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EMERGING FREIGHT TRANSPORT TECHNOLOGIES

A PIARC TECHNICAL REPORT

TECHNICAL COMMITTEE 2.3 *FREIGHT*

PIARC

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2024-2027 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were appointed by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

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EXECUTIVE SUMMARY

2023R55EN

EMERGING FREIGHT TRANSPORT TECHNOLOGIES

A PIARC TECHNICAL REPORT

"Emerging technologies in freight transport and logistics" addresses the use of materials, tools, techniques, and sources of power to make freight transport and logistics more efficient, reliable, environmentally friendly, safe and secure. Emerging technologies are technologies which are under development or recently implemented, or not yet fully implemented, or in testing phase or pilot applications."

Innovations and advances in emerging freight technologies, such as autonomous trucks, truck platooning, internet of things, robotics, drone deliveries, and digitalization of the freight industry is changing logistics and the management of the freight transport system. **These technologies have the potential to increase productivity, efficiency, reliability, flexibility, safety, sustainability, and economic benefits.** But substantial work remains to be done to advance these emerging freight transport technologies and ensure adoptions globally – specifically, around potential applications and impacts, suitable framework conditions for implementation, and the roles of both the public and private sectors in adoption.

This report discusses **emerging freight technology trends from around the world**. In developing this report, the T.C.2.3.3 Emerging Freight Technology Working Group:

- developed a short list of emerging freight transport technologies.
- conducted an extensive review of the literature on medium and high priority emerging freight transport technologies.
- developed 22 Emerging Freight Technologies Trends Fact Sheets.

- developed the Final Report. The chapters were developed by a core team of writers and reviewers, followed by compilation, editing, and a QA/QC process.

Definition of emerging technologies

To address "Application of Emerging Technologies in Freight Transport and Logistics", the T.C.2.3.3 Emerging Freight Technologies Working Group reached consensus on the following definition for emerging technologies in the field of freight transport and logistics:

Key findings and conclusions

This report discusses emerging freight transport technologies from around the world categorized as basic freight technologies, freight vehicle technologies, alternative mode of freight technologies, automated freight transport, and freight transport management. It should be noted that the individual technologies covered in this report are in different stages of development (technology readiness) and not all technologies are ready to be implemented in a Low- or Middle-Income Countries (LMICs). Regardless of readiness levels, **promising emerging technologies identified with**

substantial impacts to road authorities are autonomous trucks, autonomous delivery robots, air drones, truck parking availability systems, and national heavy vehicle access management systems.

The report also notes that **an emerging freight technology that is feasible in a High-Income Country (HIC) may not be applicable in a LMIC**. For example, transferring AI to freight transport systems in many LMICs requires a workforce with expertise in machine learning, fail-safe systems in case of an AI malfunction, and cybersecurity to protect AI. On the other hand, **air drone deliveries have applicability in both HICs and LMICs.** In LMICs, air drones can distribute medicine and medical supplies to remote areas. In HICs, air drones can deliver small packages in congested urban areas.

Recommendations

The T.C.2.3.3 Emerging Freight Technology Working Group made the following recommendations for decisionmakers and practitioners:

- Develop and clearly articulate the public sector's **vision and framework** to support the adoption of emerging freight transport technologies.
- Participate in **emerging freight transport technology pilot projects** to improve the understanding of the potential benefits, challenges, opportunities, lessons learned and best practices for transferability.
- **Research and disseminate findings** of both successful and unsuccessful freight transport technology pilot projects.
- Participate in **emerging freight transport technology peer exchanges** to share knowledge, lessons learned, and best practices (specifically between HICs and LMICs).

The T.C.2.3.3 Emerging Freight Technology Working Group made the following recommendations for PIARC:

- **Monitor and benchmark emerging freight transport technologies** and its impact on road authorities to provide information on how to address key challenges (e.g., risk, ethical issues, liability concerns) associated with many emerging technologies that are currently in the concept or pilot stage.
- Conduct a **freight technology readiness assessment for LMICs** and develop a framework for LMICs to pilot and adopt emerging freight transport technologies.
- Conduct a **special project on air drone deliveries** given the applicability of the emerging technology to both LMICs and HICs.

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1. INTRODUCTION

Innovations and advances in emerging technologies are changing the logistics and management of the freight transport system. Autonomous trucks, truck platooning, the internet of things (IoT), big data, blockchains, cloud logistics, robotics, and digitisation of the trucking industry are shaping the freight landscape of tomorrow. Higher degrees of automation in the freight transport and logistics sector could increase productivity, efficiency, reliability, flexibility, safety, sustainability, and economic benefits.

To fulfil the potential of these emerging freight transportation technologies and ensure they contribute to transport policy objectives, road authorities need to address the following important issues:

- the impact of digitisation and automation on freight movement, logistics, and supply chains;
- the impact of digitisation and automation on freight traffic, traffic management, and the multimodal transportation system;
- the benefits of digitisation and automation for road and multimodal freight transport and road traffic;
- management and operations of public road infrastructure; and
- the necessary technological, organisational, and regulatory and policy framework conditions for implementation.

The application of emerging technologies in the freight transport and logistics sector is still relatively new but making significant advancements. These technologies could transform and reshape the industry. North American, Asian, and European countries have begun field testing of truck platooning and partly autonomous trucks, as well as other applications of big data. Initial indicators have shown positive impacts to roadway safety, operational efficiencies, and productivity, and the potential to help address the shortage of truck drivers. However, substantial work remains to continue advancing these emerging technologies and wide adoption globally. These topics need further exploration, particularly around the potential applications and impacts and suitable framework conditions for implementation. In addition, the roles of both the public and private sectors need to be better defined.

Working Group 2.3.3, Emerging Freight Technologies, of Technical Committee 2.3, Freight, of the World Road Association (PIARC) prepared this report to discuss these issues. This report discusses emerging freight technology trends from around the world, covering autonomous trucks, truck platooning, truck parking information systems, drones, robot delivery, digitisation. The report also outlines key findings, conclusions, and recommendations.

This report is a culmination of the literature reviewed, information gathered, and insights obtained and is structured as follows:

- Section 2 documents the methodology for developing and evaluating the short list of emerging freight transport technologies.
- Section 3 documents the consensus understanding of emerging technologies in freight transport and logistics, as well as definitions for technology, emerging technologies, freight logistics, and freight transport.

- Section 4 discusses the six technology categories identified, the four application fields of the identified emerging freight technologies, the expected impacts of each of the identified emerging freight technologies, and the potential application of the technologies to Low- and Middle-Income Countries (LMICs).
- Sections 5 to 9 summarize the information gathered for each of the evaluated emerging freight technologies categorized as basic freight technologies, freight vehicle technologies, alternative modes of freight technologies, autonomous freight transport, and freight transport management, respectively.
- Section 10 highlights the key findings and conclusions.
- Section 11 concludes with recommendations for road authorities/decision makers and the World Road Association.
- In addition, the report includes 22 emerging freight technology trend fact sheets that discusses each of the identified technologies in detail.

2. METHODOLOGY

In preparation for this report, Working Group 2.3.3 followed a comprehensive strategy that consisted of the following actions:

1. development of a short list of emerging freight technologies,
2. conducting a literature search and review of emerging freight technologies,
3. development of a collection of emerging freight technologies trends fact sheets, and
4. development of the final report.

2.1. SHORT LIST OF EMERGING FREIGHT TECHNOLOGIES

To develop this report, Working Group 2.3.3 held several brainstorming sessions to develop a short list of emerging freight technologies to guide the process.

2.1.1. Broad Categories

The process of developing the emerging freight technologies began with the identification of six broad technology categories:

- alternative modes of freight transport,
- automated freight transport,
- freight transport management,
- freight vehicle technology (and related infrastructure),
- basic technology (that possibly improves road freight transport and logistics), and
- other technology applications.

2.1.2. Individual Technologies

The second step consisted of the identification of individual technologies within the six areas. The technologies included:

- air drones,
- autonomous delivery robots,
- autonomous trucks,
- blockchains,
- border management systems,
- digitisation.
- intelligent transport systems,
- truck parking availability systems,
- truck platooning, and
- underground freight transportation systems.

2.1.3. Application Fields

The third step entailed characterising the identified emerging freight technologies into four application fields:

- road freight transport,
- non-road freight transport,
- construction logistics, and
- logistics.

2.1.4. Impacts

The fourth step consisted of assessing the impact fields and expected impacts of each of the identified emerging freight technologies in the following areas:

- road or vehicle capacity,
- transport efficiency,
- transport reliability,
- environment,
- climate change,
- land use,
- safety,
- costs and revenue,
- asset management,
- infrastructure design,
- regulatory and policy issues, and
- COVID-19.

Disruptive technologies break with established patterns and significantly affect the way that consumers, industries, or businesses operate. This step also involved assessing the level of disruptiveness of the technologies:

- high impact,
- medium impact, or
- low impact.

2.1.5. Impact to Low- and Middle-Income Countries

The fifth step was the assessment of the potential application of the technologies to low- and middle-income countries (LMICs):

- high impact,
- medium impact, or
- low impact.

2.1.6. Prioritisation

The final step consisted of prioritising the identified technologies for further investigation by priority:

- high priority,
- medium priority, or
- low priority.

The Working Group dropped from further investigation technologies that were prioritised as low priority. Those prioritised as medium and high were assigned to Working Group members for further investigation.

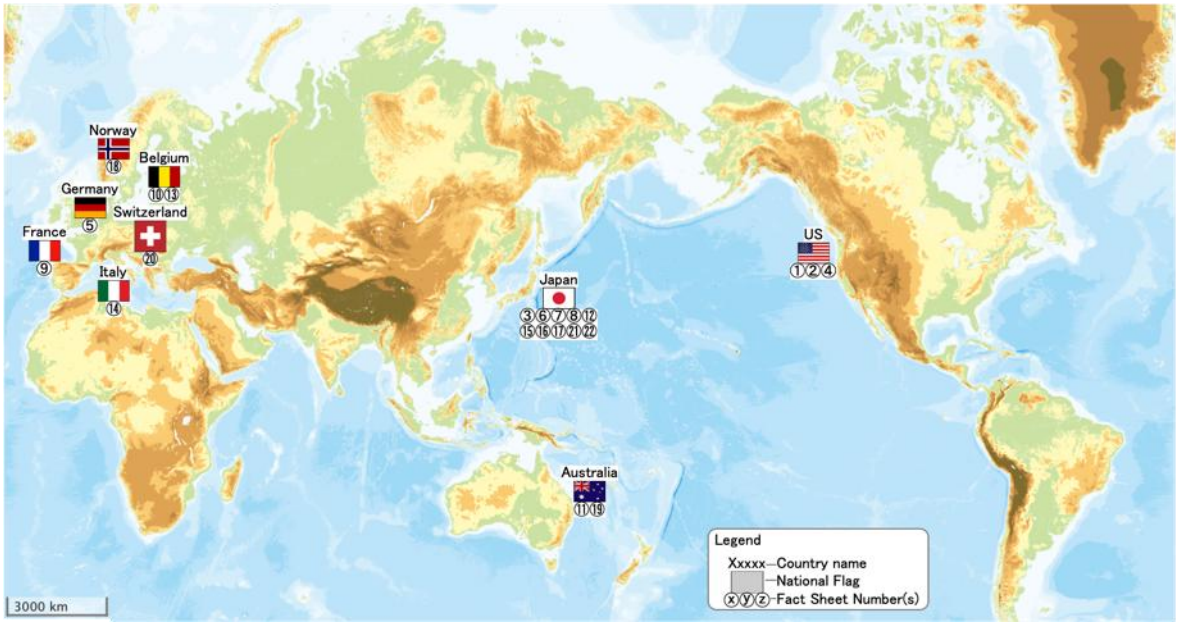
2.2. Literature Search and Review

Working Group members conducted an extensive literature search and reviewed numerous topics identified in the short list of emerging freight technologies.

2.3. Emerging Freight Technologies Trends Fact Sheets

Working Group members contributed to the development of a collection of 22 emerging freight technologies trends fact sheets. Source of the map: https://maps.gsi.go.jp/#2/85.051129/22.500000/&base=std&ls=std&disp=1&vs=c1g1j0h0k0l0u0t0z0r0s0m0f0

Figure 1 illustrates the countries of the PIARC members who contributed fact sheets.



Source of the map: https://maps.gsi.go.jp/#2/85.051129/22.500000/&base=std&ls=std&disp=1&vs=c1g1j0h0k0l0u0t0z0r0s0m0f0

Figure 1. Countries of the PIARC members who contributed fact sheets.

2.4. Final Report

The Working Group developed the final report outline. A core team of writers and reviewers then developed the chapters based on that outline. The team compiled, edited, and followed a quality control/quality assurance process to finalise the report.

3. UNDERSTANDING OR DEFINITION OF EMERGING TECHNOLOGIES

To address the application of emerging technologies in freight transport and logistics, a common understanding of ***emerging technologies*** and related terms in the field of freight transport and logistics is needed.

Technology can have varied definitions. According to the Collins dictionary (www.collinsdictionary.com), the term ***technology*** refers to 'methods, systems, and devices which are the result of scientific knowledge being used for practical purposes. According to the STANDS4 Network (www.definitions.net), ***technology*** can refer to the 'making, modification, usage, and knowledge of tools, machines, techniques, crafts, systems, and methods of organisation, in order to solve a problem, improve a pre-existing solution to a problem, achieve a goal, handle an applied input/output relation or perform a specific function'.

Emerging technologies are upcoming or appearing technologies that are more and more applied in a certain field. Emerging technologies can be applied for different reasons or goals, such as to increase productivity, efficiency, quality, environmental friendliness, safety, and security of a product or process.

Freight logistics is the process of planning and executing the efficient transportation, trans-shipment, and storage of goods from the point of origin to the point of consumption. Between these subprocesses, an exchange of information takes place. The goal of logistics is to meet customer requirements regarding quality (e.g., leading times, reliability, and flexibility) and costs.

Freight transport is the movement of goods by trucks, vans, trains, ships, barges, or airplanes.

Regarding the objectives and impacts of a technology application in freight transport and logistics, the **perspectives of a provider and user of a transport system** can be different. A truck transport company tries to fulfil its clients' requirements regarding quality and costs for the transport of goods; a transport system manager aims at an efficient, safe, and environmentally friendly use of the whole transport system.

Application of the emerging technology could be **disruptive**, which means it makes a substantial contribution to solve a problem or increase efficiency or/and quality. However, the technology application does not necessarily have to be disruptive and could also cause smaller impacts (e.g., step-by-step improvements).

After extensive discussions, Working Group 2.3.3 formed the following common understanding:

> **'Emerging technologies in freight transport and logistics'** addresses the use of materials, tools, techniques, and sources of power to make freight transport and logistics more efficient, reliable, environmentally friendly, resilient, safe, and secure. Emerging technologies are technologies that are under development, recently implemented, not yet fully implemented, or in testing phases or pilot applications.

4. SEGMENTATION AND OVERVIEW OF EMERGING FREIGHT TECHNOLOGIES

Numerous different emerging technologies have been applied in the field of freight transport and logistics. These include technologies applied for traffic management, autonomous transport, alternative transport systems, etc. Basic technologies and other technology applications that have a broad range of applications in the field of freight transport and logistics were also considered in this report. In addition to emerging technologies on roads, technologies for alternative transport means were identified because they could have an impact on the demand for road freight transport by trucks and vans.

4.1. CATEGORISATION

Categorisation of the emerging technologies allowed the Working Group to focus on technologies to be further investigated in the current cycle. The developed categorisation determined the main category, on- or off-road usage, application, impact, disruptive potential, and potential to be applied in LMICs.

Table 1 lists the different individual technologies that have been developed. The table also includes the main categories of these technologies, on- or off-road usage, and application field (freight transport, logistics, and construction logistics). The rightmost column of Table 1 shows the number of the fact sheet that describes each technology in detail (please see Appendix). This list of technologies is not complete because new technologies are continuously emerging, and this is a general assessment for the classification of the current technologies.

4.2. APPLICATION AND IMPACT

The reasons for implementing emerging technologies in the field of freight transport and logistics are usually to:

- increase capacity, efficiency and reliability;
- reduce greenhouse gas (GHG) emissions (decarbonisation);
- mitigate environmental impacts;
- improve road safety;
- prepare for, and correspond to stricter legal requirements; and
- address the shortage of workforce.

Emerging technologies could also have a medium- to long-term impact on land use (to save space or create new space), security (e.g., critical for cybersecurity), costs and revenues of infrastructure and operations, and transport and logistics services.

Table 1. Categories of emerging technologies used in freight transport and logistics.

LIST OF EMERGING FREIGHT TECHNOLOGIES			Application Field			
Category		Individual Technology	Freight Transport	Logistics	Construction Logistics	Relevant Fact Sheet numbers
Alternative Modes of Freight Transport	On roads	Transport by Small Electric Vehicles	X	X		
		Transport by Bicycles	X	X		
	Not on roads	Transport by Rail	X	X	X	
		Transport by Ship	X	X	X	
		Transport by 3D mobility (drones, balloons)	X	X		10, 11
		Transport by 3D mobility (Air ships)	X	X	X	9
		Tube Transport (High Speed, e.g. Hyperloop)	X	X		
		Tube Transport (Low Speed, e.g. Cargo Sous Terrain)	X	X		20
Automated Freight Transport	On Roads	Truck Platooning	X			2, 3
		Connected Truck Driving / Cooperated Intelligent Transport Systems (C-ITS)	X			
		Automated Truck Driving	X	X	X	1
		Autonomous Vehicles (trucks, vans)	X	X	X	1, 3
		Transport by Robots (small vehicles)	X	X	(X)	12
		Autonomous Road Loading/Unloading/Handling Systems		X	X	
	Not on roads	Autonomous Container Terminals		X		
		Other Automated Loading/Unloading/Handling Systems		X	X	
		Autonomous Trains	X	X		
		Autonomous Ships	X	X		
Freight Transport Management	On roads	Traffic Informationen Systems	X	(X)	(X)	7
		Traffic Regulation Control Systems (incl. Overload direct enforcement)	X			
		Traffic Management Systems (incl. Route guidence/selection)	X			
		Intelligent Access Management Systems	X	X	X	
		Truck parking information systems (incl. reservation)	X	(X)		4, 5, 6, 8
		Tracking and Tracing of loads/vehicles	X	X	X	
		Shared economy incl. Booking Platforms and Transport Exchanges	X	X	X	17
	Not on roads	Intramodal transport information and management systems for trains and ships	X	(X)	(X)	
		Multimodal transport information systems	X	(X)	(X)	
		Multimodal transport management systems	X	(X)	(X)	
Freight Vehicle Technology (and related infrastructure)	On roads	Electric Bikes and Trycicles	X	(X)		
		Electric Vans and Trucks	X	(X)	X	18, 22
		High Performance Batteries	X	X	X	
		High Power Charging (HPC) Systems	X	X	X	
		Biogas Vehicles	X	X	X	
		Hybrid Electric Vehicles (HEV)	X	X	X	
		Fuel Cell Vehicles (hydrogen)	X	X	X	
		Electric Road System (ERS) (non-contact, contact: over-head, road surface etc.)	X			22
		Electric Power Supply to Running Vehicles	X	(X)	(X)	22
		Heavier and Longer Trucks	X	X	X	
Basic Technology	On roads and not on roads	Big Data	X	X	X	17
		Internet of Things (IoT) and Physical Internet	X	X	X	15
		Artificial Intelligence (AI)	X	X	(X)	16
Other Technolgy Appplications	On roads and not on roads	Virtual Reality	X	X	(X)	
		Augmented Reality	X	X	(X)	
		Blockchain	X	X	(X)	13, 14
		Additive Manufacturing (3D Printing)	X	X	(X)	
		Advanced transport planning tools	X	X	X	19

Some emerging technologies could also have an impact on asset management (e.g., longer and heavier trucks) and the road infrastructure design (e.g., an electric road system). In many cases, regulatory and policy changes are necessary (e.g., automated freight transport). Some of the emerging technologies also have advantages dealing with COVID-19 (e.g., autonomous vehicles and automated tube transport).

4.3. Disruptiveness, Potential Application, and Priority

The disruptiveness, potential application for LMICs, and priority for the six broad technology categories were evaluated and summarized as follows.

- **alternative modes of freight transport:**
  - Individual technologies have mostly a low or medium disruptiveness potential and, only in a few cases, a high disruptiveness potential on the freight transport and logistics system (e.g., tube transport or use of air-based vehicles).
  - The potential application for LMICs is mainly low or medium.
  - The priority is mainly medium.
- **automated freight transport:**
  - Individual technologies have mostly a medium or high disruptiveness potential on the freight transport and logistics system (e.g., automated truck driving, autonomous vehicles, and transport by robots).
  - The potential application for LMICs is mainly low or medium.
  - The priority is mostly medium to high.
- **freight transport management:**
  - Individual technologies have mostly a low or medium disruptiveness potential on the freight transport and logistics system because such applications optimise current freight transport operations, and the use of the existing freight transport system is more in the short and medium term (e.g., truck information systems, truck management, and truck parking).
  - The potential application for LMICs is mainly medium or high.
  - The priority is mostly medium to high.
- **freight vehicle technology (and related infrastructure):**
  - Individual technologies have mostly a medium or high disruptiveness potential on the freight transport and logistics system (e.g., electric vehicles, fuel cell vehicles, and the electric road system).
  - The potential application for LMICs is mainly low or medium because the availability of green energy is currently not sufficient in many countries.
  - The priority is mostly medium.
- **basic technology:**
  - Individual technologies have mostly a medium or high disruptiveness potential on the freight transport and logistics system (e.g., big data, IoT, and artificial intelligence [AI]).
  - The potential application for LMICs is mainly low or medium.
  - The priority is medium to high, at least for more low-cost applications.
- **other technology applications:**
  - Individual technologies have mostly a medium or high disruptiveness potential on the freight transport and logistics system (e.g., virtual reality, augmented reality, and 3D printing). The disruptiveness potential also strongly depends on the diffusion of these technologies.

- The potential application for LMICs is mainly low or medium. These technologies will first be applied in high-income countries and, based on experiences, probably also in LMICs.
- The priority is low to medium.

5. BASIC FREIGHT TECHNOLOGIES

Basic emerging technologies—such as AI, big data, the physical internet (PI), and blockchain—can improve the efficiency and effectiveness of freight transport and logistics, as well as strengthen their sustainability and safety. Basic technologies are applied in a wide variety of industries and can be used in freight transport and logistics areas since modern freight transport is associated with information and communication systems. Freight transport faces difficult challenges, including customer requirements for lower costs, the high level of congestion and safety issues on road networks, negative environmental impacts, and the shortage of truck drivers. Basic technologies have the potential to help address these problems through the transformation of existing systems.

The basic freight technologies discussed in this section are:

- Artificial Intelligence (AI)
- Physical Internet (PI); and
- Blockchain

5.1. ARTIFICIAL INTELLIGENCE

AI is a set of related technologies that make machines do things that would require intelligence if done by humans. AI systems can keep improving their performance without humans having to explain exactly how to accomplish all the tasks undertaken (Wang, 2019). AI has been applied to freight transport and logistics using machine learning techniques, such as deep learning and reinforcement learning for analysing big data to find optimal solutions. AI can support robotics and automation of freight vehicles and warehouses for sustainable freight transport.

5.1.1. Expected Benefits and Impacts of Artificial Intelligence on Freight Transport and Logistics

AI has the potential to help make freight transport and logistics safer, cleaner, cheaper, smarter, resilient, and more energy efficient by processing, learning, and acting on the information provided by IoT sensors using machine learning algorithms.

5.1.1.1. Improvement of Safety

Autonomous trucks and the platooning systems that are supported by AI can dramatically improve safety through the reduction of human errors since many crashes by heavy goods vehicles are caused by humans. The automation of freight vehicles requires AI to process the big data collected by IoT sensors in vehicles and infrastructure. AI can recognise the location of the vehicle and the environment, including the movement of other vehicles, to make decisions for controlling the vehicle for safer driving. Truck platooning systems need AI to control the steering and the distance between multiple freight vehicles in order to smoothly operate and avoid crashes. The real-time communications between the lead truck and following trucks supported by AI are also key for successful operations of truck platooning.

5.1.1.2. Reduction of Greenhouse Gas Emissions

As AI helps keep road traffic flowing by using smart traffic management and real-time traffic data, AI can also reduce fuel consumption and carbon dioxide emissions by providing freight vehicles with traffic information to optimise routes.

5.1.1.3. Reduction of Costs and Effort

AI application in robotics and warehouse automation can reduce logistics costs and mundane human activities, as well as avoid human mistakes. For example, AI-based robots operate on public roads for delivering goods to customers in urban areas. AI is used for the automation of warehouses by robots and IoT sensors. Robots can unload the pallets from trailers and store them in the designated areas of the warehouse. Automatic picking of commodities in the warehouses is also executed using AI-based robots and IoT sensors. Inventory management can be optimised using AI that analyses real-time data in the e-commerce environment.

5.1.1.4. Better Logistics Management

Supply chain optimisation can potentially be achieved using AI and real-time and historical data. Modelling logistics operations in the digital twin environment can visualise freight vehicles' flow to identify problems and find innovative solutions. The ***digital twin*** represents a virtual replica of a physical object, process, or system. For example, during road network disruption by a disaster, AI can analyse the possible scenarios by modelling the traffic flow in the digital twin of urban areas and can suggest the best redevelopment of logistics hubs and delivery scheduling by trucks on the road networks.

Data-driven logistics management requires AI for optimising the schedule of vehicles and drivers, and for choosing better transport modes and logistics facilities. AI can help predict the change in customers' future demands based on big data and can find the appropriate solutions to lower costs and GHG emissions.

5.1.1.5. Energy Savings

AI can help save energy during freight transport by choosing the best combination of transport modes and logistics terminals, and by optimising the routing and scheduling in the PI.

5.1.2. Key Challenges

Although AI has the potential to help improve the productivity and safety of freight transport and reduce negative environmental impacts, challenges are associated with AI applications, such as the following (European Parliament, 2019).

5.1.2.1. New Risk Situation

While vehicles are increasingly automated but not fully autonomous, drivers who are supported by AI might be distracted and pay less attention to the road. This generates a new risky situation on roads.

5.1.2.2. Ethical issues

When faced with life-versus-life situations, an AI algorithm in a fully automated vehicle will have to make difficult decisions about how the vehicle reacts to critical conditions.

5.1.2.3. Liability of Accident

A clear boundary of liability for different automation levels should be defined so that it is possible to identify who is actually responsible when accidents occur involving automated vehicles.

5.1.2.4. Cybersecurity and Data Privacy

Cybersecurity and data privacy are important in the development of AI in automated vehicles. AI-based automated vehicles require access to a great deal of data that are often sensitive or protected.

5.1.2.5. Employment

AI can potentially contribute to the creation of new jobs, the elimination of others, and the modification of most. Truck drivers might no longer be needed in fully autonomous vehicles.

5.1.3. Outlook and Transferability

AI is a basic technology that can help in processing, learning, and analysing the big data provided by IoT sensors and other information resources using machine learning algorithms. AI has the potential to contribute to making freight transport and logistics safer, cleaner, cheaper, smarter, resilient, and more energy efficient. The application of AI encompasses the control of autonomous freight vehicles and platooning on roadways, the automation of warehouses by robots, optimisation of logistics management, digital twins, and the PI. However, AI also has potential challenges related to new risky situations, ethical issues, liability in the event of accidents, cybersecurity and privacy issues, and employment concerns.

AI can be transferred to freight transport systems in many LMICs. However, it is necessary to:

- fully understand the machine learning and other algorithms used in AI,
- provide fail-safe systems in case of the malfunction of AI, and
- ensure cybersecurity to protect AI.

5.2. PHYSICAL INTERNET

The ***physical internet*** is a 'hyperconnected global logistics system enabling seamless open asset sharing and flow consolidation through standardised encapsulation, modularisation, protocols and interfaces to improve the efficiency and sustainability of fulfilling humanity's demand for physical object services' (Montreuil, 2015). The core idea is interconnecting logistics actors on multiple layers, such as physical, digital, operational, transactional, and legal layers. Ultimately, the PI will enable universal interconnectivity with any organisation, anytime and anywhere (Ballot et al., 2021). The PI is an evolution to provide a new paradigm of worldwide logistics networks aiming to improve efficiency, sustainability, and resiliency. The PI is beyond collaborations in terms of hyperconnectivity.

5.2.1. Expected Benefits and Impacts of the Physical Internet on Freight Transport and Logistics

The PI facilitates higher freight unit consolidation, intelligent combination of loads across supply chains, smart consolidation, and reallocation of flows in supply chain networks and synchro-modality. The PI has the potential to:

- reduce logistics costs using a systematic approach of consolidation of goods,
- provide reliable and better services to customers,
- reduce GHG emissions,
- reduce distance travelled, and
- increase resilience.

The PI is about interconnecting the world's logistic networks, thus defining a new opportunity for supply chain design and operations. The PI enables seamless open asset sharing and flow consolidation, fulfils society's demand for physical objects with an order of magnitude, and provides better efficiency and sustainability, thanks to improved economies of scale and scope.

5.2.2. Critical Factors for Successful Implementation

The development of the PI in the following five areas is critical for successful implementation.

5.2.2.1. Logistics Nodes

Consolidation and deconsolidation of goods need to be done seamlessly, so operational costs are largely offset by gains in transport efficiency. Additionally, idle warehouses, terminal capacity, and transportation slots could be opened to other companies through digital services and standard procedures. Stakeholders have access to relevant data as input to optimise their own operations (e.g., the next transport leg plan may impact the position of a container in a terminal).

5.2.2.2. Logistics Networks

Logistics networks may involve many companies under the orchestration of a single company in charge of inventory management, transport planning, routing, and capacity management. Networks are expected to build seamless, agile, flexible, and resilient door-to-door services consolidating and deconsolidating all shipments within a logistics network. All assets, capabilities, and resources need to be seamlessly visible, accessible, and usable within the logistics network to make the most efficient and effective use of resources.

5.2.2.3. Systems of Logistics Networks

Further connectivity across logistics networks will require specific functionalities. These will be expanded, so there is an organic growth of interconnected logistics networks to finally create a PI with a standard and industry-agreed-upon procedure to become part of that system of logistics networks. Until this final form, the systems of logistics networks will provide services, assets, and resources that will be seamlessly accessible by multiple networks.

5.2.2.4. Access and Adoption

Currently, relatively small networks exist, with limited scope of activities (e.g., pooling of cargo and limited to sectors). Many companies are not able to organise networks on their own or get access to existing networks. One of the main objectives is to show companies within their current business setting that cooperation, even with competitors in logistics, is not only a good idea but also easy to execute and implement directly or through logistics service providers. It is also important to help companies make first steps toward this objective. There are new ways of sharing assets, services, and resources between stakeholders in vertical integrated supply chains and in horizontal collaborative networks.

5.2.2.5. Governance

Governance includes the developments needed to evolve the logistics nodes, logistics networks, and system of logistics networks into the PI. This includes the rules defined by the stakeholders forming or using the logistics nodes, logistics networks, and system of logistics networks as well as the trust-building processes and mechanisms.

5.2.3. Key Challenges

5.2.3.1. Physical Interconnectivity

Physical interconnectivity is about making sure that any physical entity can flow seamlessly through the PI. The PI generalises and significantly extends this practice by encapsulating physical objects in physical packets or containers (hereafter termed π-containers to differentiate them from current containers), packets, boxes, and so on. These π-containers are world standard, smart, eco-friendly, and modular. They are modularised and standardised worldwide in terms of dimensions, functions, and fixtures.

5.2.3.2. Digital Interconnectivity

Digital interconnectivity ensures that physical entities, constituents, and factors can seamlessly exchange meaningful information across the PI. This produces fast knowledge and fact-based decision making (Montreuil, 2012).

5.2.3.3. Operational Interconnectivity

Operational interconnectivity is about ensuring that in-the-field operational processes and business processes are seamlessly interlaced so that users can easily and efficiently utilise the PI to fulfil their logistics needs and PI constituents can seamlessly collaborate in serving these users.

5.2.3.4. Universal Interconnectivity

The concept of universal interconnectivity needs to be further investigated. Universal interconnectivity provides solutions for generalising and functionally standardising unloading, orientation, storage, and loading operations; and widely applying these solutions to PI containers in a smart automated and/or human-assisted manner.

5.2.4. Outlook

The PI paradigm opens a new way to describe and design how logistics organisations can work. The PI can have many managerial, engineering, and economical implications for supply chain performance, including sustainability and resilience (Montreuil et al. 2021).

5.3. BLOCKCHAIN

Blockchain is a technique that allows a network of users to jointly maintain a database of transactions. The database forms a chain of data. It is structured in blocks, that are chained together. The database is managed decentrally, in a network of participants (nodes). Blockchain technology goes back to 2008, when the first steps were taken in the financial world with Bitcoin. Since then, major steps have been taken and applications are being developed with blockchain technology in all kinds of sectors, including the logistics sector.

Conceptual, blockchain presents many opportunities for logistics chains. Supply chains often still rely on paper documents, a source of inefficiency and susceptibility to fraud. The documents are gradually becoming digital. Blockchain enables companies to do business in a direct, peer-to-peer way. It is a digital solution for security and mutual trust, which is very important in the logistics industry. It is meant for transactions that require verification, like contracts, intellectual property, identification, and cryptocurrencies (bitcoin and alike).

5.3.1. Expected Benefits and Impacts of Blockchain

In logistics, blockchain has the potential to improve communication and generate mutual trust between agents in the supply chain. It is safer (1), more transparent (2) and more efficient (3).

Each of the transactions executed on the network of participants is recorded and archived permanently. Information of the register cannot be modified, preventing data being deleted and double registrations;

Information is recorded in each node that make up the network;

Information must be verified automatically by various devices involved in the blockchain network. This avoids waiting for a third party to validate the data.

5.3.1.1. Smart Contracts

Smart contracts are a valuable type of blockchain for logistics. By eliminating intermediaries and simplifying processes, costs for the end consumer can be reduced. Smart contracts are distributed among all the nodes of the network. All nodes must verify and validate the contracts and prevent them from being manipulated by one of the parties.

5.3.1.2. Real-Time Traceability

Current track & trace lack real-time capabilities. In combination with IoT (Internet of things), blockchain can potentially improve the real-time traceability of products. IoT systems are connected sensors / devices to capture data without human intervention. The sensors can determine the source of components and regulatory compliances. They can be embedded in transported goods, for monitoring product damage, temperature, etc. When IoT is combined with blockchain technology, data can be shared with each participant of a supply chain (suppliers, producers, distributors, etc.). Data is updated and validated securely, with full visibility for all.

5.3.1.3. Reduction of empty truckloads

Blockchain has potential to reduce empty truckloads. It can help to match shippers with carriers.

5.3.2. Critical Factors for Successful Implementation

For the success of blockchain it is pivotal that IoT (Internet of Things) and blockchain are associated technologies. Without the link via sensors, the advantages of blockchain for the supply chain will not be maximized.

Blockchain is advantageous when interests differ and when trust could be improved. It can easily resolve disputes between participants. In addition, it facilitates faster transactions by allowing cross-border transfers with a digital currency.

5.3.3. Key Challenges

5.3.3.1. Costs

The blockchain technology can be costly. The mining (the system to validate transactions) can consume a lot of computational power. In the logistic sector, miners will need to be compensated to validate transactions.

5.3.3.2. Preparation

Some sectors still need to prepare for blockchain technology. For example, in the construction sector only a few use-cases exist. There are several reasons for that: first, the sector has low margins and contractors can be conservative towards new technology. Second, contractors and subcontractors are often long-term relationships. Third, a low percentage of revenues is invested in up-front contracting and tools for managing complex construction projects. Fourth, pilot projects can be a great help to convince the construction sector.

5.3.3.3. Standard

According to Briq, (PIARC working group 2.3.1 report) a leading American example of applying blockchain in construction, blockchain needs to be backed by a blockchain standard, in order to become an industrywide initiative. They consider just blockchain itself as hard to sell commercially.

5.3.4. Outlook

Where supply chains still rely on paper documents, there is inefficiency and a high risk of errors. The digitization process has started in many sectors. Blockchain has the potential to be the dominant infrastructure for digital supply chains in the future.

As blockchain can be linked to IoT (Internet of Things) for an optimal result, the success is dependent of that development as well.

In order to make it work in LMIC (Low- & Middle-Income Countries) the governments need to invest in the digital infrastructure, possibly with support of HIC (High Income Countries).

6. FREIGHT VEHICLE TECHNOLOGIES

Demand for the transport of freight is expected to continue increasing over the coming decades. In partnership, governments and industry have a responsibility to ensure the freight system can meet the growing freight demand. New freight vehicle technologies offer an opportunity to dramatically improve productivity, road infrastructure usage, safety, and resiliency, while also addressing public and private targets for reducing emissions. The following freight vehicle technologies are discussed in this section: battery electric vans and trucks, electric cargo bikes, biofuel vehicles, and heavier and longer trucks.

6.1. BATTERY ELECTRIC VANS AND TRUCKS

In 2019, the European Parliament adopted standards to reduce emissions from trucks by 15 percent by 2025 and 30 percent by 2030. The implementation of battery electric (BE) vans and trucks is therefore considered a key measure to reduce emissions from road freight transport. Several major manufacturers are developing battery electric vans and trucks.

Currently, the purchase price, range, charging time, and charging infrastructure are major disadvantages for BE vehicles. Battery electric trucks are therefore mostly used for short trips (e.g., in city logistics). The batteries are a main cause of the high sale prices of BE vehicles. The cost of batteries has, however, decreased. For example, the price of a lithium-ion battery decreased 89 percent from 2010 to 2020, with the volume-weighted average reaching $137/kWh. It is expected this trend will continue with the introduction of new technologies, new manufacturing techniques, and simplified battery pack designs. At the same time, driving distances are expected to increase, and charging time to decrease.

DHL Supply Chain has announced the United Kingdom's (UK) first fully electric Volvo heavy-duty tractor units. Featuring Volvo's largest 540 kWh battery which provides 666 hp, the four zero-emissions trucks have a capacity of 40 tonnes and range of up to 300km/180 miles, allowing them to complete full roundtrips. servicing DHL's retail and automotive customers across the UK.

Given lower maintenance costs and the fact that the cost of electricity is substantially lower than diesel, it is expected that battery electric vehicles will become less expensive than conventional vehicles. For example, in Norway, it is expected that both battery electric vans and trucks will be cheaper than diesel vans and trucks by 2030:

- small vans by 2021;
- large vans by 2024;
- trucks for local and regional transport by 2025;
- trucks for rock/soil transport by 2027; and
- trucks for long-haul by 2028 (see Figure 2).

Megawatt-scale charging stations and the emergence of much higher energy density batteries are, however, required for heavy-duty long-haul operations to become a viable option.

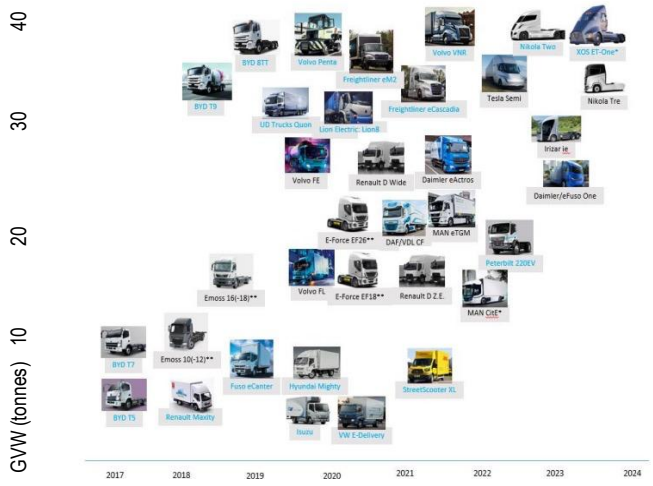


Figure 2. Announced new battery electric trucks of different sizes.

6.2. BIOFUEL VEHICLES

Replacing fossil fuels with biofuels is another mechanism for decarbonizing the road freight transport sector. Biofuels are produced from food waste, residues, and dedicated crops that do not compete with food crops (such as crops grown on marginal land).

Today, used cooking oil and waste animal fats provide most non-food-crop feedstocks for biofuel production. Given that these feedstocks are limited, new technologies will need to be commercialised to expand non-food-crop biofuel production. For instance, cellulosic ethanol and biomass-to-liquids technologies use non-food feedstocks to produce low-carbon biofuels for use in the transport sector. While the average production cost is still double to triple that of fossil fuel equivalents, it is anticipated that the cost can decline by as much as 27 percent over the next decade.

Currently, biofuel only accounts for about 3 percent of transport fuel demand. This is because biofuels are mostly consumed through blending at low percentages with fossil fuels (typically less than 10 percent by volume or unit of energy). One way of increasing the usage of biofuels is to incentivize the use of flexible-fuel vehicles – specifically in LMICs with significant feedstock resources. Flexible-fuel vehicles can operate on high biofuel blend levels or even on unblended biofuel, without modifications to engines, maintenance regimes or fuel supply infrastructure.

6.3. ELECTRIC CARGO BIKES

In African countries, such as Ghana, an increasing number of people and goods must be transported within a system of inadequate energy supply and road transport infrastructure. Electrified cargo bikes are considered a space-efficient and eco-friendly alternative for freight transportation in many African cities. Due to their low energy demand and battery capacities, they offer the potential to be supplied with electricity via the mini-grids commonly used in African countries, as a full-coverage electricity supply is not yet available everywhere. An analysis of the use of electric cargo bikes for the delivery of parcels, groceries and other goods in urban areas showed that cargo bikes have a smaller potential impact on global warming compared to diesel vans. The most important parameters for the reduction of greenhouse gas (GHG) emissions are the use of renewable energies for the charging of the batteries, the utilization of the payload capacity and the production of the

battery. It could be shown that the GHG emissions over the life cycle are significantly lower when the batteries are powered by solar energy. Including solar powered e-cargo bikes in the modal split for freight transport in the Accra region (in Ghana) would result in GHG emission savings of 4-8 percent.

6.4. HEAVIER AND LONGER TRUCKS

In most countries around the world, vehicle size and weight are defined in legislation. Australia's Performance Based Standards (PBS) is an exception. PBS is a voluntary initiative that allows heavy vehicle operators to use innovation to propose new vehicle designs to achieve greater productivity and improved safety, while minimising impacts on the environment and road infrastructure. PBS vehicles are therefore designed to perform their tasks as productively and safely as possible, and to operate on networks that are appropriate for their level of performance. In 2008 there were 73 PBS vehicle combinations and as of 31 August 2022, more than 14,500 PBS combinations have been approved.

A notice is an authorisation instrument that allows a restricted access vehicle, such as a PBS vehicle, to travel on the road network. The notice may exempt vehicles from requirements such as mass and dimension under the Heavy Vehicle National Law (HVNL) and its regulations and may require additional conditions to be met. National notices may apply to multiple jurisdictions, with state/territory notices applying to single jurisdictions. There are several national and state/territory notices that apply.

Once a PBS vehicle or vehicle combination has been approved, the National Heavy Vehicle Regulator (NHVR) assists PBS vehicle operators to obtain authorisation to access the road network. Applicants are encouraged to review existing notices and state and territory maps for intended operating routes and any constraints or conditions that may apply. If the journey is already covered by a notice, an access permit is not required.

The National Heavy Vehicle Regulator (NHVR) estimated that at the end of 2021, PBS vehicles had reduced total road freight distance travelled in Australia by over 2.74 billion kilometres. The PBS fleet is also newer, and generally fitted with better safety and environmental technologies. This contributes to fuel savings and GHG reductions, vehicle operating cost savings, infrastructure maintenance savings and early indications of safety improvements. The PBS scheme is also a key solution to mitigate the impacts of driver shortages. The NHVR estimates that over 4,000 vehicles (and by extension driver requirements) have been "saved" due to the productivity (estimated at between 15 and 30 percent) and trip reduction benefits offered by PBS vehicles.

7. ALTERNATIVE MODES OF FREIGHT TECHNOLOGIES

The traditional modes of freight transport have their own sets of technical, commercial, and operational characteristics, some still under technical development. The three main types of traditional modes are:

- land transport (i.e., road, rail, and pipeline transport),
- sea transport (i.e., ship transport), and
- air transport (i.e., planes).

This chapter focuses on emerging alternative modes for freight transportation technologies and includes:

- underground freight transport,
- large-capacity airships,
- air drones, and
- autonomous delivery robots.

7.1. UNDERGROUND FREIGHT TRANSPORT

The idea of tube transportation itself is quite an old. In the US, demonstration systems for underground carrier service for movement of small shipments, such as letters were implemented in 1869-70. During the 1970's, the idea of developing larger tubes for transporting general merchandise began to be considered. All the systems mentioned so far were pneumatically powered. In 1994, a research program on the feasibility of SUBTRANS, an underground freight system powered by linear induction motors was conducted (see Figure 3).

In Japan, a research program on the feasibility of New Freight Transport System, an underground freight transport system, was conducted in the 1990s. It was assumed that Dual Mode Truck (DMT) would be manually driven by drivers on regular surface roads and automatically driven without drivers within the system (see Figure 4).

Recently, underground logistics systems have been studied in several countries. Examples include Cargo Sous in Switzerland, Tube Cargo Express in the Netherlands, CargoCap in Germany, Mole Solutions in the United Kingdom, Pipenet in Italy and MTM in the United States. These projects are in the early stages of development.

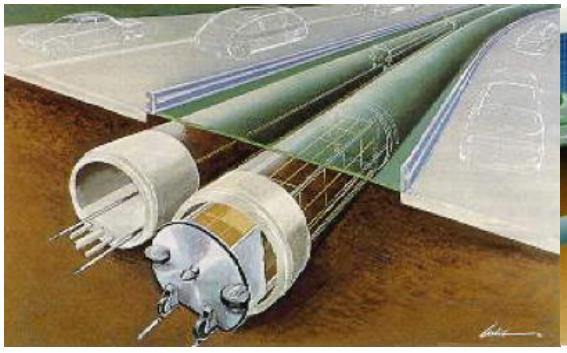


Figure 3. SUBTRANS (the United States)

Figure 4. New Freight Transport System (Japan)

The following is an overview of Cargo Sous as an example.

Cargo Sous Terrain (CST) is a Swiss underground freight transport system for the flexible transport of small components. Tunnels connect production and logistics sites within urban centres. Self-driving, unmanned transport vehicles automatically pick up and drop off loads and operate in the tunnels continuously around the clock. The vehicles travel on wheels and have an electric drive with induction rail. The goods are palletised or transported in containers by unmanned, fully automated, refrigerated transport vehicles.

Overground, CST distributes the transported goods in environmentally friendly vehicles (last-mile distribution), contributing to the reduction of traffic congestion and noise emissions. CST is ideal for deliveries and disposal (e.g., waste disposal and recycling). One hundred percent of the power to operate the system comes from renewable energy sources.

Since the Swiss Federal Act on the Underground Transportation of Goods, which provides the legal basis for CST, took effect on 1 August 2022, the first section is expected be operational by 2031. The rest of the network will be built by 2045.

7.2. Air Freight Transport

7.2.1. Example 1: Large-Capacity Airships

Airships are often associated with a transport solution of the past. However, there are signs that airships can play a role in cargo transport by air and contribute to GHG emissions reduction in the future. Cargo airships (designed specifically for the transport and handling of freight) are an emerging mode that has had many theorised designs and uses over the past decades but now looks to be finally emerging from the realms of theory into production in the near future. These airships could offer new perspectives for cargo transportation and address severe infrastructure and capacity limitations affecting roads, seaports, and airports around the world. Furthermore, airships allow regions to connect to global markets since public and private sector industry face huge challenges for special cargo transport in dense or remote areas. Likewise, heavy industries are looking for innovative, affordable, and sustainable ways to transport heavy and bulky loads. The use of cargo airships frees freight transport from the constraints of existing road infrastructure and networks (e.g., bridges, tunnels, and roundabouts).

Point-to-point transport solutions, which do not require runway infrastructures, may provide solutions to these challenges. Large-capacity airships can transport point-to-point heavy and oversized loads up to 60 metric tons. These airships can load and unload on hover flight, which means ultimate flexibility, and have a limited footprint for operations. Furthermore, airships can be equipped with environmentally friendly propulsion systems.

7.2.2. Example 2: Air Drones

In Australia, conceptual modelling has been done to test the opportunities, challenges, and risks of the widespread future use of air drones for goods deliveries and passenger flights. The concept modelling identified four plausible future scenarios for drone transport in 2036. Forecasts for drone trips for the freight use cases range between 108,000 and 278,000 trips per day, with 45 to 65 percent of these trips classified as food delivery. The impact of drone freight delivery on road transport is considered limited and mainly affecting the suburban road network, outside of peak hours. Suburban areas with lower population density show greater demand for drone deliveries. Lower demand is expected in inner-city areas where greater choice of alternative transport options (ground) makes drone delivery less competitive.

An experiment in Belgium shows potential for specific applications in cities. In Antwerp, a drone was deployed to transport human tissue over urban areas between different hospital campuses. Transport via drone is not only greener but also faster. The transport took half the time of even smooth traffic flow. The absence of traffic jams in the air ensures a reliable flight time (Focus on Belgium, 2022).

During the COVID-19 pandemic in 2020, the U.S. Federal Aviation Administration granted a Part 107 waiver for drone delivery of medical supplies and personal protective equipment (PPE) to medical facilities in North Carolina. In addition, Amazon, Walmart and other major retailers are starting to deliver packages by drones to customer homes.

Drone delivery is also being conducted in LMICs especially in Africa and has the potential to revolutionise delivery of life saving medical supplies to remote areas. In 2016, the world's first drone delivery system was launched in Rwanda operating at a national scale. As of September 2021, more than 75 percent of blood deliveries in Rwanda outside Kigali used drones to deliver to 21 facilities in less than 30 minutes. In 2019, in Ghana vaccines, blood, and medicine was being delivered by drones. In 2021, drones are delivering medical supplies to around 400,000 residents of Tanzania's remote Ukerewe island district of Lake Victoria (see Figure 5). Drone delivery services could replace existing land transport services for the same-day delivery of online purchases and medical supplies. The services could substitute for multiple deliveries by conventional vehicles. For example, takeaway food delivery trips could likely replace vehicle trips in outer suburbs and reduce the cost of travel and transport disadvantages in these areas, islands, and other remote areas.

Figure 5. Drones delivering medical supplies to residents in Tanzania.

The number and location of distribution hubs, trips per hub, and land use sensitivity adjacent to hubs and underlying flight paths would need to be carefully managed to avoid noise and privacy issues. Future regulations and restrictions should also match the risk and maximise opportunities for a viable air drone industry.

7.3. AUTONOMOUS DELIVERY ROBOTS

Autonomous delivery robots are emerging technologies for urban goods logistics and supply chains. These devices are electric robots on wheels, suitable for last-mile deliveries of relatively small and light parcels. Delivery robots have been in use for decades in privately owned closed systems like warehouses and factories, called driverless transport systems or automatic guided vehicles. The new aspect is the use of delivery robots in the public domain. Delivery robots can move autonomously in the public space, and delivery can be done directly from a store or a permanent or mobile hub. At pedestrian speed, delivery robots can safely navigate around people, animals, and objects.

The main reasons for using such robots are the high costs and negative environmental impacts of current (last mile) delivery schemes. Like any form of electrically powered transport, delivery robots are quiet and do not emit any GHG locally. They are a promising alternative solution for the last-mile delivery of goods, especially in an urban environment. The uptake of this technology could result in fewer freight trucks and vans, which are currently the predominant last-mile logistic option. Other factors possibly speeding up the introduction of delivery robots are an increasing demand for delivery in smaller orders due to e-commerce growth, and the aging and lack of truck drivers.

Urban last-mile delivery is the most expensive part of the logistics supply chain. The main reasons for this are the low average speed and the complexity of the routes (i.e., many stops and long walking distances). The need to decelerate, stop, and accelerate negatively impacts fuel efficiency. Delivery robots may contribute to the decongestion of cities because they use footpaths and do not drive and stop on the road, creating fewer conflicts during the loading/unloading process. Reaching maximum capacity on sidewalks is rarely a problem. A delivery robot is cost efficient compared to delivery by trucks and vans with a driver. Test results show costs for local deliveries 5 to 10 times cheaper than that of traditional distribution.

However, putting these systems into practical application poses challenges, including legal and insurance-related issues (e.g., in case of accidents or failed deliveries). Technologies to detect obstacles and avoid collision with them are also very expensive. These systems must also be able to consider all types of weather situations, pedestrians, and other living creatures and their sometimes-unexpected behaviour (e.g., children playing, cyclists biking, and animals roaming) in order to avoid conflicts. The issue of public acceptance of robots operating on sidewalks used by pedestrians is also important.

For example, a law of traffic rules for remotely operated small vehicles has come into effect in Japan. After April 2023 the delivery robots can drive at a speed of 6 km/h or less on sidewalks, roadside strips, or on the right side of roads without road markings. They must follow traffic rules equivalent to pedestrians, such as traffic lights, road signs, and crosswalks, and must yield to pedestrians.

8. AUTOMATED FREIGHT TRANSPORT

Automated freight transport is key to the application of emerging technologies to freight transport and logistics. Various countries in Europe, America, and Asia have developed and tested autonomous driving trucks and truck platooning. The main purposes of introducing autonomous trucks and truck platooning are:

- improving efficiency by alleviating traffic congestion, reducing fuel consumption, and lowering operation costs;
- improving safety by decreasing crashes of vehicles on roads; and
- solving the shortage problem of truck drivers by using driverless operations.

Truck platooning can reduce the aerodynamic drag acting on vehicles in the platoon by leaving only short-distance gaps between vehicles. The platooning operation is expected to decrease fuel consumption. Also, the number of trucks on highways can be increased by introducing platooning. Since about 90 percent of truck crashes are caused by human error, traffic accidents related to freight vehicles may decrease if braking and acceleration are automatically controlled. Transport companies in developed countries suffer from the common problem of a shortage of drivers. If driverless vehicles are used for the following vehicles, platooning will help solve this issue.

This section discusses the benefits and impacts, key challenges, and outlook of autonomous trucks and truck platooning for freight transport and logistics.

8.1. AUTONOMOUS TRUCKS

Autonomous trucks are one of most promising emerging technologies for freight transport and logistics. Commercial trucks can be outfitted with autonomous driving systems that offer varying levels of driver support features. Some technologies, such as lane-keeping assist, adaptive cruise control, and automatic braking, are available for operating vehicles. Self-driving capabilities are becoming more common as well although a driver is still required. The highest level of automation of vehicles would not require human interactions in most circumstances, which can lead to cost savings and safer driving. A further area of discussion is the policies that are required to promote autonomous trucks for more efficient and safer operation of vehicles, taking into account other traffic on roads.

8.1.1. Expected Benefits and Impacts of Autonomous Trucks on Freight Transport and Logistics

Autonomous trucks can help mitigate the impacts of existing Hours-Of-Service (HOS) regulations on driver shortage problems in the transport industry. If fully automated trucks are achieved, the need for drivers for long-distance segments will decrease. These drivers could be shifted to last-mile delivery in urban areas.

8.1.1.1. Freight Mobility and Reliability

Trucking companies will be better able to manage driver HOS requirements using autonomous trucks. This will increase freight mobility and reliability by optimising the operation and schedule of vehicle movements and drivers, based on AI application in logistics management.

8.1.1.2. Shifting Human Drivers

Autonomous trucks can shift human drivers from long-distance driving to managing shipments and last-mile deliveries. The change would be a solution to the driver shortage problem. This provides good opportunities for logistics companies to focus more on better services to customers, such as strict time windows.

8.1.1.3. Safety and Mobility

With the use of autonomous trucks, the level of safety and mobility will improve by decreasing the human errors in manual driving. Most traffic accidents involving heavy vehicles are caused by drivers' mistakes in recognising obstacles when operating vehicles.

8.1.1.4. Fuel Consumption

The fuel consumption of autonomous trucks will be improved by maintaining the optimal speed of vehicles with less braking.

8.1.1.5. Economic Competitiveness

Autonomous trucks can improve the economic competitiveness of trucking companies by cutting operational costs of personnel, fuel, and delay of delivery due to traffic accidents.

8.1.2. Key Challenges

8.1.2.1. Navigation in Unfamiliar Environments

Autonomous trucks, like many automated vehicles, have difficulty navigating in unfamiliar environments that either have not been tested or are not recognised by the system. The navigation systems of the Global Navigation Satellite System, digital maps, and other techniques are currently used for autonomous vehicles, but these resources do not always cover all situations on roadways. Therefore, a driver should take control in such circumstances.

8.1.2.2. Unmapped Areas and Poor Conditions of Roads

Autonomous trucks that use digital maps cannot easily run on unmapped alternative routes. Autonomous trucks also have difficulty smoothly operating under poor conditions of faded painting of the pavement if the technology uses the white line for identifying the truck's position.

8.1.2.3. Legal System

The legal system for regulation and enforcement of autonomous trucks is a challenge. Crashes involving self-driving vehicles require an appropriate legal system to determine the responsibility for accidents. Another challenge is the enforcement of traffic regulations on autonomous vehicles by law enforcement agencies on the actual roadside. In countries where the rules of the road are governed regionally, challenges can involve

implementing standards across provinces and territories.

8.1.3. Outlook

Autonomous trucks are promising technologies that give good opportunities to improve the efficiency and safety of freight transport. Policy makers need to monitor the development of this technology to maintain public safety, prepare infrastructure and traffic management systems, support workforce training, and realise the safety and efficiency benefits created by these advancements. Recent trends in the United States and Canada show that the industry focus has shifted towards higher automation rather than platooning. This is likely the result of the industry perception that driverless truck transportation is on the horizon and that a greater cost-benefit exists when compared with a lower-level automation alternative.

8.1.4. Example Of Technology Application

With the aging of the population, securing local transportation in rural areas of Japan has become an issue. The fact that Japan's transportation is also seeing its workforce decline in truck and bus operations due to the population decrease means improving productivity to handle the increasing freight trips is an urgent issue. Japan conducted a pilot program from FY2017 to FY2022. In 18 hilly and mountainous areas across the country, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) conducted a pilot program to demonstrate an autonomous driving service for passengers and freight around Michi-no-Eki because these Michi-no-Eki resting areas have started to offer retail and medical (clinic) services.

In 2020, the Japanese Road Act was amended. With this amendment, electromagnetic induction lines (see Figure 6), magnetic markers and other autonomous driving support devices (see Figure 7 and Figure 8) became legally classified as road facilities or objects on the road for exclusive use and are expected to help address the self-locating issue due to weaker GPS signals in mountainous areas, tunnels, and under bridges as identified in the pilot program.

Figure 6. Electromagnetic Induction line

Figure 7. An example of full-fledged service of autonomous driving

Figure 8. Transporting agricultural products

8.2. TRUCK PLATOONING

Cooperative truck platooning (CTP) involves the formation of a temporary convoy of two or more Class 8 tractor semi-trailer combinations, each equipped with a cooperative truck platooning system (CTPS) and travelling in close proximity to each other at highway speeds. Operationally, joining, leaving, or modifying CTP operations or manually disengaging the CTPS for any reason may occur at any time at the discretion of the driver.

In Canada, a number of on-road trials have been initiated across the country. In 2022, the province of Alberta, Canada, deployed a truck-platoon on-road trial. The trial begun with closed-track testing to evaluate dynamic performance and driver fatigue. Following track testing, real-world trials were conducted on Alberta's Queen Elizabeth Highway II – the major transportation corridor between Edmonton and Calgary. Data were collected over 41 trips (23, 115 km) conducted between January 12 and 20, 2022 to assess CTPS fuel consumption, safety, reliability, and driver experiences. The trial was launched in close collaboration with federal and provincial regulatory authorities. Results will help inform regulatory, policy, and program approaches to the introduction of connected and automated vehicle technologies in Canada. For further details, see Cooperative Truck Platooning System (CTPS) - AMTA - Alberta Motor Transport Association.

Advancements in off-road settings include a forestry company experimenting with truck platooning for transporting lumber on unregulated logging roads. The lumber would be moved on platooning trucks on private logging-only roads until they reached standardly regulated roads. Then the lumber load would revert back to single-vehicle transportation.

Research is underway to realize a truck platooning system with a driver in the lead-vehicle and without drivers in the following vehicles in Japan. The government has initiated the pilot project in FY2016 to explore the following issues:

- Tracking control algorithm and vehicle-to-vehicle (V2V) communication technology based on the concept of “electronically connected vehicles.”
- “Human Machine Interface” which shows the lead-vehicle driver the conditions of the following vehicles and the system.
- Weaving behavior of the following vehicles just after switching from manual to automatic operation mode and/or being affected by side winds.
- Difficult situations under various natural and traffic environments, including tunnels and multiple road alignments.
- The control accuracy targets (10m or less for the distance between vehicles in the longitudinal direction and ±0.5m or less for the lateral direction) at 80km/h.

The platooning pilot project revealed the following insights.

- Errors in sensing lanes due to faded road markings.
- Inconsistency in the automatic following-distance control among trucks due to the difference in acceleration/deceleration performance.
- Difficult situations at merge, diverge segments or reduced lanes when other vehicles squeezed between the platooning trucks and stayed there for a long period or found themselves difficult to merge into the main traffic.
- Reduced accuracy of “high-precision” GPS used for tracking.
- Impacts of rainfall, snowfall, dense fog and other weather condition changes.
- Pedestrian traffic in parking areas, disruption caused by the long truck platoon on other vehicles.

The government identified the following infrastructure requirements:

- Location marks to provide accurate location data.
- Magnetic markers and other positioning support systems to address reduced accuracy of GNSS measurement at certain segments such as tunnels and segments under elevated roads.
- Space for formation/deformation of truck platooning.
- Merging support system.
- Information on the traffic conditions/obstacles ahead of drivers (see Figure 9).

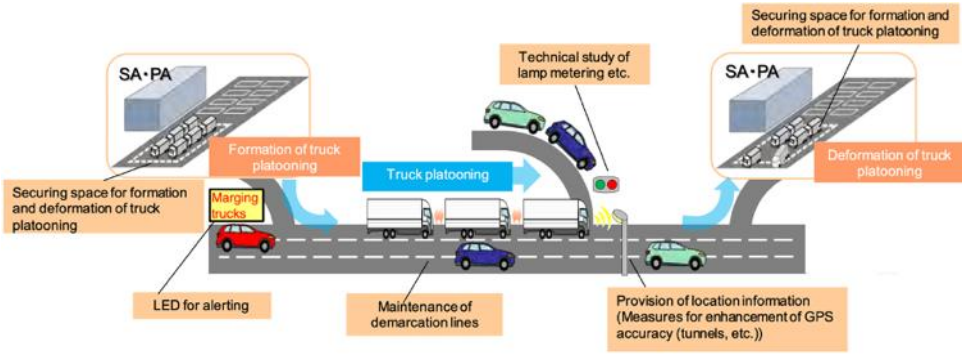


Figure 9. Image of the road infrastructure for a truck platooning system

8.2.1. Example of Platooning Technology Application

8.2.1.1. Case Study – HelmUK: The UK Platooning Trials Background

HelmUK was the UK's first real-world trial of HGV platooning technology on the road network which ran between 2017 and 2022 – including a 9-month break in activity due to the COVID 19 pandemic. The concept of this particular platooning trial was to use advanced driver assistance systems to enable HGVs to safely travel close together to save fuel via a slipstreaming effect (see Figure 10). The trials were both busy and complex and involved a variety of participating partners and stakeholders. These included TRL, who managed the project, whilst DAF provided the trucks and drivers. The project sponsor was the UK's Department for Transport and National Highways.

Helmut's exhaustive analysis of real-world trials found that platooning saved small amounts of fuel: 0.5% in comparison to Adaptive Cruise Control (ACC) in the real-world. Further analysis found that if conducted on a road network optimised for platooning, fuel savings could increase to between 2.5% and 4.1%. HelmUK also found that platooning was as safe as trucks using ACC, if risks with merging vehicles at junctions are managed.

Figure 10. Platooning formation at 0.8 seconds time-headway during Safety Case validation on UK test track and on-road.

The trials were run in three phases:

- **Phase 1 - Detailed planning, design, and build.** The development and validation of the platooning system and Safety Case including driver training and track trials.
- **Phase 2 - Network familiarisation.** On-road operation and system validation on the approved route.
- **Phase 3 - Road trials.** Real-world trials and data collection followed by data analysis and final reporting.

The road trials were conducted using three articulated HGVs fitted with a prototype DAF platooning system, which was released for road trials after track tests by DAF and TRL. The key features of this platooning system, which allowed safe operation at low following distances, were:

- Cooperative Adaptative Cruise Control which keeps the distance between the vehicles constant using short-range vehicle-to-vehicle (V2V) communication.
- Brake Performance Estimator which adjusts the distance between the vehicles based on vehicle weight to ensure safety no matter the load or order of the trucks.
- Cooperative Collision Avoidance which ensures coordinated automatic emergency braking.
- Lane Keeping Assistance which supports the driver's steering to prevent vehicles from veering out of lane.

The road trials were undertaken after a progressive series of track trials during which the truck platooning technology, the additional safety monitoring sensors and cameras were tested, and the drivers were trained and familiarised with the equipment and requirements of safe platooning in real-world trials.

A section of the Strategy Road Network was chosen. The trial route was on the M5 and M6 motorways between Avonmouth and Stafford (and then back again). The total round trip was 218 miles. When on the road, vehicles would engage platooning where it was safe to do so and only on the approved route. Based on the safety case, some junctions were considered suitable for platooning operation while others were not. The average distance between junctions was 5.59 kilometres; for motorways in England the average distance between junctions is 5.56 kilometres, so the HelmUK route was very close to the English average.

When platooning, the trucks travelled in lane 1 only, 0.8 seconds apart (19.0 metres at 53 miles per hour (85.3 km per hour)). Across the project, there were 58 days on-road covering over 12,000 miles (19,300 km) and capturing 12 million lines of data and 4,000 hours of video footage.

The trials had a number of fixed parameters:

- **Number of trial vehicles** – there were three tractor units fitted with platooning equipment and there were always three vehicles in the platoon (see Figure 11).
- **Position of the vehicles in the platoon** – Helm01 always led followed by Helm02 and Helm03.
- **Vehicle load** – each vehicle was loaded so that the combined gross combination weight of the entire platoon represented the average UK load carried by comparable vehicles on domestic freight journeys. The loads were kept constant throughout Phase 3:
    - Helm01: 22.5 tonnes / 37.2 tonnes (payload / gross combination weight).
    - Helm02: 9.2 tonnes / 23.9 tonnes.
    - Helm03: 0 tonnes (unladen) / 14.7 tonnes.

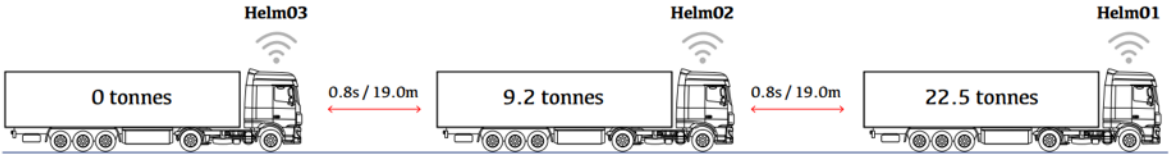


Figure 11. Position of the vehicles in the platoon

HelmUK's core aim was to conduct trials in a real-world setting. Therefore, there were a number of variables which could not be controlled for during the trials, but which can be controlled when analysing the data. These included: weather, wind direction, speed, acceleration, gradient and driver. The route was largely oriented in a north-south direction. The prevailing wind direction during the road trials was from the south-southwest at Staverton weather station (nearer the south of the route), and from the west at Birmingham weather station (nearer the north of the route). The average wind speed was between 3 and 4 metres per second (approximately 8 miles per hour).

The trials compared performance between platooning and non-platooning – mostly using adaptive cruise control.

The trials required the analysis of a range of complex scientific data for the duration of the Real-World trials. From the data the trials demonstrated the following safety and fuel economy benefits of platooning:

- **Safety**
  - The DAF platooning system was fail-safe in road trials as demonstrated in Phase 1 (track phase) of the project.
  - Platooning kept good control over the position of the vehicles relative to one another; no time was spent closer than 0.8 seconds which did occur in non-platooning operation.
  - Surrogate Safety Measures taken from vehicle data evidenced that, overall, the vehicles were safer in platooning mode.
  - Cooperative Collision Avoidance functionality reduced collision risk on a few occasions; however, there were some activations which could have posed a risk to following vehicles.
  - Platooning is not expected to introduce new collision types and is predicted to have a small beneficial effect on common, existing HGV collision types overall.
  - Driver workload did increase slightly due to platooning, but only by a very small amount – overall, driver workload was not substantially impacted.
  - For junctions which were platooned through, platooning did not increase risk to other road users or disrupt traffic flow.
  - The residual risk for platooning systems is conflict with merging vehicles at junctions, which is caused by close following distances.
- **Fuel Economy**
  - *Real-world fuel savings (0.5%).* HelmUK found that the measured fuel savings across three vehicles were 0.5%. Statistical modelling showed that fuel consumption was significantly different to trucks using ACC. Analysis confirmed that the number of junctions that could not be safely platooned through was the main reason for the low fuel savings. The vehicles could only spend 53.5% of their driving time in platoon.

- *Optimised fuel savings (2.6%).* To further explore the potential of platooning, two optimised scenarios were created from the HelmUK data to represent possible future scenarios for platooning deployment. The first looked at a route where all junctions were suitable for platooning, and the second looked at areas of the route where a high degree of platooning occurred. The measured fuel savings across three vehicles for these two scenarios rose to 1.7% (at 74.7% of time in platoon) and 1.8% (at 85.7% of time in platoon), respectively. Further statistical modelling performed on these two scenarios, which accounted for other variables on fuel consumption (such traffic flow, journey direction, platooning states, weather, etc.), showed that the fuel savings of platooning alone were marginally greater than the fuel savings directly measured at 2.5% and 2.6% respectively.
- *Perfect fuel savings (4.1%).* Finally, it was investigated what platooning could achieve in perfect conditions, where there was completely uninterrupted platooning. In this scenario, fuel measurements from HelmUK showed that platooning could produce fuel savings of 4.1% across three vehicles. Further details can be found in the full trial report: https://nationalhighways.co.uk/media/l43fgudu/helmuk-final-report.pdf.

9. FREIGHT TRANSPORT MANAGEMENT

A number of freight transport management technologies have been implemented across the globe to enhance the efficiency of freight transport operations at the border, in communicating truck parking availability, in digitisation freight, and in implementing a national heavy vehicle permitting system. This section discusses emerging freight transport management technologies with a specific focus on the outlook and transferability of these technologies.

9.1. BORDER MANAGEMENT

The truck border crossing process at the United States-Mexico border is complex due to the multiple stakeholders participating in the process from both the public and private sectors and various levels of government. Numerous technologies are being implemented to streamline the process and increase security and safety.

The typical process starts with a tractor picking up a trailer box at a warehouse, manufacturing facility, or truck yard and taking the trailer to the border crossing. At the border, there are three typical inspections:

1. Mexican Customs performs a random security check before the load reaches the border. This inspection verifies that the export documentation coincides with the cargo load.
2. U.S. Customs and Border Protection (CBP) performs a security inspection to verify that the shipment is legal and contains no contraband or other potential violations.
3. The U.S. state where the vehicle's roadworthiness is assessed performs a vehicle safety inspection.

New emerging technologies are being tested to improve the process even further. This subsection summarises current and emerging technologies being deployed at the US-Mexico border that improve border management and the truck border-crossing process, reducing logistics costs, decreasing environmental impacts, and improving vehicle safety.

9.1.1. Description of the Technologies

9.1.1.1. Radio-Frequency Identification Technologies

CBP uses radio-frequency identification (RFID) technologies to issue a tag to each commercial vehicle crossing the US-Mexico border once it pays the annual duties. CBP scans the tag, identifying the truck that has paid the fees. The truck does not have to stop while this occurs.

Tolled international bridges use RFID technology to collect tolls automatically. Similar to a toll road, the international bridge collects tolls for trucks at a gate crossing in each direction.

The Texas A&M Transportation Institute developed a system several years ago to measure border-crossing and wait times by reading any RFID tags commercial vehicles have on their windshield at four fixed stations during the border-crossing process. The Border Wait Time Measurement System (BWTMS) reads tags from trucks and estimates travel times between stations, providing that information to the public in real time. The BWTMS also provides historical data at 10 commercial international border crossings at the US-Mexico border.

9.1.1.2. Weigh-in-Motion Scales

Weigh-in-motion (WIM) systems are designed to record axle weights and gross vehicle weights as vehicles travel at reduced speeds over the weight pad. At the state vehicle safety station, inspectors monitor and identify potential violators by analysing vehicle axle and gross weights. Legal-weight vehicles can continue without interruption, while potential violators are redirected to static weighing and inspection stations. This technology provides transportation agencies with information to expedite vehicle safety inspections and allows trucks under the weight limit to bypass static scales or lengthy inspections.

9.1.1.3. Dynamic Message Signs

Dynamic message signs (DMSs) are electronic traffic signs often used on the side of the road that provide drivers with real-time traffic alerts. Typically, DMSs provide information regarding traffic congestion, accidents, amber alerts, work zones, travel times, or speed limits. In the border environment, DMSs are located to direct traffic at the various inspection stations. In Mexico, DMSs at the Mexican Customs and CBP facilities direct trucks to specific lanes for security inspections. Trucks violating the maximum axle weight at the state vehicle safety inspection stations are directed to secondary inspection via DMSs. DMSs are also used in urban areas near the border crossing to display crossing times or any incident that could result in delays.

9.1.1.4. Automatic License Plate Readers

Automatic license plate readers (ALPRs) are high-tech devices capable of capturing computer-readable images of license plates. ALPRs are installed at the CBP primary inspection booths to confirm that the tractor license plate coincides with the documentation previously presented to CBP on that particular shipment. ALPRs are also installed at the state vehicle safety station to record WIM data and match it to a particular vehicle.

9.1.2. Benefits

The implementation of these technologies makes the border-crossing process more efficient. RFID technologies allow agencies to identify vehicles, cross-check information against a database without stopping the vehicle, and have the driver provide paper documentation. RFID was crucial to developing and implementing the BWTMS, providing a systematic and consistent measurement of border-crossing and wait times.

WIM provides critical safety information that allows inspectors to target violators and expedite crossings for weight-complying commercial vehicles. ALPRs also provide license plate information that could be checked against safety or security violator databases.

The main impact of implementing these technologies is a smarter border crossing that provides efficient, secure, and safe service to all users.

9.1.3. Challenges and Opportunities

The main challenge for the implementation of these technologies to improve border management is the coordination among the multiple stakeholders participating in the process. These are agencies from two countries with different rules, regulations, and priorities. Within each country, federal, state, and local agencies participate in the process, as well as private-sector shippers, carriers, customs brokers, and other stakeholders that must be coordinated.

Opportunities include moving beyond technologies used in the transportation sector to include supply chain management and logistics to create a smart border. Smart borders are essential for more resilient international land trade and border transport. Besides the technologies mentioned here for security and vehicle safety, implementing traceability methods for trailers using QR codes/web platforms and IoT sensors will increase cross-border productivity, reducing overall logistics costs.

Going beyond the border to the next phase of the supply chain, including warehousing and distribution centres, is important. Linking technologies and information exchange at all process phases is essential, and the smart border concept plays an important role.

Logistechs are defined as the impact that exponential technologies have on logistics. Logistechs are classified as the exponential technologies that support the transport of goods, improve their handling, and expedite their customs clearance (Figure 12). Logistechs optimise the processes involved across the supply chain, from demand forecasting to route planning. Their goal is to achieve greater efficiency and raise the level of customer satisfaction.

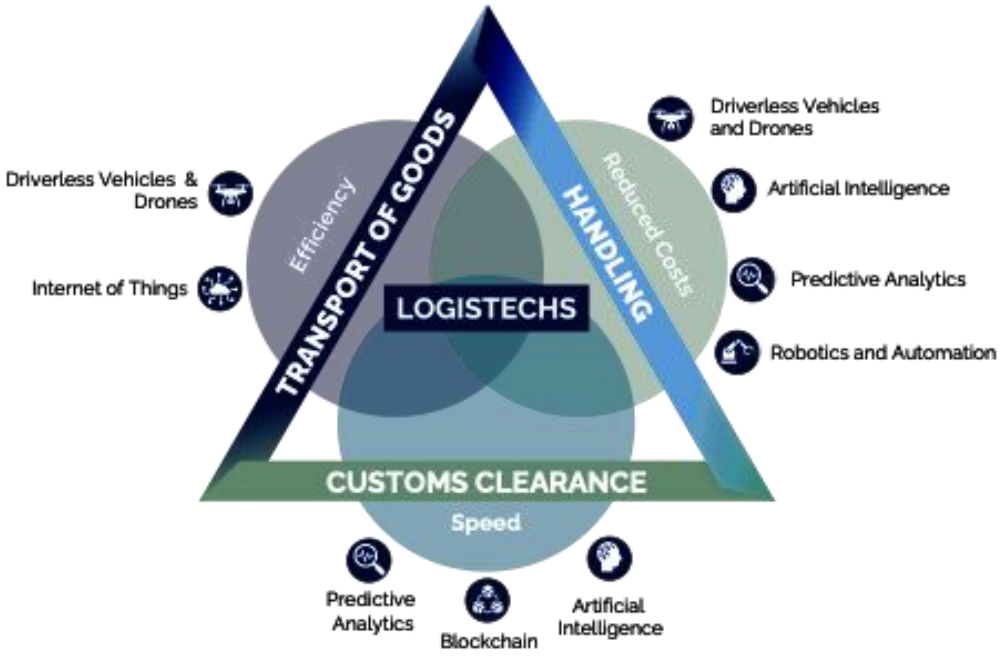


Figure 12. Logistechs support the transport of goods, improve their handling, and expedite their customs clearance.

Logistechs are revolutionising how smart borders are designed and implemented. Logistechs provide a comprehensive solution that can help balance the need for security with economic growth and efficiency in cross-border regions.

9.1.4. Outlook and Transferability

New emerging technologies are becoming more accessible and will be implemented at the international border soon. These technologies are easily transferable to other land border crossings where truck transportation volumes are high and where security and safety inspections are required. These technologies have been tested and are readily available off the shelf. Specific designs and adaptations would be needed for each environment.

9.2. Truck Parking Management

Safety rest areas (SRAs) in the United States have played a critical role in the movement of people and goods by providing convenient rest locations for travellers along the Interstate Highway System since it was established under the National and Interstate Defence Highways Act in 1956. Although SRAs are not as frequently used by the public today due to the proliferation of commercial developments along interstates, they have become increasingly important to commercial vehicle operators seeking safe and easily accessible truck parking to meet federal HOS regulations.

HOS regulations are administered by the Federal Motor Carrier Safety Administration (FMCSA) to regulate the 'maximum amount of time a driver is permitted to be on duty including driving time, and specifies number and length of rest periods, to help ensure that drivers stay awake and alert' (FMCSA, 2021). Additionally, commercial vehicle operators are required to use electronic logging devices (ELDs), which automatically record a truck's engine power status, vehicle motion status, miles driven, identification, and duty status (FMCSA, n.d.). Taken together, HOS regulations and the mandated use of ELDs have made the need for accurate, reliable, and real-time truck parking information more important than ever for drivers to operate within these rules and find safe available parking when and where it is needed. Currently, HOS regulations require a break of at least 30 consecutive minutes after eight cumulative hours of driving time.

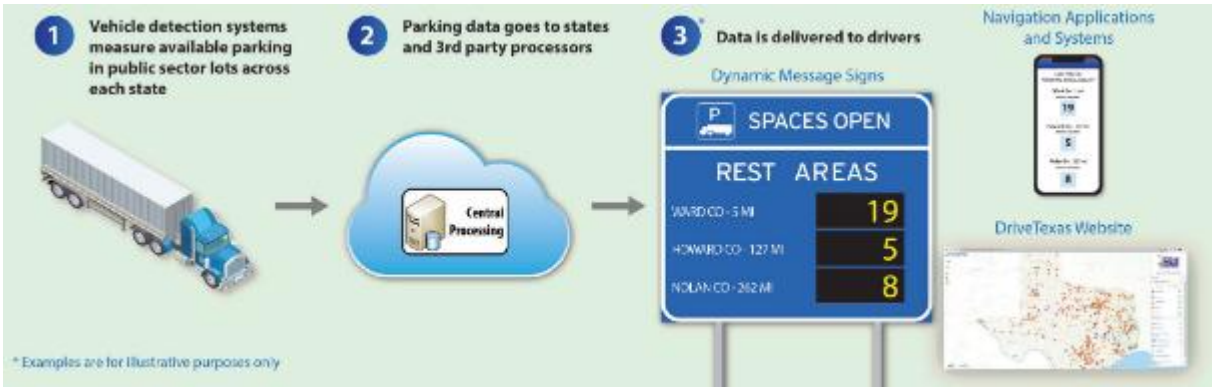
9.2.1. Emerging Technologies in Safety Rest Areas

Truck parking availability systems (TPASs) are a key strategy that state departments of transportation (DOTs) and other truck parking providers have deployed at both public and private truck parking facilities throughout the United States. These systems generally use vehicle detection devices to determine truck parking use and availability for a specific facility that can be disseminated to truck drivers or dispatchers through technology applications in near real time to:

- inform drivers where there is available and authorised parking,
- identify the number of open parking spaces,
- minimise parking at unauthorised locations like shoulders and ramps,
- reduce the time spent searching for parking, and
- improve safety for drivers and the travelling public.

Figure 13 briefly describes how a TPAS works.

Accurate and reliable truck parking availability information is a critical aspect of any TPAS and can be directly impacted by the type of technology selected for use in vehicle detection, information dissemination, and data analysis. The following subsections provide an overview of the main components of a TPAS, including various technology solutions, decision-making factors, and real-world examples.



Source: HNTB

Figure 13. How a TPAS works.

9.2.2. Detection Technology

Vehicle detection for truck parking applications can be accomplished in a number of ways using a variety of technology solutions. Utilisation counts can be performed at entrance and exit ramps to determine space availability by subtracting the total number of trucks in the facility from the total number of parking spaces. In contrast, space occupancy strategies leverage detection devices to monitor the use of individual truck parking spaces to determine real-time availability.

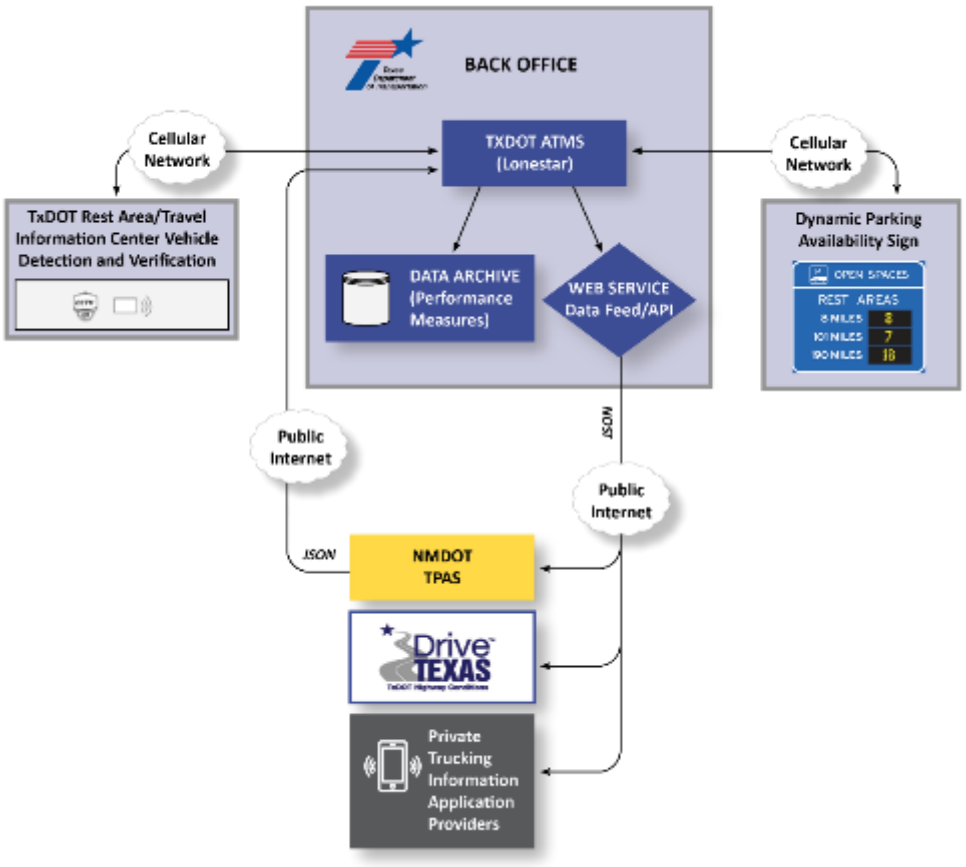
Vehicle detection technology used in most TPASs in the United States generally consists of one or more of the following:

- **In-pavement sensors.** These devices or other technology are permanently installed in the pavement to collect traffic, vehicle classification, or occupancy counts to determine truck parking use and availability within a facility. Inductive loop sensors can be used on entrance and exit ramps for general volume or classification counts, but accuracy can be an issue due to lower speeds. Magnetometer sensors or pucks can be installed along ramps or within each individual parking space to detect changes in the magnetic field when a vehicle passes or parks over a sensor, providing vehicle count or parking space occupancy information. Some in-pavement sensors also use radar technology to enhance functionality for occupancy detection.
- **Video detection devices.** These devices can be used to count and classify vehicles along entrance/exit ramps and to monitor the occupancy of individual or groups of parking spaces to determine use and availability. Cameras are generally pole mounted, and depending on the count strategy, multiple strategically located cameras may be needed to provide full-coverage monitoring of a parking facility. In addition to camera hardware, video analytics software is needed to automatically classify and count trucks to determine space use and availability.
- **Radar and lidar sensors.** These sensors are increasingly being considered as options for use in TPASs because they can monitor parking facilities in much the same way as video detection devices but are less limited during inclement weather or by other environmental factors, providing accurate use data under all conditions. These devices are mounted in a similar fashion to video detection devices. Multiple sensors are required for occupancy detection to avoid occlusion by adjacent vehicles, and analytic software is needed to collect this information.

When determining the appropriate vehicle detection technology, additional consideration should be given to the available options for network connectivity (cellular versus fibre-optic communication) and power sources (solar versus utility). Manual calibration is needed to ensure accuracy in all conditions for each of the detection types.

9.2.3. Dissemination Technology

Once truck parking use data have been collected, they must then be aggregated and processed before being disseminated to the end user. Back-end processing software can come in many forms, using existing traffic management systems that are used to manage intelligent transportation system (ITS) and signalisation programs or stand-alone software platforms that can be custom, commercial off-the-shelf, or software-as-a-service software, depending on the needs and requirements of the TPAS (see Figure 14 for an example of how data are integrated).



Source: HNTB

Figure 14. TPAS data integration process.

Unlike vehicle detection strategies, which usually involve one or two types of technology, data dissemination strategies often involve a multi-pronged approach that leverages physical infrastructure in coordination with online information systems and applications. Vehicle dissemination technology used in most TPASs in the United States generally consists of one or more of the following:

- **DMSs.** These roadside signs are strategically positioned in advance of a truck parking facility and provide real-time availability information to drivers. These signs may provide availability information for one or more facilities along a corridor as well as the number of miles to each SRA listed to allow adequate time for drivers to plan their stops if a facility is full.

- **Traveller information websites and mobile applications**. Existing traveller information websites and applications provide low-cost, easily implementable opportunities for state DOTs to disseminate truck parking availability information online. These web-based systems have the added benefit of providing additional traffic and traveller information that can be used for route planning and informed decision making.
- **Private/third-party trucking information providers.** Their websites and applications provide various information that can include truck parking availability information provided by a TPAS. To facilitate this information sharing, the TPAS will need an application programming interface (API) that the third-party information providers have access to.
- **ELDs and in-cab telematics systems.** This strategy is being considered for truck parking availability dissemination that would leverage in-cab systems, such as ELDs and telematics systems, which are becoming more common in heavy trucks and commercial vehicles. Integration with these systems requires the use of an API or online data feed that can send real-time truck parking availability information from the TPAS directly to the in-cab system without the driver having to use a website or mobile application.

9.2.4. Project Example of Truck Parking Availability Systems

Numerous TPASs have been deployed or are in various stages of development throughout the United States. The **I-10 Corridor Coalition Truck Parking Availability System** is an example of a multi-state partnership in the United States that leverages proven strategies and the most current technology to detect, monitor, and disseminate availability information at 37 public truck parking locations, including SRAs along the I-10 corridor through California, Arizona, New Mexico, and Texas. The Texas Department of Transportation (TxDOT) is the largest participant in this project, with the TPAS being deployed at 18 locations along the I-10 corridor and plans to deploy similar systems along other interstate and major freight corridors throughout the state.

The I-10 TPAS will leverage industry best practices and emerging technology outlined in the previous sections, including:

- vehicle detection sensors that include video or radar detection technologies to count trucks entering and exiting SRAs to determine truck parking availability;
- a centralised processing system that will use a dedicated data feed for dissemination; and

- multiple data dissemination strategies that include roadside dynamic parking availability signs, integration into the DriveTexas traveller information website, third-party trucking information web and mobile applications, and in-cab system integration.

9.2.5. Pricing in Parking Reservation for Effective Use of Parking Space

Japan has started to experience a shortage of parking spaces for large trucks at expressway rest areas because trucks park for long periods to rest, especially late at night. It limits the parking opportunities for trucks that park for short periods to have a break. The labor standards stipulate various regulations regarding truck drivers' working hours, such as continuous driving hours and break periods, which require a 30-minute break for every four hours of driving, and the rest period, which requires a rest of at least eight hours between working hours.

One of Japan's expressway operators began applying pricing to its parking reservation system at expressway rest areas in May 2021 (see Figure 15). The conditions and procedures for using this parking reservation system are as follows:

- Only ETC2.0-equipped freight vehicles are eligible. ETC2.0 is an ETC device that exchanges position and acceleration data between vehicles and roadside equipment.
- Users must register and provide, for example, vehicle information to use the reservation system.
- Users can make a reservation in 30-minute increments for up to 12 hours via the internet.
- When the user enters the reservation-only lane, the sensor automatically obtains the vehicle information, instantly matching it with the information in the reservation system, and automatically opens and closes the gate.
- The following fees are charged. For oversized vehicles and full trailers, 250 yen per 30 minutes from 20:00 to 5:00, a maximum fee of 1,000 yen (the first 1 hour is free). For medium and large vehicles, 120 yen per 30 minutes from 0:00 to 3:00 (the first 1 hour is free).
- If non-reserved vehicles enter by mistake, the equipment will detect the error and transmit the information to the call center. An operator will then use the intercom to direct the vehicle to the exit.
- Entry and exit times are stored as data, and usage status is quantified, collected, and analyzed.

Figure 15. Layout of the parking spaces in Toyohashi Parking Area, where the Pricing Parking Reservation system is installed.

9.3. DIGITISATION IN AUSTRALIAN–NEW ZEALAND FREIGHT AND LOGISTICS[1]

iMOVE, Australia's national centre for transport and mobility research and development, is undertaking multi-party collaborations with industry, government, and academic institutions seeking to improve the sustainable movement of people and goods using technology and data (see iMOVE Australia Cooperative Research Centre | Transport R&D).

Recently, iMOVE undertook a research project on behalf of the Australian Government with the objective of comprehensively reviewing international best practices in freight and transport digitisation. The report, *International Best Practice Digitisation in Transport and Freight—Lessons for Australia* (Swinburne University of Technology for the Commonwealth of Australia, 2021), explored freight and transport digitisation success factors from countries such as the Netherlands, Denmark, United Kingdom, Japan, and South Korea, and provided rankings and recommendations to inform decision makers about improving Australia's performance. This section discusses the findings of the digitisation study.

9.3.1. Intelligent Transport Systems and Digitisation in Australia and New Zealand

Australia and New Zealand have implemented a number of transport related ITS innovations, which have resulted in a more coordinated, efficient, safe, and sustainable use of existing infrastructure, contributed to lower congestion, and aided road users and managers in making informed travel choices.

Amongst these ITS initiatives are advanced and adaptive traffic management systems that include features such as on-ramp metering, automatic incident detection, and dynamic variable speed limits. Additionally, automation is occurring at international container terminals, and the use of telematics in heavy vehicles is growing.

While Australian and New Zealand businesses are actively pursuing the digitisation of freight transport and logistics, they recognise that more collaboration between stakeholders is required to capitalise on the expected benefits of these technologies.

9.3.2. iMove Digitisation Study

Best-practice transport and freight digitisation were compared across the 38 Organisation for Economic Cooperation and Development countries and benchmarked according to international digitisation indicators and new indices developed during the research. Australia ranked 13th.

Focused on the following key sectors, the study further characterised functional areas within each sector where it was identified that technology and digitisation could enhance performance:

- road transport;
- public transport;
- active transport;
- rail transport;
- aviation and air transport;
- maritime and shipping; and

[1] See Chapter 14 for additional resources.

- freight, logistics, and supply chain management.

9.3.3. Survey of Key Stakeholders

The digitisation study was also informed by a survey of stakeholders representing interests in the key sectors. A relatively small sample was returned (27 responses, with 22 involved in freight), with results contributing to a qualitative, thematic analysis informing the recommendations.

The following summarises the emerging, high-level themes from the survey, under each of the six survey questions (further insights are available in the report):

- Challenges—the role of data as a key enabler of digitisation, technological maturity, and the role of government;
- Opportunities—supply chain and operational efficiency, infrastructure investment and planning, and social and environment benefits;
- Key concerns/threats—data, vision, impact on competition among large and small businesses, and safety and social outcomes;
- Organisational and industrial impacts—views of positive impacts in the majority of responses and of negative or unsure impacts in the remainder;
- How to be prepared—a vision-led role of government and regulatory mechanisms, research and capability building, collaboration and coordination, data standardisation, a single national roadmap, and cultural and behavioural (socialising and sharing learnings); and
- Open recommendations—data, role of governments, vocational education and training, and possible pathways to digitisation.

9.3.4. Freight, Logistics, and Supply Chain Management

For the functional areas, the study identified solutions, technologies, and types of benefits in the freight, logistics, and supply chain sectors. Table 2 lists several key examples (the digitisation study report provides a complete list).

Table 2. Examples of solutions, key technologies, and key benefits in the freight, logistics, and supply chain sectors.

Functional area	Solutions	Key technologies	Key benefits
Warehousing and contract logistics	• warehouse/truck loading automation • real-time access to warehouse management systems	• internet of things • barcode scanning • automation • cloud computing	• supply chain traceability • customer relationship • inventory expenses • order accuracy
Last-kilometre delivery and urban freight	• tracking vehicles and consignments • route optimisation • optimised delivery and storage	• automated and low- and zero-emission vehicles • autonomous robots and drones • data analytics • global positioning system • platform-based	• reduced vehicle distance travelled, congestion, emissions, and costs • improved customer service • improved driver, vehicle, and consignment safety

Functional area	Solutions	Key technologies	Key benefits
		technologies	
Trade facilitation and documentation	• electronic processing of documents and data exchanges • integration of complex inventories into cloud-based platforms	• internet of things • sensor and cloud technologies • blockchain and distributed ledger technologies	• fewer documents and forms • transaction costs • document transmission between countries/languages
Freight forwarding, aggregation, and customs brokerage	• fleet acquisition, maintenance, and management • route optimisation	• telematics • global positioning system • internet of things • radio-frequency identification • artificial intelligence	• reduced costs • organisational workloads and fleet size and downtime • automated delivery and billing
Asset and cargo management	• collaboration and procurement • analytics • container movement visibility • temperature and humidity monitoring	• global positioning system tracking • analytics and data • automation and robotics • internet of things • artificial intelligence and machine learning • radio-frequency identification • cloud-based services	• customer service • resolve issues in real time • reduced waiting, handling, and inventory costs • planning, agility, and strategy execution • decisions backed by evidence
Technology-based services for e-commerce support	• electronic funds transfer • internet marketing • inventory management • virtual assistants	• biometric technology • facial recognition • artificial intelligence and machine learning	• improved customer service • increased sales • reduced crime and fraud

9.3.5. Success Factors and Recommendations

Finally, the study identified key success factors that resulted in countries with advanced levels of digitisation for each functional area. Premised on these factors, the study's seven recommendations to encourage wider digitisation adoption on transport (including freight) in Australia are:

- development of a national vision for smart mobility;
- new policies for smart mobility and alignment of initiatives with a national strategy;
- support of translational research and development and testing of new promising technologies;
- investment in backbone digital infrastructure to be considered with transport digitisation;

- investment in human, organisational, and institutional learning and capacity building;
- development of statewide, integrated smart mobility operations centres; and
- development of agreed-upon standards and interoperability to improve data sharing.

9.3.6. Conclusions

Australia's vision is to be amongst the top 10 nations in the implementation of digitisation in industry by 2030 (Commonwealth of Australia, Department of the Prime Minister and Cabinet, 2021), commensurate with increasing investment in a spectrum of initiatives, including those that will benefit transport- and freight-related initiatives. These initiatives and the ongoing focused efforts to develop a comprehensive national vision for Australia will be essential to achieve this ranking.

The findings from the digitisation study provide a useful snapshot of the current situation and emerging trends and, importantly, highlight potential future directions to accelerate the adoption of transport and freight digitisation in Australia.

9.4. Smart Heavy-Vehicle Rest Areas in Australia and New Zealand

Heavy-vehicle rest areas (HVRAs), provided by road authorities or commercial enterprises, are an important part of the road infrastructure for key freight routes in Australia and New Zealand. Strategically designed and located, HVRAs encourage compliance with legislation to manage driver fatigue and are an essential part of achieving national and jurisdictional road safety objectives, considerate of the growing freight task.

Austroads published a voluntary guideline for Australian and New Zealand road authorities to apply in the planning and design of HVRAs (Austroads, 2019), noting that individual road authorities may have diverse jurisdictional requirements and priorities.

9.4.1. Emerging Technologies in Heavy-Vehicle Rest Areas

Freight-vehicle operators must plan and schedule journeys to meet business requirements while also complying with fatigue and other safety regulations. In addition to the basic services provided at HVRAs, existing and emerging technologies combine to not only simplify journey planning but also maximise the productivity and efficiency of the journey.

Information and communication are important features of HVRAs and may include a combination of technical and non-technical elements such as:

- physical on-road signage, alerting drivers of upcoming rest areas and safely guiding them to HVRA entrances;
- interactive online mapping showing HVRA locations, estimated travel time, services, and availability;
-
- in-vehicle tools integrated with navigation systems; and
- smart phone applications.

The Queensland Department of Transport and Main Roads (TMR) recently upgraded six HVRAs on the Bruce Highway (a key freight route) at Ogmore, Gin Gin, Miriam Vale, Waverly Creek, Christmas Creek, and Helens Hill, which are currently operating as pilot projects for innovative ITS technologies.

For these HVRAs, heavy-vehicle drivers are provided with parking bay availability information in real time. This information assists drivers in the early identification of safe, off-road locations to rest, allowing them to better manage fatigue and ultimately leading to reduced fatigue-related incidents on Queensland roads.

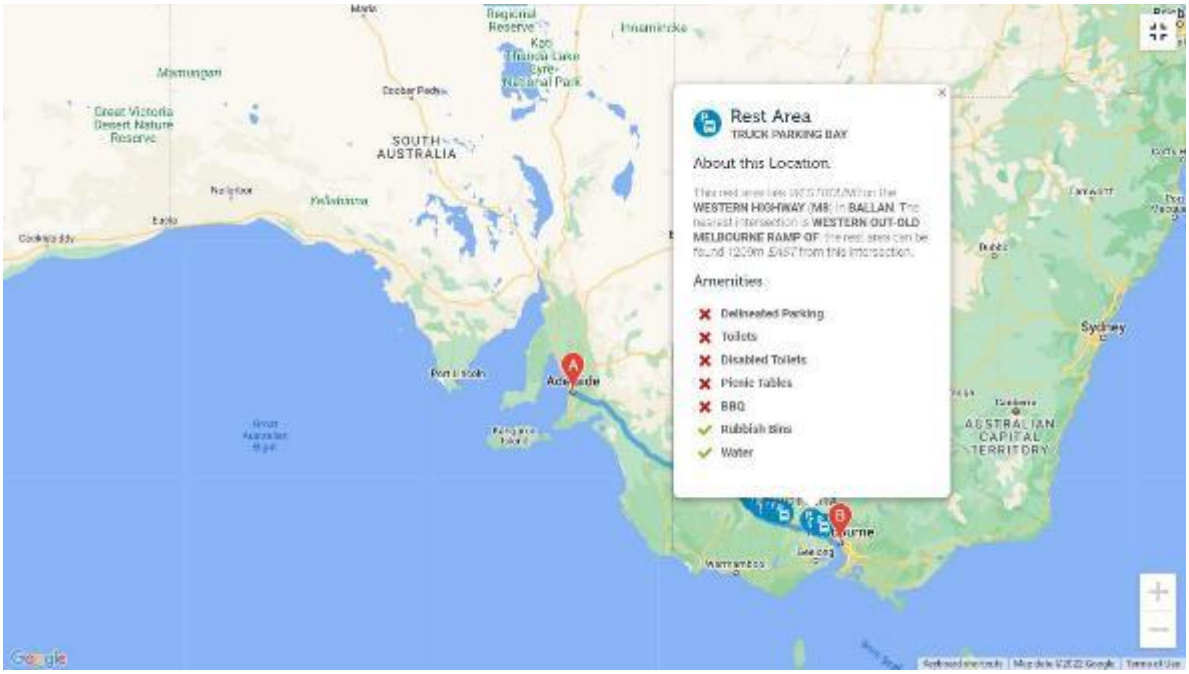
Technology installed at these HVRAs include:

- advanced electronic warning signs located on the roadside approximately 5 km from the rest area, providing early parking availability information for heavy-vehicle drivers in real time;
- a wind turbine to provide power for lighting; and
- closed-circuit television cameras to increase safety and security for drivers.

TMR will use the information gathered from the pilot project technology to analyse HVRA usage and inform improvements at/to these and other rest areas.

In a separate project, Transport for New South Wales has trialled a series of innovative technologies at seven popular rest areas for trucks on the Newell Highway between Narrabri and Gilgandra (Victoria State Government, n.d.). In this project, truck location and direction of travel information is sent to a management system via the mobile phone network. Road location, direction, distances ahead to rest areas, travel time, truck bay vacancy, and facilities information is sent to the truck.

Other Australian states provide online route planning and identification of HVRA locations in the direction of travel. Figure 16 provides an example map of HVRA locations.



Victoria State Government

Figure 16. Map of HVRA locations in the direction of travel.

9.4.2. Outlook and Transferability

The adequate provision and location of HVRAs on key freight routes, equipped with appropriate facilities to encourage positive fatigue management, are ongoing issues. With freight movements increasing each year, the possibility that HVRAs will be overallocated at some point is real. Although adding to the cost of an HVRA, emerging technologies assist heavy-vehicle operators to plan journeys, to be considerate of fatigue management needs, and when a parking space is likely be available. A rich stream of HVRA data around truck usage and configurations is also likely to help transport planners understand the demand for access to rest areas and plan accordingly.

Examples of smart HVRAs operated in other international settings exist, including in the United States and Germany (Dierk et al., 2016; National Operations Center of Excellence, 2020).

9.5. Implementation of a National Heavy-Vehicle Access Management System for Automated and Intelligent Heavy-Vehicle Access Decision Making

Austroads is currently undertaking a national project to develop and implement the Tasmanian Heavy Vehicle Access Management System (HVAMS) (Austroads, n.d.). The HVAMS is an intelligent and automated heavy-vehicle access assessment system, primarily to support road manager heavy-vehicle access decision making, and to potentially support future applications around automated and zero-emission vehicles.

Cranes, special-purpose vehicles, and high-productivity vehicles, including Performance Based Standard (PBS) vehicles, are considered restricted-access vehicles (they require authorisation to use roadways). Access authorisation for these vehicles can be a resource-intensive and time-consuming activity for road managers, regulators, and heavy-vehicle operators, and is not without risks to road infrastructure. Untimely delays and inaccurate access decisions can also inhibit freight operator productivity.

9.5.1. Description of the Technology

While it is too early to define an implementation solution in terms of the technology for a national HVAMS, at a fundamental level the architecture is likely to include the following aspects:

- a combination of a central information technology (IT) and distributed road authority IT systems;
- web interfaces for customers and road authorities, accessible by personal computers or mobile devices independent of location;
- system logic modules for access applications for routes and vehicles, and road-authority-held structural and road assessment modules and data storage; and
- cloud hosting services.

A national HVAMS would be expected to codify the road manager decision function when considering access for a specific vehicle configuration.

9.5.2. Benefits

A national HVAMS could deliver the following range of benefits to multiple beneficiaries including road managers, heavy-vehicle regulators, police, and heavy-vehicle operators:

- fewer route assessments;
- reduced or removed manual and often paper-based assessment;
- reduced time (near real time may be achievable) and effort in applying for/receiving access authorisation;
- greater confidence and certainty in potential access for new vehicles;
- reduced incentive for noncompliance;
- greater transparency about route access demand;
- greater responsiveness;
- leveraged research across multiple jurisdictions;
- greater ability to prioritise resources on other important road management activities;
- much-needed data to support future development of the road network; and
- estimated net positive benefits.

9.5.3. Impacts

Known impacts may include the following, but these may be mitigated through supporting activities:

- inflexibility for industry or road agencies of an automated system (it is expected that lessons from existing decisions could be retained in the development of a new system);
- inability to quickly adapt to changes that may occur due to policy environment, asset changes, emergencies, and natural disasters;
- loss of in-house expertise and experience in structural assessment;
- loss of visibility of heavy-vehicle movements; and
- given a level of freight contestability between road, rail, and shipping modes, uncertainty about whether improved efficiency in access authorisations could affect existing average freight modal shares on non-road modes.

9.5.4. Challenges and Opportunities

Many of the challenges and opportunities associated with a national HVAMS result from the division of responsibility for road access decisions and responsibilities between the national, state, territory, and local government road managers in Australia and New Zealand. This administrative framework must be considered to achieve the objective of an access system that delivers economic, safety, and sustainability benefits to all stakeholders.

Several examples of challenges are as follows:

- Governance will require individual government road authorities to be responsible and accountable for the outcomes of authorising heavy-vehicle access on their networks, as well as the closely related prioritisation of investment decisions around building, maintaining, and operating road networks.

- Ensuring an automated and intelligent heavy-vehicle access authorisation system preserves these responsibilities.
- Recovery of system costs, possibly through heavy-vehicle charges, will be necessary to run, maintain, and improve the system.
- System governance and architecture will be optimised.
- Overall costs and benefits will be defined.

Known opportunities include the following:

- Individual road authorities are in the best position to manage the risk of heavy-vehicle access authorisation.
- Opportunities may exist to unlock latent productivity from the road network where access decision making may have been overly cautious and conservative due to information gaps and capacity.
- Parallel heavy-vehicle reforms in charging for network access may increase telematics use and provide synergies with automated and intelligent heavy-vehicle access authorisation.
- There is potential for accommodation of zero-emission and autonomous heavy-vehicle access needs in due course.

9.5.5. Success Factors

The Australian Government; the National Heavy Vehicle Regulator (NHVR) (Australia's regulating authority for heavy vehicles); state, territory, and local governments; and New Zealand road authorities have been incrementally improving route and bridge assessment and information through a variety of systems. The following initiatives potentially contribute to the functionality of a national HVAMS, based on the Tasmanian system:

- Victoria—Future Access System;
- Queensland—enhanced assessment tools and updated structures data;
- New South Wales—more granular and rapid assessments and an online interactive map for restricted-access vehicles;
- Western Australia—a restricted-access vehicle mapping tool;
- New Zealand—heavy-vehicle definitions (Opermit), highway structural assessment data, and road asset maintenance and management;
- local government (Australia with NHVR)—the Strategic Local Government Asset Assessment project, which identifies existing and potential heavy-vehicle routes, management of road assets, heavy-vehicle definitions, and a road asset information database; and
- NHVR—an NHVR Portal including operator and vehicle data, access decision-making tools, and a route planner.

Additionally, Austroads and others have been undertaking various projects to improve the knowledge base and the regulatory environment for heavy vehicles, including:

- a heavy-vehicle national law review,
- a national transport regulatory reform report (2020),
- heavy-vehicle road reform,
- local road access for high-productivity vehicles (2018),

- investigation and development of bridge formulae for the PBS (2020), and
- the feasibility of a national heavy-vehicle bridge assessment system (2020).

The national HVAMS project will also include a pilot implementation stage, commencing with road authorities testing system functionality, allowing for refinements before wider-scale implementation.

9.5.6. Outlook and Transferability

Automated heavy-vehicle access systems do exist in other international settings, such as the United States (US Department of Transportation, Federal Highway Administration, 2018), which demonstrates the potential for transferability and adaptability to specific regulatory and assessment frameworks. New technologies can also evolve and link to existing manual or less-automated processes while improving heavy-vehicle customer interaction and service.

10. KEY FINDINGS AND CONCLUSIONS

The term *"emerging technology"* is not understood by everyone in the same way. The differences in interpretation vary by continent, but are more distinctive given the income of a country. This report therefore started by defining and developing a common understanding of emerging technologies in the field of freight transport and logistics. The report subsequently documents potential applications, benefits, challenges, and opportunities, as well as the outlook for transferability of the identified emerging technologies from around the world in the freight transport and logistics sector. Although extensive, the list of emerging technologies is not all inclusive of all innovations currently being developed and piloted in freight transport and logistics.

This report does, however, cover a wide range of medium and high priority emerging freight transport technologies that are in very different stages of development (i.e., technology readiness). Some identified emerging freight transport technologies are still in the concept stage (e.g., the Swiss underground freight transport system CST), while others are being piloted (e.g., autonomous trucks and truck platooning), and others are moving from the pilot stage into being adopted and more widely implemented (e.g., autonomous delivery robots). Regardless of readiness levels, **promising emerging technologies identified with substantial impacts to road authorities are autonomous trucks, autonomous delivery robots, air drones, truck parking availability systems, and national heavy vehicle access management systems.**

It should also be noted that an emerging freight technology that is feasible in a HIC may not be applicable in a LMIC. For example, transferring AI to freight transportation systems in many LMICs requires an understanding (and therefore human capital) of machine learning and other algorithms used in AI, fail-safe systems in case of an AI malfunction, and cybersecurity to protect AI. On the other hand, air drone deliveries have applicability in both HICs and LMICs. In LMICs, air drones can distribute medicine and medical supplies to remote areas. In HICs, air drones can deliver small packages in congested urban areas.

Table 3 summarizes the technology readiness level and application of the emerging freight transport technologies evaluated in this report.

Table 3. Technology readiness and application of emerging freight transport technologies evaluated.

Category	Individual Technology	Technology Readiness			Application	
		Concept	Pilot Project	Adoption/ Implement	HICs	LMICs
Basic freight technologies	Artificial intelligence			✓	High	Low
	Physical internet (PI)	✓			Medium/high	Low
	Blockchain		ü		Medium/high	Low
Freight vehicle technologies	Battery electric vans and trucks		ü		Medium/high	Medium/low
	Biofuel vehicles			ü	High	Medium
	Electric cargo bikes		ü		Medium	High
	Heavier and longer trucks			ü	Medium	High
Alternative modes of	Underground freight transportation (Cargo Sous Terrain)	✓			Low/medium	Low

Category	Individual Technology	Technology Readiness			Application	
		Concept	Pilot Project	Adoption/ Implement	HICs	LMICs
freight technologies	Large cargo airships	✓			Low/medium	Low
	Air drones		✓		High	High
	Autonomous delivery robots			✓	High	Medium/low
Automated freight transport	Autonomous trucks		✓		Medium/high	Low
	Truck platooning		✓		Medium/high	Medium
Freight Transport Management	Border management (radiofrequency technologies, weigh-in-motion scales, dynamic message signs, automatic license plate readers)			✓	High	High
	Truck parking management (truck parking availability systems)			✓	High	Medium
	Digitisation in freight and logistics (Intelligent Transportation Systems and Digitisation)			✓	Medium/high	Low
	Smart heavy vehicle rest areas	✓			High	Low
	National heavy vehicle access management system			✓	High	Medium/high

11. RECOMMENDATIONS

11.1. RECOMMENDATIONS FOR ROAD AUTHORITIES AND DECISIONS MAKERS

11.1.1. Develop a Vision and Framework to Support Adoption of Emerging Freight Transport Technologies

It is recommended that road authorities and public sector decision makers develop a vision and framework to facilitate the adoption of emerging freight transport technologies. Public sector decision makers should clearly articulate their vision and role, as well as the regulatory framework to support the adoption of emerging freight transport technologies. This includes setting standards, providing subsidies, and developing policy. Furthermore, it is recommended that the road authorities support research and capacity building, including workforce development, and collaboration with the private sector to facilitate the piloting and adoption of innovative emerging freight transport technologies.

11.1.2. Participate in Emerging Freight Transport Technology Pilot Projects

This report identifies a number of emerging freight transport technologies that are currently largely in the concept phase. It is recommended that road authorities and decision makers encourage innovation and work with the private sector to realise the benefits of emerging freight transport technologies, and to inform future policies and regulations by supporting pilot projects to identify and address the challenges that will move an emerging technology from concept to adoption/implementation. The road authorities should help facilitate the implementation of pilot projects to improve the understanding of the potential benefits, challenges, opportunities, and lessons for transferability. For example, in the case of the PI, public sector decision makers can support the implementation of larger pilot projects beyond the small networks that currently exist to demonstrate to companies the ease of execution and the benefits of sharing assets, services, and resources among stakeholders in vertical integrated supply chains and in horizontal collaborative networks. Through pilot projects, road authorities and decision makers can also develop an understanding of the freight transportation system benefits of higher freight unit consolidation, the intelligent combination of loads across supply chains, and smart consolidation and the associated public benefits of reduced distances travelled, reduced number of trips, reduced GHG emissions, and increased resilience.

11.1.3. Research and Disseminate Findings of Emerging Freight Transport Technology Pilot Projects

This report identifies a number of emerging freight transport technologies that are currently in the development and pilot stage. In the United States alone, more than 28 US states have passed legislation that allows autonomous vehicles to operate on highways in some capacity. It is therefore recommended that road authorities and decision makers collaborate with the private sector to document and disseminate the findings of pilot projects. Specifically, it is important to document and develop an understanding of the lessons learned, challenges experienced (including legislation, policy, and community challenges), how to overcome challenges, and resource and institutional requirements. It is also important that the findings of unsuccessful pilot projects be disseminated to clearly articulate the challenges in moving from concept to pilot to implementation.

11.1.4. Emerging Freight Transport Technology Transfer Through Peer Exchanges

This report identifies a number of emerging freight technologies that have moved from the pilot stage to adoption/implementation especially in HICs. For example, Truck Parking Availability Systems (TPASs) are an emerging technology that have moved from the pilot stage to adoption/implementation in a number of public rest areas and private truck parking facilities in HICs. It is recommended that road authorities and public sector decision makers in partnership with the private sector share knowledge and insights gathered about the freight transportation technology costs; impacts on safety, infrastructure, sustainability, and traffic operations; the need for workforce development; and any changes in public sentiment. It is recommended that private- and public sector decision makers participate in peer exchanges to share knowledge about the requirements for moving emerging freight transport technologies from pilot to adoption/implementation, as well as the results and lessons learned from monitoring the adoption/implementation of these emerging technologies. Finally, these peer exchanges would be particularly important to share emerging freight transport technology knowledge, information, lessons learned, and best practices between HICs and LMICs.

Technologies go through a cyclic process: policy making, financing, implementation, measurement, evaluation, and then the process is repeated.

11.2. Recommendations for the World Road Association

11.2.1. Monitor and Benchmark Emerging Freight Transport Technologies and Its Impact on Road Authorities

The development life cycle of emerging freight transport technologies is accelerating. Given the dynamic environment in which emerging technologies are being developed and tested, the emerging freight transport technologies listed and discussed in this report are not all inclusive. It is recommended that PIARC conduct follow-up studies to continuously identify, monitor, and benchmark new emerging technologies and their applicability to the freight and logistics sectors. This is important because there is limited understanding of how to address the key challenges (e.g., risk, ethical issues, liability concerns, and societal challenges) associated with many of the emerging technologies that are currently in the concept or pilot stage. For example, although it is generally agreed that AI can help improve productivity and safety and reduce negative environmental impacts, a number of challenges remain concerning the use of AI to increase vehicle automation. These challenges include distracted driving when vehicles are not fully automated, how AI algorithms make life-versus-life decisions in a fully automated vehicle, and who is liable in the case of an accident. Therefore, follow-up studies are necessary to document lessons learned from current pilot projects and to embrace technology transfer opportunities.

11.2.2. Conduct an Emerging Freight Transport Technology Readiness Assessment for Low- and Middle-Income Countries to Inform Policies and Programs for Road Authorities

This report highlights several emerging freight transport technologies that are believed to be transferable to LMICs but have been largely untested in LMICs. It is recommended that PIARC conduct a comprehensive emerging technology readiness assessment to identify emerging freight transport technologies that can be piloted or adopted/implemented in LMICs, and to identify the requirements (framework) for LMICs that are low on the readiness scale to pilot or adopt the identified emerging freight transport technologies.

11.2.3. Conduct a Special Project on Air Drone Deliveries

Air drone delivery is an emerging freight transport technology with applicability in both LMICs and HICs. In LMICs, air drone deliveries can overcome the infrastructure availability challenges of delivering to remote areas. In HICs, air drone deliveries can overcome the infrastructure capacity challenges of delivering in congested urban areas. A special project on air drone delivery will provide valuable lessons learned, identify challenges to overcome (including, legislation, policies, risks, and operational issues), and best practices.

12. GLOSSARY

Term	Definition
AI	Artificial Intelligence
ALPR	Automatic License Plate Reader
API	Application Programming Interface
BWTMS	Border Wait Time Measurement System
CBP	US Customs and Border Protection
CST	Cargo Sous Terrain
CTP	Cooperative Truck Platooning
CTPS	Cooperative Truck Platooning System
DMS	Dynamic Message Sign
DOT	Department of Transportation
ELD	Electronic Logging Device
FMCSA	Federal Motor Carrier Safety Administration
GHG	Greenhouse Gas
HOS	Hours of Service
HVAMS	Heavy Vehicle Access Management System
HVRA	Heavy-Vehicle Rest Area
IoT	Internet of Things
IT	Information Technology
ITS	Intelligent Transportation System
LMIC	Low- or Middle-Income Country
NHVR	National Heavy Vehicle Regulator
PBS	Performance Based Standard
PI	Physical Internet
PIARC	World Road Association
RFID	Radio-Frequency Identification
SRA	Safety Rest Area
TMR	Queensland Department of Transport and Main Roads
TPAS	Truck Parking Availability System
WIM	Weigh in Motion

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14. ADDITIONAL RESOURCES

14.1. DIGITISATION IN AUSTRALIAN–NEW ZEALAND FREIGHT AND LOGISTICS

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15. APPENDIX: FACT SHEETS – EMERGING FREIGHT TECHNOLOGY TRENDS

FACT SHEETS – EMERGING FREIGHT TECHNOLOGY TRENDS

TECHNICAL COMMITTEE 2.3
FREIGHT TRANSPORT

PIARC

EMERGING FREIGHT TECHNOLOGIES TRENDS

A COLLECTION OF FACT SHEETS

TECHNICAL COMMITTEE 2.3 *FREIGHT TRANSPORT*

INTRODUCTION

Innovations and advances in emerging freight technology trends in autonomous trucks, truck platooning, internet of things, big data, blockchains, cloud logistics, robotics and digitalization of the trucking industry is changing logistics and the management of the freight transport system. Higher degrees of automation in logistics and freight transport sector have the potential to increase productivity, efficiency, reliability, flexibility, safety, sustainability, and economic benefits.

To realize and maximize the potential of these emerging freight transportation technologies and to ensure the contribution to transport policy objectives, the following important questions will need to be addressed:

- the impact of digitalization and automation on freight movement, logistics and supply chains.
- the impact of digitalization and automation on freight traffic and traffic management on the multimodal transportation system.
- the benefits of digitalization and automation for road and multimodal freight transport and road traffic management of public infrastructure; and
- the necessary technological, organizational, and regulatory and policy framework conditions for implementation.

The application of emerging technologies in the freight transportation and logistics sector is still, relatively new, but making significant advancements and has the potential to fundamentally reshape the industry. North American, Asian, and European countries have initiated field testing in truck platooning and partly autonomous trucks, as well as other application of big data; however there remains substantial work to be done to continue the advancement of these emerging technologies and wide adoptions globally. These topics need further exploration, particularly around the potential applications and impacts and suitable framework conditions for implementation. In addition, the roles of both the public and private sectors need to be better defined.

Autonomous trucks and truck platooning are in early stages of testing and initial indicators have shown positive impacts to roadway safety, enhance operational efficiencies, productivity, and potential to help address a shortage of truck drivers.

This report provides a collection of emerging freight technology trends from around the world covering autonomous trucks, platooning, truck parking information systems, drones, robot delivery, blockchains, digitization and much more.

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FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 1 Improved Trips with Autonomous Trucks

Keywords: Autonomous trucks, automated features, full automation, hours-of-service, driver shortage

Technology category: Automated Freight Transport / On roads

DESCRIPTION IN SHORT

One of the highly anticipated emerging freight technologies is **autonomous trucks**. Commercial trucks can be outfitted with autonomous driving systems that offer varying levels of driver support features. Many automated features are available in vehicles today, such as lane assist or adaptive cruise control, and are permissible for operation on nearly all public roads. The self-driving capabilities are becoming more common as well, although a driver is still required. Vehicles with higher levels of automation would **not require human interaction** in most circumstances. These high levels of automation are the key areas of interest given their anticipated cost savings, which also spurs the question of what policies are required to promote safety for autonomous vehicles and all other road users.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

A key motivator for the adoption of autonomous trucks is their ability to help mitigate existing **hours-of-service (HOS) regulations** during a time of a **worsening driver shortage**. Autonomous trucks could help increase efficiency by eliminating the need for drivers on long-distance segments, allowing drivers to better utilize their available HOS and focus on the more complicated "last-mile" delivery. If full vehicle automation is achieved, on-board drivers would not be required, shifting responsibilities more toward coordinating local shipments and monitoring the security of vehicles en-route.

Some examples of expected impacts on logistics and freight transport include:

- Trucking companies will be better able to manage driver HOS requirements, increasing freight mobility and reliability;
- Shifting responsibilities of human drivers to managing shipments versus actual driving;
- Increasing safety and mobility by reducing human driving errors;
- Reducing fuel consumption by maintaining optimal speeds with less braking; and
- Improving economic competitiveness of trucking companies by cutting operational costs.

APPLICA-TIONS

Original Equipment Manufacturers (OEMs) and startups in the autonomous vehicle (AV) trucking industry are currently testing autonomous trucks on major interstate corridors around the world.

Some companies piloting autonomous trucks in the U.S. include:

- TuSimple — Autonomous truck pilots in Arizona and Texas
- Kodiak Robotics — Commercial Deliveries in North Texas
- Embark — Coast-to-coast autonomous truck journey

IN DEPTH DESCRIPTION (1)

- SAE International published its J3016 standard, which defines six levels of driving automation, the responsibilities of the driver under each level, and the conceptual automated driving features. Generally, "Level 0" represents no automation, "Level 5" represents full automation, and "Level 3" represents the start of where the automated vehicle can drive itself under limited conditions. As a reference point, most vehicles on the road today fall under "Level 0" through "Level 2", with some vehicles defined as "self-driving cars" falling under "Level 3."
- Although autonomous vehicle research initially focused on passenger vehicles, autonomous trucks have become a significant area of interest because their operational design domain can be much more straightforward for researchers to test. Most trucks maximize use of limited-access

IN DEPTH DESCRIPTION (2)

freeway networks, avoiding the complex local and arterial streets with stop signs and traffic signals wherever possible. Similarly, many trucks travel in rural areas with less traffic as they make cross-country trips, as opposed to the busier urban and suburban areas that are dominated by passenger vehicles. This provides a cleaner test environment. In addition, truck driver training programs can help prepare drivers for automated driving systems.

- Many autonomous truck vendors emerged from technology companies. The technical approaches between vendors differ based on how their automated driving system operates. Some vendors require a three-dimensional digitized map of their driving environment to be developed prior to operation, to guide their vehicle through this well-understood digital footprint. Other vendors rely on an extensive sensor system (LiDAR, radar, video analytics, etc.) to map their local environment in real-time and navigate utilizing GPS mapping. Each approach has its advantages and disadvantages, and a preferred or standardized solution has yet to be identified.
- Autonomous vehicle testing began on closed-loop test tracks to prove the technology. When looking to demonstrate the technology in real-world road environments, many regulations prevented or limited testing scenarios, mostly because autonomous vehicle-related policies did not exist at Departments of Motor Vehicles. Some states adopted an AV policy, with varying degrees of regulation.
- Many autonomous truck vendors demonstrated their products by moving shipments as part of their testing. Each move typically included a driver (for handling AV disengagements and responding to unknown issues) and a safety engineer (for monitoring the software, communicating with the driver, and documenting issues).

KEY CHALLENGES

- Autonomous trucks, like many AVs, have difficulties navigating in unfamiliar environments that either have not been tested or are not recognized by the system. Work zones are a common problem, as—despite following many adopted standards—no two work zones are exactly the same. Currently, technology has not developed to the point of understanding all roadway situations, which triggers an AV disengagement, requiring the safety driver to take control.
- Autonomous trucks are constrained by technology in terms of where they can drive. Autonomous trucks that utilize digital maps cannot easily transition to an unmapped alternative route. Similarly, trucks that rely on sensor suites have a more difficult time off limited-access highways as well as in locations where the roadway is in poor condition, like faded pavement markings.
- Regulatory and enforcement agencies must adapt to an AV environment. Crashes involving self-driving vehicles pose a challenge for the legal system in determining the parties that are **at-fault**. Commercial vehicle enforcement agencies need to be able to accommodate driverless trucks at roadside stops. This challenges will increase over time.

OUTLOOK

To date, more than 28 states have passed legislation that allows AVs to operate on highways in some capacity. The AV truck industry is currently focusing on testing automated driving features on limited-access routes with the eventual goal of achieving full automation in the coming years.

Autonomous trucks will remain a topic of interest especially given the truck driver shortage and new logistical challenges, such as e-commerce deliveries using traditional commercial freight vehicles, ground drones, or eventually unmanned aerial vehicles. It is important that policymakers monitor the development of this technology to maintain public safety, prepare infrastructure and traffic management systems, support workforce training, and realize the safety and efficiency benefits crated by these advancements. Initial benefits for state Departments of Transportation may include utilizing data collected by autonomous trucks to inform where potholes or poor pavement conditions exist.

MORE INFORMATION

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Publications:
Texas Freight Network Technology and Operations Plan (2020), available from https://www.txdot.gov/government/partnerships/freight-planning/texas-freight-network-technology-and-operations-plan.html

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FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 2 Improved Efficiency with Truck Platooning

Keywords: Truck platooning, vehicle-to-vehicle communications, connected vehicles, truck automation

Technology category: Automated Freight Transport / On roads

DESCRIPTION IN SHORT

Developments in automation are making their way into the trucking industry in the form of **truck platoons**. A truck platoon as envisioned for the near-term is a series of trucks following each other on the road, with **acceleration and braking controlled automatically** (steering is still manual). When any truck speed changes, the others linked behind it are instantly notified wirelessly, and those trucks respond immediately by braking or accelerating. This allows for much closer following distances, which reduces wind resistance and increases the number of trucks that can fit on the road at high speeds, thereby increasing roadway capacity. To date, at least 10 demonstrations/test programs have been, or are currently being conducted by multiple consortiums, public agencies and test partnerships around the globe, with two private companies developing what are intended to be commercially viable truck platooning systems.

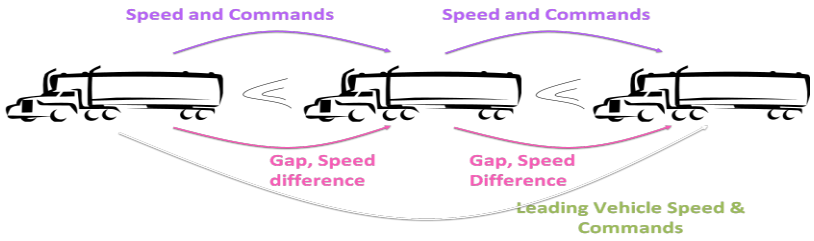
EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

- **Reduce congestion, fuel emissions and shipping costs.** Truck platoons have much **shorter safe following distances than standard vehicles,** which **reduces wind resistance and increases the number of trucks that can fit** on the road at high speeds, thereby increasing fuel efficiency and roadway capacity, **respectively**. Truck platooning can **reduce fuel emissions by up to 10% per platoon** and, with widespread adoption, reduce overall shipping costs. Additionally, it has been estimated that truck lanes on major freeway corridors **could support up to 50% more trucks if platooning were heavily utilized, effectively adding additional freight capacity.**
- **Safety**. In 2019 alone, 4,119 people died in large truck crashes. Truck platooning provides **steady-state cruising operations with precise control of acceleration and breaking**. Given these factors, an effective system could reduce the most common type of collision involving heavy trucks—end-to-end collisions—while also reducing the impact of human error, which the U.S. DOT has found to account for 90% of crashes involving heavy trucks.
- **Driver operations.** Truck platooning **can reduce stress on long-haul trips.** And in the future, as truck platooning moves to more advanced stages such as the "truck train" concept, a three-truck platoon, with only a driver in the front truck, would **provide a driver cost reduction of two-thirds**. This would be advantageous in helping **fleets address the national truck driver shortage**, which is expected to continue over the next decade as many drivers reach retirement.

APPLICATIONS

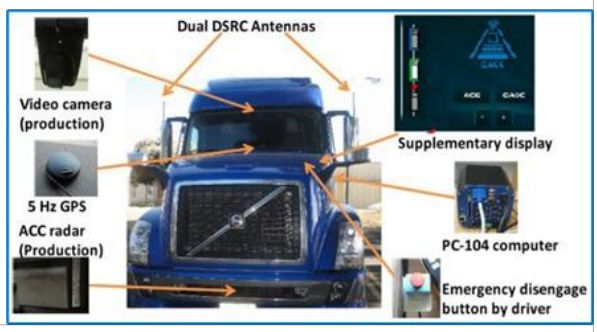
A current major demonstration program is the FHWA Truck Platooning Early Deployment Assessment Project being led by UC Berkeley/California PATH, Volvo, Westat and Cambridge Systematics, in cooperation with the I-10 Corridor Coalition states of California, Arizona, New Mexico and Texas. The project's primary goal is to gain a better understanding of the **impact truck platooning has on long-haul truck fleet drivers and operations**. Three-truck platoons carrying freight will be operating daily for 12 months beginning in late 2021 on the I-10/I-20 Corridor between truck fleet participant Roly's Trucking facilities in Rancho Cucamonga, California and Fort Worth, Texas.

EXAMPLE CONCEPT



IN DEPTH DESCRIPTION

- The trucks in a platoon use **vehicle-to-vehicle (V2V) communication** in addition to forward sensors to help maintain constant clearance vehicle following at short gaps. The software and in-vehicle technology utilized by each truck in the platoon is called **Cooperative Adaptive Cruise Control, or CACC**. CACC automatically ensures that the vehicle has information on the vehicle immediately in front (through sensors), as well as on a leading vehicle or vehicles further in front, through V2V communications of key parameters such as position, velocity, and acceleration.
- **An example platooning system** that has been developed for the California PATH platooning system is highlighted in the graphic below. Each truck in the platoon is equipped with cooperative braking and accelerating, which means the trucks could speed up, slow down or stop in tandem with the other trucks, which is one of the safety benefits of this technology. The trucks "JBUS" information network architecture connects to the platooning system using a special interface computer designed by Volvo. This interface provides the key basis for the PATH platooning system computer to access the vehicle controls for acceleration and breaking Additionally, the platoon uses V2V **Dedicated Short-Range Communications (DSRC)**, which allows each truck's platooning system to talk to each other —this is facilitated through the Dual DSRC Antennas on each truck. Also, the radar sensors and video cameras required by the CACC to determine spacing and traffic conditions are furnished with connections to appropriate computers for processing. The system also includes a driver display interface (Tablet DVI), a test system user interface (PATH Linux Laptop), a GPS antenna and an emergency switch to turn off the system.



KEY CHALLENGES

- For the near-term, with CACC-based truck platooning that does not involve autonomous trucks without drivers, the primary regulatory issues are state **"anti-convoy" laws**. Many states have anti-convoy laws that preclude truck platooning. In most cases, these laws were implemented between the 1960s and 1980s to aid state enforcement agencies in combatting unsafe truck convoys, where truck drivers attempted to convoy in closely spaced groups as a means to exceed speed limits and avoid citations.
- A recent survey of trucking fleets designed to determine the **willingness of fleets to form platoons** on roadways with other trucks showed mixed results, with similar numbers of respondents expressing a willingness to form platoons with any fleet as respondents who would prefer to only form platoons within their own fleet or with business partners.

OUTLOOK

Autonomous truck technologies can alleviate labor and hours-of-service (HOS) issues through reductions in driver time at the wheel; they can also promote safe truck operations that can reduce or mitigate accidents and associated facilities and vehicle damage. While completely autonomous trucks may not become ubiquitous with large-scale interstate freight commerce for many years, "**wireless truck trains**" with a "pilot driver" in a lead truck, followed by two or three "driverless trucks" that incorporate a more advanced version of V2V platooning technology can be seen as an evolutionary step from today's truck platooning test programs and private sector developments.

MORE INFORMATION

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FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 3 Infrastructure Development of Platooning and Autonomous Driving: Ready Roads and Parking Spaces

Keywords: Platooning and autonomous driving, Shortage of truck drivers, Long-haul operations, Practical applications of truck platooning, Merging support system

Background and Overview

Haulers in Japan have a high hope for truck platooning that may enhance operational efficiency, address a shortage of truck drivers and improve safety. Among all problems, the most serious is the truck driver shortage. With their drivers rapidly aging, haulers see this as an existential threat and have a strong need for truck platooning, hoping it should make up the driver shortage to keep long-haul operations between Tokyo and Osaka which are hard to find drivers.

To meet this need and yield various benefits from truck platooning technology which can eliminate the need for non-lead vehicle drivers , the Japanese Government started “An R&D and Pilot Project for Social Implementation of Advanced Autonomous Driving and MaaS: Pilot Project for Truck Platooning” in August 2016. FY2020 was the final year of this 5-year project.

Details

<Main initiatives up to FY2019 (platooning system)>

Aiming for yielding practical applications of truck platooning on the National Expressways, the Government has conducted the pilot project since FY2016.

-FY2016: investigated the tracking control algorithm and V2V communication technology based on the concept of “electronically connected vehicles”, and verified features of experimental vehicles on the test track.

-FY2017: improved V2V communication technology, developed “Human Machine Interface (HMI) 19” which shows the lead-vehicle driver the conditions of the non-lead vehicles and the system, and verified features of experimental vehicles on the test track.

-FY2018: conducted the first-ever platooning test via V2V communication, which took place with non-lead vehicle drivers on the 15km segment of the Shin-Tomei Expressway between Hamamatsu SA and Enshu-morimachi PA (one-way) from Jan. 22 to Feb. 26, 2019 to investigate vehicle’s weaving behavior just after switching from manual to automatic operation mode and/or being affected by side winds. As a result, the experimental truck platooning ensured the safety of the straight running and lane changing while finding issue around dealing with pedestrians who would cut in front of trucks and controlling tracking.

-FY2019: carried out another platooning test on a longer segment (140km, one-way, between Hamamatsu Inasa JCT and Nagaizumi Numazu IC, Shin Tomei Expressway) for a longer period (from June 2019 to February 2020), and identified difficult situations under various natural and traffic environments including tunnels and multiple road alignments.

<Main initiatives in FY2020 (platooning system)>

In FY2020, a long-term pilot project was carried out from June 2020 to February 2021 to ensure the system would work properly in the real world using the experimental trucks built in FY2019, aiming for the practical use of the platooning technology on the National Expressways. As a result, the experimental platooning trucks achieved the control accuracy targets (10m or less for the distance between vehicles in the longitudinal direction and ±50cm or less for the lateral direction) at 80km/h. The trucks also passed all items of the fail-safe test on the test track.

With these findings, another pilot project was carried out with no drivers for the non-lead trucks for a 15km-segment between Hamamatsu SA and Enshu Morimachi PA on February 22, 2021. The platooning, consisting of 3 trucks, successfully made 2 round trips (at the maximum speed of 80km/h, with 5-9m distance between trucks) with no accidents or troubles and the vehicle system worked as planned.

Challenges

-The platooning pilot projects conducted by MLIT and METI in FY2017 revealed various issues, including errors in sensing lanes due to almost-disappeared/faded road marks, discontinuous dotted lines on splitting points, and inconsistency in the automatic following-distance control among trucks due to the difference in acceleration/deceleration performance. Additional issues were observed on merging/splitting points or reduced lanes when other vehicles squeezed into between the platooning trucks and stayed there for a long period or found themselves difficult to merge into the main traffic.
-Another platooning pilot project conducted in FY2018 found various issues, including reduced accuracy for keeping lanes due to reduced accuracy of "high-precision" GPS used for tracking, impacts of rainfall, snowfall, dense fog and other weather condition changes, unorganized pedestrian's traffic lines in SA/PA, disruption caused by the long truck platooning on other vehicles on margin points.

Expected Outcomes

There is a high hope for truck platooning that may enhance operational efficiency, address a shortage of truck drivers and improve safety.

Future Advancements

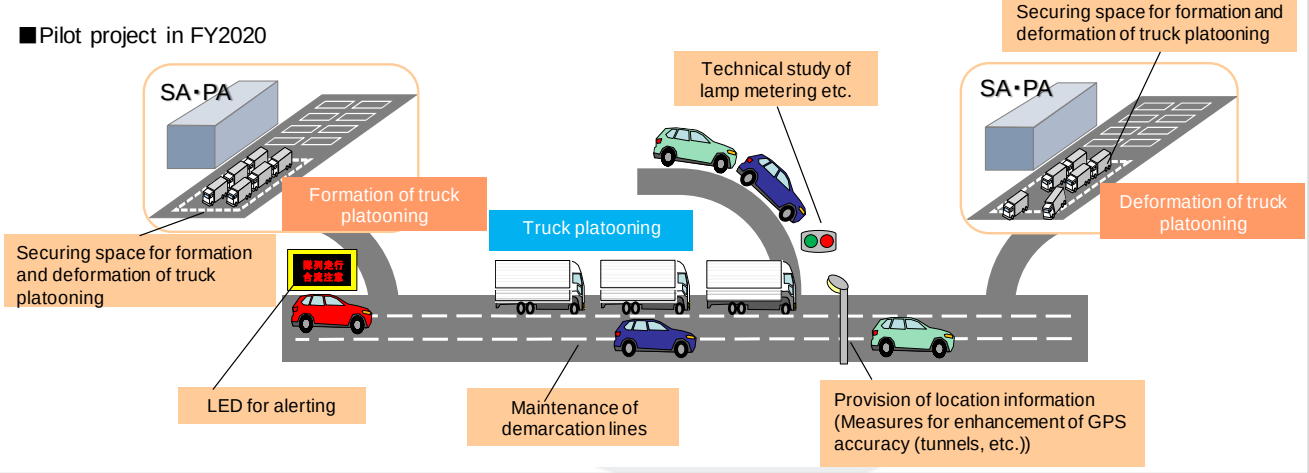
The Government expects to see a technically feasible platooning system without non-lead truck drivers on the Shin Tomei Expressway by FY2020, commercialize a platooning with non-lead trucks drivers on the National Expressways by FY2021, and commercialize a platooning without non-lead truck drivers on the Tomei Expressway (between Tokyo and Osaka) from 2023 onward.
They have identified the following tasks from the infrastructural side for some segments and spots:

(1) Support to maintain GPS measurement accuracy
-To correct location measurement errors, as observed in high-precision GPS and other GNSS systems and high-precision 3D maps, location marks which provide accurate location data and a system which obtains such location data at regular intervals need to be built.
-Magnetic markers and other positioning support systems need to be provided from the infrastructure side in order to address reduced accuracy of GNSS measurement results at certain spots and segments such as under tunnels and elevated road.

(2) Development of space for formation/deformation of truck platooning
-To prevent mixed traffic of general vehicles/pedestrians into between platooning trucks, addition of a function of formation/deformation of truck platooning to logistics centers should be explored. In doing so, it is necessary to consider role sharing between the road administrators and logistics companies (e.g. Expanding existing SA/PA, utilizing private logistics centers).

(3) Merging support system
-Since platooning trucks and general vehicles share the same traffic, merging support systems should be validated from technical/systematic standpoint and ensured safety.
-It is important to explore ways to provide information on the traffic conditions/obstacles ahead of drivers so that they can confidently change their lanes.

■Pilot project in FY2020



MORE INFORMATION

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Publications:
https://www.mlit.go.jp/road/ir/ir-council/nls/index.html （Japanese only）

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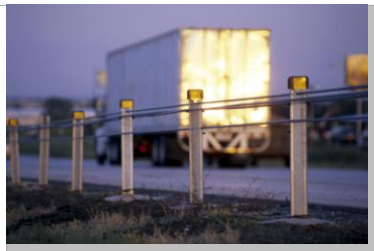
FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 4 Truck Parking Information Systems

Keywords: Truck parking, parking availability, real-time information

Technology category: Freight Transport Management / On roads

DESCRIPTION IN SHORT



Truck parking information systems provide **real-time parking availability** at designated truck parking areas. Truckers receive this information in advance, allowing an opportunity to scan the options available to them and make an informed decision on where to ultimately park their truck. This is extremely relevant to any truckers who need to manage their **hours-of-service (HOS) requirements**, especially in areas that are unfamiliar to them. Truck parking information systems can be utilized in a variety of applications, including at public rest areas, private truck stops, or gated urban truck facilities.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

Truckers in the United States rely on long-term truck parking facilities to park in order to meet their HOS requirements. While a shortage of truck parking is a widely discussed issue, the **unpredictable nature of parking utilization** at the existing parking facilities further exacerbates the challenge by leaving truckers without insight on whether parking options (which may be miles away) have any current availability. Many truck parking areas experience overflow parking, while others may be underutilized at the exact same time. Implementing **a real-time monitoring and availability reporting system** impacts the industry in many positive ways:

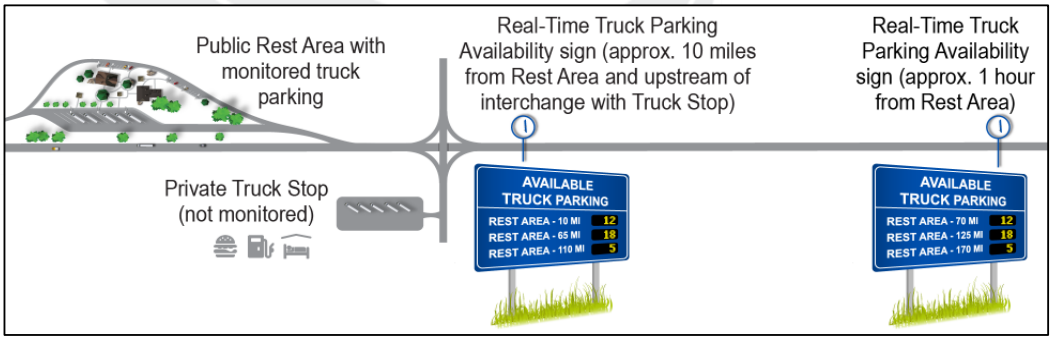
- **Truckers** receive **real-time reports on parking availability** at parking facilities along their journey, allowing them to make strategic and informed decisions on where they should park.
- **Transportation planners** utilize the abundance of hourly parking utilization data to make data-driven decisions on how and where to expand truck parking facilities.
- **Law enforcement** has real-time information available to redirect trucks parked in unauthorized locations to safer authorized locations.
- **Communities** with unauthorized truck parking issues have potential countermeasures to implement an urban truck parking solution and increase awareness of the truck parking options.

APPLICA-TIONS

Some prevalent examples of truck parking information systems include:

- Mid-America Association of State Transportation Officials – Eight-state regional truck parking information management system
- Florida Truck Parking Availability System

EXAMPLE CONCEPT



IN DEPTH DESCRIPTION

- Selected truck parking facilities are equipped with sensor technology to monitor parking utilization, frequently reporting observations to a central system. Different approaches are utilized to monitor parking utilization, depending on the size and scale of the parking facility. A common approach is to install sensors at the entrance and at the exit of the facility to monitor utilization based on how many vehicles have entered or left. Another approach is to install sensors to monitor each individual parking space and monitor utilization by how many open parking places are reported. Each approach has different capital, operating, and maintenance requirements, as well as offers different opportunities for performance monitoring data that might be desirable by the parking facility owner.
- Parking utilization data is processed to **determine the utilization**. The method for calculating utilization differs based on the selected data collection approach, but the reported utilization number is the same. This is often conducted by a **central system that receives data from multiple parking** facilities and can report several options to truckers and other interested parties.
- Real-time parking availability is provided to truckers and other interested parties through a variety of means: 1.) **Roadside signs** notify truckers en-route of upcoming parking locations and current parking availability; 2.) **Traveler Information Services** notify truckers via websites or mobile applications of current parking availability based on desired loaction; and 3.) **Fleet Dispatchers** notify truckers that utilize their dispatch service of parking options upon request, utilizing data feeds into their fleet management systems to make informed recommendations.
- Data that is inventoried by the truck parking information system provides value by helping understand parking use and travel patterns. Parking facility owners can assess the historic utilization of their lots at any time in which the system was active, allowing them to determine if additional parking capacity is necessary. For data collection approaches that monitor utilization of each parking space, parking facility owners can determine where trucks park, what services are utilized, as well as the duration of their stay. Monitoring each parking space also allows for **notifications of suspicious activity**, such as a vehicle that has been parked for multiple days.
- The operator of the truck parking information system will need to make sure the information provided to truckers and other interested parties is accurate, in order to maintain the credibility of the system. This may require activities to validate the accuracy of the reported counts.

KEY CHALLENGES

- These systems work best when they provide real-time information for several locations, which a **trucker can review and make an informed decision**. In areas where truck parking facilities are infrequent, it may be challenging to provide alternate options.
- Truck parking information must be accurate in order to maintain user confidence in the system. This requires **properly maintained sensors and frequently validated counts**. For organizations with limited resources or budgets, this may prove to be challenging.
- Truck parking is available in both public and private facilities. Truck parking information systems can be installed in either type of facility, but there has been some hesitancy by the private sector to indicate that their parking facility was full, due to concerns that this would be the equivalent of turning away potential customers who may still find a location to park.

OUTLOOK

A truck **parking shortage** remains a problem in many parts of the world, and many countries have implemented regulations to stringently mandate rest breaks for long-haul truck drivers in the interest of public safety. Construction of new parking infrastructure is costly, time-consuming, and rife with other challenges. Generating and reporting real-time truck parking information, however, is a lower-cost alternative that can help balance utilization between parking facilities. Several truck parking information systems deployed today serve as a model, and many others are currently being planned. It is very likely that the need and relevance for this technology will remain for years to come, even as physical truck parking capacity is added to the system.

MORE INFORMATION

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Publications:
Texas Freight Network Technology and Operations Plan (2020), available from https://www.txdot.gov/government/partnerships/freight-planning/texas-freight-network-technology-and-operations-plan.html

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FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 5 Truck Parking Guidance System A9

Corresponding THEMATIC fact sheet: Truck parking information systems (parking, other)

Keywords: Intelligent truck parking, truck parking information, truck parking guidance system

DESCRIPITON IN SHORT

Along the A9 motorway in the southern part of Germany an intelligent truck parking guidance system including 22 rest areas was implemented. Detectors in the entrances and exits of these rest areas detect free parking spaces. The parking space situation is made available to interested road users via www.BayernInfo.de. Besides the information about the number of available free parking lots, webcam images show the current situation. The data is also made available via the National Access Point (MDM).

Source: BayernInfo.de

BACKGROUND

The motivation of this measure was to avoid unnecessary traffic caused by truck drivers searching for parking spaces and thus increase the road safety of road users on federal motorways. For those responsible in the road haulage industry, this intended to make it easier for truck drivers to comply with driving and resting times.

The aim was to make more efficient use of existing truck parking capacities by directing drivers (mainly trucks) with telematic support to a free parking space on the motorway.

ELEMENTS

Combined Laser- and Ground-Radar-Sensors count the number of trucks entering and exiting the rest area and thus record the parking situation. For regular verification of the degree of utilization determined by the system's detectors, cameras are installed that can be used for calibration. The recorded data on the current parking space situation including webcam pictures is distributed via digital media (e.g. apps, Internet, MDM) and thus made available to service providers and users.
In addition to the installations on the 22 rest areas, one rest area has additional equipment to be used as testbed for different parking-detection-systems (see Picture).

Source: BASt

RELATED MEASURES	The recorded data on the current parking space situation including webcam pictures is distributed via digital media (e.g. apps, Internet, MDM) and thus made available to service providers and users.
IMPACTS & BENEFITS	After the installation of the 22 locations (rest areas) of the truck parking guidance system, an analysis about the effectiveness including a survey was carried out. The analysis showed that the parking guidance systems are positively evaluated by truck drivers and that a solution with variable message signs (VMS) as an important source of information and a smartphone APP as a supplement is favored by truck drivers.
SUCCESS FACTORS	Most important for the user (truck driver) is the reliability of the information of a parking guidance system about the current availability of truck parking spaces in direction of travel. This includes in the first step the real time detection of the situation/occupancy at a rest area with a sufficient accuracy and in the second step the data-processing to generate adequate information. The third step is the provision of information to the user. VMS along the motorway and at the rest areas can be used to ensure that every user can receive the information independently from the personnel technical equipment in the vehicle whereas in-vehicle information can be individually received and displayed/processed. As long as the majority of vehicles is not yet equipped with such on-board systems, a combination of both ways to provide the information can also be an approach.
OUTLOOK & TRANSFERABILITY	The “Truck Parking Guidance System A9” provides truck-parking information to road users to support them in finding a suitable parking. In this implementation the rest areas ~~of~~ are equipped with sensors in the entrance and exit to detect the occupancy. Alternatively, other detection methods or data sources could be used to estimate the occupancy of parking areas. The provision of information to the user can be realized in different ways depending on the available communication interfaces and the user's equipment.

Source: BASt

MORE INFORMATION

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Publications:
“Digital Motorway Testbed – Intelligent Truck Parking Guidance”, available from
https://www.bast.de/BASt_2017/EN

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28.01.2022, Version 0.2

PIARC **FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET**

No. 6 Application of Pricing in Parking Reservation System for Expressway Rest Area

Keywords: Parking reservation system, Pricing, Expressway rest area, Labor productivity

DESCRIPITON IN SHORT

Recently, parking spaces for large trucks at expressway rest areas have congested by trucks that park for long period to rest, especially late at night. It threatens the parking opportunities for trucks that park for short periods to break. NEXCO Central Japan, one of Japan's expressway operators, began applying pricing to its parking reservation system at expressway rest areas in May 2021. The technical feature of the system is the entry/exit control using ETC 2.0. The gate is opened and closed by matching the vehicle's information registered in advance with the vehicle information obtained by the ETC device at the site. The application of pricing can be interpreted as setting a higher priority on ensuring break than rest. As a result, the parking spaces can be used more efficiently and effectively than free by applying to price.

BACKGROUND

Japan has been facing a truck driver shortage in recent years. A significant factor is the working environment for truck drivers (long working hours and low wages), and there is an urgent need to improve this problem. The labor standards stipulate various regulations regarding truck drivers' working hours, such as continuous driving hours and break periods, which require a 30-minute break for every 4 hours of driving, and the rest period, which requires a rest of at least 8 hours between working hours.

In order to comply with these regulations, expressway rest areas where trucks can park are necessary along their routes. In Japan, however, parking spaces for large trucks at expressway rest areas used for long-distance truck transportation have become congested, especially late at night. The main cause is the high number of trucks for rest, and this congestion threatens the availability of break opportunities for truck drivers. NEXCO Central Japan began a free experiment of the parking reservation system at one of its rest areas (Toyohashi PA) in April 2019. Then the company began applying pricing to the parking reservation system from May 2021 using the usage data obtained there as a reference.

ELEMENTS

In April 2019, NEXCO Central Japan began a free experiment with a parking reservation system at the Toyohashi PA on the Tomei Expressway. Then, in May 2021, the pricing experiment of the parking reservation system began. The conditions and procedures for using this parking reservation system are as follows.

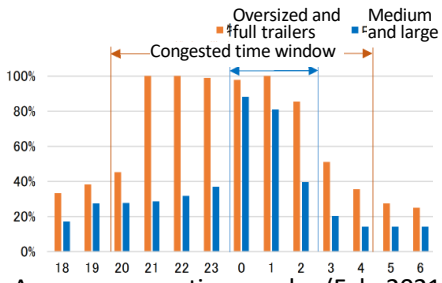
(1) Eligible Vehicles: ETC2.0-equipped freight vehicles only. ETC2.0 is an ITS device that exchanges positional and acceleration data between vehicles and roadside equipment, with approximately 6.66 million OBEs installed (as of March 2021). (2) How to register users: Register some information (such as company information and vehicle information). (3) How to make a reservation: users can make a reservation in 30-minute increments for up to 12 hours via the internet. (4) How to use: When the user enters the reservation-only lane with the ETC card inserted into the OBE, the sensor automatically obtains the vehicle information, instantly matches it with the information in the reservation system, and automatically opens and closes the gate. (5) Fees: For oversized vehicles and full trailers, 250 yen per 30 minutes from 20:00 to 5:00, a maximum fee of 1,000 yen (the first 1 hour is free), free from 5:00 to 20:00. For medium and large vehicles, 120 yen per 30 minutes from 0:00 to 3:00 (the first 1 hour is free), and free from 3:00 to 24:00. (6) Regular use: Regular use spaces (for four vehicles) are also available, and vehicles registered in advance can use the spaces without reservation. (7) Mistaken entry: If non-reserved vehicles enter by mistake, the equipment will detect the error and transmit the information to the call center. An operator will then use the intercom to direct the vehicle to the exit. (8) Data management: Entry and exit times are stored as data, and usage status is quantified, collected, and analyzed.

RELATED MEASURES

Measures to ensure reliable break/rest opportunities for truck drivers at expressway rest areas include increasing the parking spaces and providing information. (1) Increase in the parking spaces: Japanese expressway operators have increased the parking spaces by about 1,350 in FY2019 and by about 550 in FY2020 in total. In addition, "dual-use spaces" which can be used by both small and large vehicles are being developed at particularly congested rest areas. This is because the demand for small vehicles is high during the day, while the demand for large vehicles is high at night, and by changing the target vehicles according to the time of day, it is possible to use the parking spaces more efficiently. (2) Provision of information: Some expressway rest areas provide information on the availability of parking spaces by vehicle type on information boards. Users can select a more available rest area using this information.

IMPACTS & BENEFITS

The benefit of this parking reservation system is to provide truck drivers the opportunity to break. Toyohashi PA has ten parking spaces for medium and large vehicles and nine spaces for oversized vehicles and full trailers. After the free experiment started in April 2019, the number of users increased. The average reservation per day is about 30 vehicles in February 2021. During the free experiment, it was used effectively, for example, by trucks for relay transportation. However, the reservation rate was 100% during the congested nighttime hours, suggesting the existence of a need for further service provision. As a result, pricing was introduced in May 2021.



Average reservation per day (Feb. 2021)

The impact of this parking reservation system is the utilization of data. By limiting the vehicles equipped with ETC2.0, some data (such as usage time by vehicle type, day of the week, and duration of park) can be accumulated and grasped. In contrast, other expressway rest areas do not grasp real-time congestion. Furthermore, when pricing was introduced in May 2021, the actual usage data was used to set the charged time window. After introduction of pricing, the average reservation time was reduced to about 1 hour, and the average usage time was reduced to about 30 minutes, resulting in more efficient use.

SUCCESS FACTORS

(1) The parking reservation system responded to the social demand for stricter labor standards that require compliance with break/rest periods. (2) The system was launched as a free experiment, limited to logistics companies equipped with ETC2.0. (3) By conducting a free experiment for two years beforehand, NEXCO Central understood the demand for each time window. (4) The monitors provided the company to reflect the opinions of logistics companies through user questionnaires and other means (for example, changing the unit time of reservation from 1 hour to 30 minutes, reducing the parking spaces for large vehicles, and increasing the parking spaces for oversized vehicles). (5) An existing system (ETC 2.0) was already in place to obtain vehicle information. (6) The construction and operation of the system were outsourced to a specialized company with expertise in parking space management.

OUTLOOK & TRANSFERABILITY

In Japan, the parking reservation system at expressway rest areas is still in the experimental stage, with only a few locations operated by NEXCO Central Japan. However, there is a great need for the parking reservation system at expressway rest areas in Japan, as expressway rest areas continue to be crowded, especially during nighttime hours, and truck drivers cannot take sufficient breaks. Therefore, at the Toyohashi PA, pricing was applied from May 2021, after a two-year free experiment from April 2019. The introduction of pricing can be interpreted as setting a higher priority on ensuring break than rest, and future developments are expected. In addition, the need for a parking reservation system is great for oversized vehicles and full trailers that require ample space for parking. Therefore, NEXCO Central Japan has begun a new free experiment of the parking reservation system for full trailers at some expressway rest areas from April 2021. This free experiment is expected to increase productivity of truck drivers.
However, while the parking reservation system provides a reliable break/rest opportunity for truck drivers who have made reservations, it can result in empty time, reducing parking space efficiency. To address this issue, NEXCO Central Japan began applying pricing to its parking reservation system.
This may be an initiative worth considering in other countries as well depending on the environment of truck transportation (such as labor standards for truck drivers, the possibility of securing spaces for break/rest, and the possibility of ensuring safety), .

MORE INFORMATION

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Publications:
News Release of Nexco Central of Japan, April 6, 2021, available from https://www.c-nexco.co.jp/corporate/pressroom/news_release/5058.html (in Japanese)

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PIARC

FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 7 PROTECTING TRUCK DRIVERS' LIVES FROM SEVERE WEATHER IN JAPAN

Keywords: Weather, extreme weather, climate changes, truck-driver safety, cargo security, use of weather forecasts, risk management, proactive measures, Business Continuity Planning (BCP), logistic planning in case of weather disasters, transportation planning, road user

DESCRIPITON IN SHORT

Due to the climate changes, extreme weather is increasing, and Japan is no exception to these influences. With the uneven terrain and wide terrain varieties, the Japanese landscape is getting extensively exposed to climate change complications. This especially effect truck transport, with trucks overturning due to strong winds, or traffic delays because of heavy snow- or rainfall. This means logistic planning and ensuring the driver's safety are high priorities. To counter these challenges, the Japan Weather Association has developed GoStop Management System. Using highly advanced weather predictions to detect the weather risk indicators on the roads for our customers. With the weather data collection in our system, the logistics companies can reduce evaluation time and quickly decide on alternative routes or transportation if necessary, ensuring the safety of the drivers, and keep the communication between the shipper and receiver smooth and efficient.

BACKGROUND

・Increase in Extreme Weather Events due to Climate Change

In recent years, stronger typhoons and heavier snow fall has increased in Japan. Typhoon 10 in 2020 caused expressways in Kyushu to close, and transportation were halted for almost a whole day. Then the heavy snowfall in the winter of 2020 brought massive delays on Kan-Etsu and Hokuriku Expressways and causing whiteout conditions on the Tohoku Expressway leading to multiple collusions and the road partly closing. As the Japanese truck transport accounting for 91.5% of all national shipping, it is critical that the safety of the drivers and transport is properly planned.

・Weather Information Essential for the Logistics Companies

As the companies must consider all possible weather risks, they also have to keep all involved parties informed. By using reliable data and facts when explaining alternative routes or changes in schedule you create easy understanding. GoStop creates that information, then logistics companies can easily rely this to their partners.

1. Create an Environment for Efficient Transportation Planning.
   - ・Identifying risk factors (rain, wind, snow, etc.)
   - ・Consider alternative routes (distance, time efficiency)
   - ・Plan according to weather to save time and decrease working hours.
2. Use Objective Data When Explaining Route Change.
   - ・Visualising risks and obstacles
   - ・Reduce inconsistent decision making depending on personnel
   - ・Use data for justification when changing the schedule or routes

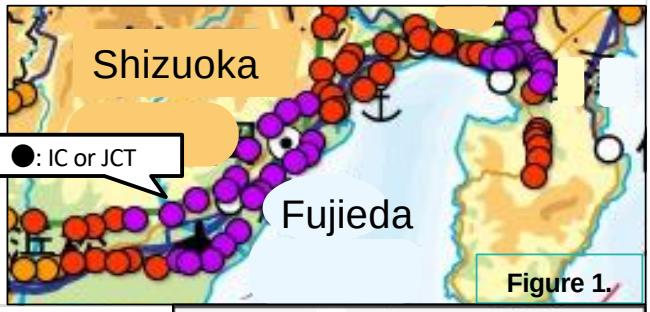

Figure 1.

ELEMENTS

The GoStop Management System specialises in the logistic field, and even received the 2021 Logistics Reward from Japan Institute of Logistic Systems (JILS).

The following content is available on our webpage as part of the service.

1. Highway impact prediction map, displaying the risk assessments for each IC and JCT within the next 72 hours, using colour codes to indicate the risk level *(see figure 1)*.
2. Highway impact prediction list displays the risk assessments in a time series with IC and JCT vertically and the hours horizontally.
3. Typhoon countermeasure support *(see figure 2),* when a typhoon has developed and is closing in on Japan, we provide highly accurate forecasting up to a week ahead, using our unique technology, and frequent comments from meteorologists.
4. Heavy snowfall counter measurements, when unusual heavy snowfall i expected we can give a good assessment of the effects up to 5 days ahead, including snowfall warning updates, along with comments from the forecasters. We also provide information on national highways, railway transport and sudden heavy downpours. Further plans are to also provide risk information for shipping.

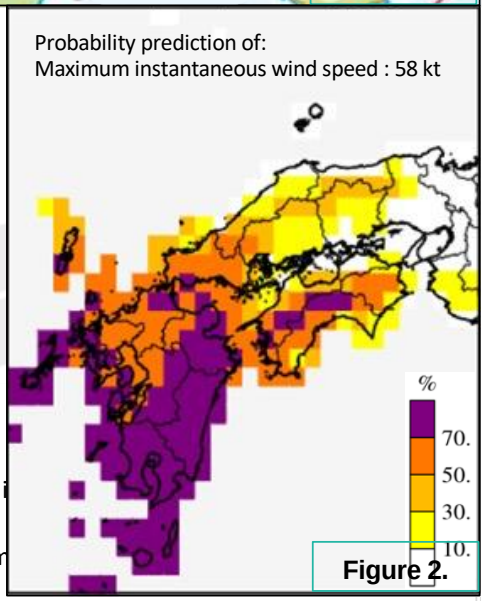

Figure 2.

RELATED MEASURES

・In March 2019, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Ministry of Economy, Trade and Industry (METI), and Ministry of Agriculture, Forestry and Fisheries (MAFF), introduced the [White Logistics] campaign. One of the clauses in that promotion regards the suspension of service in severe weather conditions.
・In February 2020, MLIT introduced guidelines for operating during sever weather. The Guideline for Measure is to ensure the transportation security, but also the safety of the driver. Set to contribute to the maintenance of sustainable logistic functions.

IMPACTS & BENEFITS

The Japanese economy and industry rely heavily on logistics in transportation, as it is very important that goods and supply arrive on time according to the schedule. The industry is always improving, and the GoStop Management System was developed to keep up with this trend. This also follows the promotion of DX in logistic businesses to further maintain and improve the efficiency.

・Guarantee the drivers safety and peace of mind.
・Unify the decision making process and creating more transparency in the transportation decisions.
・Creating transportation plans which, even under abnormal weather, is efficient and risk avoiding.
・With logistics companies, softening the decision making communication between sender and receiver

SUCCESS FACTORS

On January 9th to the 11th, 2020, a heavy snowfall hit the Hokuriku Expressway, and 1500 vehicles were stuck in the stagnation which followed. If you look at figure 3, those data were published on the 7th of January 23:00, 2 days before the heavy snowfall. It shows the possible weather warnings and advisories, and the risk of transportation delays due to predicted snowfall. The logistics companies which received this information was able to change the deliveries to alternative routes and other transportation in advance, then used these materials to explain the reason for the change to the delivery destination ahead of time. This helped the drivers return as planned, no complaints from the clients, and high valuation of service.

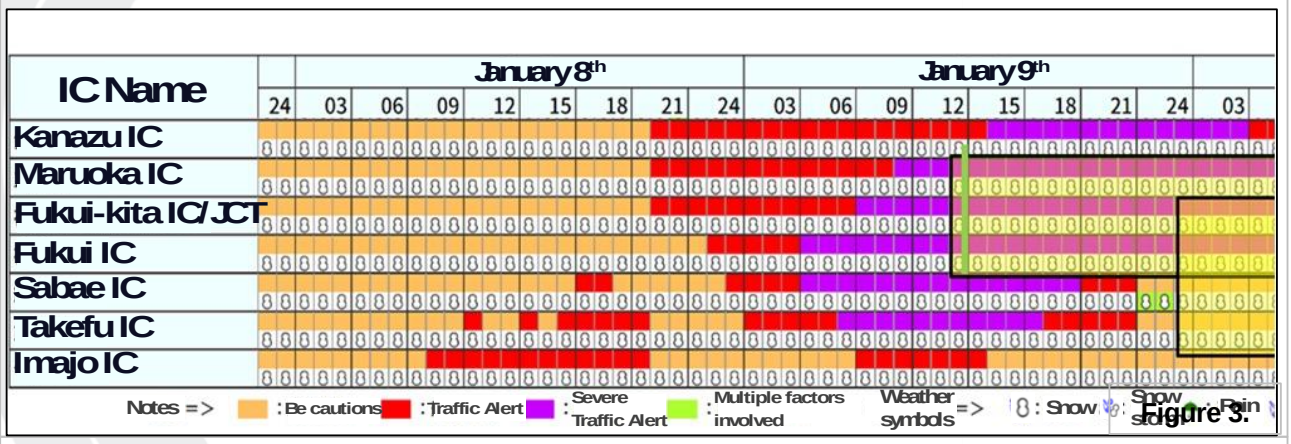

Figure 3.

OUTLOOK & TRANSFERABILITY

For the last few years, Japan has experienced little snow and mild winters, but from December 2020 to January, Eastern Japan, and specifically the western coast side has had record breaking snowfall, causing large traffic jams and delays.
Then with the Baiu Front, a stationary front, accompanying the rainy season every year, East Japan is getting more direct hits from typhoons, and severe weather phenomena is increasing in general, Japan Weather Association has developed GoStop Management System to better calculate the risk factors ahead of time. Supporting logistic companies to evaluate the weather risk impact more efficiently on expressways and national highways, creating easily understood materials for all parties involved in the transport, and to keep the safety of the drivers a high priority. The system is used by many companies already, and we have had cases of the shippers introducing GoStop to their logistic companies to create a better unified understanding of weather risks and counter-measurements.
The Japan Weather Association also provides road administrators with weather information for road maintenance and management, and to determine traffic restrictions.
With the accurate weather information, both road-workers and road-users will enforce more efficient and appropriate countermeasures against severe weather, leading to ensuring the safety and security of all people who use the road.

MORE INFORMATION

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August 2021

PIARC

FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 8 Reducing truck drivers' waiting time by using a berth reservation system

Keywords:shortage of truck drivers , long time waiting, reservation system, standardization

DESCRIPITON IN SHORT

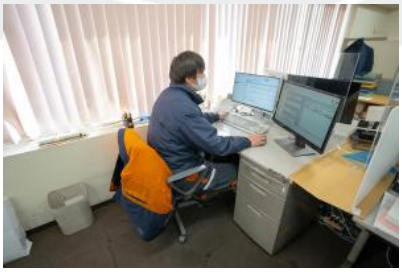
As the shortage of truck drivers has become a social problem in Japan, it has long been pointed out that drivers have to wait for a long time before they can start unloading their cargo at the destination.
This is partly due to the business practice of unloading trucks in the order of their arrival.
Under such circumstances, several IT vendors have developed and implemented so-called "berth reservation systems," which are systems for reserving berth usage times at logistics facilities with the aim of reducing waiting times.
In this paper, we present a case study of a berth reservation system implemented by a major Japanese e-commerce company in its distribution center.

BACKGROUND

Japanese supply chains often consist of manufacturers, wholesalers, 3PLs, and retailers.
Business customs and institutions were formed by activities aimed at optimizing individual companies.
Logistics companies, especially transportation companies, are an important link between the various players, but they are prone to the wrinkles of each player's business.
Statistics show that there will be a shortage of 240,000 truck drivers in Japan by 2027, making them a valuable resource. Under such circumstances, the working hours of truck drivers were more than 400 hours longer than the average of all industries, and the average waiting time for loading and unloading was 1 hour and 45 minutes, and more than 30% of the waiting time was more than 2 hours, which was an inefficient way of working.
This is due to the fact that in Japan, when trucks enter or leave a distribution center, there is no business practice of deciding on the arrival time of the truck, although there is business information on what is to be delivered and by when. This information was not necessary for the shipper to decide.
As a result, loading and unloading was accepted on a first-come, first-served basis, and vehicles were concentrated at certain times. As a result, a number of trucks were waiting on the road to take their turn, resulting in a national average waiting time of 1 hour and 45 minutes.
This waiting for trucks had become a social problem that led to long working hours for truck drivers and complaints from surrounding facilities.

ELEMENTS

This system is an online management system for truck yard reservations and entrance/exit receipts at logistics facilities. With this system, it is possible to share information on incoming and outgoing shipments, equalize the number of vehicles entering the warehouse, and reduce truck waiting time due to reservations.
This system is a general-purpose system that can be implemented at any distribution center, regardless of whether it is a manufacturer, wholesaler, retailer, or industry.


IMPACTS & BENEFITS	This system has been installed in more than 350 distribution centers and contributes to the reduction of waiting time. ASKUL, a major Japanese e-commerce company, delivers about 300 trucks / day to one distribution center. Initially, due to the long waiting time for cargo, the shipper (supplier) and truck driver called it a "center that we do not want to deliver." As a result of introducing this system and switching the arrival of trucks to a time reservation system instead of first-come-first-served basis, the following effects have been obtained. ・ The average waiting time for backordered trucks has been reduced from 45 minutes to 10 minutes. ・ The waiting rate for 1 hour or more has been reduced to 10% or less. ・ Reduced waiting time reduces CO2 emissions
SUCCESS FACTORS	There are several factors that have significantly reduced the waiting time. -The introduction of this system has allowed us to make reservations for incoming trucks, which has allowed us to spread out the entry times and reduce vehicle congestion. -The distribution center was able to know the arrival time of trucks and the cargo to be delivered, so it was able to plan the work in advance and prepare for the day. -The ability to obtain daily/monthly performance data on work hours, etc., allows us to grasp operations in numbers and take measures for improvement.
OUTLOOK & TRANSFERABILITY	Finally, the following is a list of possible future issues for "berth reservation systems" in general, including this case study. 1) Enhancement of functions If it is possible to predict the unloading time and inspection time corresponding to the combination of cargo volume (number of items, number of cases, etc.) and cargo shape (palletized, bulk, etc.) to be delivered to the destination, the dwell time at the berth will be known in advance, and the reservation time can be set more accurately. For this purpose, it is necessary to collect data on cargo volume, cargo shape, and dwell time, and to formulate a prediction formula using statistical methods. 2) Standardization "Several IT vendors are currently competing with each other in the market for berth reservation systems. While friendly rivalry is necessary for technological development, from the standpoint of truck drivers, who are the primary users of the "berth reservation system," if the system were different for each delivery destination, it would not be easy to use. While competition is necessary where it is necessary, standardization that takes into consideration the ease of use for drivers is necessary in areas where cooperation is possible.

MORE INFORMATION

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Publications:

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13/08/2021, Version 1

PIARC **FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET**

No. 9 Point to point transport by LCA60T airship

Keywords: Point to point transportation, last mile logistics, abnormal loads, air freight, heavy load

Technology category: Air freight transport / Transport by airship

DESCRIPTION IN SHORT

FLYING WHALES embraces a strong mission: opening landlocked regions with the smallest possible environmental footprint. To do so, we develop a pioneering air freight solution for abnormal loads up to 60 metric tons, by airship. Without ever landing.
Created in France in 2012, the company begun investigating technical, financial, and operational feasibility before officially starting its aeronautical program in 2017.
Since then, FLYING WHALES has been gathering more than 40 leading aeronautical companies towards the design of the world's largest flying machine, the LCA60T (Large Capacity Airship 60 Tonnes).
FLYING WHALES will both manufacture and operate the LCA60T on 5 main market segments (see Applications below). Three manufacturing sites have already been identified so that by 2032, the company will manage a fleet of 150+ LCA60T that will conduct logistics operations all over the world (see Outlook next page).

EXPECTED IMPACT ON LOGISTICS & FREIGHT TRANSPORT

The LCA60T is a disruptive technology that opens doors to a profusion of new opportunities.
Because of its capacity to conduct **point to point transportation** and to **load and unload 60 tonnes in hover**:

- Previously inaccessible areas can be reached and connected to the global economy;
- Abnormal load transport is freed from the constraints of existing infrastructures & networks;
- Transport to isolated communities can be serviced more efficiently to improve lodging, equipment, healthcare access (mobile hospitals) and services;
- Humanitarian relief logistics in response to natural or man-made disasters are enhanced, becoming faster and more efficient;
- Ecological transition and impact reduction in freight is fostered, building-up on the LCA60T hybrid and soon all-electric propulsion system, and its stationary loading/unloading capacity.

Thanks to its **97m-long cargo hold** and the ability to transport even **larger loads under slings**:

- Industries are given new leeway regarding the design and dimensions (size and weight) of equipment and prefabricated elements, and access to new markets;

APPLICATIONS

Renewable Power: As the market for renewable power rapidly expands, an industry-wide need is emerging for cost-effective transport to remote locations.
Heavy lift: Civil engineering and construction groups face huge challenges for special cargo transport in dense or remote areas.
Industry: Heavy industries are looking for innovative, affordable, and sustainable ways to transport heavy and bulky loads.
Wood: Sustainable construction calls for an increase of wood production. Sustainable forestry in steep regions will soon be possible.
Humanitarian Aid and Disaster Relief: Given that the logistics of humanitarian aid are often a real conundrum, LCA60T can simplify operations and deploy ready-to-use mobile hospitals.

IN-DEPTH DESCRIPTION	The growth of the global economy and trade has **generated unprecedented and sustained demand on the transportation industry**. Indeed, the rise of international trade volumes and the integration of local economies into a global economic system have been among the most important developments of the last century. **Transport is the critical cog** in this global trading system and the key to unlocking huge potential in many regions of the world. Therefore, new perspectives for cargo transportation must ensue in order to address **severe infrastructure and capacity limitations** affecting roads, ports, and airports around the world, and to allow regions to connect to global markets. Simultaneously, the growth of transport activity raises concerns for its **environmental sustainability**. Any innovation in the transport sector must be based on a long-term vision for the sustainable mobility of goods and people. Progress has been achieved, but more needs to be done. "Point to point" transport solutions (that do not require infrastructures), which are equipped with large payload capacity and have a very low environmental footprint – FLYING WHALES's proposal – will be powerful solutions to these issues and will become increasingly important in defining the future world. To do so, FLYING WHALES is **designing a unique aerial cargo transport solution**, the **LCA60T**, which: • Can transport "point to point" heavy and oversized loads, up to 60 metric tons capacity; • Can load and unload on hover flight: ultimate flexibility, no required infrastructure, and no footprint from operations; • And is equipped with a native hybrid propulsion system: ready for 100% electrical H_2 fuel cell implementation, on track for zero emissions. To accelerate the deployment of the LCA60T solution, FLYING WHALES proposes: • A turn-key solution: FLYING WHALES develops two companies, FLYING WHALES INDUSTRY (which designs & manufactures) and FLYING WHALES SERVICES (which operates), so that end users can either buy the solution or the service; • And a worldwide coverage: FLYING WHALES will settle on 3 continents (Europe, Americas & Asia) supported by its strong public-private shareholding structure and production site agreements.
KEY CHALLENGES	Risks are inherent to any ambitious technical development, and their assessment and mitigation guide any program management decision. The LCA60T program has already been able to overcome many challenges since its early days. • Certification: since 2019, FLYING WHALES has been a key stakeholder in the creation of the European Aviation Safety Agency (EASA) "Special Conditions for Gas Airships" that acts as an international reference for the upcoming Type Certification of Airships; • Market: a key challenge for the implementation of a disruptive technology such as the LCA60T is to make sure future users get the potential of such an innovation. From the beginning, FLYING WHALES has worked hand in hand with its first client in the forestry industry and has now been signing numerous Letters of Intent in other industries (see Applications); • Technical: bringing back airships, with an up-to-date design is a huge challenge. The company along with its industrial consortium has already passed 2 of the 4 major aeronautical milestones and is to complete the penultimate one by the end of 2021.
OUTLOOK	Airships are often associated to a transport solution of the past. Today, signs show airships will revolutionize cargo transport by air and contribute to CO_2 emissions reduction in the transport sector. FLYING WHALES has assessed a significant need for its LCA60T transport solution with over 700 units worldwide. The diversity of transport applications leads to a relatively balanced need between all continents as the lack of transport infrastructures takes different forms globally. In support of this favourable outlook, the company has already identified 3 potential production sites in France, Canada and Asia. The first of which, near Bordeaux, will see its construction start in late 2022 and the construction of the first airship begin in the year following. By 2032, FLYING WHALES Services, as a global operator of LCA60T will manage a fleet of 152 LCA60T airships, worldwide.

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PIARC

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 10 Last Mile Delivery with Ground Drones

Keywords: Last mile logistics, delivery, autonomous vehicle, driverless logistics, unmanned

Technology category: Automated Freight Transport / Transport by Robots

DESCRIPITON IN SHORT

One of the emerging technologies for urban goods logistics is the **ground drone.** These devices are electric robots on wheels, suitable for last mile deliveries of relatively small / light parcels. This can be done directly from a store or from a permanent or mobile hub. They can **move autonomously in the public space**. At pedestrian speed they can safely navigate around people and objects. The main reasons to use such robots are the high costs and the negative environmental impacts of actual delivery schemes. Like any form of electrical transport, ground drones are quiet and do not emit any CO2 locally. They are a **promising alternative** for the last mile delivery of goods, especially in an urban environment. The uptake of this technology could result in less trucks and vans, the predominant last mile logistic practice.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

Urban last mile delivery is clearly the most expensive part of the logistics chain. Main reasons for that are the low average speed and the complexity of the routes with many stops and also the long walking distances. The need to decelerate, stop, and accelerate negatively impacts fuel efficiency. Failed deliveries are also a reason for the high costs.

- Changing delivery schemes using midi and micro hubs as basis for final transport by ground drones. The final transport leg by manned vehicle or walking is replaced and the disposition of consignments will be impacted;
- Reduction of transport be trucks and vans: Ground drones may **contribute to the decongestion** of cities, because they use footpaths and do not drive and halt on the road (less conflicts during loading/unloading process. The maximum capacity on sidewalks is rarely a problem;
- A ground drone device is **cost efficient** compared to delivery by trucks and vans with a driver. Test results show a potential cost reduction for local deliveries: 5 to 10 times cheaper than traditional distribution;
- Reduction of emissions (pollution, noise);
- Reduction of CO2-emissions (when green electricity is used);
- A strong development of ground drones could lead to a loss of workplaces;
- Conflicts with pedestrians and cyclists on sidewalks.

APPLICA-TIONS

Some examples from TC2.3 member countries:

• UK	Starship Technologies ground drones
• Germany	EU-Project Efeu-Campus in Bruchsal
• USA	Amazon Scout drones in California
• Switzerland, Austria	Post trials with ground drones

IN DEPTH DESCRIPTION (1)

- The **digitization** of logistics, also known as Industry 4.0, encompasses many aspects. Ground drone devices are one of them. Nevertheless, ground drones have been already in use for decades in warehouses and factories by the name of 'driverless transport systems' and 'automatic guided vehicles. ' The new aspect is the use in the **public domain**.
- There is no official definition of a ground drone yet. **In essence** it is a vehicle that moves autonomously on the part of the public space designated for pedestrians, for the delivery of goods. Because the vehicle must be able to integrate safely in the sidewalk, its size must not exceed what is usually using it (cf. pedestrian with buggy). The size limits the **number of parcels** to a few per trip.

IN DEPTH DESCRIPTION (2)

- Ground drones must be smart in order not to collide with all commonly occurring **stationary objects**. They must also consider all types of **pedestrians and their behavior**, which is partly unexpected (children playing, people with disabilities). They need to be robust and smart, so they can deal with footpath problems (small height differences, holes,…). They must also be able to function if the sidewalk is **temporarily unusual**. This concerns puddles or snow on the one hand and works on the sidewalk on the other (works on pavement, blocked off street, presence of cables). In the first applications, **human operators** are needed top address these issues. At a later stage, **digital maps** with up-to-date information about the actual situation might suffice.
- For the orientation, detection of obstacles and security reasons the drone is equipped with **GPS, video cameras, ultrasonic sensors, inertia measurement detectors**. The drone can be used for multiple parcels and the range is about 5 km, so you need quite a dense network of fixed or mobile hubs or micro hubs. The client can open the lid after receiving a code by phone (SMS, QR).
- A **user-friendly system** for customers is key for the acceptance of this type of device. Information about the delivery should be confirmed by the customer, so there will not be a failed delivery. An easy and safe access to the items is also very important, e.g. by showing a SMS-code or QR-code on the recipient's smartphone.
- **Tech companies** are interested in developing the devices and for the sale or rental. It offers great opportunities for delivery directly from shops (e.g. delivery of daily groceries) and from the catering industry (to replace a delivery with a person on a bicycle, moped or van). **Parcel delivery companies** consider ground drones as another way to improve their business and potentially also the client experience. For large companies, already a small positive economic margin is favorable to them because of the economies of scale.

KEY CHALLENGES

- A key question is whether the ground drone will be able to **understand the environment** on the sidewalks and road crossings during different conditions (volumes, day/night, weather, etc.).
- The **success of ground drones** will depend on the combination of customer satisfaction, financial benefits and environmental friendliness. Essential as well is the fact that delivery robots compete with other techniques for last mile delivery solutions. The benefits against other delivery schemes using electric vans, cargo bikes and aerial drones will be decisive.
- There are also **regulative hurdles** to overcome. In several countries unaccompanied ground drones are not allowed on public space. It is primarily a **technological challenge** to get the robots to use the public space in a safe way for other sidewalk users. With the ongoing digitization of society, **user acceptance** does not seem to be a major challenge at first. Limiting contact between people undoubtedly has a limit, but it has not yet been reached and is unknown.
- Other challenges that needs to be addressed:
  - ✓ Cyber security: how to make sure the robot is not 'taken over' by some malicious peoples?
  - ✓ Terrorism resistant: under what conditions can a company use a ground drone? Is there a need for a license system, a request for authorization for the delivery, and an official definition?
  - ✓ How theft-proof is the delivery to multi-customers in one trip?

OUTLOOK

Ground drones have not yet been rolled out on a large scale. They are being **tested** at various locations. It is expected that the applications will start in closed environments (university campus, company grounds) before customer delivery on public streets. The devices are expected to be **implemented first in HIC** (high income countries, where labor costs are high). For that reason, it is likely that the use in LMIC (low & middle income countries) is today less promising. Also, home delivery is less common practice in LMIC's. There are several indicators that will positively influence the **uptake of ground drones**. For example, e-commerce is growing rapidly, and working from home is getting more common. The trend towards less polluting cities is also an important impulse.

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GOOD PRACTICE FACT SHEETS

No. 11 Drones Freight Opportunities Australia

Keywords: Drones, Southeast Queensland (SEQ), conceptual modelling, drone regulation and safety, food and goods delivery, vehicle kilometres travelled (VKT), aviation, airspace, planning legislation, congestion, transport disadvantage.

IN SHORT

Conceptual modelling was undertaken in an Australian study to test the opportunities, challenges and risks for the **widespread future use of drones** for goods deliveries and passenger flights. For the purpose of this report only the facts relevant to freight were considered.

BACKGROUND

- In 2020 the Queensland Government released The Queensland Transport Strategy (QTS), which provides a 30-year vision to harness emerging transporttrends to move people and products safely and efficiently into the future.
- The QTS provides strategic direction to government to enable a new generation of freight and shipping.
- The delivery of freight using drone technology provides an opportunity to achieve this direction.
- TMR has published a report: *Conceptual Modelling of Drone Transport Services – Scenarios for the Future*, which tested seven freight use cases for drones.
- The results of concept modelling **identified four, plausible future scenarios for drone transport** in 2036 (refer inset). The modelling outputs are not predictions; rather, designed to give **insight to decision-makers as to how the future narrative (on drones)** may play out.
- The report discusses the **opportunities and potential challenges for drone transport in the South-East Queensland (SEQ) region.**
- The study sought to:
  - identify potential drone transport functions
  - develop plausible scenarios to test possible 'futures'
  - model future drone demand
  - assess potential nature of the drones transport task and impact on road based traffic congestion
  - identify policy and strategy implications
  - provide policy recommendations.

Four scenarios for drone transport

ELEMENTS

- 20 million vehicle trips and approximately 140 million vehicle kilometres travelled (VKT) per day are projected, under baseline conditions, for the road network in SEQ, in 2036.
- Forecasts for drone trips for the freight use cases range **between 108 000 to 278 000 trips per day, with 45% to 65% of these trips classified under the modelled 'food delivery'** use case.
- VKT reductions are highest for Scenario 2 and Scenario 4, substituting approximately 1.2% of VKT. A large proportion of this reduction in VKT is taken from the suburban road network, outside of peak hours.
- Suburban areas with lower population density show greater demand for drone deliveries where trip length is between 1 km to 15 km. Lower demand is expected in inner-city where greater choice of alternative (ground) transport options make drone delivery less competitive. **The modelling suggests that drone freight access may be a feasible alternative to land freight access in outer suburban and regional areas.**
- Drone delivery services have the potential to replace existing land transport services for the same day delivery of online purchases. The services could substitute multiple deliveries by conventional vehicles, and takeaway food delivery trips - likely replacing vehicle trips in outer suburbs. **Lower modelled demand in inner city locations were likely attributable to cycle-courier and robo-delivery service models.**

RELATED MEASURES	• Drones have the potential to increase the use of urban and suburban airspace. Existing Commonwealth-based aviation **legislation may need to be reviewed and amended** to mitigate identified risks to safety, amenity and the environment to ensure **positive societal benefits** ensue. • Responsibility for land use planning involves multiple agencies of state and local government. **Specific instruments and guidance** to ensure acceptable drone activity at hubs and flight paths are yet to be developed. **This will be necessary to support drone industry development while mitigating risks**.
IMPACTS & BENEFITS	• Drone freight **delivery impact on reducing VKT is considered limited**. ✓ Drone deliveries **have potential to reduce the cost of travel and transport disadvantage**, particularly for outer suburban, regional and island areas. ✓ **Medical drone flights reduce the time and cost** to transport medical samples, drugs and equipment. ✓ The number and **location of distribution hubs, trips per hub and land use sensitivity adjacent to hubs and underlying flight paths would need to be carefully managed** to avoid noise and privacy issues. ✓ **Future regulations and restrictions should match the risk and maximise opportunities** for a viable drone industry.
SUCCESS FACTORS	• The Queensland Drone Strategy promotes a strategic approach towards attracting investment, industry, workforce, research, services and policy development. • The **Queensland Government Drones Use Policy** provides an overarching whole-of-government policy for the use of drones by the Queensland Government and establishes a framework for the safe, respectful, accountable and innovative use of drones. • **Australia's Civil Aviation Safety Authority (CASA)** are responsible for considering approvals for commercial drone flights. • Queensland is home to the Wing's largest commercial operation of small freight drones. **Wing Aviation has received CASA approval to operate drone deliveries to customers within 10 km of a base to deliver food, hardware, medications and other small items in North Canberra in the Australian Capital Territory and Logan in SEQ.** • **A commercial drone flight testing facility at Cloncurry Airport, Northwest Queensland** recently became operational. Drones up to 150 kilograms and flights of up to 25 km are to be tested.
OUTLOOK & TRANSFERABILITY	• A number of sensitivities to drones were identified as **potential challenges and barriers to drones** adoption, including noise. A greater body of evidence is needed to support existing knowledge to better understand these sensitivities and mitigation approaches. • The *Conceptual Modelling of Drone Transport Services – Scenarios for the Future* was based on the circumstances and the information available and relevant in SEQ, Australia in 2018. **The model was not designed to outline accurate predictions for the future, rather, designed to explore what the future could look like**. This enables an inductive policy narrative to be developed. Further quantitative analysis can be progressed as the technology develops. The study found that **freight drones could address several transport challenges in regional and remote communities** throughout Queensland. Transferability to other locations would need further assessment at least with respect to aviation and land use planning regulatory environment. Further information is available at: • Emerging aviation technologies in Australia • Drones New Zealand • Drone delivery systems • Queensland drone strategy 2018 • Cloncurry flight test range media - Boeing • Drone delivery services Australia

FACT SHEET NO. 11 DRONE FREIGHT SERVICES AUSTRALIA - DELIVERY AREA

MORE INFORMATION
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Publications:
Conceptual Modelling of Drone Transport. Scenarios for the Future. Department Of Transport and Main Roads. 2020.

Author: Department of Transport and MainRoads

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No. 12 Delivery by Robots

Keywords: Autonomous delivery robot technology, AI, Sensor technology, Image recognition by camera, Optimum route search, Delivery system, 5G communication technology, Interconnection technology among autonomous delivery robots, Last-mile delivery

Technology category: Alternative Modes of Freight Transport / Automated Freight Transport

DESCRIPTION IN SHORT

Self-driving delivery systems using an "autonomous delivery robot", which recognizes its surroundings through its camera images and GPS data and autonomously drives to its destination, are currently under development. These systems are expected to save labor, provide benefits for users, reduce congestions, and improve the environment. However, putting these systems into practical application poses challenges, including technologies for detecting obstacles to stop driving and avoid them, specification of right-of-way for these robots in road spaces, and public acceptance of the robot operation in sidewalks where pedestrians are around. Japan is now in the verification phase of these technologies through pilot programs.

BACK-GROUND

With an increasing demand for delivery in smaller orders due to the e-commerce growth and the aging of truck drivers, haulers are now unable to keep up with the demand for delivery staff and system operation, making it difficult for them to maintain logistic service levels. In particular, last-mile delivery requires a lot of man-hours and causes a shortage of manpower. On the contrary, there has been a significant progress in AI, sensor technology, camera-based image recognition, 5G communication technology, optimal route searching and autonomous driving robot technology. These technologies are expected to solve the current issues around goods delivery.

ELEMENTS

1) Pilot programs: these programs have been conducted for practical application with the help of NEDO's technology development projects. The table below shows major pilot programs with the images of robots, specifications, when and where the programs were conducted.

2) Offering services: the pilot programs are exploring how the following services can be offered:

-Robot-sharing type delivery service for helping residents in hilly and mountainous areas
-Safe and secure last-mile delivery service in residential areas by a small, low-speed robot

-Safe delivery service by an autonomous delivery robot for personal use

-In-building and/or parking space delivery service for large-scale facilities (e.g. hotels, hospitals and shopping malls) through the coordination of different types of robots
-Realization of cost-effective system

3) Technical challenges: each pilot program is exploring to address challenges in building business models and implementing some of the following technologies:

Case 1 [1]
Tsukuba City, Ibaraki
July, 2021

Case LJ
6km/h,96 x 66 x 109cm
Chiyoda Ward, Tokyo
October, 2020

Case 3 [3]
3km/h,110 x 75 x 105cm
Tamano City, Okayama
November, 2021

Case 4 [4]
4km/h,115 x 65 x 115cm
Fujisawa SST
March, 2021

Case 5 [7]
15 km/h,250 x 130 x 200
Ishikari City, Hokkaido
August, 2021

-Technologies for detecting pedestrians, bicycles and road obstacles to stop driving and avoid them
-Autonomous driving on designated routes
-A remote monitoring system with a manually operational, real-time 360-degree monitoring feature
-Automatic map generation technology which works in various settings such as urban and mountainous areas
-User interface that makes it easy for senders and recipients to communicate each other on arrival time and locations

	-Abnormalities detection for computer, sensors and driving units in the robot's main body for safe operation -Stable communication technology for real-time remote monitoring -Public acceptance of these robots (e.g. speed, distance and size) in urban/residential areas where people are around
RELATED MEASURES	1)Technologies for delivery: Autonomous driving truck, delivery by humanoid, delivery by drone 2) Basic technologies: Robot technology and AI technology 3) Infrastructure development: Road spaces that allow robots move around in a safe and smooth manner
IMPACTS & BENEFITS	1)Addressed labor shortage: Last-mile delivery by autonomous delivery robots will address the labor shortage in logistics. This also will reduce redelivery traffic, which is considered a social issue. 2)Improved traffic environment: Reduction in delivery vehicles and motorcycles means better traffic condition (e.g. less congestion) and better environment (e.g. Reduced CO_2 emissions). 3)Increased productivity: By making good use of robots to replace delivery work, which is a labor-intensive task, haulers can improve productivity, reduce redelivery, and extend delivery hours at night. They will also be able to deliver heavy goods that human operators cannot handle. This technology is expected to solve the labor shortage, and there has been no discussion regarding the loss of jobs in Japan. 4) Improved consumer's benefits: Consumers will be able to use on-demand delivery services where they can select the time and destination for the delivery. Underprivileged people who are unable to go shopping will also be able to purchase their daily essentials. These delivery robots can deliver goods and patrol at the same time for crime-prevention and security of senior citizens. 5) Prevention of infection: Non-personal and non-contact delivery services help prevent spread of infection.
SUCCESS FACTORS	Delivery by robots can be successful if the following challenges are addressed: 1) Technical challenges -Remote driving system: a system which enables a driver in a remote location to monitor and operate a robot -Collision avoidance: a system designed to avoid pedestrians, pet animals, bicycles, road facilities and obstacles, and overcome bumps and uneven surfaces -Friendliness to people around in the traffic: friendly appearance and behavior which reduce a feeling of fear 2) Regulation and deregulation -Driving speed: speed limit, safety features such as emergency stop button -Road space for robot operation: designation of the space on public roads for robot operation such as sidewalk and side strips (In Japan no space on public roads is allowed for robot operation except special cases at present.) -Road conditions: conditions for ensuring a safe robot operation, including sidewalk width and roadway width -Safety standards: visibility requirements around the robot, a front light and other operating device, and size -Vehicular classification of delivery robots in the Road Act A law of traffic rules for remotely operated small vehicles has come into effect in Japan. After April 2023 the delivery robots can drive at a speed of 6 km/h or less on sidewalks, roadside strips. They must follow traffic rules equivalent to pedestrians, such as traffic lights, road signs, and crosswalks, and must yield to pedestrians.
OUTLOOK & TRANSFERABILITY	1) Outlook: The following are expected. ‣ A hub-and-spoke autonomous robot delivery system where multiple delivery robots are transported by autonomous driving medium-sized trucks to a distant area and these delivery robots are sent out from the truck to each home to automatically deliver the goods ‣ The humanoid robot autonomously moves in various environments where there are bumps, steps, escalators, and elevators to deliver goods to each home. ‣ Similarly, the robot can collect goods from senders. 2) Transferability: Robots can act individually and autonomously, which means they can be applied to LMICs (Low- and Middle-Income Countries).

Sources: 1) Honda Motor Co., Ltd, 2) ZMP Inc., 3) TIER IV Inc., 4) Panasonic Corporation, 5) Kyocera Corporation

MORE INFORMATION

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PIARC

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 13 Blockchain in Logistics Chains

Keywords: Supply chains, data, digital solution, logistics.

Technology category: Information and Communication Technology (ICT) and Computer Technology

DESCRIPTON IN SHORT

The seemingly complicated blockchain technology requires a concise **conceptual** explanation, without an overly technical description of how the technology works. Basic knowledge can be sufficient to realize the **potential** for freight logistics.

- Blockchain is a technique that allows a network of users to jointly maintain a database of transactions. The database forms a **chain of data**. It is structured in **blocks**, that are chained together. The database is managed decentrally, in a network of participants (nodes);
- Blockchain technology goes back to 2008, when the first steps were taken in the **financial world** with Bitcoin. Since then, major steps have been taken and applications are being developed with blockchain technology in all kinds of sectors, including the logistics sector;
- Conceptual, blockchain presents many **opportunities for logistics chains**. Supply chains often still rely on paper documents, a source of inefficiency and encouragement for fraud. The documents are gradually becoming digital;
- Blockchain enables people to do business in a direct, **peer-to-peer** way. It is a digital solution for security and mutual trust, which is highly important in the logistics world. It is meant for transactions that require verification, like contracts, intellectual property, identification and cryptocurrencies (bitcoin and alike).

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

In logistics, blockchain can improve communication and generate mutual trust between agents in the supply chain. It is safer (1), more transparent (2) and more efficient (3).

1. Each of the transactions executed on the network of participants is recorded and archived permanently. Information of the register can not be modified, preventing data being deleted and double registrations;
2. Information is recorded in each node that make up the network;
3. Information must be verified automatically by various devices involved in the blockchain network. This avoids waiting for a third party to validate the data.

Chain of data in a blockchain database

Smart contracts are a valuable type of blockchain for logistics.

- By eliminating intermediaries and simplifying processes, costs for the end consumer can be reduced. Smart contracts are distributed among all the nodes of the network. All nodes need to verify and validate the contracts and prevent them from being manipulated by one of the parties.

Current track & trace lack real-time capabilities. In combination with IoT (Internet of things), blockchain can improve the **real-time traceability** of products.

- **IoT systems** are connected sensors / devices to capture data without human intervention. The sensors can determine the source of components and regulatory compliances. They can be embedded in transported goods, for monitoring and (e.g. product damage, temperature, etc.)
- When IoT is **combined with a blockchain** technology, data can be shared with each participant of a supply chain (suppliers, producers, distributors, .). Data is updated and validated securely, with full visibility for all.

Blockchain has potential to **reduce empty truckloads**. It can help to match shippers with carriers.

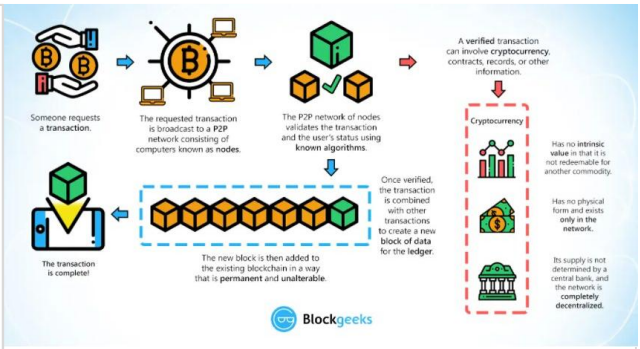
APPLICA-TIONS

Some examples from TC2.3 member countries:

- Belgium blockchain solutions in ports (Antwerp, Rotterdam & Singapore). http://t-mining.be/
- Switzerland refrigerated air freight container for biopharmaceuticals
- US trucking supply chain platform BiTA (Blockchain in Transport Alliance) www.bita.studio
- Australia / US construction blockchain Briq / Brickschain (US), Probuild (AUS)

IN DEPTH DESCRIPTION

- The most common use for blockchain so far has been as a **ledger for transactions;**
- A blockchain is a **type of database** that forms a chain of data. A database, a collection of information stored in a computer system, is typically structured in a table format. A blockchain, structures its data differently, into blocks chained together. Each block hold sets of information. When a block is filled, it is chained onto the previously filled block;



Transaction Cycle, infographic from www.blockgeek.com

- The essence of blockchain technology: databases are **managed decentrally** in a network of participants. As it is a decentralized system the system does not go down. When a transaction is made all participants are notified and, after a verification process, the blockchain is updated with a new block. All participants, nodes, will receive the most recent version of the blockchain;
- Blockchain is advantageous when interests differ and when trust could be improved. it can easily resolve disputes between participants. Besides, it facilitates faster transactions by allowing **cross-border transfers** with a digital currency.

According to Blockchain Partner(France), blockchain is especially **useful in the following sectors:**

- Food industry: to reduce the cost of **fraud** in the food supply chain;
- Maritime transport & international trade: greatly reduce fraud and errors, as well as current **transit and shipping times**. An international shipment of goods today needs to be inspected on average by nearly 30 agencies during its journey;
- Luxury Diamonds. A digital register identifying transactions, for more **transparency**;
- Wine: improve bottle **traceability**, guarantee integrity, fight against **counterfeiting** and resale;
- Real estate / buildings: tracing contributions and interactions of each stakeholder within a building to save on **maintenance and litigation;** and build new services from this data.

KEY CHALLENGES

- For the success of blockchain it is pivotal that **IoT** (Internet of Things) and blockchain are **associated technologies**. Without the link via sensors, the advantages of blockchain for the supply chain will not be maximized;
- The blockchain technology can be **costly**. The **mining** (the system to validate transactions) can consume a lot of computational power. In the logistic sector, miners will need to be paid to validate transactions;
- Some sectors still need to **prepare** for blockchain technology. For example, in the construction sector only a few use-case exist. There are several reasons for that: in the first place, the sector has low margins and constructors can be conservative towards new technology. Next to that, contractors and subcontractors are often long-term relationships. Also, a low percentage of revenues is invested in up-front contracting and tools for managing complex construction projects. Pilot projects can be a great help to convince the construction sector;
- According to Briq, a leading American example of applying blockchain in construction, blockchain needs to be backed by a **blockchain standard**, in order to become an industrywide initiative. They consider just blockchain itself as hard to sell commercially.

OUTLOOK

- Where supply chains still rely on paper documents, there is inefficiency and a high risk of errors. The **digitization** process has started in many sectors. Blockchain may be the dominant infrastructure for digital supply chains tomorrow;
- As blockchain can be linked to **IoT** (Internet of Things) for an optimal result, the success is dependent of that development as well.
- In order to make it work in LMIC (low- & middle-income countries) the governments need to invest in the digital infrastructure, possibly with support of HIC (high income countries).

Key publications

- ITF report (2021): Forging Links. Unblocking Transport with Blockchain?

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FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 14 Use of Blockchain in Supply Chain

Keywords: Distributed digital ledger, Logistics efficiency, Supply chain reability

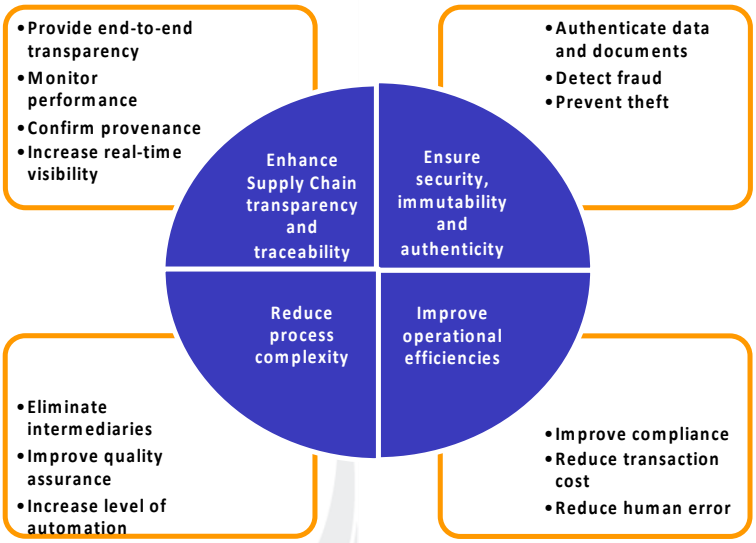
Technology category: Digitalized Logistics/Supply chain

DESCRIPITON IN SHORT

The blockchain is a **distributed digital ledger database for recording transactions** between parties verifiably and permanently. This definition includes the three most important properties of a Blockchain: **decentralized, verified and immutable**. Blockchain initially emerged as a leading technology layer for financial applications. Nevertheless, in the recent years, the attention of researchers and practitioners moved to the application of the Blockchain technologies also to other domains, like the logistics supply chain. Why logistics? Logistics is becoming increasingly complex, with more parties directly or indirectly involved in supply chains. This complexity is creating challenges related to communication and end-to-end visibility between partners, making logistics processes inefficient. In this field, thanks to its capability of ensuring data immutability and public accessibility of data streams, **Blockchain can increase the efficiency, reliability, and transparency** of the overall supply chain, and can optimize the inbound processes.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

The Blockchain is a disruptive innovation due to its capability of **ensuring data immutability** and **public accessibility of data streams**. This technology can create an en**crypt digital records that track goods** at every stage in the supply chain. It makes any irregularities that could disrupt a shipment clearly visible, enabling companies to solve problems quickly. Moreover, its decentralized and distributed infrastructure prevents the problems of the present centralized approaches, **including trust issues, such as fraud, corruption, tampering and falsify information, and their limited resiliency**. Centralized systems are vulnerable to collapse since a single point of breakdown might lead the whole system to be crashed.



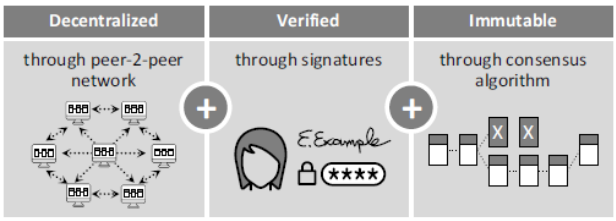
APPLICA-TIONS

Some examples of Blockchain systems already in operation:

- Easy Paperwork Processing in Ocean Freight: TradeLens (IBM with Maersk, Hapag-Lloyd, ONE).
- Open-Source collaborative platform to advance cross-industry blockchain technologies: Hyperledger (created by Linux Foundation. Poste Italiane uses this system for its Blockchain Logistics application).
- Facilitate Supply Procedures: Coca Cola Co. with Ethereum and Hyperledger Fabric.
- Operate the Internet of Things: Walmart with DLT Labs, Hyperledger Fabric.

IN DEPTH DESCRIPTION

As anticipated, the three most important properties of a Blockchain are:



- **Decentralized** because the **network is entirely run by its members**, without relying on a central authority or centralized infrastructure that established trust. To add a transaction to the ledger, the transaction must be shared within the Blockchain's **peer-2-peer network**. All members **keep their own local copy of the ledger.**
- **Verified** because the members sign the transactions **using public-private-key cryptography** before sharing them with the network where every member of the network has access to the **same data, providing a single point of truth**. Therefore, only the owner of the private key can initiate them. However, the members can stay **anonymous** because the keys are not linked to real-world identities.
- **Immutable** thanks to its consensus algorithm: one or more transactions are grouped together to form a new block. **All members of the network can verify the transactions in the block**. If no consensus on the validity of the new block is reached, the block is rejected. If consensus exists and the transactions in the block are valid the block is added to the chain. A cryptographic hash is then generated for each block. Each block not only **holds transaction records** but also the hash of the previous block. This creates a block interdependency linking up to a chain: the Blockchain. Altering a transaction on the Blockchain retroactively would require not only to alter the local records on most of the networks members' devices but also altering the cryptographic hash of every block down the chain.

Nowadays most of the more advanced Blockchain are **open to the public (permissionless),** but there are also **private (permissioned)** implementations. The permissionless are systems where everyone can operate without authentication and without any authorizations. The permissioned are systems controlled by a central authority where it is possible to operate only when authorized.

The set of rules and conditions between the different ecosystem parties and for the consensus of blocks are written directly in the system code called **"Smart Contracts".**

KEY CHALLENGES

Hurdles of Blockchain implementation:

- **Lack of trust** among companies who are nervous about sharing data on open platforms although Blockchain in fact is building trust ("Trust paradox").
- Integration issues due to **variety of individual solutions** used from each party involved.
- **Very specific use cases** and requirements of existing blockchain solutions (e.g. online payment).
- **Lack of clear legal framework** to govern blockchain transactions in various domains.
- **Redundancy of intermediates** in the logistics chain.

OUTLOOK

Blockchain offers the potential to create value in logistics, however its implementation and use **has not shown a real breakthrough yet**. The solution framework lack in terms of **standard methodology** to design, develop and validate the overall system, and there is still limited evidence of the **value for the actors, the overall costs and benefits**. The consequence is that there are very **few Blockchain projects** with high longevity and that have moved from the pioneering phase to a more mature exploitation phase. The market offers very fragmented systems and looks waiting for a solution to emerge for complete logistics functions. There has to be a big push from, for example, the retail, the international shippers, or main logistics carriers to develop and show a **viable scale-wide solution beyond pilots.**

Key publications

- Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases – Politecnico di Torino
- Blockchain in logistics and supply chain: Trick or treat? – Hamburg University of Technology
- Unchaining business through the Blockchain – Engineering Group
- Blockchain for business: in che modo le aziende stanno utilizzando la tecnologia Blockchain? - Politecnico di Milano

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PIARC

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 15 Physical Internet

Keywords: Hyperconncted logistics system, interconnectivity, open asset sharing, encapsulation, interfaces, protocols

Technology category: Basic technology

DESCRIPITON IN SHORT

Physical Internet (PI) is a "hyperconnected global logistics system enabling seamless open asset sharing and flow consolidation through standardized encapsulation, modularization, protocols and interfaces to improve the efficiency and sustainability of fulfilling humanity's demand for physical object services." (Montreuil, 2015). The core idea is interconnecting logistics actors on multiple layers, such as physical, digital, operational, transactional, and legal. Ultimately, the Physical Internet will enable universal interconnectivity with any organization, anytime and anywhere if the systems are legally and economically accomplished. (Ballot et al., 2021). Physical Internet is an evolution to provide a new paradigm of world-wide logistics networks aiming at improving efficiency, sustainability and resiliency. Physical Internet is beyond collaborations in terms of hyperconnectivity.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

Physical Internet facilitates higher freight unit consolidation, intelligent combination of loads across supply chains, smart consolidation, and reallocation of flows in supply networks and synchro-modality using PI (π)-node (Figure 1) and PI (π)-containers (Figure 2). Physical Internet can reduce logistics costs, CO_2 emissions, improve resilience.

- Reduction of logistics costs: systematic approach of consolidation of goods
- Provision of reliable and better services to customers
- Reduction of CO_2 emissions
- Reduction of distance travelled
- Increase resilience

The Physical Internet is about interconnecting the world's logistic networks and is thus defining a new opportunity for supply chain design and operations, enabling seamless open asset sharing and flow consolidation, fulfilling society's demand for physical objects with an order-of-magnitude better efficiency and sustainability, thanks to improved economies of scale and sope.

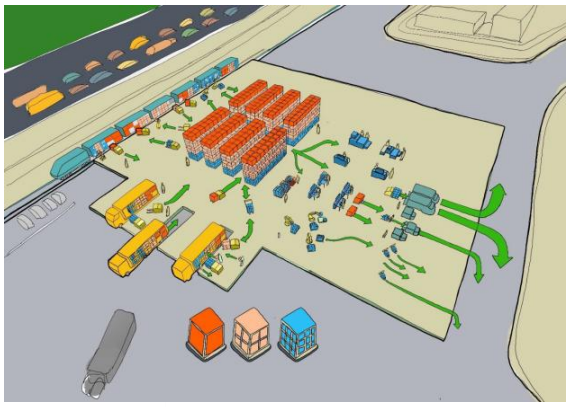

Figure 1 PI (π)-node (SENSE 2020)

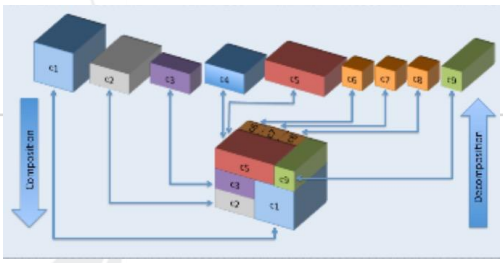

Figure 2 PI (π)-containers (Montreuil, 2011)

APPLICA-TIONS

Some examples from TC2.3 member countries:

- EU projects: SENSE, ICONET, ALICE etc.
- USA and Canada
- Japan

IN DEPTH DESCRIPTION (1)

The developments of Physical Internet in five areas are critical for the successful implementation.

1. **Logistics nodes:** Consolidation and deconsolidation of goods needs to be done seamlessly so operational costs are largely offset by gains in transport. Additionally, idle warehouse, terminal capacity as well as transportation slots could be opened to other companies, through digital services and standard procedures. Stakeholders have access to relevant data as input to optimize their own operations (e.g. next transport leg plan may impact the position of a container in a terminal).
2. **Logistics networks:** Logistics Networks may involve many companies under the orchestration of a single company in charge of the inventory management, transport planning, routing, and

IN DEPTH DESCRIPTION (2)

capacity management. Networks are expected to build seamless, agile, flexible and resilient, door-to-door services consolidating and deconsolidating all shipments within a logistics network in which all assets, capabilities and resources are seamlessly visible, accessible and usable within the logistics network to make the most efficient and effective use of resources.

3. **Systems of logistics networks:** Further connectivity will be foreseen across logistics networks that will require specific functionalities. These will be expanded so there is an organic growth of interconnected logistics networks as described in the previous chapter finally creating a Physical Internet when there is a standard- and industry-agreed procedure to be part of that System of Logistics Networks. Meantime, Systems of Logistics Networks will be created in which services, assets and resources will be seamlessly accessible by multiple networks.
4. **Access and adoption:** In current practice, we see relatively small networks exist, with a limited scope of activities (pooling of cargo, limited to sectors, etc.). Many companies are not able to organise networks on their own or get access to existing networks. One of the main objectives is to show companies within their current business setting that cooperation, even with competitors in logistics, is not only a good idea but it is also easy to execute and implement directly or through logistics service providers. It is also important to help companies to make first steps in this respect. There are new ways of sharing assets, services and resources between stakeholders in vertical integrated supply chains and in horizontal collaborative networks.
5. **Governance:** Governance includes the shaping of adequate framework conditions needed to evolve the Logistics Nodes, logistics networks and the System of Logistics Networks into the Physical Internet, i.e., the rules defined by the stakeholders forming or using them as well as the trust building processes and mechanisms. Appropriate funding is also required to accomplish the Physical Internet.

KEY CHALLENGES

Montreuil et al. (2012) highlighted the key challenges of Physical Internet:

1. **Physical interconnectivity** is about making sure that any physical entity can flow seamlessly through the Physical Internet. The Physical Internet generalizes and significantly extends this practice by encapsulating physical objects in physical packets or containers (hereafter termed π-containers shown in Figure 2 so as to differentiate them from current containers), packets, boxes and so on. These π-containers are world-standard, smart, ecofriendly and modular. They are modularized and standardized worldwide in terms of dimensions, functions and fixtures.
2. **Digital interconnectivity** ensures that physical entities, constituents and factors can seamlessly exchange meaningful information across the PI, fast knowledge and fact-based decision-making in action.
3. **Operational interconnectivity** is about ensuring that in-the-field operational processes as well as the business processes are seamlessly interlaced so that it is easy and efficient for users to exploit Physical Internet for fulfilling their logistics needs and for Physical Internet constituents to seamlessly collaborate in serving the logistics users of Physical Internet users.
4. **Universal interconnectivity**, i.e. the solutions for generalising and functionally standardising unloading, orientation, storage and loading operations, widely applying them to PI containers in a smart automated and/or human-assisted manner.

OUT LOOK

The Physical Internet paradigm opens a new way to describe and design how logistics organizations can work, with many managerial, engineering, and economical implications on supply chain performance, including sustainability and resilience (Ballot et al. 2021).

Key publications

- Montreuil, B. (2015). The physical internet: A conceptual journey, In Keynote presentation at 2nd international physical internet conference, Paris, France.
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PIARC

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 16 Artificial Intelligence

Keywords: Autonomous vehicles, platooning, robotics, big data, optimization, digital twins, Physical Internet
Technology category: Basic technology

DESCRIPITON IN SHORT

Artificial intelligence (AI) is a set of related technologies that make machines do things that would require intelligence if done by humans. AI systems have the ability to keep improving their performance without humans having to explain exactly how to accomplish all the tasks undertaken (Wang, 2019). AI have been applied in logistics and freight transport using the machine learning techniques including deep learning, reinforcement learning for analyzing big data in order to find optimal solutions. Robotics and automation of freight vehicles and warehouses is another application of AI in sustainable logistics and freight transport.

EXPECTED IMPACTS ON LOGISTICS & FREIGHT TRANSPORT

AI can help making logistics and freight transport safer, cleaner, smarter and more efficient by processing, learning and acting on the information provided by Internet of Things (IoT) sensors using machine learning algorithms.

- **Improvement of safety:** Autonomous trucks and the platooning systems which are supported by AI can dramatically improve safety through the reduction of human errors, since many of crashes by heavy goods vehicles are caused by human errors.
- **Reduction of Green House Gas (GHG) emissions:** As AI helps road traffic flowing by smart traffic management using real-time traffic data, it can also reduce the fuel consumption and CO_2 emissions in providing freight vehicles with traffic information to optimize the route.
- **Reduction of costs and works:** AI application in robotics and warehouse automation can reduce logistics costs and awful human works as well as avoid human mistakes. AI based robots are operated on public roads for delivering goods to customers in urban areas.
- **Better logistics management:** Supply chain optimization can be achieved utilizing AI and real-time and historical data. Modelling logistics operations in the digital twin environment can visualize the freight vehicles' flow to identify the problems and find innovative solutions.
- **Energy savings:** AI can help saving energy of freight transport by choosing the best combination of transport modes, logistics terminals, as well as optimizing the routing and scheduling in the Physical Internet.

APPLICA-TIONS

- Autonomous freight vehicles
- Truck platooning
- Robots and automated warehouses
- Logistics management
- Digital twins for modelling freight transport
- Physical Internet

Application of AI for truck platooning in Japan

IN DEPTH DESCRIPTION (1)

- **Autonomous freight vehicles:** The automation of freight vehicles requires AI to process the big data collected by IoT sensors in vehicles and infrastructures. AI can recognize the location of vehicle and the environment including the movement of other vehicles to make decision for controlling the vehicle on roadways.
- **Truck platooning:** Truck platooning systems need AI to control the steering and the distance of multiple freight vehicles for allowing them to smoothly run and avoid crashes. The real-time communications between the lead truck and following trucks supported by AI is also a key for successful operations of truck platooning.

IN DEPTH DESCRIPTION (2)

- **Automated warehouses:** AI is used for the automation of warehouses by robots and IoT sensors. Robots can unload the pallets from trailers and store them in the designated areas of warehouse. Automatic picking of commodities in the warehouses is also executed using AI based robots and IoT sensors. The optimization of inventory management can be accomplished using AI which analyses the real-time data in the e-commerce environment.

- **Logistics management:** The data-driven logistics management requires AI for optimizing the schedule of vehicles and drivers as well as choosing better transport modes and logistics facilities. AI can help predicting the change of future demands of customers based on big data and finding the appropriate solutions to lower the costs and GHG emissions.

- **Digital twin:** The digital twin represents a virtual replica of a physical object, process and system. For example, in cases of road networks disruption by disasters, AI can analyze the possible scenarios in modelling the traffic flow in the digital twin of urban areas and suggest the best redevelopment of logistics hubs and delivery scheduling by trucks on the road networks.

- **Physical Internet:** In the Physical Internet AI plays an important role for operating the hyperconnected global logistics systems through open asset sharing and flow consolidation of freight transport. It enables the optimal use of transport modes and hubs for sustainable freight transport in the cooperation of stakeholders.

KEY CHALLENGES

Although AI can help improving productivity, safety of freight transport, as well as reducing the negative environmental impacts, there are challenges associated with AI application (European Parliament (2019)).

- **New risky situation:** In an interim period, when vehicles are increasingly automated but not fully autonomous, drivers might be distracted and pay less attention to the road. It generates a new risky situation on roads.

- **Ethical issues:** When faced with life-versus-life situation, an AI algorithm in a full-automated vehicle should make a difficult decision how the vehicle reacts in the critical conditions.

- **Liability of accident:** In case an accident arises for automated vehicles, a clear boundary of liability of different automation level should be defined, so that it is possible to identify who is actually responsible for the accident.

- **Cyber security and data privacy:** Cyber security and data privacy are of particular importance in the development of AI in automated vehicles. AI-based automated vehicles require access to a lot of data that is often sensitive or protected.

- **Employment:** AI can contribute to the creation of new jobs, the disappearance of others and the modification of most. Truck drivers might no longer be needed in a fully autonomous vehicles.

OUTLOOK

AI is a basic technology which can help processing, learning, analyzing big data provided by IoT sensors and other information recourses using machine learning algorithms. AI can contribute to make logistics and freight transport safer, cleaner, smarter, and more efficient. The application of AI encompasses controlling autonomous freight vehicles and platooning on roadways, the automation of warehouses by robots, optimizing logistics management, the digital twins, Physical Internet. However, challenges of new risky situations, ethical issues, liability of accidents, cyber security and privacy, and employment issues.

Key publications

- Wang, Y. (2019). Understanding the impact of emerging technologies on the freight sector, Foresight, Government Office for Science, UK.
- European Parliament (2019). Artificial Intelligence in transport – Current and future developments, opportunities and challenges.

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FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 17 Digitization of operation management and timely grasp of profits in the motor truck transportation business.

Keywords: digitization, transportation business, sharing, standardization, physical internet

DESCRIPITON IN SHORT

There are more than 60,000 motor truck transportation business operation Japan, but most of them are micro businesses, and the digitization of operations is delayed compared to other industries in Japan. On the other hand, although large and medium-sized companies are becoming more digital, their information systems are customized. These information systems also need to undergo major changes toward the coming “Sharing Society” and “Sharing Economy”. Under these circumstances, some startup IT venture companies have developed systems that emphasize standardization rather than customization.
Ascend, which was founded in 2020, is also such a venture company, and it seems that the logistics model that the company is aiming for is a matching model inspired by the "Physical Internet."
This paper introduces the concept of ascend's matching model and an example of digitization by a logistics company in Toyama Prefecture, which is the first step toward realizing this concept.

BACKGROUND

Most of the operations of operation managers in the general motor truck transportation business operator still consist of recording with analog tools such as telephone, fax, and paper, and posting to tools such as Excel and Access.
This method of operation has problems such as the occurrence of multiple inputs and the personalization of business.

[Problems in the transportation business]
Logistics demand is on the rise due to the progress of smaller lots and more frequent small lots of logistics, while the supply of logistics is on the decline as a result of excessive competition and a declining labor force, and supply shortages are becoming apparent. Despite these macro trends, the logistics industry is not profitable.The following three factors can be pointed out.
・The first point is that the logistics business is a commodity service and an asset business, so logistics companies have weak bargaining power with shippers.
Logistics companies may receive orders even for shipper projects that are expected to be in the red.
・The second point is that there are many analog operations, so the workload is high and data and recording are often dispersed.
As a result, the automation of operations has not progressed, multiple inputs cannot be reduced, and excellent workers have no choice but to carry out the work, and the work is becoming more personalized.
・The third point is the lack of IT literacy as an industry. The root cause of this is that the overwhelming majority of players in the transportation industry are small and medium-sized businesses with low capital.
The transportation industry is in a negative chain where IT literacy does not increase because it cannot invest.
[Purpose of this demonstration experiment]
As the first step to solve the problem, we verified the effect of digitizing operations using Ascend's operation management SaaS.
・ Whether or not it is possible to streamline and standardize operations and build a system to grasp profit information in a timely manner using this operation management SaaS.
・ Matters to keep in mind when constructing this operation management SaaS

ELEMENTS

Ascend's operation management SaaS is a service aimed at operation managers of transportation companies, with the aim of contributing to improvement of business efficiency and quality and management improvement through data analysis.
[Main functions]
-The system supports the entire process of receiving orders, dispatching vehicles, outputting various forms, registering results, and issuing invoices, enabling centralized management of business data and eliminating multiple entry tasks.
-When inputting case information, the system registers regular cases, which account for a large portion of the transportation business, enabling input assistance and reducing the workload.
-The system allows for the timely viewing of income and expenditure information based on pre-registered cost information and daily case information.

IMPACTS & BENEFITS

As a result of using this operation management SaaS, the following results were obtained.
A series of operations, from receiving orders, dispatching vehicles, outputting various forms, registering results, and issuing invoices, can be transferred without any problems, reducing multiple entries and realizing centralized management of case information. The system can reduce the number of multiple entries and achieve centralized management of case information.
By utilizing the centrally managed case data, the man-hours required for data processing were greatly reduced, and by building a system that enables timely and multifaceted analysis of the profit status of the business, the man-hours and waiting time previously required by the management were greatly reduced.
By analyzing data by customer, by vehicle, by project, etc., the company was able to objectively identify problems for improving profitability. In addition, the company was able to make better portfolio decisions by taking into account not only case information but also the status of its own resources (asset utilization status).
The fact that the daily operation management work is directly related to the visualization of the company's profitability is now understood by the workers in the field, and this has led to improved motivation for their work.

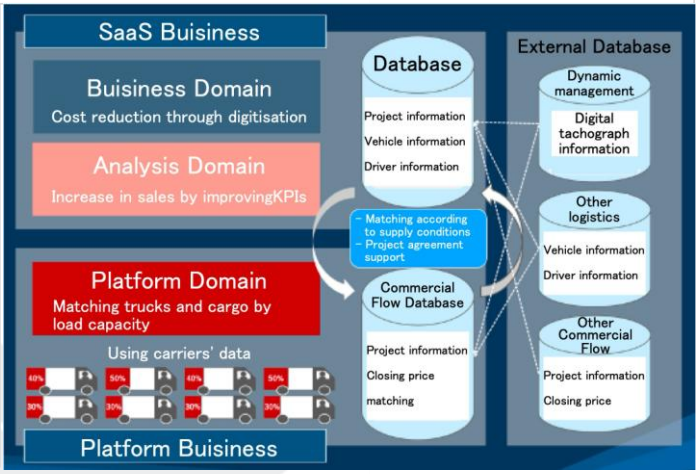
SUCCESzS FACTORS

The success factors of this demonstration experiment can be summarized as follows.
-The decision makers (management), with the ultimate goal of realizing Digital Transformation (DX) over the medium to long term, decided not simply to "systemize current operations" but to "restructure operations into a desirable form using the system" and demonstrated this in action to the field.
-The staff with knowledge of both the use of IT and the logistics field took the lead and were able to involve the field in achieving the company's ideal image.
-In order to reconstruct the operations in a form that can be fully reproduced at the site, we conducted careful business interviews, adjusted the system based on the interviews, and designed the business flow.

OUTLOOK & TRANSFERABILITY

In the general motor truck transportation business, it is commonplace for deals to be closed through existing connections, and it is easy to infer that many of the deals flowing onto the platform are "cheap deals" that were not closed through existing connections. Nevertheless, in limited areas such as long-distance return shipments and light cargo, matching is still possible because of the weaknesses and distortions of the industry, such as "it is better than carrying nothing. In order to create a platform that can be widely and healthily used in the general motor truck transportation business, it is important for both shippers and logistics companies to share the information necessary for transportation and delivery on the platform in an accurate and timely manner, and to improve the loading ratio by matching additional projects with available space in the vehicle fleet. Ascend's products enable the acquisition of necessary information for the platform by consistently digitizing the operation management business. In terms of "maintaining reasonable prices," the company plans to use the accumulated sales and cost information of logistics companies to grasp their standard profit margins and marginal costs in a multifaceted and quantitative manner, and to incorporate order data from shippers to create a pricing engine.

A platform can only be realized if the transaction volume of both supply and demand exceeds a certain threshold.
On the supply side, logistics capacity is processed into segmented digital data through the linkage of this system with other systems. The open logistics platform is completed when the supply-side data is connected to the demand-side digital data through the formation of common rules with the demand-side, including prime contractors and shippers. It is expected that the value transformation of the logistics industry will be achieved through both DX (Digital Transformation) in the form of the correct use of data and rule making with a focus on standardization.



MORE INFORMATION

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Publications:
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PIARC

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 18 Battery electric vans and trucks

Keywords: ZE (zero-emission) freight transport, BE (battery electric) trucks and vans, technology development

DESCRIPTION IN SHORT

Fast implementation of battery electric (BE) vans and trucks is a key measure to cut emissions from freight transport by road in Norway. The targets are: By 2025, 100% of new small vans should be zero emission (ZE), and by 2030, 100% of new large vans and 50% of new trucks, as well as close to ZE city logistics. To achieve these targets, technological development, serial production of ZE trucks and bonus-malus instruments are needed. Public procurement, taxes and fees will play an important role. Charging and filling infrastructure must be available. The cost of vehicles and battery packs is expected to fall and the range to increase. By the early 2020s, the net economy for BE vans is estimated to be favourable compared to diesel, and for BE trucks by the late 2020s.

BACKGROUND

In 2019, the European Parliament adopted standards to reduce emissions from trucks by 15% by 2025 and 30% by 2030. A system of super-credits will be established for low or zero emissions vehicles. From 2025, a bonus scheme based on sales targets will be introduced. ZE vehicles are a key measure in the Norwegian Climate plan to ensure 50% emission cuts by 2030. Several major manufacturers are developing BE trucks. Many new models are expected in the coming years, first as production in small-scale series.

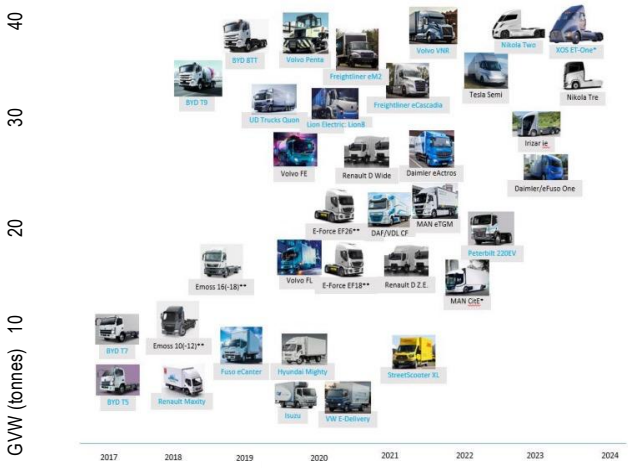

Figure: Announced new battery electric trucks of different sizes.

ELEMENTS

The costs of purchase, range, charging time and charging infrastructure are major disadvantages for BE vehicles. Some BE trucks are in small-scale production suitable for short trips like for city logistics.

- With a range up to 200 km, the gross weight could be up to 30 tonnes (payload above 10 tonnes);
- With increased range up to 300 km, the gross weight decreases below 20 tonnes;
- In rebuilt versions, BE trucks in Norway have gross weights up to 50 tonnes.

Batteries are a main cause of the high sale prices for BEVs. Lithium-ion battery pack prices fell 89% from 2010 to 2020, with the volume-weighted average hitting $137/kWh. Underlying material prices will play a larger role in the future, but the introduction of new chemistries, new manufacturing techniques and simplified pack designs keeps prices falling (Bloomberg NEF, 2021). At the same time, driving distances are expected to increase, and charging time to decrease.

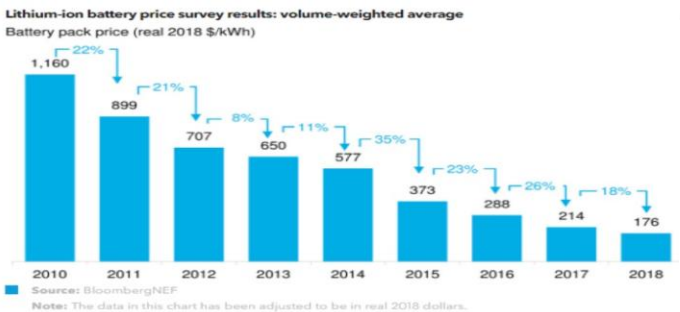

Figure: The prices for battery packs have decreased by 85% from 2010 to 2018. Source: Bloomberg

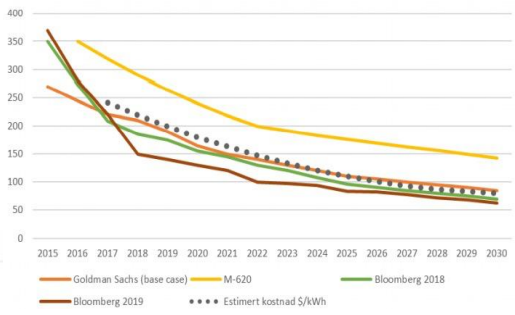

Figure: Estimated production cost for battery packs for battery electric vehicles, $/kWh

RELATED MEASURES

For BEVs to be efficient climate measures, their power supply must be climate neutral.
To compensate for the weight of batteries, the EU has increased the permissible weight limit.
Norwegian authorities allow up to 2 tonnes increased weight for BE trucks.
The parallel development of BE trucks and BE buses may give synergies since some components could be shared, and this and serial production may lower the sales prices.

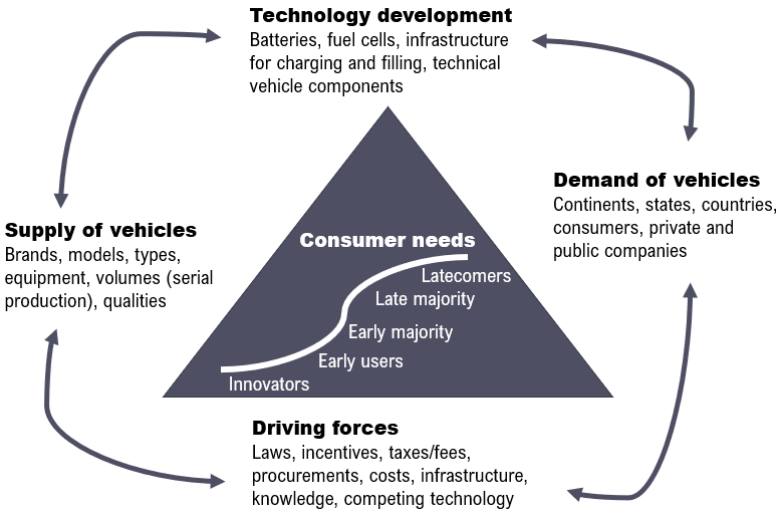

Figure: Elements that influence the implementation of ZE vehicles. Source: TØI report 1744/2019.

IMPACTS, BENEFITS

ZE road freight transport and change to renewable power supply will probably be necessary to reach the climate targets in the Paris agreement. At the same time, both the EU and Norway have targets for economic growth. BEVs may be a main component in both. Operation costs may be reduced due to lower cost of maintenance. In Norway, the cost of electricity is substantially lower than diesel (per km), making the cost of BE driving cheaper. BEVs do not have local emissions or engine noise.

SUCCESS FACTORS

Important success factors are:

- The technological development;
- Clear public and private climate targets;
- Long-term reliable framework conditions;
- Cooperation between public and private parties;
- The demand for BEVs will depend on public procurement and other available ZE options like fuel-cell electric vehicles (FCEV);
- Subsidies and reduced taxes and fees for as long as needed.

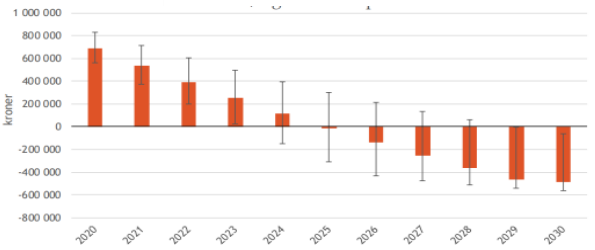

Figure: Net present value of additional costs when investing in a BE truck for local and regional transport compared to diesel. Source: Climate Cure 2030.

OUTLOOK & TRANSFERABILITY

Both BE vans and trucks are expected to be cheaper than diesel ones by 2030 in Norway:

- Small vans by 2021;
- Large vans by 2024;
- Trucks for local and regional transport by 2025;
- Trucks for rock/soil transport by 2027;
- Trucks for long-haul by 2028.

The transferability to other HICs and LMICs may be good when purchasing new trucks and vans. In urban duty cycles, BE trucks of any size will globally become the cheapest option for several use cases in the 2020s. Megawatt-scale charging stations and the emergence of much higher energy density batteries by the late 2020s will result in BE trucks becoming a viable option for heavy-duty long-haul operations, especially for volume-limited applications (Bloomberg NEF). The production of energy must shift to ZE.

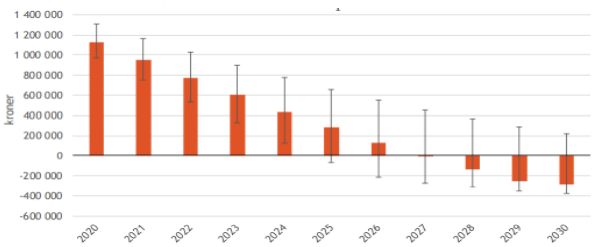

Figure: Net present value of additional costs when investing in a BE truck for rock/soil transport compared to diesel. Source: Climate Cure 2030.

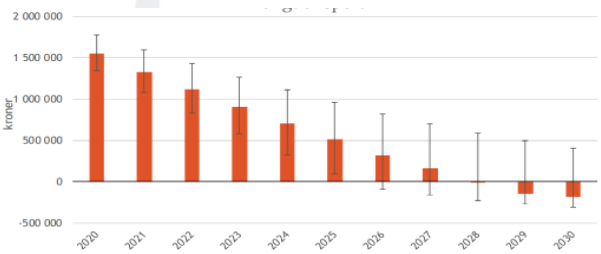

Figure: Net present value of additional costs when investing in a BE truck for long-haul compared diesel. Source: Climate Cure 2030 from Norway.

MORE INFORMATION

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20.07.2021, Version x

Publications (some in Norwegian):

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360 degree analysis of the potential for zero-emission vehicles, TØI report 1744/2019
Electric Vehicle Outlook 2021, Bloomberg NEF

FREIGHT EMERGING TECHNOLOGY THEMATIC FACT SHEET

No. 19 Modelling of freight transport in Australia using TraNSIT – Transport Network Strategic Investment Tool

Keywords: infrastructure, investment priority, freight, vehicle costs, commodities, supply chain, industry, data, model, transport costs, route optimisation

DESCRIPITON IN SHORT

Over time, road agencies and research organisations have developed several useful tools and methodologies to **model future freight transport scenarios** based on present and expected future freight flows and demand for logistics services. A new modelling tool – **TraNSIT (Transport Network Strategic Investment Tool)** has emerged over the last decade and has been applied on several important projects within Australia and Asia.

BACKGROUND

Good quality transport infrastructure is essential for the **efficient movement of freight**. Many roads in Australian regional and agricultural production areas are in a lesser condition, resulting in reduced vehicle speed and higher costs for vehicle maintenance.

TraNSIT represents state-of-the-art **transport and logistics modelling**, developed to better understand and inform:

- **agricultural, forestry, fuels, mining, manufacturing and general freight supply chains**
- transport cost savings
- investment in road and rail upgrades such as sealing, widening, bridges, and access to higher productivity vehicles (HPV)
- location of freight hubs and facilities
- **outcomes of regulatory changes** including fatigue management, animal welfare and biosecurity.

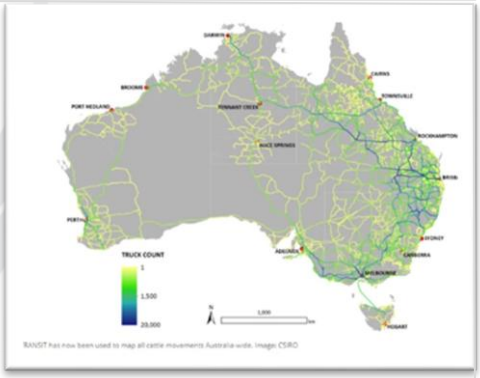
TraNSIT continues to evolve, with the addition of commodities, enterprises and supply chains, improved information granularity and currency, and freight network and vehicle parameters.

Extensive quality data sets from supply chain participants and governments across Australia inform the broad freight strategies and underpin the feasibility of potential infrastructure investments. **Data provided by industry at this level can be commercially sensitive** and subject to confidentiality agreements.

A version of TraNSIT including a web interface is available to government agencies. This is a user-friendly, web interface to the base case modelling. TraNSIT-web does not provide for scenario modelling capability. Confidential information is successfully managed through desensitisation of enterprise level data.

ELEMENTS

TraNSIT uses granular and dynamic industry data at the enterprise level, **focussing on all transport paths between enterprises**, capturing the industry specific characteristics. **Transport logistics and costs between enterprises** are modelled and optimised based on available routes, vehicle choice and operational infrastructure factors. **Monthly average agricultural production volumes** from representative locations are estimated from annual data. **Annual throughputs and supply chain paths for each commodity, including known enterprise locations**, are developed with industry input. TraNSIT analyses complement existing modelling approaches which may, for example, use a range of publicly available information on regional agricultural production and flows through the supply chains, combined with counts of freight vehicles at locations throughout the network.



IMPACTS & BENEFITS

Several case studies have been analysed by the TraNSIT team using the model. Examples are briefly presented below to demonstrate the versatility of TraNSIT to investigate **financial impacts of transport scenarios such as, new road investment, road closures due to flooding, feedlot location in grain cropping regions, increased heavy vehicle access (associated road investment) and mode shift**. Further detail on the impact on freight movements and transport costs are presented in the referenced documents.

- ✓ An assessment was undertaken of a 41 km major road freight route bypass between a regional city centre and a state capital. The existing route involved a steep decent and negotiating the city centre. The baseline analysis determined numbers of **existing semi-trailer movements of livestock and agricultural commodities and total transport cost** using this route. Total annual transport cost savings upon project completion and **commodity dependant savings per trailer load** (one-way) were estimated. Benefits result from the diversion semi-trailer loads from the regional city centre and associated congestion.
- ✓ The potential location of two, 10 000 head sheep feedlots and a co-located stockfeed processing enterprise was investigated, with the preferred location informed by the **minimisation of supply chain transport costs**. The initial investigation found all feedlot options resulted in higher transport costs compared to the baseline.
- ✓ Based on an actual flooding event, the **additional transport costs in a region of grain, cotton, dairy and livestock production during a 2-month period of widespread road closures** were estimated. Additional hypothetical scenarios were also tested. The analysis demonstrated the ability to determine the additional transport costs due to heavy vehicles having to take longer detours to reach freight destinations. Vehicles operating under Performance Based Standards (PBS) are constrained to approved routes and are impacted to a greater extent. Hypothetical analyses of longer-term road closure in the region highlighted **potential advantages to operate larger PBS Level 3A vehicles on an alternative approved route** for longer distance freight tasks.

SUCCESS FACTORS

TraNSIT has demonstrated utility **informing where infrastructure improvements can make a positive difference** to commodity transport including:

- prioritisation of submissions for upgrades to roads where transport livestock and agricultural produce occurs
- freight planning at a regional scale
- air freight capacity for horticulture
- supply chain inefficiencies and cross border bottlenecks in Indonesia and Vietnam
- transport reduction costs due to mode shift from road to rail and an alternative future rail network
- estimated transport cost of plantation forestry source materials over 25 years
- benefits to the grain industry of upgrading intermodal facilities, roads and rail track upgrades and new train combinations
- impact of road improvements for the Australian tourism industry
- provision of 'Transit Web' to government, allowing testing of infrastructure/regulatory changes.

OUTLOOK AND TRANSFERABILITY

TraNSIT has been **applied in external countries including Indonesia, Laos and Vietnam** to improve supply chain efficiency and bottlenecks. The range of TraNSIT is expected to include weather related events that can impact supply chains and be updated as opportunity arises.

CSIRO is open to partner with government and industry nationally and internationally to assist with freight transport, refer to https://www.csiro.au/en/Research/LWF/Areas/Landscapes/Transport-logistics-TRANSIT .

MORE INFORMATION

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Andrew Higgins, CSIRO, Andrew.Higgins@CSIRO.au

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Author: Department of Transport and Main Roads December 2020

PIARC

FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 20 Cargo sous terrain

Keywords: Underground freight transport, urban logistics, greening freight, Switzerland

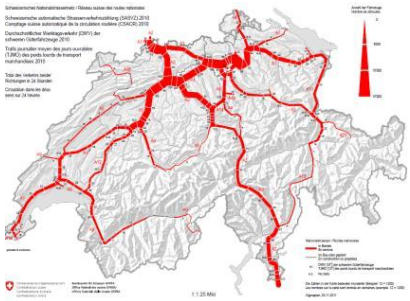
DESCRIPITON IN SHORT

Cargo sous terrain (CST) is a complete logistics system for the flexible transport of small-component goods. Tunnels connect production and logistics sites with urban centres. Overground, CST distributes the transported goods in environmentally-friendly vehicles, contributing to the reduction of traffic and noise emissions. The first section will connect the Härkingen-Niederbipp hub with Zurich from 2031. The rest of the network will be built until 2045. CST is ideal for supply and disposal. 100% of the power to operate the system comes from renewable energy sources.

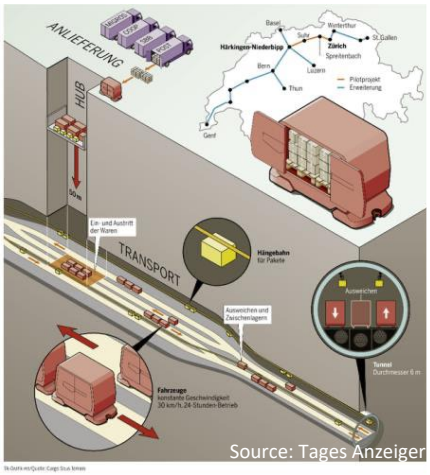
BACKGROUND

The original driving force behind cargo sous terrain were big retail companies, which are dependent on reliable and cost-effective transport. Switzerland faces increasing congestion on the road and rail transport network, especially in the conurbations. The freight transport market faces therefore increasing problems with the reliability and costs of freight transport. Another challenge in Switzerland is the climate change. In 2013 a public private development association was established to finance and carry out a first feasibility study on such an underground freight transport system. In 2017 the development association was transferred into a fully private limited company. Further studies on the network development, intercity and city logistics, digitization and Information Technology (IT), technology and system design, hub locations, construction planning and eco-nomic viability followed. The main idea was to create an efficient and reliable freight transport system, which is separated from passenger transport and which is linking existing infrastructures (logistics centres, airports, freight stations, etc.) with urban centers. Already existing technologies are to be used but put together in a new and innovative way. CST will be fully privately financed.

Road freight flows on Swiss main road network



Systems overview



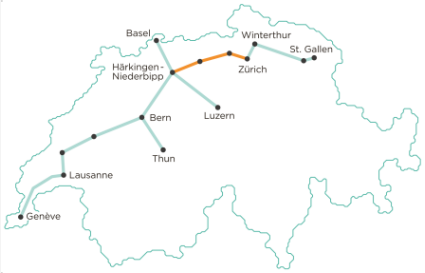
Source: Tages Anzeiger

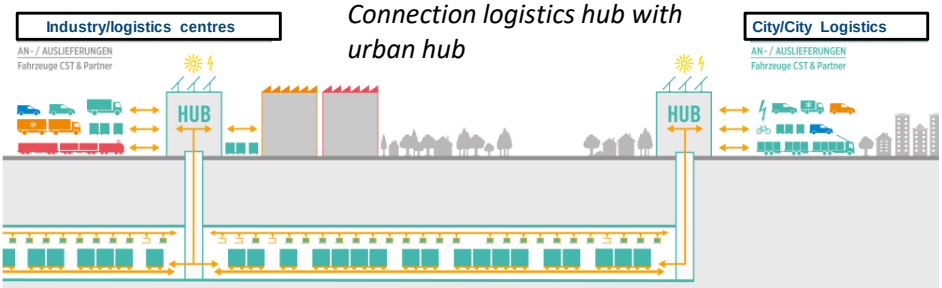
ELEMENTS

CST consists of the following **systems elements**:

- Tunnel, hubs, unmanned vehicles, overhead parcel conveyor, low emission vehicles for final distribution and an IT Integration of all elements.
- The principle is the same as that of an automatic conveyor system. Self-driving, unmanned transport vehicles that can automatically pick up and drop off loads at lifts operate in the tunnels around the clock. The vehicles travel on wheels and have an electric drive with induction rail. The goods are palletized or transported in containers of similar size by unmanned, refrigerated transport vehicles fully automatically.
- The vehicles travel in three-lane tunnels (diameter: 6m) at a constant speed of around 30 kilometres (km) per hour.
- The hubs along the route serve as interfaces to other modes of transport, with seam-less IT integration into the logistics companies business processes.

Planned network





Connection logistics hub with urban hub

RELATED MEASURES

- **National regulation on underground freight transport:** covering the access to the system, expropriation rules, integration in national and regional transport and landuse plans, planning and approval procedure
- **Climate change strategy** to reduce Greenhouse gas emissions

IMPACTS & BENEFITS

The following **positive impacts** and **benefits** are expected:

- Increase reliability and efficiency of freight transport
- Decrease in road freight traffic, especially also in urban areas (increasing traffic safety)
- Environmental improvements (less noise, less pollution)
- Substantial reduction in GHG-emissions (only green electricity)
- Reduced land use (less space used)
- Profitable investment
- Technology with the potential to be exported
- Economic benefits

The following **investment costs** are expected:

- First part: 3 to 3.5 bln US-Dollar (USD)
- Complete network: 30 to 35 bln USD

SUCCESS FACTORS

Today the following **success factors** can be derived:

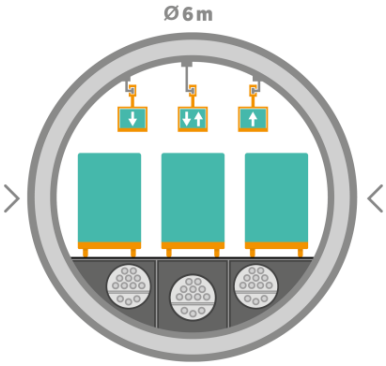
- National regulation for the planning and approval process
- Competitive services by CST compared to road (prices, quality) and corresponding market uptake
- Achieving very high operating reliability
- No major overrun of the construction and system costs
- Appropriate phasing of nationwide network development
- Coordination of spatial planning and network with hubs/ finding space and realization of the hubs
- Reaching full IT integration within CST and with clients of CST
- Lean infrastructure planning procedures/support by approval authorities

OUTLOOK & TRANSFERABILITY

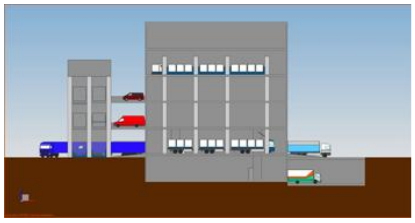
The national regulation on underground transport systems has been approved in 2022. The network (hubs, connections) will be integrated in national and regional planning procedures 2022-2024. After the detailed systems planning of stage one the building permit is expected for 2025 and the construction will start. The operation of stage one is expected to start in 2031. This kind of underground transport system can be transferred to countries and regions with comparable framework conditions.

Tunnel with unmanned automatic vehicles

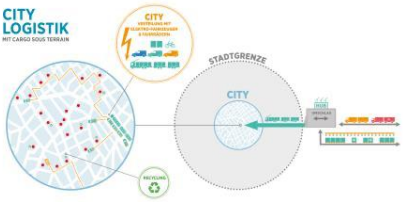
Tunnel cross section



Space-efficient hubs



Interface to city logistics



Hub locations at the first part of the network

MORE INFORMATION

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- Martin Ruesch, Rapp Trans AG, martin.ruesch@rapp.ch, +41 58 595 72 43

Publications:

- Website of CST AG: https://www.cst.ch
- Cargo Sous Terrain, Presentation at the PIARC TC B.4 Meeting in Zurich, Patrik Aellig, CST AG, 15th May 2019
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PIARC **FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET**

No. 21 Autonomous Driving Transportation Services in Hilly and Mountainous Areas

Keywords: Autonomous driving transportation, Aging society, Shortage of truck drivers
Technology category: Automated Freight Transport / On roads

Background and Overview

With the aging of the population and more elderly Japanese voluntarily returning deriver's licenses, securing local transportation in rural areas becomes an issue in Japan. The fact that Japan's transportation is also seeing its workforce decline in truck and bus operations due to the population decrease means improving productivity to handle with increasing freight trips is an urgent issue.
Given that the practical application of autonomous driving and use of such driving technologies are expected to solve various rural issues, Japan is conducting a pilot program called "Autonomous driving service around Michi-no-Eki resting areas in hilly and mountainous areas" from FY2017 to FY2022.

Details

<Main initiatives up to FY2020>
In 18 hilly and mountainous areas across the country, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) started a pilot program to demonstrate the autonomous driving service around Michi-no-Eki in order to provide means of passenger and freight transportation, given that these Michi-no-Eki resting areas are now increasing services for everyday life such as product sales and clinic.
Experimental vehicles were used in the autonomous driving solution(2 types) and the Vehicle-Infrastructure (VI) integration solution (2types).
-In FY2017, the MLIT conducted a week-long short-term demonstration in 13 locations mainly for verifying technical issues and considering business models.
-In FY2018, five more locations were selected for the short-term demonstration. The MLIT also conducted a long-term demonstration lasting one to two months in four locations among the 13 tested locations mainly for the purpose of building a business model.
-In FY2019, the MLIT launched a full-fledged service in one location where the long-term demonstration for the VI solution was completed.
-In FY2020, the Road Act was amended. With this amendment, electromagnetic induction lines, magnetic markers and other autonomous driving support devices are now legally classified as road facilities or objects on the road for exclusive use and are expected to help solve self-locating issue due to weaker GPS signals in mountainous areas, tunnels, and under bridges as identified in the demonstration.

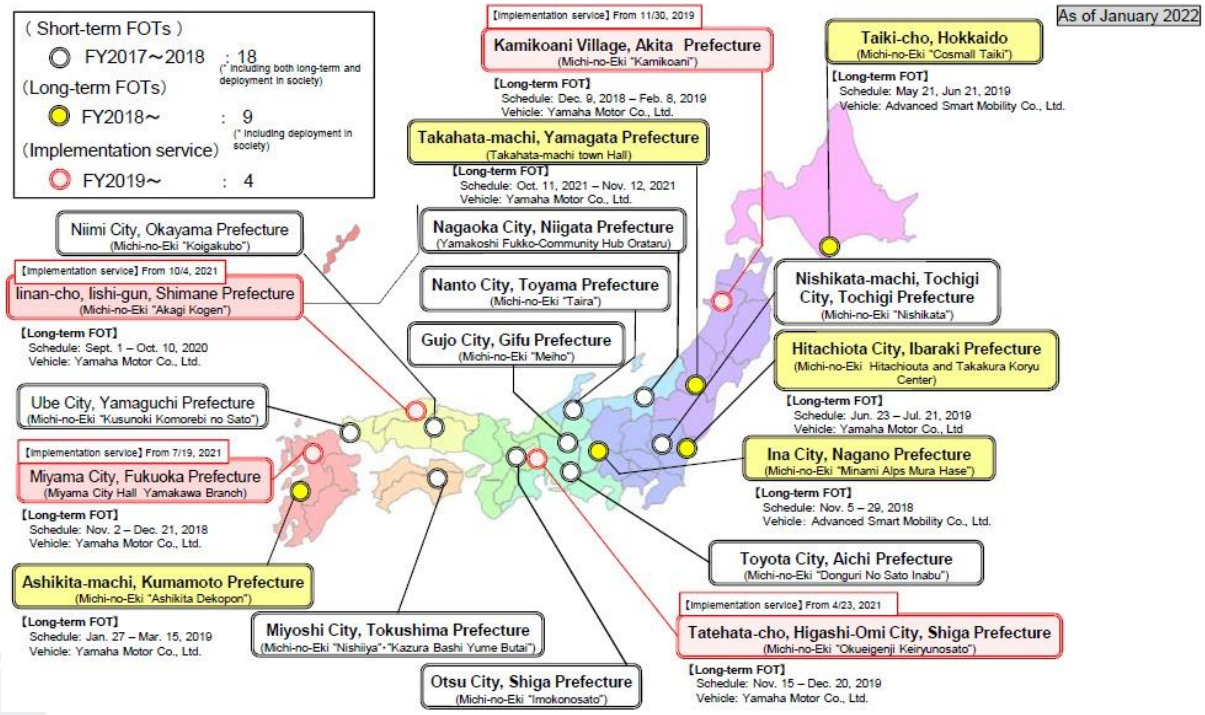
<Main initiatives in FY2021>
-In FY2021, a full-fledged service started in three more locations where the long-term demonstration for VI solution was completed. Adding one more location that started the service in FY2019, demonstrations are now conducted in a total of 4 locations.
-This service is used as a means of transportation not only for the elderly people but also for agricultural products to Michi-no-Eki where a morning market is held.

Electromagnetic induction line

An example of full-fledged service in Kamikoani , Akita

Transporting agricultural products to Okueigenji Keiryu-no-sato in Shiga

Details



Locations of Demonstration for Autonomous Driving Services around Michi-no-Eki resting areas in Hilly and Mountainous Areas

Challenges

-Self-locating function of autonomous driving vehicles does not work well in mountainous areas, tunnels, and under bridges where GPS signals are weak.
-LiDAR (Light Detection And Ranging) and other on-board sensors do not work as expected depending on local weather, such as snowfall and fog.
-Human intervention is inevitable when autonomous driving vehicles are passing opposite traffic in narrow road segments with parked vehicles or other obstructions, or avoiding pedestrians or bicycles on the driving lane.
-Profitability needs to be improved to continue the service.
-Further studies are required to expand this service to crowded cities.

Expected Outcomes

This service is expected to provide a means of transportation for the elderly people without access to mobility in rural areas where public transit is not available due to low ridership, and transportation of daily necessaries, helping solve various rural issues.

Future Advancements

Given that profitability is a major challenge to continue the service as a rural public transit, ridership needs to be increased by working with welfare and/or school bus services and improving the connection with other public transits. Based on the experiences of the experimental autonomous driving transportation services around Michi-no-Eki in hilly and mountainous areas, VI and other smart road systems need to be further considered in order to expand the service to include cities where more pedestrians, bicycles, and automobiles are mixed in the traffic.

MORE INFORMATION

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Publications:
https://www.mlit.go.jp/road/ITS/j-html/automated-driving-FOT/index.html (Japanese)

PIARC FREIGHT EMERGING TECHNOLOGY CASE FACT SHEET

No. 22 Zero-Emission Vehicles

Keywords: Zero-Emission, Electric Vehicle, Fuel-cell vehicle, Hydrogen Vehicle, Biofuel Vehicle, e-fuel Vehicle

Technology category: Zero-Emission Vehicles and Electric Power Supply

DESCRIPTION IN SHORT

A zero-emission vehicle (ZEV), which is powered by electricity, hydrogen, biofuel, e-fuel or other carbon-free energy sources and emits no CO2 on the road, is still under development. Power sources include onboard battery, external power supply, and onboard storage containing gas/liquid fuel. Powertrains include electric motor and internal combustion engine. In combination with these powertrains, battery electric vehicles, externally powered electric vehicles, fuel cell vehicles, internal combustion engine vehicles using hydrogen, biofuel and e-fuel are being developed.

BACK-GROUND

To tackle climate change's negative impacts, world leaders reached the Paris Agreement in 2015, agreeing to achieve a balance between anthropogenic emissions by sources and removals in the second half of this century. Toward this goal, in October 2020, the Japanese government pledged to go carbon neutral by 2050. To that end, Japan is committed to reducing emissions of CO2, the primary greenhouse gas, from road transport. Zero emission road transport is considered as an essential element in the vehicles' entire life cycle, which ranges from raw material extraction to final disposal.

ELEMENTS

1. Classification: ZEVs can be grouped into several types according to the element technologies as shown in the following table:

Energy source	Method of power supply					Powertrain	Status
Electricity	Onboard battery	Power is recharged from a charger to batteries when the vehicle is parked.				Electric motor	In practical use
	External power supply	Power is supplied from the road infrastructure.	Power is fed by a pantograph sliding on an overhead line.				Under development
			Power is transferred from collector shoes via road surface rails.				
			Power is transferred from collector shoes via road-side rails.				
			Contactless inductive power transfer from coils integrated in/below the road surface	Receiving coils in the vehicle	Bottom of the vehicle		
					Axles		
					In wheel		
Hydrogen	Onboard tank	Gas/liquid fuel is refilled in the tank when the vehicle is parked.	Power generation by fuel cell				In practical use
			Cylinder injection and combustion in engine --> Power generation --> Battery charging				Under development
			Cylinder injection and combustion in engine for motive power			Internal combustion engine	
Biofuel	Onboard tank	Liquid fuel is refilled in the tank when the vehicle is parked.	Cylinder injection and combustion for motive power				In practical use
e-fuel							Under development

2.Technologies for on-road power transfer: they are energy-efficient and environmentally friendly due to less vehicle weight and wasted batteries. Technologies under development include:

1) Contact power transfer: Power is fed through pantograph by cable, which is placed over the road, on the road surface, or in the safety guard.

a. Power is fed by a pantograph sliding on an overhead line [1)]

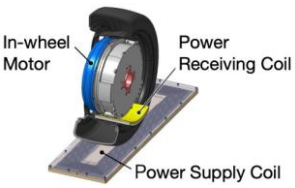
b. Power is fed by a pantograph sliding on a rail on the road [2)]

c. Power is fed by a pantograph sliding on a roadside rail[3)]

2)Contactless power transfer: Power is fed through onboard receiving coils from inductive coils installed on the road surface.

d. Power is fed through coils placed at the bottom of the vehicle [4)]

e. Power is fed through coils placed in axles [5)].

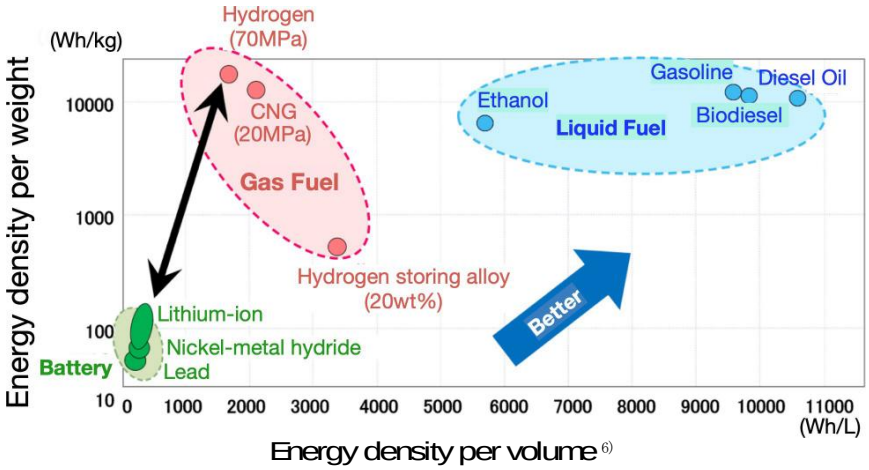


f. Power is fed through in-wheel coils [5)]

ELEMENTS

3. Characteristics of zero-emission energy

The figure on the right shows energy density per weight and volume. For a given amount of energy supplied to a car, batteries are heavier and larger while hydrogen gas takes more space compared to gasoline and other liquid fuels. For this reason, battery makes a vehicle heavier and less energy-efficient. Gas fuels are limited in the amount of energy because they take up a large space in the vehicle.



4.Number of registered/sold ZEVs: In Japan, the numbers of registered ZEVs account for 0.17% and sold ZEVs account for 0.62% of the totals between 2020 and 2021 [7], showing they do not have much of presence.

RELATED MEASURES

a. Technology to manufacture carbon-free hydrogen, biofuel, e-fuel using energy sources that do not emit CO2 such as renewable energy and nuclear energy.
b. Technology that does not emit CO2 during raw material extraction, transport, manufacturing, and maintenance stages
c. Efficient contactless power transfer technology

IMPACTS & BENEFITS

a. Realize zero-emission road transport during the use-stage in the life cycle of vehicles to contribute to mitigating climate change
b. Reduce emissions of NOx, SOx, PM and other air pollutants, in addition to CO2, contributing to improved air quality
c. More electric-powered vehicles on the road mean less traffic noise.

SUCCESS FACTORS

a. Tank for high-pressure hydrogen and technology for liquid hydrogen storage need to be developed.
b. Onboard batteries need to be improved so that they can accommodate higher energy densities per weight and volume.
c. Batteries have a major issue of recycling and disposal. On-road power transfer is a better option in the long run.
d. Contact power transfer places burden on facility development and maintenance. Contactless option is preferred.
e. Deploying on-road power transfer to large networks requires a standard for power transfer methods. If multiple technologies are to be introduced, they will be applied to limited road segments.
f. A great number of energy supply stations for hydrogen, biofuel and e-fuel need to be set up.
g. To expand use of ZEVs, their prices need to be lowered, by using public subsidies for example.

OUTLOOK & TRANSFERABILITY

a. Outlook: ZEVs account for less than 1% of the total number of registered vehicles. Of all ZEVs, only battery electric vehicles, fuel cell vehicles, and biofuel vehicles are currently in practical use. It will take 10 years or longer to replace all vehicles with ZEVs after they are introduced into the market. Considering that there are only 30 years until 2050, it will take an enormous effort to replace them all.
b. Transferability: Battery electric vehicles, fuel cell vehicles and other technologies that are based solely on the vehicle technologies are transferable to LMICs. On-road power transfer, however, requires peripheral technologies such as development of infrastructure and power supply facilities, and hard to transfer to LMICs in a short period.

SOURCES: 1) SIEMENS, 2) Volvo, Alstom, 3) The Japan Society of Mechanical Engineers (JSME), 4) Imura Lab, Tokyo University of Science, 5) Fujimoto Lab, University of Tokyo, 6) TOYOTA MOTOR CORPORATION, 7) Next Generation Vehicle Promotion Center, Japan Automobile Dealers Association

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16. GLOSSARY (IF NEEDED)

Term	Definition
AADF	Average Annual Daily Flow
AC	Alternating Current
APS	Aesthetic Power Supply
B	Magnetic Field
BM	Business Model
BMS	Battery Management System
CAN	Controller Area Network
CBA	Cost Benefit Analysis
CO_2	Carbon Dioxide
CRF	Centro Ricerche Fiat
CWD	Charge While Driving
DBFO	Design Build Finance Operate
DC	Direct current
DEFRA	Department for Environment, Food and Rural Affairs
DWPT	Dynamic Wireless Power Transfer
eBus	Electric Bus
EC	European Commission
ECU	Electronic Control Unit
EFC	Emissions Forecasting Tool
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
ERS	Electric Road System

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World Road Association (PIARC)

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