming providers to the public. Due to the fact that preloading concepts are targeted and the charging park should be accessible 24/6 or 24/7 to open it up for monetization, it is reasonable to place it in the trailer yard, where tractors only or tractor-trailer combinations are able to charge. Reservation systems can ensure that the own fleet can be charged whenever needed. Autonomous charging systems have already been piloted—commercial Megawatt Charging System (MCS)-capable systems will be available by 2025 that enable charging of long-haul trucks within 30 minutes.

To enable and orchestrate these different technologies on the autonomous hub, an integrated systems approach should be applied. This includes systems such as transport management systems (TMS) alongside involved telematics, warehouse management systems (WMS) and existing yard management systems (YMS), which govern access management as well as charging management systems (CMS) and the platform to teleoperate yard tractors (teleops / fleet management systems). These systems communicate accordingly and control the different actors to perform all necessary of yard operation tasks.

To summarize this chapter, individual technology enablers are well on their way to commercialization. A near-term technical implementation of individual technologies seems feasible. An exemplary implementation could happen in three steps. First, a lighthouse project in a dedicated hub area for a limited period of time can be initiated. Based on the learnings, continuous operations in dedicated areas are possible before scaling operations to the entire hub and across hubs. The subsequent step to the incorporation of individual technologies will be to develop an integrated approach from a system perspective that interlinks those different technology enablers and therefore establishes a concept of an autonomous hub that is future-proof to support the ramp-up of autonomous hub-to-hub operations.

As the technological maturity of different key enablers has been assessed, questions concerning required investment and operational savings might arise. These will be discussed in the next chapter.

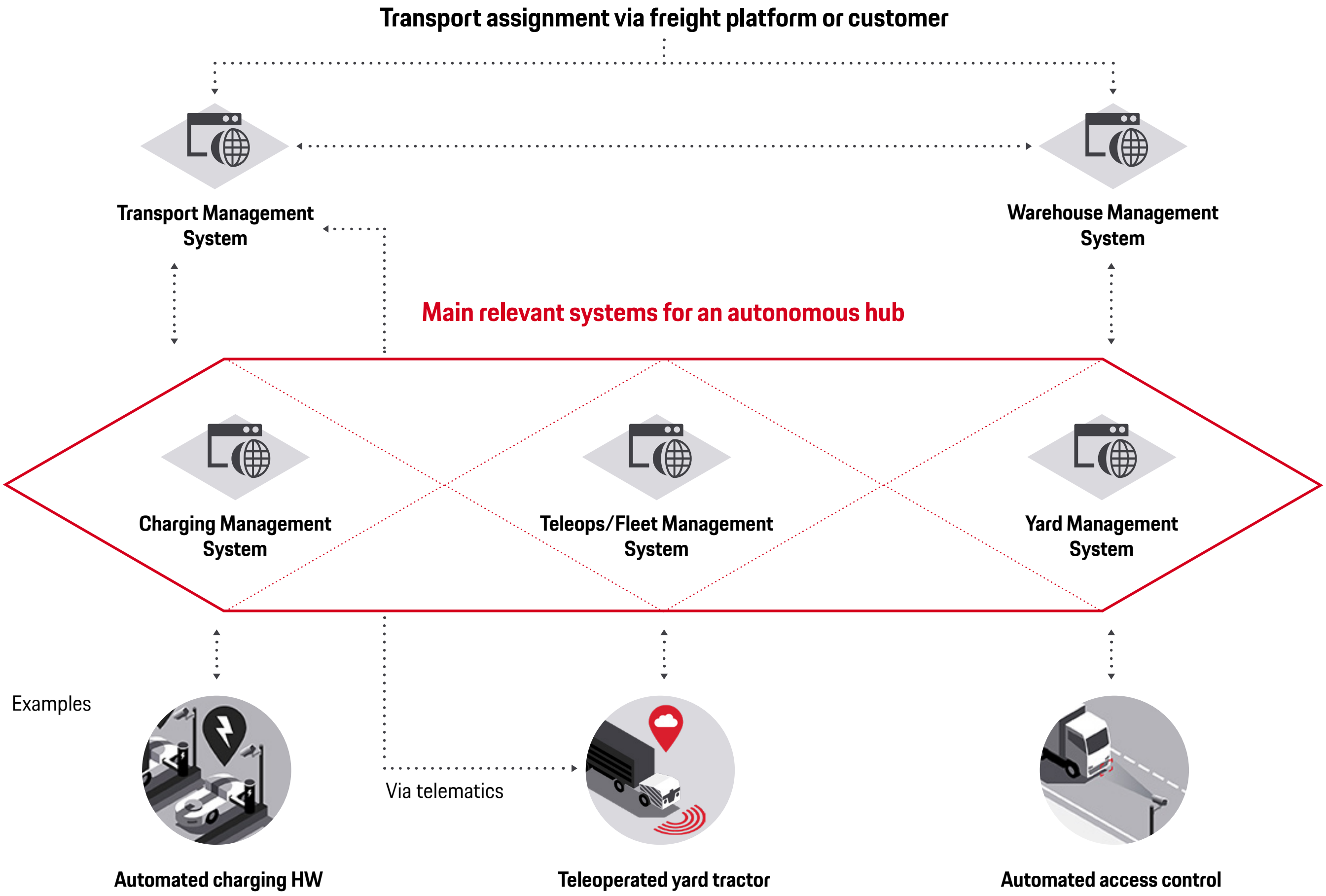
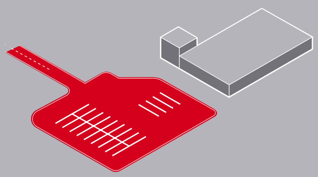
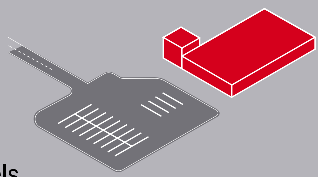


Figure 7. Main relevant systems needed for autonomous hub operations

A Day in the Life of an Autonomous Logistics Hub





Time of day	**Trailer Yard** all day	**Inner Yard** 1- or 2-shift models
Night shift (until 6 am)	1. Autonomous trucks arrive at the hub, gaining access via automated access control	Yard tractors are recharged for the day shift
Day shift (until 2 pm)	2. They drop off trailers in the trailer yard and pick up new, dedicated preloaded trailers with the help of autonomous coupling technologies 3. Trucks can be charged using automated charging	Teleoperated yard tractors perform shunting activi-ties from and to the docks, loading/unloading trailers and storing goods within the warehouse
Late shift (until 10 pm)	4. Autonomous trucks leave the hub with new trailers using automated check-out	In the case of a 2-shift model, simultaneously to ongo-ing warehouse operations, pre-loading activities are conducted to prepare trailer pick-up by autonomous trucks during night shift

Trailer yard, allowing for continuous on-road transport operations

Inner yard as main dock interface in line with warehouse operations

Autonomous operations in logistic hubs can enable cost savings of up to 70%, amortizing upfront investments.

03 | Economic viability of the autonomous hub

Based on effects on yard personnel and vehicles, gate administration and dwell time, the operational savings of various autonomous technologies are calculated in line with required investment needs. In a large hub, operational savings of more than 70% percent can be realized. Especially in these large hubs, these operational savings amortize upfront investments quickly, so that a breakeven of under three years can be expected.

In this chapter, investment costs for different hub sizes are depicted in line with operational cost savings. For simplicity, a 3PL player is assumed that performs both transport and warehouse operations, owning 100% of the trailer fleet

From an investment perspective, the required capital differs between different hub sizes according to Figure 8. The investment figures shown include the setup of an automated access and truck control system including costs for necessary system adaptions, coupling technologies for the yard tractors, the set-up of the teleoperations platform combined with the purchase of autonomous yard tractors and the necessary IT enablement of the hub infrastructure. The investment need of those technologies is subject to further technological improvements and realized economies of scale. The results show that especially for large depots, the investments in autonomous technologies are quickly amortized. This is mainly driven by the large throughput, enabling significant operational savings.

	Small depot	Medium depot	Large depot
Characteristics (Shift model, throughput & yard tractors)	1-shift · Up to 20x per day · 1x tractor	2-shift · Up to 100x per day · 4x tractor	3-shift · Up to 500x per day · 10x tractor
Investment needs (Hub only)	Up to **5 MEUR**	Up to **10 MEUR**	Up to **15 MEUR**
Operational savings (Maximum utilization)	Up to **0.5 MEUR** p.a.	Up to **3 MEUR** p.a.	Up to **13 MEUR** p.a.
Breakeven	**After 10 – 15 years**	**After 3 – 6 years**	**After 2 – 3 years**

High potential of autonomous hub due to early breakeven

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Figure 8. Investment requirements to realize an autonomous hub concept, based on different depot sizes

The operational savings are driven by improvements in three cost dimensions: yard personnel and shunting vehicles savings, gate administration cost savings as well as lowering dwell time of trucks within the hub. The latter might be considered of low importance as truck drivers need to have mandatory rest breaks and have maximum workings hours today. This changes with the shift towards autonomous operations. The opportunity cost of transport operations can be calculated based on an average freight price of €1.57/km[14] and the dwell time of the truck within the hub.

Figure 9 shows the yard operation savings—driven by technology enablers and operational adaptions—for an exemplary large depot with a throughput of 500 trucks per day operating in a three-shift model.

Step 1 | 100 percent preloading via trailer yard—The first improvement is an operational improvement. Instead of unloading at the dock, shunting vehicles and personnel are introduced that ensure upfront placement of preloaded trailers in the trailer yard. By doing that, the hub dwell time is reduced significantly.

Step 2 | Automated access and truck control—The second improvement relates to automated yard access. This reduces the dwell time of trucks due to time savings at the gate entrance and truck checks such as tire and load checks. Gate administration costs can be significantly lowered, too.

Step 3 | Automated coupling—While today's coupling technologies are still at an early stage and low volume, mass adoption will certainly be realized once autonomous hub-to-hub trucks are in operation. These technologies reduce current coupling times by 50 percent for both trucks and yard tractors, facilitating more efficient transport and yard operations.

Step 4 | Teleoperated yard tractors—To fully automate the yard tractor shunting activities, teleoperations can be introduced to further achieve savings in terms of personnel costs. Savings will be realized as soon as the driver to truck ratio drops below 1. In this case, a 1:20 factor by 2030 is expected, assuming high maturity of teleoperations and scaling effects across hubs and operators as well, due to a common teleoperations center. Introducing teleoperations, a 15 percent increase in the price of the yard tractors, and additional platform cost of teleoperations will arise as these providers will also claim their margin.

The shown investments and operational savings confirm that, next to an operational and technological feasibility, the transition towards autonomous hub operations is also economically feasible.

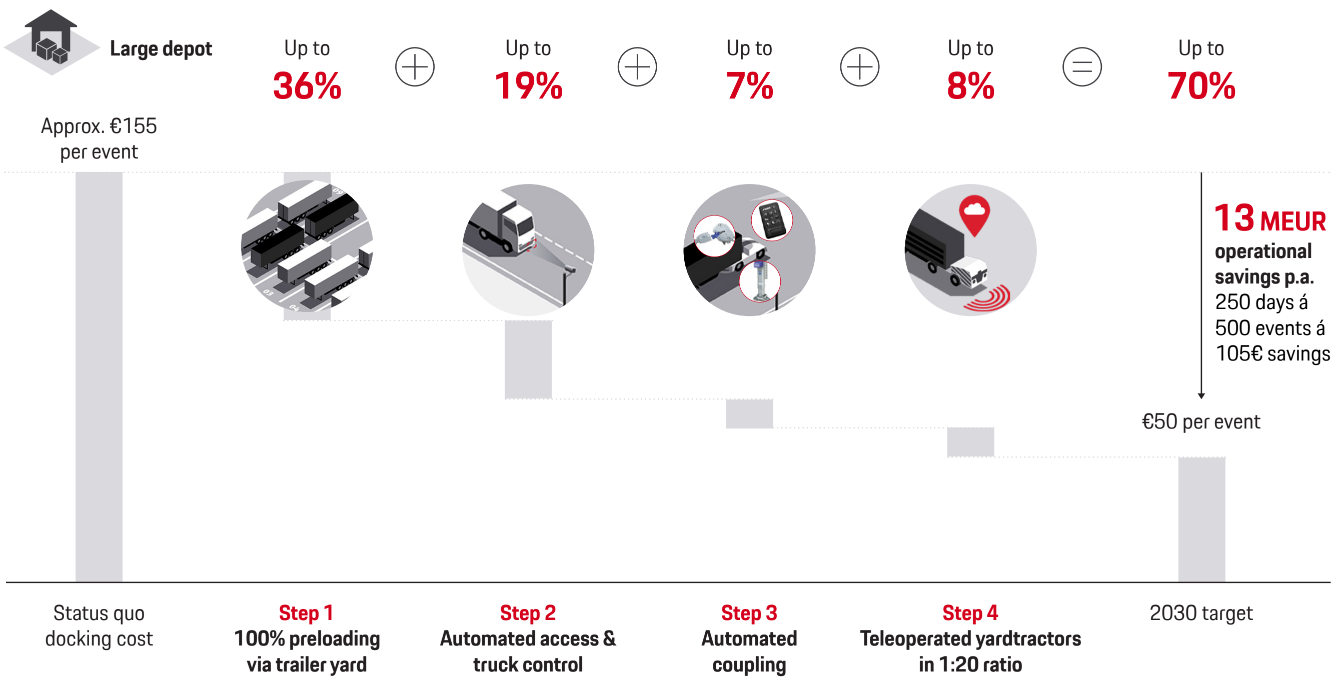


Figure 9. Docking cost savings in a large logistics hub due to different technology enablers

Autonomous hubs paving the way to an automated logistics chain

While public on-road autonomous transport happens in a more complex environment, the autonomous hub is the ideal first use case that helps to explore autonomous technologies within predefined, enclosed environments. Fewer legal requirements apply and the safety risk is much more manageable compared to other use cases.

From an operational point of view, the split into a trailer and inner yard enables decoupling of warehouse and transport operations and autonomous preloading concepts, which reduces the dwell time of autonomous trucks on the hub so that additional transport assignments can be conducted on-road. This requires that frequently arriving third-party operators have exchange trailers that stay within the yard to be moved by the hub operator.

Key technology enablers such as automated access control, automated trailer coupling, and teleoperation with yard tractors are well on their way to commercialization. The total hub, including the yard dock area, needs to be enabled from the IT communication perspective and with sensors such as cameras allowing for supervision of the operations. All relevant warehouse, transport, teleoperations, and yard management systems need to be interlinked—also in the interface towards third-party operators that have to be registered prior to entering the hub. This will especially be required to set up an overall concept that is future-proof to support future autonomous hub-to-hub operations.

Over time, the autonomous hub holds significant operational saving potentials that will justify initial investment needs of up to 15 million euros and lead to an investment breakeven of under three years within medium and large hubs. For a large hub, more than 70 percent of operational cost improvements can be achieved. Future platform costs for teleoperations and the development of sensors could affect the level of these savings.

Challenges such as 360 degree obstacle detection could be removed by superposition of sensor technologies from autonomous yard tractor and infrastructure or improvement of sensor technologies. The current high costs for technology enablers such as automated coupling technologies will be lowered with higher volumes and further product iterations. The autonomous hub of the future holds high potential—especially for 3PL logistics players that need to prepare for the future of autonomous transport. Near-term technical implementation of individual technologies is possible, as technology providers have developed solutions that are ready for deployment. Later, the operational learnings and organizational know-how can be transferred to use cases such as autonomous hub-to-hub transportation. Economies of scale and improvement of technological maturity will decrease costs even further, leading the way into a fully automated logistics chain.

In Brief

01 The autonomous hub as an enclosed area is the ideal first use case to enter the world of autonomous logistics. The target picture is to enable a fully automated logistics chain—from production of goods to final customer delivery.

02 The key drivers for the automation of hub operations are high personnel costs, lack of skilled personnel, and high safety risks due to manual, repetitive processes.

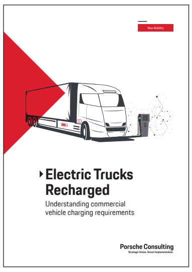
03 The autonomous hub of the future is split into two sections—a trailer yard and inner yard—to decouple warehouse operations and continuous transport operations enabled by preloaded trailers that are placed in the trailer yard.

04 Six technological enablers—automated access control, automated coupling technologies, autonomous yard tractors, teleoperations, automated charging, and automated loading/unloading—are required for fully autonomous hub operations.

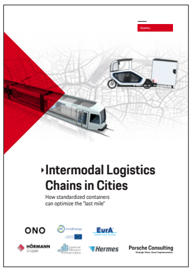
05 These technologies are well on their way to commercialization; thus, near-term technical implementation of individual technologies is possible. Hub operators can introduce autonomous operations step by step (initially as lighthouse projects limited in time and to dedicated hub areas).

06 Autonomous operations in logistics hubs enable significant yard operation savings of up to 70 percent, which quickly amortize upfront investments of up to 15 MEUR, especially in medium and large hubs.

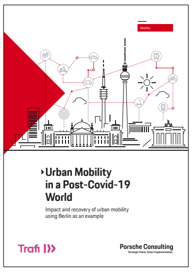
Further reading



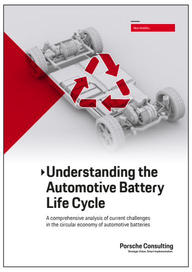
Electric Trucks Recharged



Intermodal Logistics Chains in Cities



Urban Mobility in a Post-Covid-19 World



Understanding the Battery Life Cycle

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Appendix

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