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WP1: Building blocks for Intelligent Access

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Executive summary

Overview

The CEDR ISAC (Intelligent Access Surface Community) project is a two-year initiative funded by CEDR under the Transnational Road Research Programme (CEDR Call 2023) [21]. The project explores how Intelligent Access can improve the management of cross-border road freight transport, optimising infrastructure use and enhancing sustainability.

The ISAC consortium brings together experts to investigate how digitalisation and connected vehicle technologies can help National Road Authorities (NRAs) improve road efficiency, safety, and lessen the environmental impact of freight transport.

Key findings

Definition and types of Intelligent Access

Intelligent Access is a method and regulatory framework that aligns freight vehicle characteristics with the condition and capacity of transport infrastructure. Final goal is to ensure that the right vehicle, with the right load, is on the right road at the right time.

It is anticipated that Intelligent Access will start by better facilitating and monitoring road freight traffic – in particular, by automating information sharing. For example, by providing additional information services (for instance, about road conditions) and gathering information about the vehicles (for instance, from in-vehicle weighing sensors).

Intelligent Access can be implemented using various mechanisms, including:

- **Permitting and zoning systems:** controlling where and when freight vehicles can operate.
- **Dynamic routing and traffic control:** optimising routing with actual road and traffic data
- **Automated compliance enforcement:** ensuring adherence to weight, emissions, and safety regulations.

Existing Intelligent Access implementations and pilots

The report reviews Intelligent Access applications worldwide, providing insights from Australia, Estonia, Italy, the Netherlands, Sweden, Austria, Spain, Norway, and Germany.

Notable examples include:

- **Australia's Intelligent Access Program (IAP):** a nationally regulated telematics framework to manage heavy vehicle access.
- **Italy's TWeb system:** a digital platform for managing exceptional transport authorisations.
- **Estonia's VELUB system:** an eFTI-compliant platform for monitoring heavy vehicle operations, reducing emissions, and optimising freight transport.
- **Urban Access projects,** such as UVARExchange, can provide insights from similar initiatives in the urban realm.

Benefits of Intelligent Access

Intelligent Access presents a range of benefits for NRAs and transport operators, including:

- **Enhanced management of assets and traffic** for optimised infrastructure maintenance, design and usage, based on robust statistics and dynamic information services on roads and traffic.

- **Improved road safety:** preventing overloading, monitoring compliance, and enhancing incident response.
- **Sustainability and emissions reduction:** supporting low-emission zones, prioritising cleaner vehicles, and enabling multimodal freight integration.
- **Enhanced cross-border operations:** streamlining electronic documentation and regulatory compliance.
- **Fairer competition and compliance:** ensuring a level playing field among hauliers through automated enforcement.

Challenges and barriers to implementation

Despite its benefits, Intelligent Access faces several challenges:

- **Leadership:** There is currently no defined leader to champion the approach and coordinate stakeholders.
- **Legal and regulatory barriers:** differences in national laws and GDPR compliance issues.
- **Data and hardware standardisation issues:** ensuring interoperability across digital freight systems.
- **Stakeholder acceptance:** concerns over privacy, cost, and operational changes.
- **Cross-border integration:** the need for harmonised frameworks for freight movement between countries.

Stakeholder engagement and workshop findings

A stakeholder workshop conducted in June 2024 gathered insights from regulators, industry leaders, and logistics experts. Key takeaways included:

- Strong interest in Intelligent Access for emissions control, safety, and regulatory compliance.
- Privacy concerns and lack of harmonisation were seen as major obstacles.
- Pilot projects and clear business cases are needed to drive adoption.

Data gap analysis

The report identifies several data gaps that could hinder successful implementation of Intelligent Access:

- **Lack of infrastructure data:** NRAs need to provide accurate information services on road limitations specific for trucks (i.e. height and weight) or all vehicles (e.g. road closures) to be taken into account by the planning and executing of trips and routes.
- **Insufficient vehicle data:** limited availability and integration of weight, emissions, and location tracking, reduces effective control.
- **Fragmented data sharing across borders:** inconsistent regulations and data formats between countries create barriers to seamless Intelligent Access implementation.
- **Limited digital permit systems:** many transport permits are still paper based, delaying authorisations and increasing administrative burdens.
- **Data privacy concerns:** GDPR and other data protection laws restrict how Intelligent Access systems can store and share vehicle tracking data, and hauliers may be concerned about the security of their loads. Any Intelligent Access pilot or initiative needs to clearly demonstrate the legal basis for using such data for limited purposes and the proportionality of means.
- **Commercial sensitivity:** Freight producers or consumers, handlers, or shippers may have commercial concerns about their freight information being shared.

The report recommends developing harmonised digital data-sharing frameworks and expanding monitoring capabilities to close these gaps.

Building blocks of Intelligent Access

The report outlines key steps for designing and implementing an Intelligent Access system:

1. **Define the problem:**
 - Identify the specific transport issue Intelligent Access should address (e.g. road or bridge damage, emissions, or congestion).
 - Establish measurable goals for the system.
2. **Build the solution**
 - Select appropriate access management mechanisms.
 - Determine the data required to make the system intelligent. Establish data collection points, such as onboard vehicle telematics and potentially the European Electronic Toll Service, road sensors, and compliance databases.
 - Ensure interoperability with existing systems or services on private and public sites.
 - Design a system that aligns with the goals of the NRA.
3. **Check legal feasibility:**
 - Review existing national and EU laws to determine how to make Intelligent Access implementation fully legally justified.
 - Ensure compliance with data protection and privacy regulations.
4. **Focus on critical success factors:**
 - Secure support (funding, governance, stakeholders), build robustness (resilience, secure, privacy), and make the system user friendly (adaptable, scalable, efficient).
5. **Address cross-border considerations:**
 - Coordinate Intelligent Access policies with neighbouring countries to enable seamless international freight movement.
 - Develop common standards for digital permits and vehicle tracking.

By following these steps, NRAs can ensure Intelligent Access systems are effective, legally compliant, and scalable across different transport networks.

Legal basis for Intelligent Access implementation

A clear legal foundation is required to ensure Intelligent Access adoption aligns with existing regulations and industry standards. So, the report reviews the legal framework supporting Intelligent Access within EU transport laws and international agreements, including:

- **Directive 96/53/EC** Weights and Dimensions of Heavy Goods Vehicles – permits certain vehicles to exceed standard dimensions and requires Member States to implement systems.
- **EU eFTI regulation (2020/1056)** – mandating digital freight documentation.
- **ITS directive (2010/40/EU)** and delegated act 2022/670/EU for Real Time Traffic Information – supporting interoperable and reliable digital information services for road users
- **GDPR (2016/679)** – ensuring data protection and privacy compliance.
- **European Electronic Toll Service (EETS)** – facilitating cross-border digital tolling.

Conclusion and next steps

Intelligent Access has significant potential to revolutionise road freight transport by improving efficiency, safety, and sustainability. However, its full-scale implementation requires:

1. **Legal foundation** and policy alignment across Europe.
2. **Pilot projects** to demonstrate feasibility and business benefits.
3. **Stakeholder collaboration** to address data-sharing concerns.
4. **Investment in digital infrastructure** and data integration.

By addressing these challenges, Intelligent Access can become a key tool for modernising European road freight transport while supporting economic, environmental, and regulatory goals.

1. Introduction

The **ISAC (Intelligent Access Surface Community)** project is funded through CEDR, to run over a two-year period from Spring 2024, under the **CEDR Transnational Road Research Programme (CEDR Call 2023)** [21]. The principal output will be the identification of scenarios where Intelligent Access could be applied to the management of cross-border road transport of goods.

The ISAC consortium brings together an experienced team of impartial leading subject matter experts to investigate how Intelligent Access has the potential to help National Road Authorities (NRAs) to optimise the use of infrastructure capacities and contribute to more environmentally sustainable road transport of freight.

This section provides background to the project, the definition of Intelligent Access, and existing implementations of Intelligent Access in the real-world.

1.1 Background

National Road Authorities (NRAs) face a range of pressing challenges, including budgetary constraints and the need to optimise the efficiency of existing road infrastructure. Additionally, they must address the growing climate and safety challenges associated with road transport. Intelligent Access, when applied to road freight transport, presents an innovative solution that can help NRAs tackle these issues effectively.

The ongoing digital transformation within both NRAs and the logistics sector offers significant opportunities to enhance road monitoring and control access to road usage. Currently, NRAs primarily rely on traditional tools such as visual counts via cameras, counting loops, weighing loops, and surveys to monitor road usage. While valuable, these methods provide only limited insights into road freight transport activities and offer minimal options for control.

At the same time, a wealth of actionable data is available within freight vehicles and transport companies or more specific their service providers for planning and execution of trips and routing. Intelligent Access leverages this data to create a smarter, more integrated approach to road usage management. By employing Intelligent Access, the responsibility for aligning road usage with access conditions set by NRAs and other authorities shifts to haulage companies.

The overarching objective of Intelligent Access is to ensure *'the right vehicle with the right load on the right road at the right time.'* By harnessing the potential of digitalisation on public and private site and specifically connected vehicle services, Intelligent Access offers a range of benefits, including:

- **Optimised infrastructure usage:** Facilitating traffic management based on time and location to maximise road capacity.
- **Reduced road degradation:** Improving management of vehicle weight, speed, and routing to minimise wear and tear on infrastructure.
- **Improved authority knowledge:** National or local highway authorities will know more about what freight goods their roads are carrying.
- **Support for climate goals:** Reducing congestion, prioritising low-emission vehicles, and enabling greener logistics through initiatives such as low-emission zone management.
- **Enhanced road safety:** Mitigating risks associated with heavy vehicles (including vehicle overloading, speed differentials (such as mixing slow moving vehicles carrying abnormal loads with fast moving traffic), and mixing with vulnerable road users such as pedestrians and cyclists) and providing better insights into safety incidents across the road network.

- **Fair competition:** Creating a level playing field for hauliers/carriers and ensuring better compliance with regulations.
- **Improved oversight of special transport:** Facilitating better control over abnormal loads and hazardous goods.
- **Support for high-capacity vehicles:** Allowing for the controlled introduction of these vehicles onto the road network.
- **Streamlined cross-border operations:** Accelerating and standardising the processing of transport documents through digitalisation.

By adopting Intelligent Access, NRAs can address their financial and environmental challenges while enabling smarter, safer, and more sustainable logistics for road users.

1.2 Aim and objectives of sub-topic 1

The aim of sub-topic 1 was to develop the building blocks for Intelligent Access, exploring how road freight infrastructure use can be better aligned with social and business goals through the application of Intelligent Access. The result of this aim is the Intelligent Access building blocks described in Section 6.

To achieve this aim, a set of objectives were created. These objectives are shown in Table 1 alongside the location in this report where the relevant information can be found.

Table 1. The objectives of sub-topic 1.

Objective	Reference in this report
a. Map out the lessons learned from Australia, USA and Europe, indicating best practices.	The literature review identified the lessons learned (Section 4.2.9) and best practices (Section 4.2.8).
b. Explore how IA can be used to take the tasks of NRAs to the next level.	The use of Intelligent Access for tasks such as asset management and improving road safety identified in various sub-sections of the literature review (Section 4).
c. Explore how enforcement of vehicles could be taken to the next level.	The use of Intelligent Access for advanced enforcement, such as data-driven approaches, identified in various sub-sections of the literature review (Section 4).
d. Elaborate application possibilities of IA based on the interests of stakeholders other than NRAs.	Responses from stakeholders (Section 3) and evidence found in the literature in response to specific research questions (Section 4).
f. Investigate how IA be used to tackle the main challenges in decarbonising road freight transport.	The use of Intelligent Access to tackle such challenges in the literature review (Section 4).

g. Make a functional analysis of the required information. Show per aspect what the gap is between the actual and the desired situation.

Data gap analysis (Section 5).

1.3 Previous research by CEDR

The Conference of European Directors of Roads (CEDR) Working Group on Road Freight Transport (WG RFT) has conducted significant research on Intelligent Access through Task Group 2 (TG2) [17], [19], [20]. This work focused on collecting best practices and providing recommendations for implementing Intelligent Access, culminating in the publication of a report (CEDR Technical Report 2022-01).

The research highlights that many NRAs view Intelligent Access as a valuable tool for enforcement, offering opportunities for NRAs, transport companies, and society as a whole. While the concept originated in Australia, where Intelligent Access is applied as a *'technical, functional, and regulatory national framework to manage heavy vehicle access through telematics'* [64], it cannot be directly transferred to the European context due to differences in regulations and conditions. The framework must be adapted to align with European standards and practices.

The key findings from this prior CEDR research include:

1. **Monitoring and coordination:** While Intelligent Access is often seen as an enforcement tool, most European NRAs do not have enforcement powers and instead utilise Intelligent Access primarily for monitoring and supporting compliance. Intelligent Access supports improved traffic and logistics coordination and optimises infrastructure usage, benefiting carriers, shippers, and society.
2. **Case studies:** Several implementations have been carried out by NRAs in various parts of the world, and in various stages of development (from pilots to full implementation). For example,
 - **Australia:** The Australian Intelligent Access Program (IAP) demonstrates the successful use of telematics to regulate heavy vehicle access based on compliance with conditions like vehicle weight and route requirements [1].
 - **Italy:** An example from Italy shows how digitalising the process for managing abnormal transports (TEWeb, Anas S.p.A.) benefits all stakeholders by streamlining operations [10].

Both cases illustrate the transformative potential of Intelligent Access in transitioning from manual to digital processes and building trust between NRAs and transport companies. This trust ensures compliance with access conditions such as vehicle dimensions, weights, and prescribed routes.

3. **Opportunities and challenges:** Intelligent Access offers substantial benefits to NRAs and other stakeholders, including better service quality, improved infrastructure usage, and enhanced coordination. However, its implementation is complex and cannot be achieved overnight. Additionally, Intelligent Access is not yet suitable for cross-border freight transport, a significant limitation given the international nature of logistics.
4. **Cross-border potential:** Expanding Intelligent Access to cross-border freight transport could significantly benefit both NRAs and the transportation industry, as freight movement does not stop at national borders. Establishing governance frameworks and conditions for cross-border Intelligent Access could also serve as foundational steps for national-level implementation.

CEDR's research underscores the potential of Intelligent Access to revolutionise road freight management through digital transformation. However, its successful adoption requires careful adaptation to European conditions and the establishment of governance frameworks, especially for cross-border applications. These insights form the foundation for further research in the ISAC project and the development of practical Intelligent Access solutions in Europe.

1.4 Definition of Intelligent Access

Following a review of the literature and discussion with stakeholders, the following definition of Intelligent Access meets the consensus:

***Intelligent Access** refers to a system and regulatory framework that matches the performance and characteristics of a road freight vehicle and load with the state and capability of a specific section of the transport infrastructure or traffic situation. The primary objectives are to enhance management of road assets and traffic, road safety, improve compliance with regulations, optimise transport efficiency, and improve sustainability. Data from vehicles (such as location, speed, and weight), load, and road/traffic are combined in private services and partly shared for public purposes.*

Intelligent Access is commonly described as an idealised outcome: **The right vehicle with the right load is on the right road at the right time**. Although this phrase appears easy to comprehend, it begins to fall short when actors are introduced. For instance, the 'right' vehicle, road, or time may differ between a vehicle operator and a road operator. However, it is an epigrammatic way to express the concept and therefore remains useful.

Amongst the literature about Intelligent Access, there is an implicit assumption that the goal is to **achieve a win-win situation between vehicle operators and road operators**. Otherwise, the implementation is more likely a typical traffic or asset management approach.

The following are definitions of Intelligent Access from specific literature references:

- 'Intelligent Access is a technology that utilise positioning and tracking systems together with wireless communication technologies to monitor and control where, when, and how heavy vehicles operate (Australia 2012). A hypothesis is that Intelligent Access technologies can support both to ensure compliance and integration of high-capacity vehicles in the earth material transportation and construction domain.' [51]
- 'Intelligent Access has been identified as a necessary component to get acceptance from the road owner and the operators of heavier trucks.'
- 'Intelligent access therefore offers a new set of instruments and interplay public and private parties with a role and interest in admission, supervision and application of special road transport.' [81]

The key components of Intelligent Access systems as described by the literature include:

1. **Telematics devices:** Onboard devices installed in vehicles that collect and transmit data related to vehicle movements, driver behaviour, and compliance with regulations.
2. **Data analytics:** Advanced analytics tools that process and analyse the collected data to provide actionable insights and support decision-making.
3. **Monitoring:** Monitoring of vehicle movements and road conditions to ensure compliance with access conditions and detect any violations.

4. **Automated compliance:** Automated systems that issue permits, penalties, or alerts regarding compliance, reducing the need for manual inspections and enforcement.
5. **Integration with existing systems:** Seamless integration with existing road tolling, traffic management, and regulatory systems to enhance overall efficiency and effectiveness.
6. **Stakeholder collaboration:** Collaboration between government agencies, transport operators, technology providers, and other stakeholders to ensure the successful implementation and management of Intelligent Access systems.

1.5 Types of Intelligent Access

Intelligent Access starts with an NRA goal and is implemented through a combination of mechanisms to manage freight vehicle access to the road network.

Access refers to the means, conditions or opportunity to enter or use certain roads . **Intelligence** means the system can perceive and respond in a digital form to the world around it, or it can learn, think, and adapt. This means Intelligent Access can vary the means or opportunity to enter or use the highway based on some factors that are being monitored.

The design of any Intelligent Access implementation relates directly to an NRA goal. For instance, this could be reducing road surface defects, improving road safety, or reducing journey times. If managing freight access to the highway is way to contribute to such a goal, then an Intelligent Access implementation could be designed.

Within the literature, this is most commonly discussed as some form of **permitting or zoning**. However, it could also be achieved through **processing efficiencies**, manipulating **preferred routing**, or **positive reinforcement**. The former would likely require some mechanisms to measure compliance and deliver enforcement (the stick or penalties approach), whereas the latter would likely require demonstrable benefits to the user (the carrot or rewards approach). It is more common for the literature to discuss Intelligent Access in terms of the stick approach.

2. Existing Intelligent Access implementations

2.1 TCA IAP in Australia

The Intelligent Access Program (IAP) in Australia is a pioneering initiative designed to enhance the management of heavy vehicle access to the road network using advanced telematics and digital technologies [64]. It ensures that vehicles operate in compliance with specific conditions, such as designated routes, times, and weight limits, thereby balancing the needs of the transport industry, government, and the community.

Purpose and creation

The IAP was developed in response to the growing demands of Australia's road freight transport, which is expected to double over time. Traditional methods of road enforcement were insufficient to address challenges such as increasing freight demand, infrastructure constraints, and the risks posed by larger and heavier vehicles. The program was conceived in the mid-1990s and became operational in 2008, with its administration overseen by Transport Certification Australia (TCA). It is underpinned by national legislation and performance-based standards, ensuring a structured framework for its operation [1], [40].

IAP forms part of Framework for Cooperative Telematics Applications for Regulated commercial freight Vehicles (TARV), the core elements of which were recognised and adopted into ISO 15638 in 2012.

How it works

The IAP uses in-vehicle telematics, including position data from Global Navigation Satellite System (GNSS) devices, alarm status (for example indicating downtime or tampering) and vehicle- and load-specific data (for example, the weight and type of load being carried), to monitor heavy vehicles 24/7. These are handled centrally by an IAP Service Provider (IAP-SP), which may be a commercial body which has obtained certification from TCA for such work. To obtain this certification it must demonstrate both the integrity and confidentiality of the data which it handles.

This monitoring ensures compliance with access conditions set by road authorities. Certified service providers collect and report data, focusing on exception-based reporting to address non-compliance while maintaining privacy safeguards. This system allows for tailored access arrangements, enabling vehicles to operate more flexibly and efficiently while ensuring safety and infrastructure protection.

Benefits realised

The IAP has delivered significant benefits across various domains:

1. **Productivity gains:** By enabling vehicles to carry heavier loads and access restricted routes, the program has improved freight efficiency. For example, vehicles operating under Higher Mass Limits (HML) can legally carry additional weight, leading to substantial economic benefits [40].
2. **Safety improvements:** Enhanced monitoring has contributed to safer road operations by ensuring compliance with speed, weight, and route conditions [1].
3. **Environmental benefits:** More efficient vehicle operations have reduced emissions and collision costs [98].
4. **Infrastructure protection:** The program helps mitigate wear and tear on road assets by ensuring vehicles adhere to designated routes and weight limits [40].

Economic impact

The IAP has been integral to Australia's broader transport reforms, contributing an estimated AU\$1.2 billion in productivity value over 20 years. It has also supported other initiatives like Performance-Based Standards (PBS) and expanded network access for restricted vehicles, further amplifying its economic and operational impact [98].

In summary, the IAP represents a transformative approach to managing heavy vehicle access, leveraging technology to achieve a safer, more efficient, and sustainable road transport system in Australia.

2.2 eFTI regulations

The EU's 2020/1056 Electronic Freight Transport Information (eFTI) regulations stipulate that from 21 August 2024 EU member states must handle digital transport documents at the level of competent authorities. A variety of programmes have been implemented to meet this and other legislative specifications.

2.2.1 Estonia: VELUB

The VELUB system, developed by the Estonian Road Administration (ERA), is a pioneering digital platform designed for monitoring and managing heavy vehicle transport, particularly for vehicles carrying abnormal loads like 52-ton timber trucks. It represents a significant step towards more efficient, greener, and safer road freight transport in Estonia [55].

The system will help Estonia comply with the EU's eFTI regulations through the use of electronic consignment notes (eFTI/eCMR). Following the switch to eFTI mandated by the European Union on 21 August 2024, legislation has been put in place to allow eFTI to be fully rolled out throughout the country [36].

Key features and functions of the VELUB system include:

1. **Digital permitting and monitoring:** The VELUB system allows operators to apply for special vehicle permits for up to one year. This includes permits for 52-ton vehicles, which must meet specific requirements such as having a minimum of six axles and GPS tracking. The system uses GNSS (Global Navigation Satellite System) to monitor vehicle movements in real-time, ensuring compliance with designated routes and load limits.
2. **Temperature-based access:** Initially, the system was designed for wintertime transport when roads were frozen to a depth of at least 0.5 meters. Digital temperature sensors installed across Estonia determine road conditions, enabling safe heavy vehicle operations during specific periods.
3. **Smart road corridors:** The VELUB system integrates with Estonia's Smart Road digital map, marking strong corridors (purple lines) suitable for heavy vehicles. These corridors exclude weaker infrastructure, such as certain bridges, to protect road assets.
4. **E-cargo paper and data integration:** Drivers use a mobile app to initiate e-cargo papers, which include details about the load and route. GNSS data is transmitted every five minutes, allowing authorities to monitor compliance and improve traffic management. Future developments aim to integrate data from onboard weighing systems (OBW) to automate the initiation of e-cargo papers and enhance monitoring accuracy. The weights are now self-declared and not validated.
5. **Economic and environmental benefits:** The system has led to an estimated 25% increase in transport efficiency and a 20% reduction in greenhouse gas emissions. By requiring more

axles and double tyres, it reduces pavement stress by over 50%, contributing to infrastructure longevity.

6. **Continuous development:** The VELUB system is part of a broader theoretical model called the Multidimensional Vehicle Movement Controlling System (MVMC). It is constantly being tested and improved, with aspirations to expand its application across Europe.

The VELUB system involves various stakeholders, including transport operators, road authorities, and law enforcement. It also supports Estonia's e-residency program, allowing international users to engage with the system for logistics operations or testing.

The system is evolving towards VELUB 2.0, which will feature enhanced GNSS log file controls and automated alerts for non-compliance. It serves as a model for integrating digital solutions in transport management, with potential applications in other countries.

In summary, the VELUB system exemplifies how digital innovation can transform road freight transport, balancing efficiency, environmental sustainability, and infrastructure protection.

2.3 Italy: TEWeb

In Italy, TEWeb is an online platform developed by Anas S.p.A., the national road authority, to manage exceptional transport—vehicles and loads that exceed standard legal limits for size and weight. The platform streamlines the application and authorization process for such transports, ensuring safety and infrastructure protection [10].

The key features of TEWeb are:

- **Digital application process:** Transport operators can submit applications for exceptional transport permits through TEWeb, reducing paperwork and processing times.
- **Fee information:** The platform provides updated tables of charges and processing fees associated with exceptional transport permits.
- **Authorisation verification:** Users can verify the authenticity of exceptional transport authorisations via the platform, enhancing compliance and enforcement.
- **Mobile application:** TEWeb offers a mobile app for authorised exceptional transports, facilitating on-the-go access to permits and related information.

By digitising the management of exceptional transports, TEWeb enhances efficiency, transparency, and safety in Italy's road transport sector.

2.4 Intelligent Access pilots

Several countries have carried out pilots of Intelligent Access. These are summarised in the following sub-sections.

2.4.1 Netherlands: Intelligent Access Pilot for Special Road Transport

The Intelligent Access Pilot for Special Road Transport in the Netherlands [79], conducted from September 2021 to June 2023, was a pioneering initiative by the Ministry of Infrastructure and Water Management. The pilot aimed to explore the feasibility and scalability of Intelligent Access for special road transport, particularly focusing on the European Modular System 1 (EMS1) vehicles, which are long and heavy vehicles used in cross-border transport in Europe.

The reports highlight a peculiar discrepancy in the Netherlands: information about ships on inland waterways (origin, destination, cargo, owner) are instantly available to public authorities. However, there is as yet no such complete system for road freight.

Purpose of the pilot

The primary objective of the pilot was to evaluate how Intelligent Access could enhance the management of special road transport, which includes vehicles with deviating weights and dimensions or those carrying dangerous goods. The pilot sought to assess the technical and organisational feasibility of such a system and its potential to improve road safety, infrastructure management, and enforcement efficiency.

How the pilot worked

The pilot involved two consortia (Collect+Go, a specialist eCMR providers, and V-Tron, transportation connectivity specialists), each comprising logistics companies, service providers, and research institutions. These consortia developed and tested a real-time monitoring system that logged compliance with infrastructure access conditions. The system utilised data from Fleet Management Systems (FMS) and Transport Management Systems (TMS) to provide insights into vehicle movements and compliance with road regulations.

Key performance indicators (KPIs) guided data collection, and a dashboard was created to visualise the data for public authorities.

GDPR considerations limited the available data to a shortlist of 5 types: commodity types, route, weights, safety events and traffic and emissions performance. More immediate data were available for two types of cases of urgent notifications, in which safety is a factor. The first involves two types of data: driving for more than 5 minutes on a route unspecified for the type of vehicle, and exceeding vehicle weight limit by over 25%. The second involves data which are made available after an incident – for example a collision.

The pilot also included a Data Protection Impact Analysis (DPIA) to ensure compliance with privacy regulations. Approval was given for the pilot. Upscaling requires a new DPIA and clear legal ground.

Findings of the pilot

The pilot demonstrated that a real-time monitoring system could provide valuable insights for both logistics companies and road authorities. It highlighted the potential for such systems to improve transparency and efficiency in road transport management. However, challenges were identified, including data reliability, the need for digitalisation of road maps, and the standardisation of product codes and terminal abbreviations.

Issues encountered in the implementation included complications in the assessment of total vehicle weight, the conversion of raw data into KPIs, agreement between different government departments of which KPIs should be measured and on what timescale, and privacy or GDPR considerations which precluded, for example information on driver qualifications, from being processed within the system.

In addition, the question of whether enhancing the efficiency of road freight would lead to an undesirable shift from waterways or rail to road also had to be addressed. The pilot ran for too short a time for any such effect to be observed directly, and ambiguities in the classification of bulk goods made comparisons with past studies inconclusive.

The study recommended the involvement of an independent intermediary to manage data, ensuring quality and addressing privacy concerns. The pilot also emphasised the importance of collaboration between public and private stakeholders to achieve the desired outcomes.

Benefits demonstrated

The Intelligent Access system showed several benefits:

- **Enhanced road safety:** By monitoring compliance in real-time, the system could prevent overloading and reduce the risk of accidents.
- **Improved infrastructure management:** The system provided additional and missing data for informed decisions on road maintenance and infrastructure investments.
- **Increased efficiency:** The pilot indicated a potential reduction in enforcement costs and improved traffic flow due to better compliance with road regulations.
- **Sustainability:** By optimising vehicle loads and routes, the system could contribute to reduced emissions and more sustainable transport practices.

Overall, the pilot confirmed the feasibility of implementing an Intelligent Access system for special road transport, provided that data quality issues are addressed, and an appropriate legal framework is established [59] [74] [81].

2.4.2 Sweden: abnormal loads and frozen roads

Sweden has undertaken several initiatives to implement Intelligent Access (IA) systems for managing abnormal loads and High-Capacity Transport (HCT) vehicles. Here's an overview of key projects:

- Intelligent Access Program (IAP) Pilot

In 2014, the Swedish Transport Administration (Trafikverket) launched a pilot of the Australian Intelligent Access Program (IAP) in collaboration with Transport Certification Australia (TCA). This initiative aimed to manage heavy vehicle access using certified GNSS-enabled telematics services. The pilot involved stakeholders such as the Swedish Transport Agency, Lund University, CLOSER, Skogforsk, Scania, and Volvo. The goal was to enhance productivity, safety, and environmental outcomes by ensuring that the right truck is on the right road at the right time

- ITK System Demonstration for 74-Ton Vehicles

Between 2016 and 2018, Trafikverket coordinated a project to develop and test Intelligent Access Control (ITK) systems for 64–74-ton vehicles on designated BK4 roads. Some 12 percent of timber transports in Norrland, Sweden, use frozen roads. These can take heavier loads than when not frozen, but bridges on the network may still have a weight limit. A team from the RISE Research Institutes of Sweden conducted a pilot using both active and passive measures to reduce the speed of 74 tonne timber trucks while crossing bridges – and hence the stress on the structures – using geofencing. Both passive (emitting a warning signal to the driver if the speed was too high) and active (slowing the speed, but by a process which could if necessary be over-ridden) proved acceptable to drivers [48]. The project demonstrated three prototype systems developed by Volvo, Scania, and Vehco. These systems aimed to verify compliance with access conditions, prevent overloading, and reduce road wear. The project concluded that ITK systems are technically feasible and can lead to better infrastructure utilization and lower environmental impact.

- High-Capacity City Transport (HCT-City) Pilot

Pilots in Varberg and Stockholm explored the application of the HCT concept in urban settings. A series of pilot trials in Varberg and Stockholm tested optimised trucks equipped with sensors and implemented digital access control, including geofencing for speed and route management. The aim was to improve construction and transport efficiency, potentially reducing CO₂ emissions by up to 40% [51] [2]. Preliminary results have identified issues with weight distribution as measured by weight-in-

motion (WIM) sensors on bridges and other locations, which, if resolved, could improve weight compliance, and hence road wear and safety.

2.4.3 Norway: 74-ton timber transport

Following a decision by the Ministry of transport and communications to consider increasing the weight limit for timber transport from 60 to 74 tonnes, a trial for 74 tonne timber transport was carried out [5].

Between February and May 2022, 2,000 data points from nine trucks and trailers from 5 different timber transporters were captured and analysed. Errors in the data were detected by noticing that the separate axle weights did not add up to the trucks' total logged weights. Initial findings have included that many of these errors were due to failure of one of the axle weights to register (or registered as zero weight). Errors were found to be independent of the model or age of the truck, and to be more likely to occur in situations of low speed (below 20 km/h). Work is ongoing to resolve these issues.

2.5 Related projects (not Intelligent Access)

There continues to be many research and pilot projects investigating challenges like those being addressed by Intelligent Access. Below are three projects provided as examples.

2.5.1 Austria: Connecting Austria project

The **Connecting Austria** project, active from 2018 to 2021, was an Austrian initiative aimed at advancing energy-efficient and semi-automated truck platooning within the country's unique transit landscape. The project focused on leveraging cooperative intelligent transport systems (C-ITS) to enhance the logistics sector, particularly through the implementation of truck platooning strategies [24]. This is not considered an Intelligent Access project as there is no relation to asset management, monitoring, or control of factors such as weights or routes.

The key objectives were:

- **Energy efficiency:** The project aimed to validate energy savings of approximately 15% through the use of truck platooning, thereby enhancing the competitiveness of Austria's logistics and telematics industries [25].
- **Adaptation to Austrian conditions:** Recognising Austria's challenging topography and its role as a transit country, the project focused on topics specific to these conditions, bundling national innovation excellence to address them effectively.
- **Evidence-based evaluation:** A key objective was to provide an evidence-based evaluation of energy-efficient truck platoons as a prerequisite for the competitive strength of Austria's logistics and telematics industries.

The main project activities were:

- **Testing in mixed traffic:** Starting in 2019, the project conducted tests in mixed traffic conditions on public roads, addressing the challenges associated with semi-automated truck platooning in real-world environments [23].
- **Use case demonstrations:** The project demonstrated and evaluated four use cases for semi-automated and energy-efficient truck platoons, bringing together technology leaders and end-users to showcase practical applications [91].

Overall, the Connecting Austria project provided valuable insights into the practical implementation of truck platooning, highlighting its potential benefits in energy efficiency, environmental impact, technological feasibility, economic competitiveness, and safety within Austria's specific transit context.

2.5.2 Spain: EMS2

The European Modular System (EMS) is a framework that allows the combination of standard freight modules into longer and sometimes heavier vehicle configurations, enhancing the efficiency of road freight transport [39]. In Spain, the EMS2 project focuses on testing and implementing these high-capacity vehicles (HCVs) under real operating conditions. This is not an Intelligent Access related initiative, but the standardisation of freight modules is relevant.

The primary goal of the EMS2 project in Spain is to evaluate the performance of HCVs, specifically those configured under the EMS framework, in actual transport scenarios. This involves assessing their impact on fuel consumption, emissions, and overall transport efficiency.

The EMS works by allowing for the combination of existing loading units into vehicle combinations up to 25.25 meters in length and weighing up to 60 tonnes. In Spain, these configurations are currently being tested by companies such as Grupo Sesé. The testing involves real-world routes and various load configurations to gather data on performance metrics.

Preliminary findings from these tests indicate several potential benefits:

- **Reduced fuel consumption:** The use of EMS-configured vehicles has shown a decrease in fuel consumption per unit of cargo transported.
- **Lower emissions:** Correspondingly, there is a reduction in CO₂ emissions, contributing to environmental sustainability.
- **Improved efficiency:** By transporting larger volumes of goods per trip, logistics operations become more efficient, potentially leading to cost savings.

These outcomes suggest that the EMS2 project could play a significant role in advancing sustainable and efficient freight transport in Spain.

2.5.3 Germany: developing and testing a system architecture

The German Research Center for Artificial Intelligence (DFKI) has developed the Freight Service Intelligence Platform (FSIP), a web-based application designed to enhance data-driven services in freight transport operations. This initiative leverages Internet of Things (IoT) technologies, particularly mobile telematics, to facilitate information sharing among various stakeholders in global transport chains [28]. As this application only considers the private side of the transport ecosystem it is not an Intelligent Access system.

The FSIP aims to transform freight transport by providing a shared platform that supports intelligent services across three primary dimensions:

1. **Transport management:** Optimising the planning, execution, and monitoring of freight movements.
2. **Fleet management:** Enhancing the utilisation and maintenance of transport assets.
3. **Risk management:** Identifying and mitigating potential risks associated with freight operations.

The development of the FSIP followed a design science research approach, which included a literature review and stakeholder interviews. A web-based prototype was developed incorporating

features such as performance analytics, anomaly detection, risk assessment with predictive capabilities, data exchange, communication tools, and integration with information systems.

The prototype was evaluated with six transport stakeholders and logistics software vendors to assess its effectiveness and gather feedback for further refinement.

The FSIP was found to offer several potential benefits:

- **Enhanced decision-making:** By providing real-time data and analytics, stakeholders can make more informed decisions.
- **Improved efficiency:** Streamlining operations through better management of transport and fleet activities.
- **Risk mitigation:** Proactively identifying and addressing risks to minimize disruptions.
- **Collaborative platform:** Facilitating seamless information sharing among various actors in the transport chain.

This initiative underscores the potential of IoT and data-driven services to revolutionise freight transport operations, promoting efficiency, safety, and collaboration among stakeholders. These findings support Intelligent Access development and implementation.

2.6 Urban Access projects

Many urban areas across the EU have implemented new enforcement mechanisms to tackle their urban highway issues, to improve air quality, reduce congestion, and protect the urban environment. These include low emission zones, congestion charge zones, and pedestrian zones. Examples of such projects are provided below.

2.6.1 UVARExchange

The UVARExchange project is a European initiative designed to enhance the implementation and enforcement of Urban Vehicle Access Regulations (UVARs) across the European Union.

The key objectives of UVARExchange were [106]:

1. **Harmonising information for drivers:** The project focuses on standardising physical road signs and Variable Message Signs to ensure consistent communication of UVARs to drivers throughout the EU. Additionally, it explores the use of Cooperative Intelligent Transport Systems to deliver real-time UVAR information directly to vehicles, enhancing driver awareness and compliance.
2. **Facilitating cross-border enforcement:** UVARExchange addresses the challenges of enforcing UVARs on foreign vehicles by promoting the cross-border sharing of vehicle and driver information. This approach aims to reduce the need for pre-registration in different cities and streamline compliance checks, making enforcement more efficient and equitable.
3. **Developing guidance and demonstrations:** The project has produced guidance documents on best practices for UVAR signage and information dissemination. It has also conducted demonstrations in various cities to showcase the practical application of its recommendations, working closely with local authorities and stakeholders.

Launched in September 2021, UVARExchange is a continuation of the earlier UVARBox project and is funded by the European Parliament under Preparatory Action 2. The project is coordinated by Panteia and involves partners such as Armis, AustriaTech, CORTE, MAPtm, TRT, Sadler Consultants, and AlbrechtConsult [105]. The project highlights lessons learned relevant for Intelligent Access – namely

the harmonisation or standardisation of information, the importance of cross-border considerations, and supporting adoption through demonstration and guidance.

2.6.2 CLOSER

The **CLOSER** initiative, based at Lindholmen Science Park in Sweden, is a collaborative platform focused on enhancing transport efficiency and sustainable urban logistics. It spearheads several projects aimed at improving urban access through digital solutions and innovative traffic management [107]. It has helped to coordinate projects concerning urban access:

HasT – Speed-Controlled Traffic Zones: The HasT project is a large-scale demonstration of geofencing technology in urban environments. In spring 2024, over 100 vehicles in central Enköping participated in a trial where digital geofencing enforced speed limits within a 2 km zone, enhancing safety for pedestrians and cyclists. The project involved collaboration between the municipality, freight carriers, and public transport providers, aiming to showcase how digital tools can improve traffic safety and compliance.

Smart Urban Traffic Zones: This initiative explores the use of digital solutions like geofencing, sensors, and digital signage to create flexible and efficient urban spaces. Pilots in Gothenburg and Stockholm tested concepts such as dynamic loading zones and shared urban areas, aiming to reduce emissions, improve traffic flow, and enhance safety. The project brought together 25 organisations from various sectors to collaboratively develop and evaluate these smart urban solutions.

3. Stakeholder engagement and findings

The ISAC consortium identified over one hundred and fifty potential stakeholders including government regulators, academics, logistics managers, navigation software developers, and fleet managers. All stakeholders were contacted and invited to take part in an online workshop in June 2024. Of these 26 attended the workshop. Attendees were from countries including Austria, Belgium, Finland, France, Germany, Ireland, Netherlands and Norway, Sweden, Switzerland, and the United Kingdom.

Stakeholders discussed and agreed upon the specific applications of Intelligent Access. These were:

- Emissions control
- Dangerous goods/ hazardous materials
- Control on weights and lengths
- Lorry parking management
- Abnormal roads
- Ability of hauliers to demonstrate compliance
- Protection of vulnerable areas such as bridges
- Convoy management
- Wintery conditions
- Curfews
- Easier border control
- Road user charging
- Deriving real-time data.

The necessary components were identified as data from vehicles, information about infrastructure, a digital roads network with a standardised process for sharing data, and political and governance framework including funding.

Stakeholders were asked to envisage the benefits to their organisations of Intelligent Access. Identified benefits were:

- Better use and utilisation of infrastructure
- Potential for improved road safety and security
- Support for compliance with regulations
- Reduction of stress on infrastructure and people
- Increased fairness through enforcement, leading to fairer competition
- Positive environmental impacts
- Improved air quality
- Making planning of transport more predictable
- Quicker access to new data

They were then asked for reasons why they believed Intelligent Access, in spite of offering all these advantages, has not been more widely adopted. Their responses included:

- Privacy concerns
- Access to data and data compatibility
- Legal and political issues, such as GDPR compliance
- Lack of understanding of the topic and no clear definition
- The need to harmonise standards and processes across Europe
- Economic barriers (cost)
- Lack of a clear business case
- Lack of data sharing
- Lack of standards

Implementation of Intelligent Access was then discussed. For this, it was found that good business cases need to be made, drawing on examples of best practice and with systems compliant with METR (Management of Electronic Traffic Regulations) [75]. Pilot projects involving smaller businesses may be a good starting-point, with the need to demonstrate that the system was secure. The support of OEMs, hauliers and ideally the general public should be cultivated. Ultimately, co-operation should be sought on a cross-border and regional basis.

The systems were most likely to be implemented in countries with either already well-developed transport networks, rapid growth (such as Eastern Europe), or a particular issue for logistics, such as the necessity for quarantine.

Countries and regions which are predominantly rural, or lack government support for Intelligent Access, were deemed to be the least likely to implement the measures.

Discussion then moved on to the skills needed, and likely obstacles. Skills ranged from expertise in road and bridge maintenance, through to legal, contractual, and technological knowledge, as well as knowledge of the supply chain and stakeholder 'ecosystem'. The need for a 'can-do', delivery-focused mindset was also mentioned.

Likely obstacles included hesitancy due to the need for GDPR compliance, unwillingness to share data, and reluctance of some players to comply with new rules. Cost considerations are also an obvious factor.

4. Literature review

The review set out to answer the following research questions:

How can Intelligent Access:

1. *be used to manage assets more effectively – including optimal use, and assistance with maintenance?*
2. *be used to manage traffic better – including self-management?*
3. *be used to make traffic safer?*
4. *be used to make optimal use of the limited road network capacity?*
5. *support the efficient use of electric vehicles, through effective use of working time limits?*
6. *be used to tackle the main challenges in decarbonising road freight – including inter- and multi-modality?*
7. *support compliance with regulations?*
8. *be managed cross-border and on parts of the network not managed by NRAs – including connection to urban areas?*

What is/are the:

9. *potential legal challenges?*
10. *potential effects on infrastructure?*
11. *data-driven compliance/enforcement processes that minimise human resource requirements? Can existing systems (e.g. HGV tolling) be used as a basis?*
12. *data management requirements?*
13. *interests of non-NRA stakeholders related to Intelligent Access?*
14. *challenges related to the cooperation between public and private organisations?*
15. *best practice from existing Intelligent Access implementations in Australia, USA, and Europe, which have the potential to be scaled up?*
16. *lessons learned from Intelligent Access implementation and investigation in Australia, USA, and Europe?*
17. *known challenges/barriers for Intelligent Access implementation based on existing studies and pilots in Australia, USA, and Europe?*
18. *legal basis for the introduction of Intelligent Access?*

The following sections examine the literature to answer these questions with relevant supporting evidence. A full list of references used during this literature review can be found in Appendix A.

4.1 Meta-analysis of literature relevant to Intelligent Access

A broad automated search of literature sources was performed to understand the main pillars of Intelligent Access for road transport. Initially, three major sources were reviewed, and the following number of relevant papers were found:

- Scopus (8)
- Web of Science (3)

- Scholar (1,480)

Text mining of a sample (610) of these papers was performed. This involved term extraction, term co-occurrence, the creation of a two-dimensional map, clustering, and finally visualisation. The end result was the cluster visualisation as shown in Figure 1.

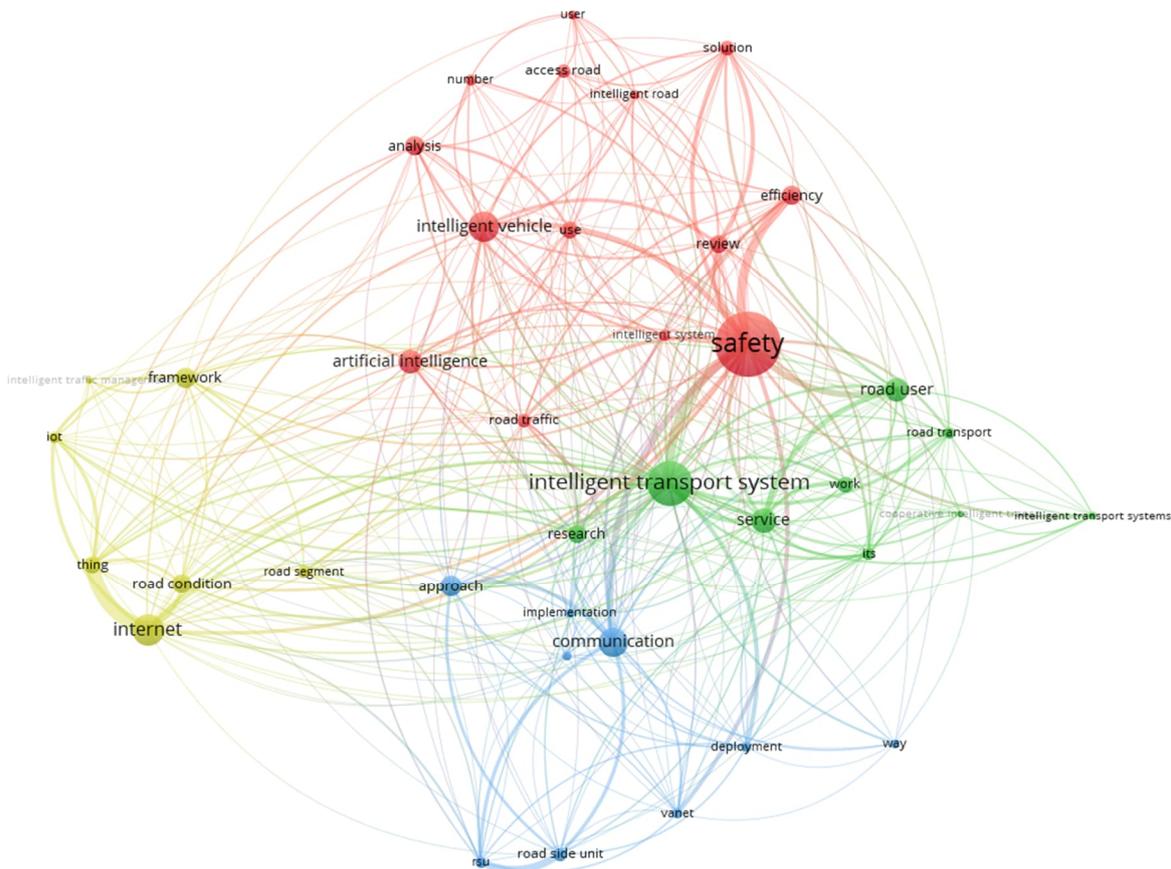


Figure 1. Visualisation of terms used in literature about Intelligent Access.

The preliminary conclusion from this exercise is that dual clustering shows a strong integration of safety measures with advanced technological solutions. In particular, there is a **safety cluster**, linked to *intelligent vehicle*, *ITS*, *communication*, and *road users*, and there is an **ITS cluster** linked to *safety*, *AI*, *intelligent vehicle*, *communication*, and *internet*.

This could imply that safety measures, enabled by intelligent transport systems, can be ensured by real-time monitoring systems verifying that vehicles and road users access specific roads, as determined by legislation issued by NRAs. Hence, it can be deduced that the literature for Intelligent Access has a strong road safety compliance aspect enabled by real-time monitoring systems.

Subsequently, this report is based on a selection of approximately 100 separate documents or articles relevant to Intelligent Access. A list of these references is available in Appendix A. Figure 2 shows that articles relevant to Intelligent Access are relatively young, with the majority published with the previous decade.

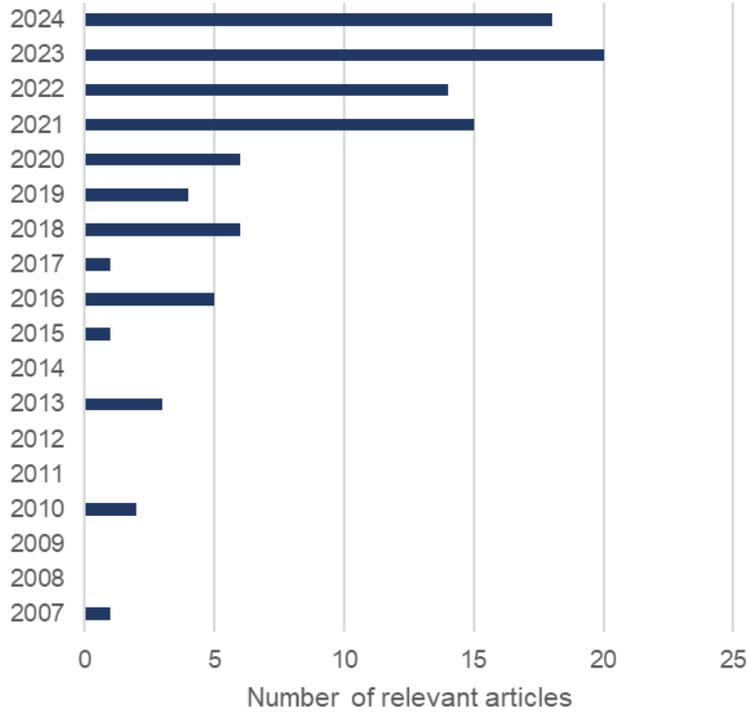


Figure 2. The number of relevant articles used in this sub-topic report by year of publication.

4.2 Answers to the research questions

The following sub-sections summarise the evidence found in relation to the research questions outlined at the beginning of Section 4.

For questions 1 to 7, the literature reveals some common answers and themes. To aid the reader, a summary is provided in Table 2, and detailed answers to these questions are available in Appendix A.

Table 2. Themes generated from answers to questions 1 to 7.

Theme →	Real-time monitoring	Optimised or dynamic routing	Traffic signal optimisation	Data-driven decision making	Enhanced compliance and	Resource allocation	Sustainability goals	Priority access	Incident management	Public information and alerts	Enhanced vehicle tracking	Geofencing and restricted zones	Driver assistance systems	Enhanced freight logistics	Infrastructure integration
How can Intelligent Access:															
1. <i>be used to manage assets more effectively – including optimal use and maintenance?</i>	✓	✓		✓	✓	✓	✓								
2. <i>be used to manage traffic better – including self-management?</i>	✓	✓	✓	✓	✓			✓	✓	✓					
3. <i>be used to make traffic safer?</i>	✓	✓	✓	✓	✓			✓	✓		✓	✓	✓		
4. <i>be used to make optimal use of the limited road network capacity?</i>		✓		✓		✓		✓	✓	✓		✓		✓	
5. <i>support the efficient use of electric vehicles, through effective use of working time limits?</i>	✓	✓	✓				✓	✓					✓		✓
6. <i>be used to tackle the main challenges in decarbonising road freight?</i>	✓	✓		✓		✓	✓	✓				✓		✓	✓
7. <i>support compliance with regulations?</i>	✓				✓				✓	✓	✓	✓			✓

4.2.1 How can Intelligent Access be managed cross-border and on parts of the network not managed by NRAs (including connection to urban areas)?

The literature infers several points about how Intelligent Access can be managed cross-border and on parts of the network not managed by national road authorities, ensuring consistent monitoring, compliance, and coordination through interoperable systems, data sharing, and collaboration:

1. **Interoperable systems and standards:** To manage Intelligent Access across borders and on networks not managed by national road authorities, it is essential to develop interoperable systems and standards. This ensures that data and information can be seamlessly shared and understood by different jurisdictions and authorities.
2. **Legal base for cross-border data sharing:** Establishing the legal base for data-sharing between countries and regions is needed to facilitate the exchange of information related to vehicle movements, compliance, and road conditions. This helps to ensure that vehicles remain compliant with regulations as they move across borders.
3. **Integration with private road operators:** Intelligent Access systems can be integrated with the systems used by private road operators and other non-national road authorities. This ensures that vehicles are monitored and managed consistently across the entire network, regardless of ownership.
4. **Harmonised regulatory frameworks:** Developing harmonised regulatory frameworks for Intelligent Access can help to ensure that vehicles are subject to consistent rules and standards across different jurisdictions. This reduces complexity for operators and enhances compliance.
5. **Cross-border monitoring:** Intelligent Access systems can provide monitoring of vehicles as they move across borders. This includes tracking their location, speed, and compliance with regulations, ensuring that any violations are promptly detected and addressed.
6. **Centralised data repositories:** Creating centralised data repositories that store information on vehicle movements, compliance, and road conditions can support cross-border management. These repositories can be accessed by different authorities to ensure consistent monitoring and enforcement.
7. **Collaboration with international organisations:** Collaborating with international organisations, such as the European Union or the United Nations, can help to develop and implement cross-border Intelligent Access initiatives. These organisations can provide guidance, funding, and support for harmonised systems and standards.
8. **Use of blockchain technology:** Blockchain technology could be used to create secure and transparent records of vehicle movements and compliance across borders. This ensures that data is tamper-proof and can be trusted by all parties involved.
9. **Cross-border incident management:** Intelligent Access systems can support cross-border incident management by providing information to authorities in different jurisdictions. This ensures a coordinated response to incidents and enhances overall road safety.
10. **Stakeholder engagement and training:** Engaging with stakeholders, including road operators, transport companies, and regulatory authorities, is essential for the successful implementation of cross-border Intelligent Access. Providing training and resources can help to ensure that all parties are aware of and adhere to the relevant standards and procedures.

Agencies involved in Intelligent Access must recognise the varying rules and regulations across borders [80]. Knowing the impact of different Identity Providers (IDPs) on business operations is crucial.

Cross-border partnerships and agreements must be established, with standardised protocols and data formats for seamless integration [68] [75].

Identity and authorisation need to be decoupled. For instance, separate identity and authorisation functions from applications. This enables support for multiple IDPs and policies across regions.

4.2.2 What are the potential legal challenges?

The literature covers the potential legal challenges related to the introduction of Intelligent Access at an abstract level:

1. **Data privacy and security:** The collection, storage, and sharing of data related to vehicle movements and driver behaviour raise significant privacy and security concerns. Ensuring compliance with data protection regulations, such as the General Data Protection Regulation (GDPR) in Europe, is critical. Legal challenges may arise if data is mishandled or if there are breaches in data security.
2. **Liability and accountability:** Determining liability in the event of an accident or incident involving Intelligent Access systems can be complex. Questions may arise regarding who is responsible for ensuring compliance with regulations and maintaining the integrity of the system—whether it is the vehicle operator, the technology provider, or the road authority.
3. **Interoperability and standardisation:** The lack of standardised protocols and interoperability between different Intelligent Access systems can create legal challenges. Ensuring that systems from different providers and jurisdictions can work together seamlessly is essential to avoid legal disputes and ensure consistent enforcement of regulations.
4. **Regulatory compliance:** Ensuring that Intelligent Access systems comply with existing and evolving regulations can be challenging. Legal issues may arise if systems are not updated to reflect changes in laws or if there are discrepancies between national and regional regulations.
5. **Consent and transparency:** Obtaining informed consent from drivers and operators for the use of Intelligent Access systems is crucial. Legal challenges may arise if individuals are not adequately informed about how their data will be used or if they feel that their privacy rights are being violated.
6. **Cross-border legal issues:** Managing Intelligent Access across borders introduces additional legal complexities. Differences in regulations, enforcement practices, and data protection laws between countries can create challenges in ensuring consistent compliance and addressing legal disputes.
7. **Intellectual property and licensing:** The development and deployment of Intelligent Access systems involve various technologies and software, which may be subject to intellectual property rights. Legal challenges related to licensing, patents, and proprietary technologies can arise, potentially hindering the implementation of these systems.
8. **Public acceptance and legal challenges:** Public acceptance of Intelligent Access systems is essential for their successful implementation. Legal challenges may arise if there is resistance from stakeholders, such as transport companies or drivers, who may challenge the legality or fairness of the systems in court.
9. **Contractual agreements:** The introduction of Intelligent Access systems often involves contractual agreements between various parties, including technology providers, road authorities, and transport operators. Legal disputes may arise if there are disagreements over the terms and conditions of these contracts.
10. **Ethical and legal considerations:** The use of Intelligent Access systems raises ethical and legal considerations related to surveillance, autonomy, and the potential for discrimination.

Ensuring that these systems are designed and implemented in a manner that respects ethical principles and legal standards is crucial to avoid legal challenges.

These inferred points highlight the potential legal challenges related to the introduction of Intelligent Access, emphasising the need for careful consideration of data privacy, liability, regulatory compliance, and cross-border legal issues.

Notably, the handling of personal data is a specific challenge. Personal data (vehicle owners and their personal information, for example employment details, working hours, and relevant health issues) will be handled by the systems. Compliance with data protection regulations such as GDPR and its UK equivalent is essential [85] [99]. In the case where Artificial Intelligence is used in, for example, route optimisation decisions in Intelligent Access, care must be taken that the data used for training the AI cannot be used to identify individuals. GDPR and its UK equivalent also specify that no decision of legal significance must be made exclusively by the AI (i.e. without human intervention).

4.2.3 What are the potential effects on the infrastructure?

The literature highlights the following potential effects on road infrastructure from the introduction of Intelligent Access, emphasising improvements in maintenance, safety, capacity optimisation, and environmental impact, as well as support for multimodal transport and data-driven planning:

1. **Improved road maintenance and management:** Intelligent Access systems provide data on vehicle movements and road conditions, enabling more proactive and efficient road maintenance. This can lead to better-managed road surfaces, reduced wear and tear, and extended infrastructure lifespan.
2. **Optimised use of road capacity:** By optimising vehicle routing and managing traffic flow, Intelligent Access systems can make more efficient use of existing road capacity. This reduces congestion and the need for costly infrastructure expansions.
3. **Enhanced safety features:** Intelligent Access systems can enhance road safety by monitoring compliance with speed limits, weight restrictions, and other regulations. This reduces the risk of accidents and damage to infrastructure, contributing to safer roads.
4. **Targeted infrastructure investments:** The data collected through Intelligent Access systems can inform targeted infrastructure investments. Authorities can identify high-traffic areas, bottlenecks, and regions requiring upgrades, ensuring that resources are allocated effectively.
5. **Reduced environmental impact:** By promoting optimised routing and the use of low-emission vehicles, Intelligent Access systems can reduce the environmental impact of road transport. This contributes to cleaner air and less pollution-related damage to road infrastructure.
6. **Support for multimodal transport:** Intelligent Access systems can facilitate the integration of road transport with other modes of transport, such as rail and waterways. This reduces the burden on road infrastructure by promoting multimodal transport solutions.
7. **Infrastructure monitoring:** Intelligent Access systems can include sensors and monitoring devices that provide information on the condition of road infrastructure. This enables timely detection of issues such as potholes, structural weaknesses, or other damage.
8. **Increased compliance and reduced overloading:** By ensuring compliance with weight and dimension regulations, Intelligent Access systems reduce the incidence of overloading, which can cause significant damage to road infrastructure. This helps to preserve the integrity of roads and bridges.
9. **Enhanced traffic management:** Intelligent Access systems enable more effective traffic management, reducing congestion and improving the flow of vehicles. This leads to less stop-and-go traffic, which can cause wear and tear on road surfaces.

10. **Data-driven infrastructure planning:** The comprehensive data provided by Intelligent Access systems can support long-term infrastructure planning. Authorities can use this data to forecast future traffic patterns, plan new roads, and upgrade existing infrastructure to meet evolving needs.

Any implementation of Intelligent Access described in the literature would require additional infrastructure in vehicles, at the roadside, and centrally – including for GDPR compliance. Each of these will introduce a higher level of complexity, as a result of which care must be taken to design and implement systems which are as robust and easily-maintained as possible – especially given that in many cases (for example, eFTI) there may no longer be back-up systems.

It is also necessary to implement security measures, both against casual vandalism of physical infrastructure (for example, the theft of electronic units, similar to the crimes currently being experienced by farmers [26]) and hacking by malicious actors.

4.2.4 What are the data-driven compliance/enforcement processes that minimise human resource requirements? Can existing systems (e.g. HGV tolling) be used as a basis?

For Intelligent Access, data-driven compliance and enforcement processes can significantly minimise human resource requirements by leveraging automation, AI, and data monitoring. Here are some key processes:

1. **Automated data collection and analysis:** Using sensors and IoT devices to collect data on vehicle movements, load weights, and compliance with regulations [57]. This data can be analysed in real-time to identify non-compliance and trigger automated responses.
2. **AI-powered monitoring:** AI algorithms can monitor vast amounts of data to detect patterns and anomalies that indicate non-compliance. This allows for proactive enforcement and reduces the need for manual inspections.
3. **Automated reporting and alerts:** Systems can automatically generate reports and send alerts to relevant authorities when non-compliance is detected. This ensures timely intervention without the need for constant human oversight.
4. **Integration with existing systems:** Existing systems like EETS for HGV tolling can indeed be used as a basis. These systems already collect valuable data that can be repurposed for compliance monitoring. By integrating tolling data with other data sources, a comprehensive view of compliance can be achieved.
5. **Policy-based access control:** Implementing policy-based controls that automatically enforce compliance rules based on predefined criteria. This reduces the need for manual checks and ensures consistent enforcement.

The literature suggests several processes for how data-driven compliance and enforcement processes can minimise human resource requirements by leveraging automation, data analytics, and integration with existing systems like road tolling. This ensures efficient and effective enforcement while reducing the administrative burden on human resources. These processes are summarised below:

1. **Automated compliance monitoring:** Intelligent Access systems can use telematics and sensors to automatically monitor compliance with regulations such as speed limits, weight restrictions, and route adherence. This reduces the need for manual inspections and enforcement by human personnel.
2. **Real-time data analytics:** By analysing real-time data from vehicles, Intelligent Access systems can identify non-compliance issues instantly. Automated alerts can be sent to

operators and authorities, enabling swift corrective actions without the need for extensive human intervention.

3. **Integration with road tolling systems:** Existing road tolling systems can be integrated with Intelligent Access systems to monitor and enforce compliance. For example, tolling data can be used to verify that vehicles are using approved routes and adhering to weight limits. This leverages existing infrastructure to enhance compliance efforts.
4. **Automated penalty issuance:** Intelligent Access systems can automatically issue penalties for non-compliance based on data collected from vehicles. This includes fines for speeding, overloading, or unauthorised route usage. Automated penalty issuance reduces the administrative burden on human resources.
5. **Geofencing and restricted zones:** Geofencing technology can be used to create restricted zones where only compliant vehicles are allowed. Automated systems can monitor entry and exit points, ensuring that only authorised vehicles access these areas. This minimises the need for manual checks.
6. **Electronic Logging Devices:** ELDs can be used to automatically record driver hours of service (HOS) and ensure compliance with regulations on driving and rest times. This reduces the need for manual logbook inspections and enhances enforcement efficiency.
7. **Predictive analytics for maintenance and compliance:** Predictive analytics can be used to forecast maintenance needs and potential compliance issues based on historical data. This allows for proactive interventions, reducing the need for reactive enforcement and inspections.
8. **Centralised data repositories:** Creating centralised data repositories that store information on vehicle movements, compliance, and enforcement actions can streamline the compliance process. Authorities can access and analyse this data to ensure consistent enforcement without extensive human involvement.
9. **Automated reporting and auditing:** Intelligent Access systems can generate automated reports and audits on compliance metrics. This provides authorities with detailed insights into compliance trends and issues, enabling targeted enforcement actions without the need for extensive manual analysis.
10. **Remote monitoring and control:** Remote monitoring and control systems can be used to oversee compliance across large geographic areas. This allows authorities to manage compliance efforts from a central location, reducing the need for on-site personnel.

4.2.5 What are the data management requirements? (who?, where?, etc.)

The literature infers several points about the data management requirements for Intelligent Access, emphasising the importance of data accuracy, security, integration, processing, privacy compliance, analytics, quality management, scalability, governance, and collaboration:

1. **Data collection and accuracy:** Intelligent Access systems require accurate and comprehensive data collection from various sources, including vehicle telematics, sensors, GNSS, and road infrastructure. Ensuring the accuracy and reliability of this data is crucial for effective monitoring and compliance. High-quality data is critical for accurate Intelligent Access implementation. Efficiently categorising and labelling data is essential for Intelligent Access. Artificial Intelligence (AI) can be used in data classification and extraction, and in verification AI helps reduce errors in data by identifying inconsistencies and anomalies [52].
2. **Data storage and security:** Secure data storage solutions are essential to protect sensitive information related to vehicle movements, driver behaviour, and compliance. This includes implementing encryption, access controls, and secure data centres to prevent unauthorised access and data breaches.

3. **Data integration and interoperability:** Intelligent Access systems must be able to integrate and interoperate with existing data systems, such as road tolling, traffic management, and regulatory databases. This requires standardised data formats and protocols to ensure seamless data exchange and compatibility.
4. **Real-time data processing:** For some Intelligent Access implementations, the ability to process data in real-time is critical to provide timely alerts, compliance checks, and traffic management. This requires robust data processing infrastructure capable of handling large volumes of data with minimal latency.
5. **Data privacy and compliance:** Compliance with data privacy regulations, such as the GDPR, is essential for Intelligent Access systems. Any specific legislation regarding the use of data in Intelligent Access would need to operate within this framework by defining the legal basis (for instance, the data is processed for compliance with a legal obligation).
6. **Data analytics and reporting:** Advanced data analytics capabilities are required to derive actionable insights from the collected data. This includes the ability to generate reports, identify trends, and perform predictive analytics to inform decision-making and policy development. Historic data generated by Intelligent Access implementations may have significant value.
7. **Data quality management:** Ensuring the quality of data is essential for the effectiveness of Intelligent Access systems. This includes implementing data validation, cleansing, and normalisation processes to maintain data integrity and consistency.
8. **Scalability and flexibility:** Intelligent Access systems must be scalable and flexible to accommodate growing data volumes and evolving requirements. This includes the ability to scale data storage and processing capabilities and adapt to new data sources and technologies.
9. **Data governance and accountability:** Establishing clear data governance policies and accountability frameworks is crucial for managing data within Intelligent Access systems. This includes defining roles and responsibilities, setting data management standards, and ensuring compliance with regulatory requirements.
10. **Data sharing and collaboration:** Facilitating data sharing and collaboration between different stakeholders, such as road authorities, transport operators, and regulatory bodies, is essential for the success of Intelligent Access systems. This requires establishing data-sharing agreements and ensuring data interoperability.

4.2.6 What are the interests of non-NRA stakeholders related to Intelligent Access?

The literature points out the diverse interests of stakeholders who are not national road authorities related to Intelligent Access, emphasising the importance of efficiency, compliance, safety, environmental impact, and data-driven decision-making:

1. Transport operators and logistics companies:

Efficiency and cost savings: Transport operators and logistics companies are interested in Intelligent Access systems to optimise routing, reduce fuel consumption, and lower operational costs. Any stakeholders involved in cross-border trade will have an interest in the development of Intelligent Access to allow for ease of movement of freight across borders.

- **Compliance and safety:** Ensuring compliance with regulations and enhancing safety for drivers and cargo are key interests. Intelligent Access systems help monitor and enforce compliance with weight limits, speed restrictions, and other regulations.

- **Data and analytics:** Access to data (real-time and historic batch data) and analytics allows these stakeholders to make informed decisions, improve fleet management, and enhance overall operational efficiency.
2. **Technology providers and telematics companies:**
 - **Market opportunities:** Technology providers and telematics companies see Intelligent Access as an opportunity to develop and deploy innovative solutions, such as telematics devices, data analytics platforms, and compliance monitoring systems.
 - **Integration and interoperability:** Ensuring that their technologies can integrate and interoperate with existing systems and infrastructure is crucial for these stakeholders.
 - **Data security and privacy:** Addressing data security and privacy concerns is essential to gain the trust of users and comply with regulatory requirements.
 3. **Local and regional governments:**
 - **Traffic management and congestion reduction:** Local and regional governments are interested in using Intelligent Access systems to manage traffic flow, reduce congestion, and improve overall transport efficiency within their jurisdictions. In urban areas, planners and traffic management authorities may implement Smart Loading, enabled by Intelligent Access, to optimise use of limited kerbside space [94].
 - **Environmental impact:** Reducing emissions and promoting sustainable transport are key interests. Intelligent Access systems can help monitor and enforce environmental regulations.
 - **Public safety:** Enhancing road safety and reducing accidents through better compliance monitoring and traffic management are important goals for local and regional authorities.
 4. **Freight and logistics associations:**
 - **Advocacy and policy development:** These associations are interested in advocating for policies and regulations that support the adoption of Intelligent Access systems and benefit their members.
 - **Industry standards:** Developing and promoting industry standards for Intelligent Access technologies and practices is a key interest to ensure consistency and interoperability.
 - **Training and education:** Providing training and educational resources to their members on the benefits and implementation of Intelligent Access systems is important.
 5. **Insurance companies:**
 - **Risk management:** Insurance companies are interested in using data from Intelligent Access systems to assess and manage risks more effectively. This includes monitoring driver behaviour, vehicle compliance, and accident data.
 - **Premium adjustments:** Access to detailed data allows insurance companies to offer customised premiums based on the risk profile of individual operators and vehicles.
 - **Fraud prevention:** Intelligent Access systems can help detect and prevent fraudulent claims by providing accurate and verifiable data on vehicle movements and incidents.
 6. **Public and private road operators:**

- **Infrastructure maintenance:** Intelligent Access systems provide valuable data on road usage and conditions, helping operators plan and prioritise maintenance activities.
- **Revenue generation:** For toll road operators, Intelligent Access systems can enhance toll collection and compliance, ensuring accurate revenue generation. Law enforcement agencies will also have a stake in the use of data from Intelligent Access, both for enforcement and for understanding the extent of compliance.
- **Service quality:** Improving the quality of service for road users through better traffic management and reduced congestion is a key interest.

7. Environmental and community groups:

- **Sustainability and emissions reduction:** These groups are interested in promoting the use of Intelligent Access systems to reduce emissions, improve air quality, and support sustainable transport initiatives. NGOs and other stakeholders, including national governments, who wish to reduce carbon emissions also have an interest in improving the efficiency of freight transport, including enabling multi-modality.
- **Community impact:** Ensuring that transport activities do not negatively impact local communities, such as through noise pollution or traffic congestion, is a key concern.
- **Advocacy and awareness:** Raising awareness about the benefits of Intelligent Access systems and advocating for their adoption to achieve environmental and community goals.

8. General public:

- **Vulnerable road users:** such as pedestrians and cyclists, primarily have a road safety interest in the management of heavy vehicles.
- **Correct handling of dangerous goods:** The public need to be satisfied that the transport of dangerous goods is not a threat to them. For instance, if they live close to a highway.
- **Taxpayer value for money:** For instance, the damage to highways caused by inappropriately large vehicles may require taxpayer money to be spent on repairs.

4.2.7 What are the challenges related to the cooperation between public and private organisations?

The literature highlights the challenges related to the cooperation between public and private organisations in the introduction of Intelligent Access, emphasising the importance of data sharing, interoperability, alignment of objectives, regulatory compliance, funding, trust, technical expertise, stakeholder engagement, implementation, and accountability:

1. **Data sharing and privacy concerns:** Public and private organisations may have differing policies and concerns regarding data sharing and privacy. Ensuring that data is shared securely and in compliance with privacy regulations, such as GDPR, can be a significant challenge.
2. **Interoperability and standardisation:** Achieving interoperability between different systems and technologies used by public and private organisations is crucial for the success of Intelligent Access. The lack of standardised protocols and data formats can hinder seamless integration and cooperation.
3. **Differing objectives and priorities:** Public organisations may prioritise public safety, regulatory compliance, and environmental impact, while private organisations may focus on

operational efficiency, cost savings, and profitability. Aligning these differing objectives and priorities can be challenging.

4. **Regulatory and legal barriers:** Navigating the complex regulatory and legal landscape can be a challenge for both public and private organisations. Ensuring compliance with various regulations and addressing legal barriers to data sharing and cooperation requires careful planning and coordination.
5. **Funding and resource allocation:** Securing funding and allocating resources for the implementation of Intelligent Access systems can be a challenge, particularly when public and private organisations have different budget constraints and funding mechanisms.
6. **Trust and collaboration:** Building trust and fostering collaboration between public and private organisations is essential for successful cooperation. Historical mistrust or competition between entities can hinder effective collaboration and data sharing.
7. **Technical expertise and capabilities:** Public and private organisations may have varying levels of technical expertise and capabilities. Ensuring that all parties have the necessary skills and knowledge to implement and manage Intelligent Access systems can be a challenge.
8. **Stakeholder engagement and communication:** Engaging and communicating with a diverse range of stakeholders, including government agencies, private companies, and the public, is crucial for the success of Intelligent Access initiatives. Ensuring clear and consistent communication can be challenging.
9. **Implementation and maintenance:** Coordinating the implementation and ongoing maintenance of Intelligent Access systems across different organisations requires careful planning and collaboration. Ensuring that systems are maintained and updated consistently can be challenging.
10. **Performance measurement and accountability:** Establishing clear performance metrics and accountability frameworks is essential for evaluating the success of Intelligent Access initiatives. Ensuring that both public and private organisations are held accountable for their roles and responsibilities can be challenging.

Cooperation between **public** and **private organisations** can be both beneficial and challenging. The benefits flow from the pooling of expertise between government and commerce. This necessitates excellent, transparent communication and trust both between and within the parties involved, including on such issues as setting an exact brief. It also requires that the public sector partner should be assiduous drawing up the contracts.

The success of implementation will also depend upon the partners' reputations, among any system's end users (for example, commercial drivers and other road users) for trustworthiness, transparency and commercial probity. In times of emergency, such as Covid-19 or a natural disaster, care must be taken not to allow urgency to overwhelm these processes [83].

In the UK, Public-Private Partnerships (PPP), funding approaches for collaboration between public and private entities, have proven controversial in that they have not always given better return on investment than either fully public or fully commercial funding. Often the remediation of any obvious faults falls to civil society organisations such as voluntary or campaigning entities or, occasionally, individual lawmakers or investigative journalists [95].

4.2.8 What is the best practice in Australia, USA, and Europe, and what has the potential to be scaled up? (From existing Intelligent Access implementations)

The literature highlights the following best practices related to the implementation of Intelligent Access in Australia, the USA, and Europe, and their potential for scaling up to improve compliance, safety, efficiency, and interoperability on a global scale:

Best practices in Australia

Transport Certification Australia are among the first to implement a full technical, functional and regulatory framework to manage heavy vehicle access through the use of telematics [63]. Their system now forms the platform for Intelligent Access systems proposed for use in Europe.

1. **National telematics framework:** Australia has developed a National Telematics Framework that provides a standardised approach to telematics and Intelligent Access. This framework ensures interoperability and consistency across different systems and jurisdictions.
2. **Intelligent Access Program (IAP):** The IAP in Australia is a well-established program that uses telematics to monitor heavy vehicle compliance with access conditions. It has been successful in improving road safety, reducing infrastructure damage, and enhancing regulatory compliance.
3. **Stakeholder engagement:** Australia emphasises strong stakeholder engagement, involving government agencies, transport operators, technology providers, and industry associations in the development and implementation of Intelligent Access systems.

Best practices in the USA

1. **Electronic Logging Devices:** The USA has mandated the use of ELDs to monitor driver hours of service (HOS) and ensure compliance with regulations. This has improved road safety and reduced administrative burdens for transport operators.
2. **Integrated Corridor Management:** ICM initiatives in the USA use intelligent transportation systems (ITS) to optimise the use of existing infrastructure. This includes real-time traffic management, dynamic routing, and coordinated incident response.
3. **Public-Private Partnerships:** The USA leverages PPPs to implement Intelligent Access systems, combining public sector oversight with private sector innovation and investment. This approach has facilitated the deployment of advanced technologies and infrastructure.

Best practices in Europe

In Europe, the eCMR system implemented in Estonia, as outlined in section 2.2 provides a useful template for roll-out across the European Union. Regular published updates, webinars and conference contributions are facilitating dissemination of this knowledge.

1. **European Electronic Toll Service:** EETS provides a standardised framework for electronic tolling across Europe, ensuring interoperability between different tolling systems. This facilitates cross-border transport and reduces administrative complexity.
2. **Smart tachographs:** Europe has introduced smart tachographs to monitor driver activity, vehicle speed, and distance travelled. These devices enhance compliance with driving and rest time regulations and improve road safety.
3. **Harmonised regulations and standards:** Europe emphasises harmonised regulations and standards for Intelligent Access systems, ensuring consistency and interoperability across different countries. This includes initiatives like the European Union's ITS Directive.

Potential for scaling up

1. **Standardised frameworks and interoperability:** The development of standardised frameworks, like Australia's National Telematics Framework and Europe's EETS, has the potential to be scaled up globally. These frameworks ensure interoperability and consistency, facilitating cross-border transport and cooperation.
2. **Telematics and real-time monitoring:** The use of telematics and real-time monitoring systems, as seen in Australia's IAP and the USA's ELD mandate, can be scaled up to improve compliance, safety, and efficiency in other regions.
3. **Public-Private Partnerships:** The PPP model used in the USA can be scaled up to leverage private sector innovation and investment while ensuring public sector oversight and regulatory compliance. This approach can facilitate the deployment of Intelligent Access systems in other countries.
4. **Harmonised regulations and standards:** The emphasis on harmonised regulations and standards in Europe can be scaled up to ensure consistency and interoperability across different regions. This includes developing international agreements and standards for Intelligent Access systems.
5. **Stakeholder engagement and collaboration:** The strong stakeholder engagement practices seen in Australia can be scaled up to ensure that all relevant parties are involved in the development and implementation of Intelligent Access systems. This includes government agencies, transport operators, technology providers, and industry associations.

4.2.9 What are the lessons learned from Intelligent Access implementation and investigation in Australia, USA, and Europe?

The literature provides several lessons learned from the implementation of Intelligent Access in Australia, the USA, and Europe, emphasising the importance of standardisation, stakeholder engagement, technology integration, data-driven decision-making, harmonised regulations, cross-border cooperation, sustainability, data privacy, scalability, training, and performance measurement:

Lessons learned in Australia

1. **Standardisation and frameworks:** The success of Australia's National Telematics Framework highlights the importance of developing standardised frameworks for Intelligent Access. Standardisation ensures interoperability and consistency across different systems and jurisdictions.
2. **Stakeholder engagement:** Engaging stakeholders, including government agencies, transport operators, technology providers, and industry associations, is crucial for successful implementation. Collaborative efforts lead to better-designed systems that meet the needs of all parties involved.
3. **Compliance and enforcement:** The Intelligent Access Program (IAP) in Australia has shown that real-time monitoring and data-driven compliance enforcement can significantly improve road safety and reduce infrastructure damage. Automated systems reduce the need for manual inspections and enhance regulatory compliance.

Lessons learned in the USA

1. **Technology integration:** The implementation of Electronic Logging Devices (ELDs) in the USA demonstrates the importance of integrating technology into compliance and enforcement processes. ELDs have improved road safety and reduced administrative burdens for transport operators.
2. **Public-Private Partnerships:** The use of PPPs in the USA has facilitated the deployment of advanced technologies and infrastructure. Combining public sector oversight with private

sector innovation and investment leads to more effective and efficient Intelligent Access systems.

3. **Data-driven decision making:** The USA's Integrated Corridor Management (ICM) initiatives highlight the value of data-driven decision-making. Real-time data and analytics enable optimised traffic management, dynamic routing, and coordinated incident response.

Lessons learned in Europe

1. **Harmonised regulations and standards:** Europe's emphasis on harmonised regulations and standards, such as the European Electronic Toll Service (EETS) and smart tachographs, ensures consistency and interoperability across different countries. This facilitates cross-border transport and reduces administrative complexity.
2. **Cross-border cooperation:** The success of Intelligent Access systems in Europe underscores the importance of cross-border cooperation. Collaborative efforts between countries lead to more effective implementation and management of Intelligent Access systems.
3. **Need for clear legal basis:** Pilots studies such as that carried out in the Netherlands (see section 2.4) have demonstrated the need for clear legal basis. This now needs support from policy makers to realise this legal basis by adapting regulations such as Directive 96/53/EC Weights and dimensions.
4. **Sustainability and environmental impact:** Europe's focus on sustainability and reducing environmental impact through Intelligent Access systems demonstrates the importance of aligning technology implementation with broader environmental goals. Monitoring and enforcing emission standards contribute to cleaner air and reduced pollution.

General lessons learned

1. **Data privacy and security:** Ensuring data privacy and security is a critical lesson learned from all regions. Compliance with data protection regulations, such as GDPR, and implementing robust security measures are essential to gain the trust of users and protect sensitive information.
2. **Scalability and flexibility:** Intelligent Access systems must be scalable and flexible to accommodate growing data volumes and evolving requirements. Designing systems with scalability in mind ensures they can adapt to future needs and technological advancements.
3. **Training and education:** Providing training and educational resources to stakeholders is crucial for the successful implementation of Intelligent Access systems. Ensuring that all parties understand the benefits, requirements, and best practices leads to more effective adoption and use.
4. **Performance measurement and accountability:** Establishing clear performance metrics and accountability frameworks is essential for evaluating the success of Intelligent Access initiatives. Regular monitoring and reporting ensure that systems are meeting their objectives and provide opportunities for continuous improvement.

4.2.10 What are the known challenges/barriers for Intelligent Access implementation based on existing studies/pilots in Australia, USA, and Europe?

The literature provides a useful source of known challenges and barriers for the implementation of Intelligent Access in Australia, the USA, and Europe, emphasising the importance of addressing data privacy, interoperability, cost, regulatory compliance, public acceptance, technical expertise, cross-border coordination, infrastructure compatibility, data integration, technology adoption, stakeholder coordination, legal considerations, maintenance, and performance evaluation:

Challenges in Australia

1. **Data privacy and security:** Ensuring compliance with data privacy regulations and securing sensitive information is a significant challenge. The collection and sharing of telematics data must adhere to strict privacy standards to gain public trust.
2. **Interoperability and standardisation:** Achieving interoperability between different telematics systems and ensuring standardisation across jurisdictions can be challenging. Variations in technology and data formats can hinder seamless integration.
3. **Cost and funding:** The initial cost of implementing Intelligent Access systems, including technology acquisition and infrastructure upgrades, can be a barrier. Securing funding and demonstrating a clear return on investment is essential for widespread adoption.

Challenges in the USA

1. **Regulatory compliance:** Navigating the complex regulatory landscape and ensuring compliance with federal, state, and local regulations can be challenging. Differences in regulations across states can create inconsistencies in implementation.
2. **Public acceptance and trust:** Gaining public acceptance and trust in Intelligent Access systems is crucial. Concerns about surveillance, data privacy, and potential misuse of information can hinder adoption.
3. **Technical expertise and resources:** Ensuring that all stakeholders have the necessary technical expertise and resources to implement and manage Intelligent Access systems can be a barrier. Training and capacity-building efforts are needed to address this challenge.

Challenges in Europe

1. **Cross-border coordination:** Coordinating Intelligent Access initiatives across multiple countries with different regulatory frameworks, languages, and administrative structures can be complex. Ensuring harmonised implementation and cooperation is essential.
2. **Infrastructure compatibility:** Ensuring that existing road infrastructure is compatible with Intelligent Access technologies can be a barrier. Upgrading infrastructure to support new technologies requires significant investment and planning.
3. **Data integration and management:** Integrating data from various sources and managing large volumes of data in real-time can be challenging. Ensuring data quality, accuracy, and consistency is crucial for effective implementation.
4. **Clear legal justification:** Intelligent Access needs to be legally justified. This is complicated by the cross-border nature of freight transport. There are legislative changes being made through EC directives that need to be considered and influenced.

General challenges and barriers

1. **Technology adoption and upgradability:** The rapid pace of technological advancements can make it challenging to keep systems up to date. Ensuring that Intelligent Access systems are future-proof and can adapt to new technologies is essential.
2. **Stakeholder coordination:** Coordinating efforts among diverse stakeholders, including government agencies, private companies, and industry associations, can be challenging. Clear communication and collaboration are necessary for successful implementation.
3. **Legal and ethical considerations:** Addressing legal and ethical considerations related to data collection, usage, and sharing is crucial. Ensuring that Intelligent Access systems comply with legal standards and respect ethical principles is essential.

4. **Maintenance and sustainability:** Ensuring the long-term maintenance and sustainability of Intelligent Access systems can be a barrier. Continuous funding, technical support, and system upgrades are necessary to maintain effectiveness.
5. **Performance evaluation and accountability:** Establishing clear performance metrics and accountability frameworks to evaluate the success of Intelligent Access initiatives can be challenging. Regular monitoring and reporting are needed to ensure systems meet their objectives.

Most notably, the literature highlights the following **key challenges** [98]:

- *While Intelligent Access originated in Australia, it cannot be directly copied to the European context. Adaptation to regional regulations and conditions is necessary. This is specifically in the case where European legislation and national legislation may differ. For instance, some countries are resisting the amendment to 96/53/EC Weights and dimensions, due to concerns about the impact of megatrucks on infrastructure, increasing competition for rail freight transport, and potentially ceding control of future regulations on these types of trucks.*
- *Developing effective controls for Intelligent Access remains institutionally and politically challenging. Crafting policy and regulatory systems that balance efficiency and compliance is crucial.*
- *Intelligent Access concepts continue to evolve, responding to different local conditions and constraints. Flexibility in design and policy is essential for successful implementation.*

4.3 What is the legal basis for the introduction of Intelligent Access?

Intelligent Access leverages digital systems to monitor and control vehicle access, data management, and regulatory compliance within the transportation and logistics sectors.

Article 91(1) of the Treaty on the Functioning of the European Union (TFEU) provides a general legal basis for the EU to adopt measures concerning transport, particularly in the context of establishing a common transport policy. While it does not specifically mention Intelligent Access, it does offer a solid legal foundation for measures that support the regulation and management of freight transport, including those involving digital and telematics-based systems like Intelligent Access.

Intelligent Access can also support the implementation of other regulations. Below are the requirements from relevant regulations and how Intelligent Access helps meet them:

1. **Intelligent Transport Systems (ITS) Directive (2010/40/EU) of the European Parliament and of the Council of 7 July 2010 on ITS [34]**

Relevant Clause: Article 3(a) specifies that ITS services should enhance road safety and traffic efficiency. Article 6 elaborates on ensuring interoperability of ITS applications across the EU.

How Intelligent Access supports this:

- **Traffic management & safety:** Intelligent Access supports the Directive's goal to improve traffic efficiency and safety by enabling real-time access control, vehicle tracking, and route management, in line with Article 3(a).
- **Interoperability of data:** As stated in Article 6, Intelligent Access helps ensure seamless data sharing across systems, providing standardised, secure communication between different stakeholders (e.g., transport operators, and public authorities).
- **Justification:** By supporting automated traffic control and safe routing, Intelligent Access answers the core requirements of the ITS Directive to optimise traffic flow, reduce congestion, and minimise accidents.

2. Revision of Directive 96/53/EC – Weights and Dimensions of Heavy Goods Vehicles [7]

Relevant Clauses: Article 4(4): This article permits certain vehicles to exceed standard dimensions if equipped with aerodynamic devices or running on alternative fuels, provided they meet specified safety and efficiency conditions. Article 10: Outlines requirements for Member States to implement systems that ensure vehicles comply with weight and dimension regulations, particularly regarding enforcement and monitoring.

How Intelligent Access supports this:

- Vehicle dimension and weight monitoring: Intelligent Access systems enable automatic monitoring of vehicle dimensions and weights, ensuring that vehicles with aerodynamic features or alternative-fuel technologies comply with the special allowances under Article 4(4).
- Enabling transition to alternative fuels: Intelligent Access can be used as the system to monitor vehicle weights and dimensions and thus provide a mechanism to allow higher limits for vehicles using alternative fuels (such as zero-emission electric vehicles).
- Automated enforcement: Intelligent Access assists Member States in fulfilling their obligations under Article 10, as it automates checks for vehicle dimensions and weights, reducing manual inspection efforts and enhancing enforcement capabilities.
- Data-driven compliance: Intelligent Access provides accurate, real-time data that helps authorities verify that vehicles meet the conditions of Article 4(4), which is crucial for vehicles exceeding permissible limits due to special allowances for fuel efficiency and safety improvements.

Justification: Intelligent Access systems directly address the requirements outlined in Article 4(4) and Article 10 by offering automated, data-driven solutions that monitor vehicle compliance with dimensional and weight limits. This ensures road safety, minimises infrastructure damage, and allows authorities to efficiently manage enforcement, particularly for vehicles utilising permissible exemptions.

3. Commission Implementing Regulation (EU) 2019/1213 of July 2019 on the Implementation of the Directive 2010/40/EU [87]

Relevant Clauses: Regulation (EU) 2019/1213 governs the use of on-board weighting equipment in EU freight vehicles to enforce weight compliance under directive 96/53/EC. Article 1 outlines the scope of Regulation, focusing on the deployment of intelligent transport systems and their applications to enhance road safety and efficiency. Article 2 details the requirements for data and information exchange between different transport systems to promote interoperability and integration. Article 4 emphasises the need for compliance with data protection regulations while implementing ITS solutions.

Established under Directive 96/53/EC, this regulation sets uniform conditions for the interoperability and compatibility of OBW systems across EU member states. Member States may choose to require OBW installation to identify vehicles or vehicle combinations likely to exceed authorised weight limits. Alternatively, they can implement weight monitoring through roadside infrastructure systems such as weigh-in-motion (WIM). The use of the words ‘may choose’ is a challenge for the standardisation of systems that may be necessary for Intelligent Access.

The regulation does provides a steer for both implementation and certification of weighing equipment, anchored in recognised ISO standards – validating the use as part of Intelligent Access or other freight compliance systems. However, it is narrow by design, as it identifies ITS-G5 as the sole short-range communication protocol for data exchange and is focused on EU-registered vehicles. This reflects the Commission's intention to prioritise rapid deployment of a single interoperable standard,

but it does mean that alternative technologies (such as C-V2X or other communications channels) are excluded. The reference to ISO 11992 (CANbus / EBS interface) is helpful because it leverages existing vehicle electronic architecture rather than imposing new hardware layers, making it possible for equipment providers to integrate weighing functionality in a predictable way.

How Intelligent Access supports this:

- Promoting interoperability: Intelligent Access systems facilitate the requirements laid out in Article 2 by enabling seamless data exchange across various transport modes and systems, thus enhancing overall transport efficiency and integration.
- Enhancing road safety and efficiency: By providing real-time data on vehicle operations and traffic conditions, Intelligent Access supports the objectives of Article 1, contributing to improved road safety and transport system efficiency.
- Data protection compliance: Intelligent Access systems incorporate measures to ensure compliance with Article 4, safeguarding personal data and adhering to relevant data protection laws while implementing intelligent transport solutions.
- Justification: Intelligent Access systems directly support the aims of Commission Implementing Regulation (EU) 2019/1213 by promoting interoperability and enhancing road safety through efficient data exchange. By ensuring compliance with data protection regulations, Intelligent Access contributes to the responsible implementation of intelligent transport systems, aligning with the legislative framework established by the Regulation.

4. Regulation (EU) 2019/1242 setting CO₂ emission performance standards for new heavy-duty vehicles

Relevance: Introduced CO₂ emissions performance standards for new heavy-duty vehicles. Key elements include emissions performance standards (including targets to reduce average CO₂ emissions from new heavy vehicles) and reporting and monitoring (from manufacturers and national authorities).

How Intelligent Access supports this:

- Supporting low-emission vehicle access policies: Intelligent Access platforms could identify clean vehicles based on real-time data (CO₂ performance or vehicle certification), enabling preferential routing or permit priority for low- and zero-emission trucks.
- Enabling compliance-based incentives: NRAs can tie access rules (e.g. entry to low-emission zones or road pricing) to real-time emission performance data, reinforcing the incentives created by Regulation 2019/1242.
- Data feedback loop for better monitoring: Telematics within Intelligent Access systems can provide operational CO₂ performance data, offering practical validation of manufacturer claims and supporting real-world emission monitoring.
- Integration into holistic fleet management: Intelligent Access enables enforcement and infrastructure access control to be aligned with CO₂ objectives – helping authorities to regulate freight movement not only by vehicle weight or route, but also by emission standards.

5. Council Directive 92/106/EEC – Combined Transport

Relevant Clause: Article 2(1) encourages the development of combined transport to reduce road traffic congestion, while Article 3 promotes transparency in transport operations.

How Intelligent Access supports this:

- Monitoring intermodal transport: Intelligent Access facilitates real-time tracking and verification of goods transported across different modes (road, rail, sea), supporting Article 2(1)'s push for better transport coordination.
- Transparency in operations: Intelligent Access provides real-time data and reporting on the movement of goods, aligning with Article 3's emphasis on transparency and compliance with combined transport operations.
- Justification: Intelligent Access ensures compliance with combined transport regulations by tracking the movement of freight and reporting emissions, furthering the sustainability and efficiency objectives of this Directive.

6. Regulation (EC) No 1072/2009 – Access to the International Road Haulage Market

Relevant Clause: Article 3(1) requires operators to possess valid community licenses, and Article 8(2) limits cabotage operations to prevent excessive road use.

How Intelligent Access supports this:

- License and certification checks: Intelligent Access automates the verification of community licenses and certificates of drivers, ensuring compliance with Article 3(1) for international road haulage.
- Cabotage monitoring: Intelligent Access systems can track vehicle movements and ensure compliance with cabotage limits, helping to enforce the restrictions set out in Article 8(2).
- Justification: Intelligent Access enhances the enforcement of these rules by automating checks for operator licenses and cabotage compliance, reducing administrative errors and ensuring adherence to international haulage regulations.

7. General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679) [85]

Relevant Clause: Article 25 requires data protection by design and by default, and Article 32 emphasises the need for secure processing of personal data.

The legal basis for introducing Intelligent Access involves complying with data protection regulations. Controllers must rely on one of the six legal bases for processing personal data under Article 6(1) of the GDPR. Common bases include consent, legitimate interests, legal obligation, or contractual necessity. When developing and deploying Intelligent Access systems, it's crucial to choose the most appropriate lawful basis and document the decision.

How Intelligent Access supports this:

- Data protection by design: Intelligent Access systems incorporate encryption and secure protocols, aligning with Article 25's requirement for data protection by design, ensuring that all personal and transport data are securely handled.
- Transparency and security: Intelligent Access offers transparency in data access and usage, adhering to Article 32's requirements for secure processing of personal data and safeguarding sensitive information in transportation and logistics operations.
- Justification: By complying with these data protection standards, Intelligent Access ensures the secure and lawful handling of data, particularly in cross-border transport where data must be protected and shared transparently.

8. eFTI Regulation (EU 2020/1056) – Electronic Freight Transport Information [36]

Relevant Clause: Article 3 outlines that freight information must be electronically accessible to competent authorities. Article 4 specifies that all data exchanges must be secure and protected.

How Intelligent Access supports this:

- Electronic data accessibility: Intelligent Access facilitates the electronic transmission of freight data to authorities, as required in Article 3, automating the documentation process for inspections and reducing reliance on paper records.
- Data protection and security: Intelligent Access systems ensure that data is transmitted securely, supporting Article 4's requirement for secure data exchanges.
- Justification: By enabling secure, real-time access to freight documentation, Intelligent Access aligns with eFTI's objective of improving communication efficiency between logistics operators and authorities, ensuring compliance and reducing administrative burden.
- Article 5 mandates the availability, accuracy, and security of this electronic data. Article 9 outlines the technical requirements for eFTI platforms, which must ensure data interoperability, security, and accessibility for authorities.
- Data accuracy and security: Intelligent Access ensures the data integrity and security required under Article 5, facilitating compliance with eFTI regulations by securing the flow of sensitive transport information, and therefore preventing unauthorised access.
- Interoperability: Intelligent Access platforms are designed to meet the interoperability requirements specified in Article 9, ensuring that different systems across regions or countries can seamlessly share and process freight information.
- Justification: Intelligent Access systems directly support the implementation of eFTI by automating the exchange, accuracy, and security of freight information, ensuring full compliance with the requirements for digital freight operations outlined in REGULATION (EU) 2020/1056. This promotes operational efficiency and transparency in freight transport.

9. European Electronic Toll Service [35] [38]

Relevant clause: Directive (EU) 2019/520, Article 3: This article establishes the requirement for interoperability and cross-border data exchange in electronic tolling, facilitating the adoption of uniform standards across Member States. It mandates the creation of harmonised electronic tolling systems that support Intelligent Access by promoting technology-neutral interoperability, ensuring that toll systems across the EU operate compatibly enabling a single market for transport.

Commission Decision 2009/750/EC Defines the EETS service requirements and technical specifications, enabling toll systems to share essential data between toll operators and EETS providers. The decision Intelligent Access functions and laying the groundwork for effective Intelligent Access systems

Directive 2004/52/EC: Directive 2004/52/EC forms the original foundation of EETS by mandating electronic toll systems' compatibility across Member States. This directive encourages the use of interoperable tolling technology, which is critical for the functionality of Intelligent Access systems as they depend on real-time data sharing across multiple jurisdictions.

How Intelligent Access supports this:

- Enhanced cross-border transport: EETS supports Intelligent Access by streamlining cross-border transit, reducing administrative and technical barriers for logistics providers. It allows a single tolling contract to cover multiple regions, promoting smoother and more efficient transportation. For Intelligent Access, this setup minimises disruptions and increases mobility for logistics and freight operators moving across national borders.
- Supporting Intelligent Transport Systems (ITS): The EETS framework promotes technological developments crucial to Intelligent Access, including Dedicated Short-Range Communication (DSRC) and Global Navigation Satellite System (GNSS). These

technologies enable real-time connectivity (such as V2X, or Vehicle-to-Everything), which is essential for some Intelligent Access functions like route optimisation and compliance monitoring.

- Data consistency and interoperability: Interoperability standards mandated by EETS facilitate data sharing, compliance, and alignment with other Intelligent Transport Systems (ITS) initiatives. The standardised data exchange required by EETS supports Intelligent Access systems by ensuring data reliability and reducing discrepancies across toll systems, making it possible to implement intelligent, data-driven decisions in real time.
- Payment of fees: EETS provides a useful mechanism for hauliers, as they coordinate the payment of tolls across various geographic areas. The haulier benefits as it requires only one registration, and enforcement is similarly simplified.

10. Delegated Regulation (EU) 2022/670 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services

Relevant clause: Delegated Regulation 2022/670 supplementing Directive (EU) 2010/40/EU, Article 6.5: For the purpose of providing appropriate information directly to the end-users and optimising road maintenance and road safety, road authorities and road operators may request holders of in-vehicle generated data and service providers to provide the data types on the state of the network they collect and update.

Notably, it sets standards for the accessibility, exchange, re-use, and updating of traffic, infrastructure, and restriction data, ensuring it is available in a digital, machine-readable format, interoperable across member states. Access conditions relevant to Intelligent Access – such as weight limits, tunnel or bridge restrictions, low emission zones, and temporal access windows – are required to be published in machine-readable form via the NAP, making them available for Intelligent Access platforms to consume and enforce in real time.

There is a phased rollout for certain road classes (e.g. TEN-T and motorways) with obligations that began in 2024/25. Compliance of countries with this rollout plan is believed to be poor.

How Intelligent Access supports this by enabling interoperable, digital, and data-driven road freight transport management:

- Digitisation of access conditions: Intelligent Access systems can translate legal and regulatory access rules (e.g. for weight, emissions, size) into machine-readable digital formats, in line with Article 3 of the Regulation.
- Real-time compliance monitoring: Intelligent Access enable real-time collection and processing of vehicle data (weight, location, emissions, route), supporting dynamic enforcement of access rule.
- Support for automated and connected vehicles: Delegated Regulation 2022/670 aims to make access rules available to connected and automated vehicles. Intelligent Access systems integrate with telematics and onboard systems to guide vehicles in real-time, ensuring they comply with road access rules autonomously.
- Cross-border harmonisation: Intelligent Access contribute to standardised access frameworks across member states, a key goal of the Regulation.
- Better decision support for NRAs: Intelligent Access provides analytics and monitoring dashboards that help National Road Authorities enforce and adjust access policies in line with Regulation requirements.

11. Directive (EU) 2023/2661 of the European Parliament and of the Council of 22 November 2023 on the Promotion of Digital and sustainable Transport [33]

Relevant Clauses: Article 1: Establishes the purpose of the Directive, which is to promote the digitalisation and sustainability of transport systems across the EU. Article 5: Outlines the obligations for Member States to implement measures that facilitate the integration of digital technologies in transport operations. Article 8: Addresses the importance of ensuring data privacy and protection in the deployment of digital transport solutions.

How Intelligent Access supports this:

- Facilitating digital integration: Intelligent Access systems align with Article 5 by enabling the integration of digital technologies across various transport modes, promoting efficient operations and improving the overall sustainability of transport systems.
- Enhancing sustainability: By optimising transport routes and reducing fuel consumption through real-time data analytics, Intelligent Access supports the objectives set forth in Article 1 for creating more sustainable transport practices.
- Data protection compliance: Intelligent Access systems are designed to adhere to the principles outlined in Article 8, ensuring that personal data is handled securely and in compliance with relevant data protection regulations during the implementation of digital transport solutions.

Justification: Intelligent Access systems directly support the objectives of Directive (EU) 2023/2661 by facilitating the digitalisation of transport operations and enhancing sustainability through data-driven insights. By prioritising data privacy and protection, Intelligent Access contributes to the responsible integration of digital technologies in transport systems, aligning with the legislative requirements established by the Directive.

Summary

Article 91(1) TFEU provides a broad and valid legal basis for the introduction of Intelligent Access at the EU level, particularly when:

- It relates to cross-border freight movement.
- It aims to improve road safety and infrastructure usage.
- It is implemented as part of broader transport policy measures (e.g. via delegated regulations, ITS frameworks, or digital transport infrastructure legislation).

To introduce Intelligent Access systems at national level, Member States can also rely on Article 91(1) as a legal reference point when transposing EU rules or aligning with common frameworks.

Intelligent Access systems fulfil the requirements outlined in various other regulations by automating compliance, enhancing operational transparency, and ensuring data protection in line with European legal frameworks.

5. Intelligent Access data

The data is what will produce the intelligence in an Intelligent Access application. For most of the applications of Intelligent Access described in the literature, the types of data proposed are already in use for some other purpose – they are part of a related data system. For instance, some traffic management systems and all EETS use GNSS-derived position information of vehicles. It is also more feasible to build an Intelligent Access application using data and systems that are already in existence.

Therefore, this review examined existing data systems and analysed the data within them for use in an Intelligent Access application.

In analysing Intelligent Access data, the aim was to identify and address gaps in the existing knowledge by systematically categorising and evaluating the data used for Intelligent Access systems. To achieve this, we reviewed a range of literature documents, which are detailed in Appendix A, to identify key types of data relevant to Intelligent Access systems. These were categorised based on their descriptions, units, formats, and associated focus areas of Intelligent Access, along with the countries employing them.

Each type of data was then rated on a performance scale from 1 to 3, with a brief explanation for the rating. This process enabled the visualisation of data gaps using spider diagrams, where higher ratings resulted in more balanced, circular diagrams, while gaps were indicated by irregular shapes or critical omissions.

5.1 Methodology to review data

The approach involved a structured review of literature to systematically extract and categorise Intelligent Access data. Data was classified into several attributes: type, description, unit category, format, focus area, and geographical usage. Following categorisation, performance ratings were assigned to each data type based on its completeness, relevance, and applicability within Intelligent Access systems. Ratings ranged from 1 (low performance) to 3 (high performance), with explanations provided to justify each rating. The ratings were then visualised in spider diagrams, highlighting areas with comprehensive data coverage and those with deficiencies. This methodology allowed for a comparative assessment across focus areas and regions, facilitating a deeper understanding of where gaps exist and their criticality to system performance.

A summary of the results of this systematic review is provided in Section 5.2, and a detailed review of each data system can be found in Appendix C.

5.2 Results of data review

The analysis revealed notable disparities in data performance and usage across Intelligent Access systems. While certain data types, such as those related to vehicle characteristics and infrastructure compatibility, achieved high ratings due to their robust applicability and integration, others, like environmental impact data or real-time dynamic data, were rated lower due to inconsistent formats, limited usage, or lack of standardisation.

Spider diagrams visually demonstrated these findings, with higher ratings forming near-complete, circular diagrams, while lower-rated data resulted in fragmented shapes, indicating critical gaps. This method effectively pinpoints specific data gaps and provides actionable insights for enhancing the development and deployment of Intelligent Access systems. By identifying underperforming areas, this approach contributes to a roadmap for improving data integration and addressing gaps in Intelligent Access systems.

5.2.1 Review of existing data systems

This section provides an overview of the data systems that were reviewed to identify data that could be utilised for Intelligent Access implementation. ***The data in these systems could provide the intelligence for an Intelligent Access application.*** Although some of the systems may appear to serve very similar purposes (such as traffic management), there are subtle differences, and it is not the purpose of this project to classify them. The full reviews of each data system can be found in Appendix C. The data systems reviewed were:

- **Weigh in motion (WIM)** systems weigh vehicles to increase transportation safety and reduce the damages caused by over-weighted vehicles, but without having to stop the vehicle.
- **Adaptive Signal Control Technology** systems use detection technologies to automatically adjust the timing of traffic signals to work with changing traffic conditions.
- **Driver behaviour monitoring and control** systems analyse the speed and acceleration of drivers during transportation operations and provide feedback for improving driving.
- **Delivery space booking** systems allow the space for parking to be booked for a specific vehicle to load or unload freight during a specific time period.
- **Vehicle identification** systems collect information such as the type and class of vehicles, their registration numbers and other identification information is used in different transportation operations for transportation resource management, as well as being used by authorities for controlling the security of transportation operations.
- **Crash prevention** systems use technologies such as sensors to reduce the probability of accidents.
- The **VELUB** system allows road owners and police monitor abnormal heavy vehicle movements in Estonia. It is a cloud monitoring platform, that is currently in the live testing phase.
- **Closed circuit television** systems are video monitoring systems placed along highway or intersections that transmit video for real-time viewing for uses such as identifying signal outages or incidents.
- **Connected vehicle technologies** enable the exchange of safety messages among vehicles and the highway infrastructure. Connected vehicle technologies may use short-range radio signals.
- **Detection devices** are a variety of technologies including inductive loops and video detection systems (i.e. cameras) used to detect vehicles and other users of the road on a highway, potentially including pedestrians and bicyclists.
- **Dynamic message signs** are electronic road signs used to inform travellers of incidents, travel times, detours, or special events. They are generally connected to a control centre.
- **Emergency vehicle pre-emption** uses a signal transmitted by emergency vehicles to alter planned traffic signal timing to give green lights to emergency vehicles going through intersections.
- **Ramp meters** are traffic signals on highway on-ramps or slip roads that regulate the rate at which vehicles enter freeway traffic.
- **Road weather information** systems process information from environmental sensor stations along a highway to alert traffic managers or the public about hazardous conditions.

- **Critical infrastructure management** systems involve the monitoring, maintenance, and protection of essential facilities and systems, such as transportation networks, power grids, water supply, communication systems, and bridges.
- **Intelligent route guidance** systems calculate the optimum route for freight using processed data from the traffic management centre on the current traffic situation, considering specialties for HGVs (e.g. emission model, fuel consumption model, bridge and road damage index).
- **Accident warning information** systems provides accident information to nearby vehicles to enable users to reduce the effect of accidents. For example, queue build up, chain accidents, fire, and rear end collisions.
- **Theft alarm and recovery** systems provide real-time location and status information about stolen goods and vehicle to the goods owner, traffic and transport managers.
- **FLUXNET infrastructural spatial model** is a model under development which focuses on optimising or adding terminals, infrastructure and modes on three different scale levels.
- **Transport order handling** systems provide real-time order information sharing between the goods owner, transport manager, driver, and other parties, as well as feedback when the orders are satisfied.
- **Transport resource optimisation** systems attempt to optimise overall resources including road infrastructure, vehicle capacities, vehicle trips, so that the optimisation of subsystems (e.g. routing, driver planning) may not negatively affect other systems such as road maintenance.
- **Vehicle follow-up** systems collect and analyse vehicle performance-related data including empty mileage, fuel consumption and vehicle status, then reports such data to different stakeholders such as fleet owners and vehicle inspection agencies.
- **Route guidance** systems provide information relevant to specific corridors related to, for instance, zebra crossings or school children, as well as helping the infrastructure owners influence the use of a given route.
- **Road User Charging (RUC)** systems collect charges related to the use of road infrastructure based on location, time, road type and vehicle type.
- **Real-time track and trace of goods** systems provides information such as speed, location and status of goods to goods owners, transport managers and other stakeholders, that can enable tracking of such goods if necessary.
- **Urban Vehicle Access Regulation (UVAR)** systems aim to establish a form of a traffic management system that regulates access to specific urban areas and locations. Access is conditional upon a vehicle type, age, or emission category for a specific time of the day or day of the week, for example as practiced in the NORDICWAY project.
- **Mobile telematics** devices include radio frequency identification (RFID), sensor-tracking devices, and GNSS telematics units enabling IoT services to optimise transport operations.
- **On-board safety and security monitoring** systems help the driver to constantly monitor the vehicle and its contents without manual checks. These systems continuously track and monitor vehicle conditions, cargo status, and safety parameters in real time.
- **Pay-as-you-drive** systems provide location-related information to insurance companies to help reward drivers according to risk attitudes and exposure and reinforce good driving.

- **Remote monitoring** systems RMS allow dispatchers and fleet owners to continuously track the status and location of vehicles in real time.
- **Road hindrance warning** systems provide real-time information about road obstacles, traffic jams, construction zones, and other disruptions. These systems also offer suggestions for avoiding delays and rerouting vehicles in real-time to optimise travel times.
- **Intelligent Speed Adaptation (ISA)** systems provide dynamic information about the current speed limit that can lead to a reduction in collisions and in fuel consumption.
- **Transit signal priority** systems adjust normal traffic signal timing to give priority to public transit vehicles (e.g., buses). A device aboard the bus sends a signal picked up by a detection device along the highway.
- The **eCall** system reduces the time taken to locate and rescue victims of a collision as well as the vehicle and its contents. It reduces the total cost related to incidents by preventing deaths and reducing incident severity and waiting time.
- **Advanced driver log** systems record various time-based activities for HGV drivers and help the driver avoid driving under the influence of external factors such as alcohol. They are digital records that track drivers' hours, vehicle usage, and driving behaviour.
- **Infrastructure repair and maintenance** systems provides real-time information on the status and maintenance history of infrastructure.
- **Geofencing / geo-tracking** devices provide control support for areas of interest such as corridors, military areas, incident areas, parking areas and tunnels without using physical barriers. Users include vehicle fleet owners, infrastructure owners, gate operators, vehicle parking operators, and loading / unloading units.
- **Information on truck parking** systems provide parking related information in real-time to drivers and facility owners.
- **Remote declaration** systems enable the declaration of information to be transferred electronically at places such as gates, control stations, and loading/unloading stations reduce delays. RDS are used to declare shipments, vehicle details, and other relevant data remotely, reducing congestion at busy entry points and ensuring smoother, faster, and more efficient processes.
- **Staff monitoring** systems track employee activities, presence, performance, and compliance with safety regulations in real time using technologies including GNSS, biometric data, RFID, and software-based monitoring tools. These systems play a crucial role in ensuring that workers in logistics, transportation, and warehousing follow prescribed routes, meet operational guidelines, and maintain safety standards.
- **On-board mass (OBM)** systems allow for the digital collection of axle mass measurements, which are combined with vehicle position data to provide richer insights into vehicle movement, load, and configuration. This data is used to manage compliance with road transport laws and to improve road safety and infrastructure management.

5.2.2 Identified data gaps

The analysis of Intelligent Access data has revealed several critical gaps that impede the optimal deployment and performance of Intelligent Access systems. These gaps are associated with specific types of data, their accessibility, standardisation, and the challenges involved in their integration.

Below, we detail the common data gaps identified, their implications, and the factors contributing to these deficiencies.

1. On-board weighing systems

Gap identified: Limited adoption and cost barriers

On-board weighing (OBW) systems, which provide axle and gross vehicle weight measurements, are critical for ensuring compliance with weight regulations and infrastructure safety. Currently, OBW systems are not widely adopted in the on-road vehicle fleet due to high installation and maintenance costs, particularly for smaller transport operators. Moreover, data from OBW systems is often siloed, with limited integration into broader Intelligent Access frameworks due to inconsistent data formats and a lack of standardisation across vehicle types and manufacturers. However, this is likely to change for two main reasons:

- The on-road fleet is renewed (almost all new vehicle makers now include air suspension systems that can be used as OBW systems and solutions are being developed to make this information more easily available).
- The ISO standard 11992 (CANbus / EBS interface) included in regulation 2019/1213 (see section 4.3) ensures that the data source for weighing calculations is standardised and reliable across different vehicle types and manufacturers. This provides a valuable opportunity for the application of Intelligent Access, as there will be a marginal extra cost involved.

2. Real-time dynamic data

Gap identified: Inconsistent availability and network limitations

Real-time data, such as vehicle location, speed, and operational status, is fundamental for dynamic Intelligent Access policies (although not all Intelligence Access implementations require real-time data). However, this data often suffers from inconsistent availability, particularly in rural or remote areas with poor network coverage. Additionally, the lack of interoperability among telematics providers complicates data sharing and integration. The cost of enabling real-time data transmission, including network upgrades and telematics systems, further exacerbates the gap.

3. Environmental impact data

Gap identified: Lack of standardisation and incomplete data sets

Data on vehicle emissions, fuel consumption, and environmental performance is vital for supporting green access policies. However, such data often lacks standardisation, making it difficult to compare or integrate across different systems and regions. Additionally, comprehensive environmental data is often unavailable for older or retrofitted vehicles, limiting the scope of Intelligent Access policies targeting emissions reductions.

4. Infrastructure condition data

Gap identified: Insufficient monitoring and high costs

Accurate and up-to-date data on road and bridge conditions (including bridge pavement strength) is essential for matching vehicle performance to infrastructure capacity. However, many regions lack the monitoring systems needed to collect this data comprehensively. High costs associated with deploying sensors and maintaining data collection systems further contribute to this gap. Additionally, where such data exists, it is often not integrated into Intelligent Access frameworks due to differing formats and the lack of a unified data-sharing platform.

5. Data privacy and security concerns

Gap identified: Resistance to data sharing

While data sharing is critical for the success of Intelligent Access systems, concerns over privacy and competitive advantage frequently limit collaboration among stakeholders. Logistic operators and fleet managers may hesitate to share sensitive data, such as vehicle routes or load information, due to fears of misuse or competitive disadvantage. These concerns are compounded by a lack of robust governance frameworks to ensure data protection and fair usage.

6. Standardisation across jurisdictions

Gap identified: Fragmented policies and systems

The absence of harmonised policies and data standards across different jurisdictions creates significant barriers to the seamless implementation of Intelligent Access systems. Variability in how data is categorised, collected, and interpreted limits the scalability of such systems, particularly for cross-border operations. The lack of a unified framework for integrating data into a pan-European Intelligent Access policy is a critical gap.

7. Cost and resource constraints

Gap identified: High implementation costs

Many of the gaps identified are underpinned by cost and resource constraints. Small and medium-sized enterprises (SMEs) in the logistics sector often lack the financial resources to invest in advanced telematics, OBW systems, or environmental monitoring devices. Additionally, public road authorities face budgetary constraints that limit their ability to deploy the necessary infrastructure for Intelligent Access policies.

5.2.3 Risks or implications of the data gaps

These gaps hinder the realisation of the full potential of Intelligent Access systems, impacting their efficiency, scalability, and environmental benefits. For example:

- **Operational efficiency:** Limited access to dynamic and real-time data reduces the ability to optimise vehicle routing and scheduling.
- **Safety and infrastructure longevity:** Inadequate monitoring of vehicle weights and infrastructure conditions increases risks of overloading and structural damage.
- **Environmental sustainability:** The lack of comprehensive environmental data limits the enforcement of green transport policies.

The following are potential mitigation measures for the data gaps:

- **Investment in technology:** Incentives for adopting OBW systems, telematics, and environmental monitoring tools can reduce cost barriers.
- **Standardisation efforts:** Harmonising data formats, standards, and policies across jurisdictions will enhance interoperability and scalability.
- **Data governance:** Establishing robust frameworks to ensure data privacy and fair usage can address stakeholder concerns and encourage data sharing.
- **Collaborative research:** Joint efforts between public and private sectors can focus on innovative, cost-effective solutions for data collection and integration.

- **Pilot programs:** Targeted trials can help test and refine approaches to filling data gaps, particularly in regions with limited resources.

6. Intelligent Access building blocks



6.1 Introduction to the building blocks of Intelligent Access

Building blocks are a term used to help break down the complexities of Intelligent Access into more easily understandable and accessible chunks. They do not specify how something should be done but articulate what factors need to be considered. These building blocks provide a high-level perspective of things that need to be considered or actions that need to be taken to ensure Intelligent Access is built correctly, does what it's meant to and no more, and does so legally and ethically.

The point is that the value that each block adds to a system will depend on the needs of that system and this will vary depending on the maturity of the work, the area of use, and other factors. Therefore, adequately addressing each building block will require some degree of engagement with experts, or reference to supporting materials, to ensure each building block is properly understood.

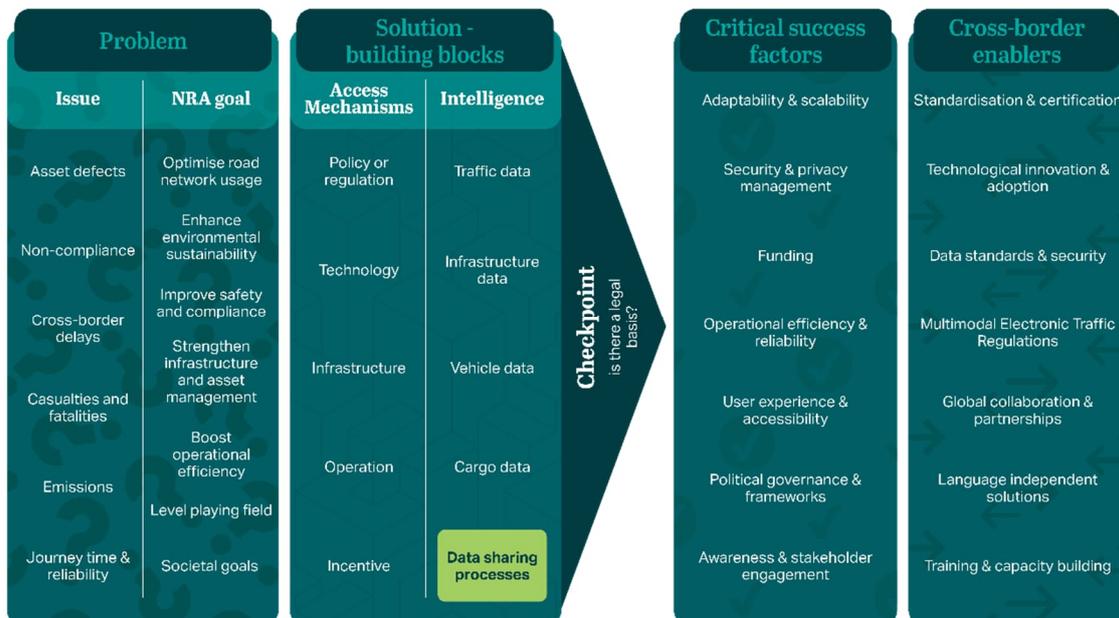


Figure 3: The building blocks of an Intelligent Access system

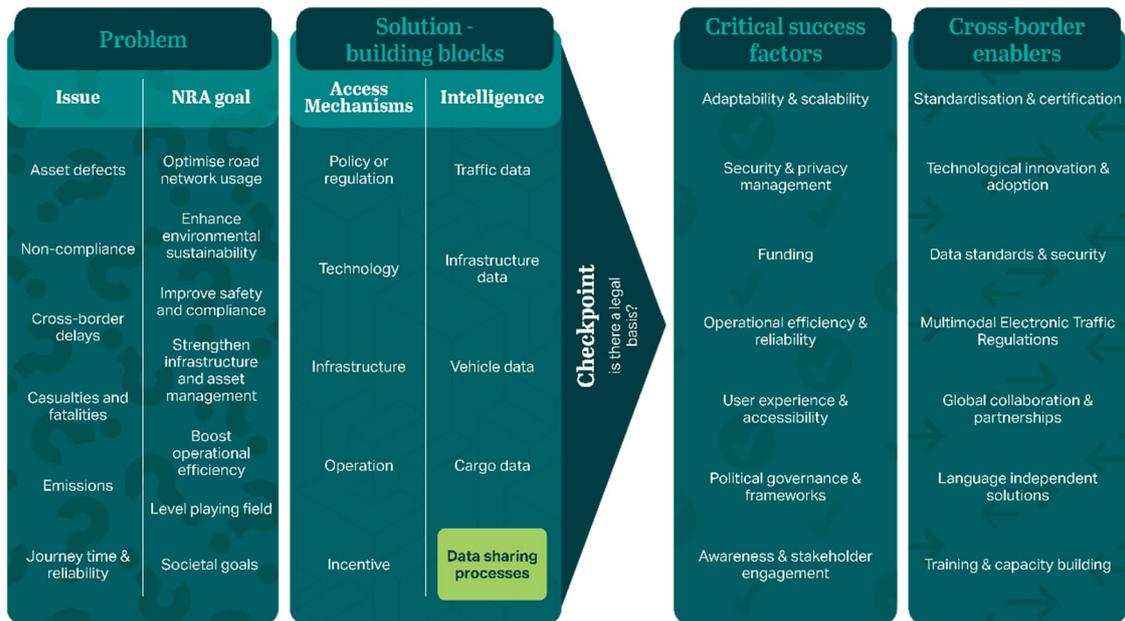


Figure 3 provides an overview of the building blocks for Intelligent Access. Further details about each block are provided in the following sections. These building blocks form a framework for Intelligent Access, which will help road freight infrastructure to be better aligned with social and business goals.

6.2 Start with the problem

The design of an Intelligent Access system should be in response to an issue and related NRA goal that is trying to tackle that issue.



6.2.1 What is the issue?

As with most initiatives, it is important to understand the issue it is trying to address. The most common issues are:

- 1. Casualties and fatalities:** Freight traffic poses significant road safety risks due to the size, weight, and stopping distances of heavy vehicles. Collisions involving lorries often result in severe injuries or fatalities, particularly for vulnerable road users and occupants of smaller vehicles. Common causes include driver fatigue, poor visibility, mechanical failures, and unsafe manoeuvres. Improving safety measures through Intelligent Access, speed monitoring, and vehicle compliance can help mitigate these risks.
- 2. Asset defects:** Heavy freight vehicles contribute to accelerated wear and tear on road infrastructure, leading to defects such as potholes, rutting, and bridge deterioration. Overloaded or improperly distributed cargo increases the strain on pavements and bridges, reducing their lifespan and increasing maintenance costs. Effective weight monitoring and route optimisation can help NRAs manage infrastructure resilience and minimise damage.
- 3. Emissions:** Freight transport is a major contributor to CO₂, NO_x, and particulate matter emissions, affecting air quality and climate change. Diesel-powered lorries are particularly responsible for pollution in urban areas and along major freight corridors. Strategies to reduce emissions include promoting low-emission zones, incentivising electric or hydrogen-powered trucks, optimising freight routes, and may include reducing congestion through Intelligent Access-based traffic management.
- 4. Journey time and journey time reliability:** Delays and unpredictability in freight journeys lead to increased operational costs for logistics companies and inefficiencies in supply chains. Causes of unreliable journey times include congestion, roadworks, weather conditions, and

incidents. Intelligent Access can improve journey time reliability by providing dynamic traffic control, route planning, and prioritised access for time-sensitive deliveries.

5. **Cross-border delays:** International freight movement face delays due to customs checks, regulatory differences, and logistical inefficiencies at border crossings. These delays disrupt supply chains, increase fuel consumption, and lead to driver fatigue. Standardised digital documentation, harmonised regulatory frameworks, and Intelligent Access solutions could streamline cross-border freight transport and reduce waiting times.
6. **Non-compliance with freight regulations:** Some transport operators fail to comply with regulations regarding vehicle weight, emissions, speed limits, and driver working hours. Non-compliance can lead to safety risks, unfair competition, and increased infrastructure damage. Intelligent Access could improve enforcement by using telematics, geofencing, and real-time vehicle monitoring to detect and prevent violations.

6.2.2 What is the NRA goal?

The issues will inherently have a related NRA goal. These goals will aim to tackle the issues. It is possible that the Intelligent Access system may be designed to support multiple goals. New or more specific goals may be created in response to new issues.

1. Optimise road network usage

- Enable efficient access for heavy vehicles, high-capacity vehicles, abnormal loads, and dangerous goods.
- Promote seamless cross-border freight operations to enhance international logistics.
- Improve route planning, journey time reliability, and traffic control to minimise congestion and delays.

2. Enhance environmental sustainability

- Reduce emissions and promote the use of clean, low-emission vehicles.
- Support environmental management and resource optimisation for greener logistics.
- Enable efficient fuelling and charging infrastructure for sustainable transportation.

3. Improve safety and compliance

- Ensure adherence to speed limits, weight limits, and other regulatory requirements.
- Enhance safety for all road users by monitoring vehicle compliance and managing dangerous goods transport.
- Provide driver support to reduce human error and improve operational safety.

4. Strengthen infrastructure and asset management

- Minimise road wear and optimise asset management to prolong infrastructure lifespan.
- Support infrastructure planning and development through data-driven insights.
- Facilitate better management of vehicle parking and roadside facilities.

5. Boost operational efficiency

- Streamline document processing for faster and unified transport operations.
- Improve fleet management and vehicle tracking for logistics optimisation.
- Support resource management by ensuring vehicles and infrastructure are used effectively.

6. Level the playing field

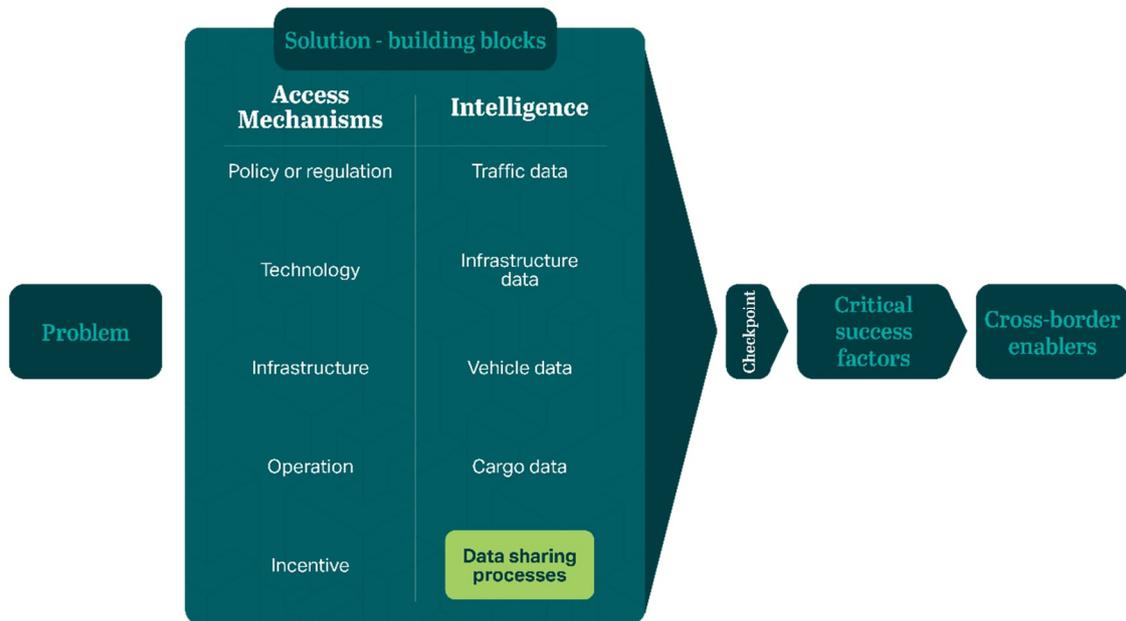
- Ensuring that all freight operators compete fairly and adhere to consistent standards.
- Enforce consistent compliance with regulations (e.g. weight limits, emissions, access restrictions) regardless of operator size or origin.
- Detect and penalise non-compliance using real-time monitoring and automated enforcement, reducing the advantage of rule-breakers.
- Support smaller or compliant operators by reducing the enforcement burden and simplifying digital permit processes.
- Enhance transparency of regulatory data and access conditions across regions and borders.

7. Societal goals

- Aligning freight transport with broader public interests such as health, safety, and sustainability.
- Reduce environmental impacts through emissions monitoring and low-emission zone enforcement.
- Improve road safety by managing speed, overloading, and routing of high-risk or dangerous goods vehicles.
- Minimise community disruption from freight traffic in sensitive urban areas via dynamic access control.
- Contribute to national climate and energy targets by incentivising greener logistics and cleaner fleets.
- Enhance public trust in road authorities by demonstrating proactive, data-driven governance.

6.3 Build the solution

Once the NRA goal is established, the appropriate combination of Access and Intelligence is defined. **Access** refers to the means or opportunity to enter or use the highway. **Intelligence** means the system can perceive and respond to the world around it, or it can learn, think, and adapt.



6.3.1 Chose a mechanism to manage the access

1. **Policy-based mechanisms:** NRAs can implement regulatory frameworks and guidelines to govern freight vehicle access:
 - **Access permits:** Require permits for specific vehicle types (e.g., abnormal loads, dangerous goods, high-capacity vehicles) to ensure compliance with road access rules.
 - **Zoning policies:** Define access restrictions based on location, time, and vehicle type (e.g., low-emission zones, urban delivery time windows).
 - **Weight and dimension limits:** Set and enforce restrictions on vehicle weights and dimensions to protect infrastructure.
 - **Tolling and road pricing:** Implement dynamic tolling based on vehicle weight, emissions, or time of use to incentivise sustainable behaviour.
2. **Technology-driven mechanisms:** Modern digital tools and telematics systems can enhance monitoring and control:
 - **Telematics:** Used monitor and enforce access conditions, such as vehicle routes, weights, and compliance with speed limits.
 - **Geofencing:** Establish virtual boundaries where vehicle access is restricted or controlled based on time, emissions, or cargo.
 - **Real-time data sharing:** Require vehicles to share live data on location, speed, weight, and emissions for monitoring and control purposes.

- **Digital permit systems:** Automate the application and approval of permits for specific vehicles and loads.
 - **Automated enforcement:** Deploy cameras, sensors, and ANPR (Automatic Number Plate Recognition) to monitor compliance without physical stops.
- 3. Infrastructure management mechanisms:** Optimising physical infrastructure helps regulate access effectively:
- **Designated routes:** Assign specific routes for heavy vehicles, high-capacity vehicles, and dangerous goods to minimise risks and infrastructure damage.
 - **Weigh-in-motion (WIM) systems:** Install sensors to measure vehicle weights dynamically and identify violations.
 - **Smart parking facilities:** Provide parking zones for freight vehicles, integrated with real-time availability and booking systems.
 - **Charging and fuelling infrastructure:** Create dedicated stations for low-emission and electric freight vehicles.
 - **Traffic flow optimisation:** Use traffic signals and signage to prioritise freight vehicles on key corridors or during specific times.
- 4. Operational and collaborative mechanisms:** Coordinated operations and partnerships with stakeholders ensure smoother implementation:
- **Freight corridors:** Develop dedicated freight corridors with managed access and support services.
 - **Integrated freight platforms:** Collaborate with logistics companies to share data and coordinate vehicle movements.
 - **Cross-border agreements:** Establish harmonised regulations and systems for seamless international freight transport.
 - **Driver training and education:** Promote compliance through awareness programmes targeting drivers and transport operators.
- 5. Incentive-based mechanisms:** Encouraging compliance through positive reinforcement can improve outcomes:
- **Subsidies and incentives:** Offer financial benefits for adopting low-emission vehicles or complying with access rules.
 - **Preferred access:** Grant priority access to compliant vehicles (e.g. clean vehicles or those with advanced telematics systems).
 - **Recognition programmes:** Acknowledge companies demonstrating exemplary compliance and sustainability practices.

6.3.2 Chose data to provide the intelligence

The intelligence part of an Intelligent Access system is produced by four key data pillars — Vehicle, Goods, Roads, and Traffic — which collectively provide the essential data needed for Intelligent Access to function effectively. These pillars integrate existing systems and data to ensure that Intelligent Access builds on and optimises what already exists. Additionally, the biggest impact of

Intelligent Access is realised during the planning stage, where data-driven insights inform decision-making, rather than during transit.

1. **Traffic data:** Captures traffic patterns, incidents, and environmental conditions like weather, enabling dynamic adjustments to Intelligent Access systems and predictive analytics for smoother operations.
2. **Infrastructure data:** Includes digital representations of road networks, infrastructure conditions, lane configurations, speed limits, and construction zones. Infrastructure data supports route planning, congestion management, and safety protocols.
3. **Vehicle data:** Encompasses telematics information such as speed, location, axle load, emissions, and operational conditions. This data forms the backbone of compliance checks, monitoring, and predictive maintenance.
4. **Cargo data:** Provides insights into the type, weight, and destination of transported goods, enabling optimised routing and regulatory compliance. This is especially critical for sensitive or time-critical cargo.

By anchoring Intelligent Access on these four pillars, existing infrastructure, policies, and technologies are leveraged effectively, reducing redundancy and increasing operational efficiency.

In addition, the intelligence should have **processes for sharing data**. Systems and protocols for collecting data from telematics devices and transmitting it to central databases. This includes wireless communication technologies such as cellular networks, satellite communication, and dedicated short-range communication (DSRC). Efficient processes for sharing data are crucial to ensuring that information flows seamlessly between different Intelligent Access stakeholders. This includes data exchange between vehicle operators, infrastructure managers, and regulatory bodies. Streamlined data-sharing processes allow Intelligent Access systems to operate cohesively across various networks, making sure data is readily available for operational decisions and regulatory compliance. The ISO 11992 and rFMS (revised Fleet Management System) standards are key frameworks for enabling CANbus data sharing from heavy-duty vehicles to external systems such as third-party fleet services or Intelligent Access platforms. ISO 11992 defines the communication protocol between towing and towed vehicles (e.g. truck and trailer) via the CANbus, ensuring interoperability for key vehicle parameters like weight, braking, and axle loads. The FMS standard – originally developed by major truck manufacturers – specifies a common data interface (FMS Gateway) that makes selected CANbus data (e.g. fuel consumption, speed, engine load) accessible in a standardised, non-proprietary format. The revised FMS standard (rFMS) introduces remote access via web services (API), allowing telematics data sharing with authorised third parties, including regulators or Intelligent Access systems, while incorporating security and privacy controls. However, rFMS does not currently specify access to axle weight data from a second trailer, which limits its effectiveness for multi-trailer combinations. In addition, the frequency of weight data updates in rFMS is relatively low, reducing its usefulness for effective monitoring and control by hauliers or public authorities. These limitations highlight the need for complementary standards or enhancements to ensure Intelligent Access systems can reliably support both regulatory oversight and operational efficiency in complex freight operations.

Data from vehicles or telematics devices involves the collection of data from vehicles, such as speed, location, and operational conditions, which is essential for monitoring and managing road traffic and vehicle compliance. Onboard devices installed in vehicles that collect and transmit data related to tolling, vehicle movements, driver behaviour, and compliance with regulations. These devices include GNSS units, sensors, and communication modules. This information enables intelligent decision-making in areas like traffic control and fleet management, forming the backbone of an Intelligent Access system by providing data that supports analytics and predictive insights.

The **Information about Infrastructure** is pivotal for Intelligent Access systems, providing comprehensive and timely data about highways, traffic signals, construction zones, and other critical infrastructure elements. This information enables Intelligent Access systems to deliver accurate and timely guidance for route planning, traffic management, and incident response, enhancing overall transportation efficiency and safety. By having up-to-date details on road conditions, closures, and infrastructure changes, Intelligent Access can optimise traffic flows, reduce congestion, and promptly address emergencies, thereby improving the reliability and responsiveness of transport networks. Additionally, detailed infrastructure data supports predictive analytics, allowing Intelligent Access systems to anticipate and mitigate potential disruptions before they impact traffic.

The necessity of this data lies in its ability to ensure that Intelligent Access systems are informed by the latest infrastructure developments, facilitating seamless integration with existing transport management frameworks. While significant strides have been made in collecting and disseminating infrastructure information, there remains a need for more extensive and timely data coverage, especially in rapidly developing urban areas and across diverse geographical regions. Enhanced collaboration between governmental bodies, infrastructure providers, and Intelligent Access developers is required to standardise data formats and improve data accessibility, ensuring that Intelligent Access systems can leverage infrastructure information to its fullest potential.

The **Digital Road Network** is an essential component of Intelligent Access, providing a digital representation of physical road infrastructure, including lane configurations, speed limits, traffic signs, and navigational landmarks. This digital mapping allows Intelligent Access systems to interpret and respond to real-world conditions accurately, enabling advanced functionalities such as dynamic route optimisation, congestion management, and predictive maintenance of roads. By integrating with data on traffic patterns and incidents, a digital road network enhances situational awareness for connected vehicles and infrastructure systems, leading to smoother traffic flow and improved safety. The EU regulation 2022/670 regarding real-time traffic information sets standards for this data, including the requirement for it to be machine readable and for national road authorities to provide it. In addition, under the ITS Directive, there is an obligation to establish agreements between public and private service providers on minimum data quality by December 2025. This obligation is expected to provide a trusted legal basis for advanced use cases such as highly automated route planning and geofencing.

A comprehensive digital road network is particularly important for cross-border interoperability, as it ensures that vehicles and systems from different regions can interpret road layouts and regulations consistently. This building block also facilitates the integration of new technologies like autonomous driving, where precise digital maps are critical for navigation and decision-making. While advancements in digital road network mapping have been significant, especially in urban areas, there remains a need for expanded and regularly updated digital road data, particularly in rural and less mapped regions, to support a fully integrated Intelligent Access system.

Connectivity and coverage requirements —are fundamental to the effective implementation of Intelligent Access. This connectivity enhances the accuracy and responsiveness of Intelligent Access systems, enabling them to coordinate traffic flows, manage lane changes, and provide crucial alerts to drivers. Connectivity is especially important for coordinating responses to unforeseen conditions, such as adverse weather or sudden congestion, enhancing the safety and efficiency of transport networks. As Intelligent Access systems grow, consistent and robust connectivity will remain critical, ensuring that data flows seamlessly between various components, both within and across national boundaries, to create a safer, more integrated transportation system.

As well as suitable connectivity technology, coverage of communications is also key. For example, the ability to connect to 4G or 5G networks across Europe.

Interoperability and system integration are essential building blocks for Intelligent Access as they ensure seamless interaction and compatibility across diverse systems, platforms, and devices. In an

Intelligent Access framework, data must be able to flow reliably between different components—whether they are access control systems, AI-driven analytics, or data management platforms—without technical barriers. Interoperability allows systems to "speak the same language," enabling efficient communication and data sharing across different technologies and networks. This compatibility fosters a cohesive, user-friendly experience, where access is consistent regardless of location or device. Furthermore, system integration brings together varied Intelligent Access elements, ensuring they work in unison, thus reducing complexity for administrators, enhancing data accuracy, and strengthening security protocols by preventing gaps that isolated systems might create. Ultimately, interoperability and system integration not only drive the functionality and resilience of Intelligent Access systems but also future proof them for technological advancements and scaling across global regions.

6.4 Checkpoint: Is there a legal basis?



Before implementing an Intelligent Access system, a NRA must establish the **legal justification** for its introduction. This involves demonstrating that the system serves a **legitimate public interest**, **complies with legal principles**, and **aligns with existing regulatory frameworks**. The following steps outline how an NRA can assess whether there is a legal justification for Intelligent Access:

1. **Identify the legal basis for Intelligent Access implementation:** The NRA must determine whether Intelligent Access is supported by existing laws or if new legislation is required. The legal basis could be derived from:
 - **Road traffic and transport laws:** Do national laws permit digital monitoring and control of freight vehicle access? In the EU, this is established in EU regulation 96/53/EC Weights and dimensions. Member States are able to implement this through national regulations for exemptions.
 - **Infrastructure protection laws:** Is Intelligent Access necessary to prevent excessive road wear, manage heavy vehicles, or protect critical infrastructure?
 - **Environmental regulations:** Can Intelligent Access be justified under legal commitments to reduce emissions, air pollution, or congestion?
 - **Safety and public welfare laws:** Does Intelligent Access support road safety, reduce collisions, or improve compliance with freight regulations?

If these laws already authorise access control and compliance monitoring, Intelligent Access could be justified as a modern enforcement mechanism.

2. **Establish the legitimate public interest:** To be legally justified, Intelligent Access must serve a clear public interest. Common justifications include:
 - **Road safety:** Preventing overloaded or unsafe vehicles from using restricted roads.
 - **Infrastructure management:** Reducing highway damage caused by excessive loads and unauthorised vehicles.

- **Environmental protection:** Enforcing low-emission zones and reducing pollution from freight traffic.
- **Efficient transport operations:** Ensuring fair competition and compliance among transport operators.
- **Cross-border harmonisation:** Supporting seamless international freight operations and compliance with EU or international transport agreements.

If Intelligent Access contributes to these objectives **more effectively** than existing methods, it strengthens the legal justification.

3. Assess necessity and proportionality: Legal frameworks, particularly in Europe, require that any regulatory intervention be necessary and proportionate to its objective. The NRA should consider:

- **Is Intelligent Access the least restrictive means to achieve the goal?** If traditional enforcement (e.g. roadside checks) is sufficient, Intelligent Access may not be justified.
- **Does Intelligent Access create an undue burden on businesses?** The system should not disproportionately impact transport operators or small businesses.
- **Are there alternative approaches?** If similar objectives can be met with existing laws, Intelligent Access may require stronger justification.

For example, if Intelligent Access only affects non-compliant operators and improves fairness in enforcement, its justification becomes stronger.

4. Compliance with data protection and privacy laws: If Intelligent Access involves tracking vehicles, collecting telematics data, or using automated enforcement, the NRA must ensure compliance with privacy laws (e.g. GDPR in the EU). Key considerations include:

- **Legal basis for data collection:** Does the law allow the collection of vehicle, operator, and driver data?
- **Data minimisation:** Is only the necessary data collected, and is it stored securely?
- **Transparency and consent:** Are operators informed about data usage, and do they have rights over their data?
- **Proportionality of surveillance:** Does Intelligent Access avoid excessive monitoring beyond what is needed for compliance?

If Intelligent Access respects privacy rights and provides safeguards, it is more likely to be legally justified.

5. Ensure alignment with international and regional laws: For cross-border freight traffic, Intelligent Access must align with:

- EU Transport and environmental regulations (if applicable).
- Bilateral and multilateral freight agreements.
- UNECE transport treaties (e.g. regulations on dangerous goods).

If Intelligent Access supports international regulatory compliance, its justification is stronger.

6. Conduct legal and public consultation: To reinforce legal justification, the NRA should:

- **Consult legal experts** to assess whether Intelligent Access complies with national and international law.

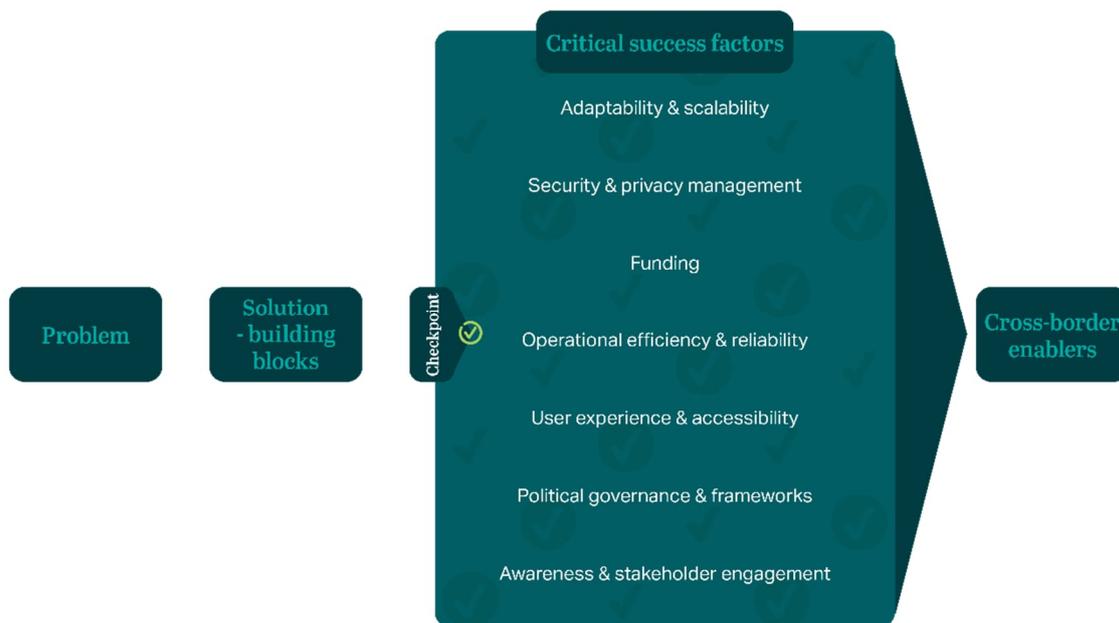
- **Engage industry stakeholders** (transport operators, logistics firms) to evaluate economic and operational impacts.
- **Consider public and political acceptance**, ensuring Intelligent Access aligns with public interest concerns.

If consultation identifies strong support and minimal legal objections, Intelligent Access is more likely to be legally defensible.

If these criteria are met, the NRA may **legally justify** Intelligent Access as an essential tool for modern road freight management.

6.5 Factors to achieve success

These factors provide advantage, consent, and confidence. These are not part of an Intelligent Access system but are critical to the system's successful development and deployment. The success of Intelligent Access is reliant on this group of blocks being solid. Some of these blocks can be weaker than others.



1. Adaptability and scalability: Adaptability and scalability are essential building blocks and success factors for Intelligent Access because they enable Intelligent Access systems to evolve alongside changing technologies, user demands, and environmental conditions. Adaptability ensures that Intelligent Access solutions can integrate new features, update security measures, and respond to emerging threats or regulatory changes without requiring a complete system overhaul.

This flexibility allows Intelligent Access to stay relevant and reliable as technologies like AI, IoT, and 5G continue to advance. Scalability, on the other hand, is crucial for supporting growth in user numbers, data volumes, and access points without compromising performance or security. As Intelligent Access systems expand across locations, devices, and complex user needs, scalability allows them to handle increased loads seamlessly, ensuring consistent and efficient access experiences. Together, adaptability and scalability future-proof Intelligent Access systems, allowing organisations to maximise the long-term value and effectiveness of their access infrastructure while staying agile in a dynamic landscape.

2. Security and privacy management: Security and privacy management are crucial success factors and foundational building blocks for Intelligent Access, as they protect sensitive information, build user trust, and ensure compliance with regulatory standards. In Intelligent Access systems, vast amounts of data—often personal or sensitive—are processed and stored, making robust security protocols and privacy protections essential. Effective security management involves layers of defences, such as encryption, access controls, and continuous threat monitoring, to safeguard data from cyber threats and unauthorised access.

Privacy management complements this by embedding privacy-by-design principles into Intelligent Access infrastructure, ensuring that users' data is handled responsibly and transparently, which is vital for gaining trust and facilitating widespread adoption. Additionally, adherence to regulatory

frameworks like GDPR protects users and shields organisations from legal and financial repercussions. Together, security and privacy management create a resilient Intelligent Access system that prioritises user safety, aligns with global standards, and fosters a trusted environment where users can confidently interact with Intelligent Access solutions.

3. Funding: The Funding building block is a fundamental element for the successful development, deployment, and maintenance of Intelligent Access systems. Adequate funding ensures that Intelligent Access projects have the necessary resources to support infrastructure investments, technology upgrades, system integration, and ongoing operational costs. Funding also plays a critical role in supporting research and development (R&D) efforts aimed at advancing Intelligent Access technologies, such as data interoperability, cybersecurity measures, and advanced connectivity features. A possible option to secure funding is through EETS.

Securing sustainable funding is essential not only for initial project rollouts but also for long-term operational viability, particularly in cross-border contexts where standards and interoperable systems are required. Funding from governmental bodies, private sector partnerships, and public-private initiatives can foster innovation, while also ensuring compliance with regulatory requirements and international standards.

However, the current funding landscape indicates a need for increased investment and broader financial support, particularly for scaling Intelligent Access systems across regions and addressing potential gaps in less developed areas. Expanding funding sources can accelerate Intelligent Access adoption and support essential functions such as maintenance, workforce training, and system updates, ensuring that Intelligent Access infrastructure can adapt to evolving technological and regulatory environments.

4. Operational efficiency and reliability: Operational efficiency and reliability are critical success factors and building blocks for Intelligent Access systems, ensuring that they perform consistently, meet user expectations, and support seamless access experiences. Operational efficiency focuses on optimising resources, such as processing power, storage, and bandwidth, to deliver quick response times and minimise delays during access. This efficiency helps prevent bottlenecks, especially during high-demand periods, and ensures that systems remain cost-effective while supporting rapid, timely access.

Reliability, meanwhile, is vital for building trust and confidence in Intelligent Access systems by ensuring continuous uptime and dependable access. Redundancy measures, backup systems, and proactive maintenance are key components of reliability, preventing disruptions that could impact productivity, security, and user satisfaction. Together, operational efficiency and reliability form the backbone of Intelligent Access, providing a stable, high-performance environment that enhances user trust, meets organisational needs, and supports sustainable growth and innovation.

5. User experience and accessibility: User experience (UX) and accessibility are pivotal success factors for Intelligent Access, as they ensure that systems are intuitive, inclusive, and fully functional for all users. A well-designed UX enables users to interact with Intelligent Access systems effortlessly, reducing the likelihood of errors and fostering a smoother, more efficient access process. Accessible design ensures that Intelligent Access solutions are usable by individuals of varying abilities, whether they have physical disabilities, sensory impairments, or different technological proficiencies. By focusing on accessibility, Intelligent Access systems accommodate a diverse range of users, providing equal access and removing barriers that could limit functionality or adoption.

Additionally, clear and user-friendly interfaces, along with straightforward navigation, improve user satisfaction and build trust, as people feel more comfortable and confident in the system. Together, UX and accessibility enhance the overall effectiveness and inclusiveness of Intelligent Access, making it more likely to succeed across varied environments and user demographics.

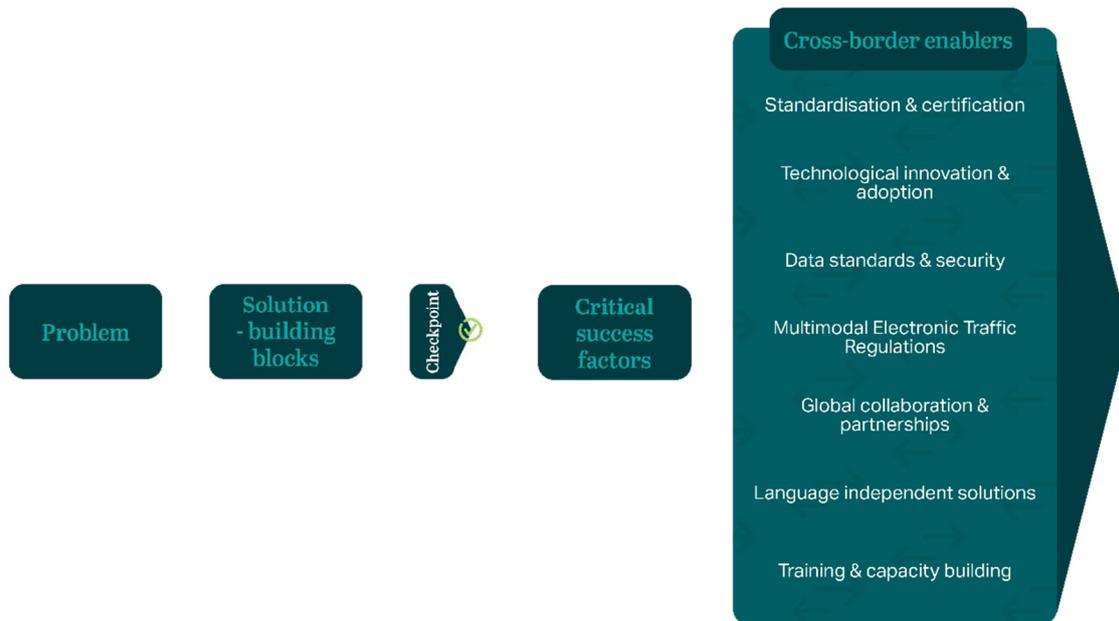
6. Political Governance and Frameworks: Political governance establishes the legislative and regulatory framework under which Intelligent Access systems operate. Supportive governance is essential for setting Intelligent Access standards, ensuring compliance, and fostering cross-border cooperation, making it a foundational element for scaling Intelligent Access to broader applications. Governance frameworks differ across countries. NRAs, police, and local authorities may have different powers in different jurisdictions. This creates a challenge for the Intelligent Access architecture and the allocation of responsibilities.

7. Awareness Raising / stakeholder collaboration and engagement: The Awareness Raising building block is critical for promoting understanding and adoption of Intelligent Access systems across diverse stakeholder groups, including government bodies, transport operators, and the general public. Raising awareness helps communicate the benefits, applications, and operational standards of Intelligent Access, ensuring that stakeholders are informed about how Intelligent Access improves safety, efficiency, and environmental sustainability within transport systems. By educating stakeholders on the capabilities of Intelligent Access – such as optimising traffic flows, reducing emissions, and enhancing road safety – awareness efforts can foster collaboration and gain support for Intelligent Access initiatives.

Awareness raising also supports regulatory compliance and aligns stakeholders on data privacy, security, and interoperability standards, which are vital for the success of Intelligent Access. Increasing familiarity with Intelligent Access technology encourages buy-in from decision-makers and users, paving the way for smoother implementation and greater public acceptance. Though some awareness initiatives exist, there remains a significant need for structured, ongoing campaigns and educational programs to clarify the role of Intelligent Access in smart transport infrastructure and to bridge knowledge gaps among stakeholders.

6.6 Cross-border enablers

These blocks are required to realise the potential of Intelligent Access through cross-border implementation. They need expertise and enterprise. These are the things that bring everything together and are required to deliver Intelligent Access at scale.



1. Standardisation and certification: Standardisation and certification are foundational building blocks for Intelligent Access in cross-border environments, as they establish consistent protocols, quality benchmarks, and trusted practices essential for global interoperability. Standardisation ensures that Intelligent Access systems, regardless of origin, follow common specifications for data exchange, security, and access controls, allowing seamless integration across different regulations and technologies. An example is EETS. This uniformity reduces complexity, speeds up deployment, and prevents compatibility issues, making it easier for multinational organisations to implement Intelligent Access solutions consistently.

Certification, on the other hand, provides formal validation that Intelligent Access systems meet specific international standards for security, privacy, and reliability, fostering trust among users and partners. With certified Intelligent Access solutions, stakeholders are assured that the systems adhere to rigorous criteria, which is particularly vital when handling sensitive data across borders. Together, standardisation and certification promote a unified framework, reducing operational risks and ensuring Intelligent Access systems can operate securely and efficiently in a global context.

2. Technological innovation and adoption: Technological innovation and adoption are fundamental building blocks for Intelligent Access as a cross-border enabler because they provide the tools and frameworks necessary to streamline operations across diverse markets. By leveraging advanced technologies such as AI, machine learning, and robotic process automation (RPA), businesses can standardise processes, improve efficiency, and reduce operational costs globally. This enables seamless collaboration and data exchange between regions, overcoming barriers such as time zones, language differences, and regulatory complexities. Through the automation of repetitive tasks and optimisation of workflows, companies can enhance their ability to scale operations, deliver consistent service quality, and respond quickly to market demands across borders, fostering international growth and competitiveness.

3. Data standards and security: This building block is essential for Intelligent Access systems, ensuring consistent, high-quality data that is reliable and protected. Data standards establish uniform protocols for collecting, structuring, and sharing information across Intelligent Access networks, making it possible for systems from various regions or providers to integrate and communicate seamlessly. This interoperability is crucial for applications like cross-border logistics, where data consistency allows accurate tracking, compliance, and efficient information sharing. Security within this framework ensures the protection of sensitive data, such as vehicle identifiers and location information, by safeguarding it from breaches and unauthorised access, which is vital for maintaining user privacy and operational integrity. Secure data management in Intelligent Access builds trust among stakeholders by aligning with regulatory requirements like GDPR and by incorporating advanced encryption and access controls. Although progress has been made in Intelligent Access data standardisation and security, further refinement is necessary to meet evolving interoperability and cybersecurity demands, especially as Intelligent Access systems grow in scale and complexity.

4. Multimodal Electronic Traffic Regulations (METR): METR refers to regulations governing the sharing and usage of electronic traffic data across multiple transport modes. This supports seamless data flow across systems, helping Intelligent Access systems integrate with other transportation networks and creating a unified traffic management approach that enhances overall efficiency and compliance with multimodal transport standards.

5. Global collaboration and partnerships: Global collaboration and partnerships are essential building blocks for Intelligent Access in cross-border environments, as they foster the alignment, interoperability, and innovation needed to create seamless, secure access systems across regions. In an interconnected world, Intelligent Access systems must work across varying legal, technical, and cultural landscapes, making collaboration between governments, regulatory bodies, and technology providers crucial. These partnerships enable the creation of unified standards, shared best practices, and compatible technologies, helping Intelligent Access systems operate consistently across borders. Working together also drives innovation, allowing stakeholders to co-develop advanced security, privacy, and data-sharing protocols that respect diverse regulations while safeguarding user data. Additionally, cross-border partnerships allow for pooled resources and shared expertise, enabling organisations to address complex challenges more effectively than they could alone. By promoting global alignment and facilitating smooth interoperability, collaboration and partnerships empower Intelligent Access systems to support safe, efficient access on a global scale.

6. Language-independent solutions: Language-independent solutions are a critical building block for Intelligent Access as a cross-border enabler because they facilitate seamless operations across diverse linguistic and cultural landscapes. These solutions can help bridge communication gaps and standardise processes regardless of language differences. Language independence allows Intelligent Access systems to scale more easily in international markets, enabling organisations to maintain consistency, ensure regulatory compliance, and optimise operations without the need for region-specific adaptations. This flexibility fosters greater agility in cross-border expansion and creates efficiencies that are critical to staying competitive in a global marketplace.

7. Training and capacity building: Training and capacity building are essential components in the successful adoption and implementation of Intelligent Access, particularly when scaling across borders. By equipping employees with the necessary skills and knowledge, organisations can ensure that they are not only able to utilise new technologies effectively but also adapt to evolving digital landscapes. Training programmes focused on Intelligent Access tools and techniques, as well as fostering an understanding of global market dynamics, empower staff to leverage automation in a way that aligns with the organisation's strategic goals. Capacity building goes beyond technical skills; it involves fostering a culture of continuous learning, where employees are encouraged to innovate, collaborate, and problem-solve. This enables organisations to drive sustainable growth, build resilience across borders, and maximise the potential of Intelligent Access solutions, while maintaining consistency and quality in a global context.

Appendix A. Detailed answers to research questions

How can Intelligent Access be used to manage assets more effectively – including optimal use, and assistance with maintenance?

Based on the general principles and objectives of Intelligent Access discussed in the literature, there are several ways in which Intelligent Access might be used to manage assets more effectively:

1. **Monitoring:** Intelligent Access systems use telematics and data analytics to provide timely monitoring of vehicles and infrastructure. This allows for immediate detection of any issues or inefficiencies, enabling timely interventions and maintenance.
2. **Optimised routing:** By ensuring that the right vehicle is on the right road at the right time, Intelligent Access can optimise routing for freight and heavy vehicles. This reduces wear and tear on infrastructure and ensures that assets are used more efficiently.
3. **Data-driven decision making:** The data collected through Intelligent Access systems can be analysed to inform decision-making processes. This includes identifying trends, predicting maintenance needs, and planning infrastructure investments more effectively.
4. **Enhanced compliance and safety:** Intelligent Access systems can ensure compliance with regulatory requirements, such as weight limits and route restrictions. This enhances safety and reduces the risk of damage to infrastructure, thereby prolonging the lifespan of assets.
5. **Resource allocation:** By providing detailed insights into the usage and condition of assets, Intelligent Access systems enable more effective allocation of resources. This includes prioritising maintenance activities and optimising the deployment of vehicles and equipment.
6. **Sustainability goals:** Intelligent Access can contribute to sustainability goals by reducing fuel consumption and emissions through optimised routing and efficient asset utilisation. This not only benefits the environment but also reduces operational costs.

Examples of the use of Intelligent Access in the effective management of assets include the Australian Intelligent Access Programme (IAP), which involves the electronic monitoring of vehicle movements 24/7, including compliance to speed, time of travel, vehicle weight and route travelled [98]. Such programmes also enable predictive maintenance.

These points highlight how Intelligent Access can be leveraged to manage assets more effectively, ensuring that infrastructure and vehicles are used optimally, maintained proactively, and aligned with regulatory and sustainability objectives.

How can Intelligent Access be used to manage traffic better – including self-management?

The literature claims several ways in which Intelligent Access might be leveraged to better manage traffic, ensuring smoother flow, enhanced safety, and more efficient use of road infrastructure better manage traffic:

1. **Traffic monitoring:** Intelligent Access systems use telematics and data analytics to provide timely monitoring of traffic conditions. This allows for immediate detection of congestion, accidents, or other disruptions, enabling quick responses to manage traffic flow.
2. **Dynamic routing:** By using real-time data, Intelligent Access systems can dynamically route vehicles to less congested roads. This helps to distribute traffic more evenly across the network, reducing bottlenecks and improving overall traffic flow.
3. **Priority access for certain vehicles:** Intelligent Access can be used to grant priority access to certain types of vehicles, such as emergency services or public transport. This ensures that

critical services can move through traffic more efficiently, improving response times and service reliability.

4. **Traffic signal optimisation:** Intelligent Access systems can be integrated with traffic signal control systems to optimise signal timings based on real-time traffic conditions. This can help to reduce waiting times at intersections and improve the overall efficiency of traffic flow.
5. **Incident management:** In the event of an incident, Intelligent Access systems can provide detailed information to traffic management centres, enabling them to coordinate responses more effectively. This includes deploying emergency services, setting up detours, and informing the public about alternative routes.
6. **Data-driven traffic planning:** The data collected through Intelligent Access systems can be analysed to inform long-term traffic planning and infrastructure development. This includes identifying trends, forecasting future traffic patterns, and planning road improvements to accommodate growing traffic volumes.
7. **Enhanced compliance and enforcement:** Intelligent Access systems can monitor compliance with traffic regulations, such as speed limits and restricted zones. This helps to enforce traffic laws more effectively, improving safety and reducing the risk of accidents.
8. **Public information and alerts:** Intelligent Access systems can provide real-time traffic information and alerts to the public through various channels, such as mobile apps and electronic road signs. This helps drivers make informed decisions about their routes, reducing congestion and improving travel times.

Aspects of Intelligent Access have been successfully used in traffic management in locations including Ontario (to provide real-time information about traffic incidents), Amsterdam (for resolving traffic jams), and Copenhagen (to prioritise public transport) [67].

How can Intelligent Access be used to make roads safer?

The literature outlines how Intelligent Access might be used to enhance road safety, ensuring that vehicles operate within safe parameters, hazards are promptly addressed, and infrastructure improvements are data-driven and targeted:

1. **Monitoring and alerts:** Intelligent Access systems use telematics to monitor vehicle movements and road conditions in real-time or near-real-time. This allows for immediate detection of hazardous situations, such as accidents or road obstructions, and the issuance of alerts to drivers and traffic management centres.
2. **Compliance with safety regulations:** Intelligent Access ensures that vehicles comply with safety regulations, such as weight limits, speed limits, and designated routes. This reduces the risk of accidents caused by overloaded or speeding vehicles and ensures that vehicles are operating on suitable roads.
3. **Enhanced vehicle tracking:** By tracking the location and status of vehicles, Intelligent Access systems can identify risky driving behaviours, such as harsh braking or rapid acceleration. This information can be used to provide feedback to drivers and promote safer driving practices.
4. **Priority access for emergency vehicles:** Intelligent Access can grant priority access to emergency vehicles, ensuring they can reach incident sites quickly and efficiently. This improves response times and enhances the overall safety of road users.
5. **Dynamic traffic management:** Intelligent Access systems can dynamically manage traffic flow based on real-time data, reducing congestion and the likelihood of accidents. For example, adjusting traffic signal timings or rerouting traffic away from accident-prone areas.

6. **Data-driven safety improvements:** The data collected through Intelligent Access systems can be analysed to identify high-risk areas and patterns of unsafe behaviour. This information can inform infrastructure improvements, such as better signage, road design changes, or targeted enforcement actions.
7. **Geofencing and restricted zones:** Intelligent Access can implement geofencing to create restricted zones where only authorised vehicles are allowed. This can be used to keep heavy vehicles out of residential areas or sensitive zones, reducing the risk of accidents and enhancing pedestrian safety.
8. **Driver assistance systems:** Intelligent Access can integrate with advanced driver assistance systems (ADAS) to provide real-time guidance and warnings to drivers. For example, alerting drivers to upcoming hazards, road conditions, or changes in traffic regulations.
9. **Incident response coordination:** In the event of an incident, Intelligent Access systems can provide detailed information to emergency responders, enabling them to coordinate their response more effectively. This includes real-time location data, traffic conditions, and the status of other vehicles in the area.

The concept of Intelligent Access can be extended to include autonomous vehicles. In the UK, the Automated Vehicles Act (AV Act) governs the safe operation [92]. Self-driving technology, together with automated vehicle safety checks before each drive, can offer an improvement to road safety by eliminating human error, which is presently responsible for 88% of road collisions, and reducing the probability of mechanical failure.

How can Intelligent Access be used to make optimal use of the limited road network capacity?

Based on the general principles and objectives of Intelligent Access discussed in the literature, there are various ways Intelligent Access may be used to optimise the use of limited road network capacity, ensuring that traffic is managed efficiently, congestion is minimised, and infrastructure is used to its fullest potential:

1. **Dynamic routing and traffic management:** Intelligent Access systems can dynamically route vehicles based on real-time traffic data, ensuring that traffic is evenly distributed across the road network. This helps to prevent congestion and makes more efficient use of available road capacity.
2. **Prioritisation of high-capacity vehicles:** By prioritising access for high-capacity and high-productivity vehicles, Intelligent Access systems can maximise the amount of goods transported per trip. This reduces the number of trips needed, thereby freeing up road capacity for other users.
3. **Time-based access control:** Intelligent Access can implement time-based access control, allowing certain types of vehicles to use specific roads during off-peak hours. This helps to spread traffic demand more evenly throughout the day, reducing peak-time congestion.
4. **Geofencing and restricted zones:** Intelligent Access can create geofenced areas where only certain types of vehicles are allowed. This ensures that heavy vehicles use designated routes, preventing them from contributing to congestion in sensitive or high-traffic areas.
5. **Real-time traffic information and alerts:** Providing real-time traffic information and alerts to drivers helps them make informed decisions about their routes. This can reduce the likelihood of congestion and ensure that road capacity is used more efficiently.
6. **Optimised traffic signal control:** Intelligent Access systems can integrate with traffic signal control systems to optimise signal timings based on real-time traffic conditions. This reduces waiting times at intersections and improves the overall flow of traffic.

7. **Data-driven infrastructure planning:** The data collected through Intelligent Access systems can be analysed to identify patterns of road usage and areas of congestion. This information can inform infrastructure planning and investment, ensuring that road capacity is expanded where it is most needed.
8. **Load balancing across the network:** By monitoring the load on different parts of the road network, Intelligent Access systems can balance traffic across multiple routes. This prevents overloading of specific roads and makes better use of the entire network.
9. **Enhanced freight logistics:** Intelligent Access can improve the efficiency of freight logistics by optimising delivery routes and schedules. This reduces the number of vehicles on the road at any given time and ensures that road capacity is used more effectively.
10. **Incident management and rapid response:** In the event of an incident, Intelligent Access systems can quickly reroute traffic and deploy emergency services. This minimises the impact of incidents on road capacity and ensures that traffic continues to flow smoothly.

Intelligent Access could compliment other initiatives aiming to enhance the use of limited road network capacity by enabling dynamic congestion pricing (adjustment of tolls to discourage peak-time travel), lane management (for example reversible lanes), 'smart' traffic signals which prioritise high-demand routes to reduce overall delays, and route optimisation algorithms for even distribution of traffic [18].

How can Intelligent Access support the efficient use of electric vehicles, through effective use of working time limits?

The literature highlights how Intelligent Access can be leveraged to support the efficient use of electric vehicles, ensuring that they are integrated seamlessly into the transport network, used optimally, and supported by the necessary infrastructure and incentives:

1. **Optimised routing for EVs:** Intelligent Access systems can provide optimised routing for electric vehicles, considering factors such as battery range, charging station locations, and real-time traffic conditions. This ensures that EVs can travel efficiently without running out of charge.
2. **Integration with charging infrastructure:** Intelligent Access can integrate with EV charging infrastructure to provide real-time information on the availability and status of charging stations. This helps EV drivers plan their routes, and charging stops more effectively, reducing downtime and ensuring efficient use of charging resources.
3. **Priority access for EVs:** Intelligent Access systems can grant priority access to electric vehicles in certain areas, such as low-emission zones or dedicated EV lanes. This encourages the use of EVs and ensures that they can travel more efficiently through congested areas.
4. **Energy-efficient driving guidance:** By providing real-time driving guidance and feedback, Intelligent Access systems can help EV drivers adopt energy-efficient driving practices. This includes optimising speed, acceleration, and braking to maximise battery life and reduce energy consumption.
5. **Data-driven infrastructure planning:** The data collected through Intelligent Access systems can be analysed to identify patterns of EV usage and demand for charging infrastructure. This information can inform the planning and deployment of charging stations, ensuring that they are located where they are most needed.
6. **Dynamic load management:** Intelligent Access can support dynamic load management by coordinating the charging of multiple EVs to avoid overloading the grid. This ensures that charging is done efficiently and sustainably, minimising the impact on the electrical grid.

7. **Enhanced fleet management:** For fleets of electric vehicles, Intelligent Access systems can provide detailed insights into vehicle usage, battery health, and maintenance needs. This helps fleet operators manage their EVs more efficiently, ensuring optimal performance and reducing operational costs.
8. **Incentives for EV adoption:** Intelligent Access can be used to implement incentives for EV adoption, such as reduced tolls, access to priority lanes, or exemptions from certain restrictions. This encourages more drivers to switch to electric vehicles, supporting broader sustainability goals.
9. **Real-time monitoring and alerts:** Intelligent Access systems can monitor the status of EVs in real-time and provide alerts for potential issues, such as low battery levels or maintenance needs. This ensures that EVs are always in optimal condition and can be used efficiently.
10. **Support for autonomous EVs:** As autonomous electric vehicles become more prevalent, Intelligent Access systems can provide the necessary infrastructure and data support for their efficient operation. This includes real-time traffic data, optimised routing, and integration with charging infrastructure.

How can Intelligent Access be used to tackle the main challenges in decarbonising road freight transport (reduce emissions, encourage multimodality)? (including inter- and multi-modality)

Based on the principles and objectives of Intelligent Access discussed in the literature, there are several ways Intelligent Access can be used to tackle the main challenges in decarbonising road freight transport, ensuring that emissions are reduced, and multimodality is encouraged through optimised routing, monitoring, and integration with other transport modes:

1. **Optimised routing for reduced emissions:** Intelligent Access systems can optimise routing for freight vehicles to minimise fuel consumption and emissions. By avoiding congested routes and selecting the most efficient paths, these systems can significantly reduce the carbon footprint of road freight transport.
2. **Integration with low-emission zones:** Intelligent Access can manage access to low-emission zones, ensuring that only compliant vehicles are allowed entry. This encourages the use of cleaner vehicles and helps to reduce emissions in urban areas.
3. **Emission monitoring:** By equipping vehicles with emission monitoring devices, Intelligent Access systems can track and report emissions data. This information can be used to enforce emission standards and identify high-emission vehicles for maintenance or replacement.
4. **Support for electric and alternative fuel vehicles:** Intelligent Access systems can provide optimised routing and charging infrastructure support for electric and alternative fuel vehicles. This includes information on charging station availability and integration with dynamic load management systems to ensure efficient charging.
5. **Encouraging multimodality:** Intelligent Access can facilitate the integration of road freight transport with other modes of transport, such as rail and waterways. By providing data and coordination, these systems can optimise the transfer of goods between different transport modes, reducing reliance on road transport and lowering emissions.
6. **Dynamic load management:** Intelligent Access systems can coordinate the loading and unloading of freight vehicles to ensure optimal load distribution. This reduces the number of trips needed and improves fuel efficiency, contributing to lower emissions.
7. **Data-driven decision making:** The data collected through Intelligent Access systems can be analysed to identify trends and patterns in freight transport. This information can inform policy

decisions and infrastructure investments aimed at reducing emissions and promoting multimodality.

8. **Incentives for low-emission vehicles:** Intelligent Access can be used to implement incentives for the use of low-emission vehicles, such as reduced tolls, priority access, or exemptions from certain restrictions. This encourages the adoption of cleaner technologies in the freight sector.
9. **Geofencing for emission control:** Intelligent Access can implement geofencing to create zones where only low-emission vehicles are allowed. This helps to control emissions in sensitive areas and promotes the use of cleaner vehicles.
10. **Intermodal hubs and coordination:** Intelligent Access systems can support the development and operation of intermodal hubs, where goods can be efficiently transferred between road, rail, and water transport. By coordinating schedules and providing real-time data, these systems can enhance the efficiency and sustainability of multimodal transport networks.

Other related initiatives include the Greening Freight package from the European Commission – a new proposal adopted to combine transport modes for more sustainable freight [37]. Enabled by the sharing of Electronic Freight Transport Information (eFTI) [86], this will target support to freight operations having the highest potential for carbon reduction by the switching of transport modes (e.g. part of the route transferred to rail or barge).

Battery Electric Trucks (BET) can be integrated with ITS to optimise routes and charging schedules, reducing downtime and improving efficiency. However, challenges include the size and weight of batteries, long charging times, and the need for a widespread network of high-power charging points. Hydrogen Fuel Cell trucks (FCET) would require a network of fuel storage and suppliers [53].

For fuel consumption reduction, systems can provide drivers with real-time feedback on driving behaviour, promoting fuel-efficient driving practices. It can also be used to optimise logistics (for example, route optimisation) including truck platooning, in which multiple trucks travel closely together, reducing air resistance.

Developments in all these areas are ongoing, and progress in all areas will be required to enable the necessary carbon reductions to be made [100]. In the UK, the government has invested £200 million to develop electric HGVs and charging infrastructure. Intelligent Access could help to optimise routes and charging schedules, reducing downtime and improving efficiency [49].

In the USA, the *National Blueprint for Transportation Decarbonization* is a comprehensive strategy for decarbonising the entire Transport sector, including freight [104]. Other strategies include the Avoid-Shift-Improve (ASI) framework and Decarbonization Pathways. The U.S. government is encouraging the use of low emissions transport including hydrogen, electric, and bio-fuelled vehicles.

How can Intelligent Access support compliance with regulations?

The literature outlines various ways Intelligent Access can be leveraged to support compliance with regulations, ensuring that vehicles operate within legal parameters, and regulatory requirements are met through monitoring, automated checks, and data integration:

1. **Monitoring and reporting:** Intelligent Access systems use telematics to monitor vehicle movements and operations in real-time or near-real-time. This allows for the immediate detection of any non-compliance with regulations, such as exceeding speed limits, overloading, or deviating from approved routes. The data can be reported to regulatory authorities for enforcement.
2. **Automated compliance checks:** Intelligent Access systems can perform automated compliance checks against regulatory requirements. This includes verifying that vehicles meet weight, dimension, and emission standards before granting access to specific roads or zones.

3. **Geofencing for restricted areas:** Intelligent Access can implement geofencing to create restricted areas where only compliant vehicles are allowed. This ensures that vehicles entering low-emission zones, residential areas, or sensitive locations meet all regulatory requirements.
4. **Driver alerts and notifications:** Intelligent Access systems can provide real-time alerts and notifications to drivers regarding regulatory requirements. For example, drivers can be alerted to upcoming speed limits, weight restrictions, or route changes, ensuring they remain compliant.
5. **Data integration with regulatory systems:** Intelligent Access systems can integrate with regulatory databases and systems to streamline compliance processes. This includes sharing data on vehicle inspections, permits, and certifications, making it easier for authorities to verify compliance.
6. **Enhanced record-keeping:** The data collected through Intelligent Access systems can be used to maintain detailed records of vehicle operations and compliance. This provides a transparent and auditable trail that can be used for regulatory reporting and inspections.
7. **Support for electronic logging devices:** Intelligent Access can support the use of electronic logging devices (ELDs) to track driver hours of service (HOS) and ensure compliance with regulations on driving and rest times. This helps to prevent driver fatigue and enhances road safety.
8. **Compliance incentives:** Intelligent Access systems can be used to implement incentives for compliance, such as reduced tolls or priority access for vehicles that meet regulatory standards. This encourages operators to adhere to regulations and invest in compliant technologies.
9. **Training and education:** Intelligent Access can provide training and educational resources to drivers and operators on regulatory requirements and best practices for compliance. This helps to ensure that all stakeholders are aware of and adhere to the relevant regulations.
10. **Incident reporting and management:** In the event of a regulatory violation or incident, Intelligent Access systems can provide detailed reports and data to authorities. This includes information on the location, time, and nature of the violation, enabling prompt and effective enforcement actions.

Notably, in the European Union, from 21 August 2024, all Freight Transport Information (FTI) must be handled electronically (eFTI). There is further information about the potential legal challenges and the legal basis for Intelligent Access in sections 4.2.2 and 4.3.

Appendix B. List of references

Ref	Title	Author	Link	Year
[1].	Australia's Intelligent Access Programme	John Baring, Chris Koniditsiotis		2020
[2].	A Framework for Intelligent Access and Compliance Assurance for High Capacity Transport	Thomas Asp, Sten Wandel	Link	2023
[3].	A future state for the UK motorway network	Colin Wilson - ITS UK		2024
[4].	Access Management Framework for Oversize-Overmass (OSOM) vehicles in Tasmania	M. Elischer, S. Buxton, A. Percy		2016
[5].	Accuracy of weight measurements on heavy vehicles: 74-ton timber transport trial	Heine Andreas Arntzen Toftegaard		2021
[6].	AEROFLEX AERodynamic and FLEXible Trucks, Rethinking Long Distance Road Transport	Ben Kraaijenhagen, Cor van der Zweep, Andreas Lischke, Julius Engasser	Link	2020
[7].	Amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic	European Commission		2023
[8].	An Overview of Freight Intelligent Transportation Systems	Vahid Mirzabeiki	Link	2013
[9].	Anas TEWEB App	Anas SpA	Link	
[10].	ANAS TE-web Special Transport: TEWeb Anas S.p.A	Anas SpA	Link	
[11].	Applying a risk-based approach to road access using telematics	Gavin Hill, Scott Greenow	Link	2021
[12].	Australia IAP (TCA page)	Web page	Link	2024
[13].	Best of two worlds: A study of heavy vehicle access in Japan and Australia	Matt Elischer, Hideyuki Wakishima	Link	2022

Ref	Title	Author	Link	Year
[14].	CEDR Call 2015 - Freight and logistics in a multimodal context	CEDR, Fluxnet	Link	2018
[15].	CEDR Contractor Report - Opportunities from RUC beyond finance - digital road services to authorities and your customers	CEDR	Link	2022
[16].	CEDR IA-GDPR Expert Meeting	CEDR		2022
[17].	CEDR joint webinar CEDR - PIARC "Intelligent access"	CEDR		2022
[18].	CEDR SAFEPAATH: Safely increasing highway capacity	CEDR	Link	2022
[19].	CEDR Technical Report 2022-01	CEDR		2022
[20].	CEDR Technical Report 2022-01: Intelligent Access (IA): current NRA practices	Loes Aart, Thomas Asp	Link	2022
[21].	CEDR Transnational Road Research Programme call 2023 Intelligent Access Description of Research Needs (DoRN)	Thomas Asp, Loes Aarts		2023
[22].	Challenges Faced by Local Governments Considering Road Access Approval for High Productivity Freight Vehicles	R. Di Cristoforo	Link	2018
[23].	Connecting Austria – first results of C-ITS-focused level 1 truck platooning deployment	Wolfgang Schildorfer, Matthias Neubauer, Walter Aigner, Andreas Kuhn, Thomas Novak	Link	2019
[24].	Connecting Austria - Linking efficient and automated freight traffic from the motorway to the city	European Commission	Link	2020
[25].	Connecting Austria Project Outline	Walter Aigner, Andreas Kuhn, Thomas Novak, Wolfgang Schildorfer	Link	2022
[26].	Cost of GPS thefts rocket in 2023	NFU Mutual	Link	2023
[27].	Demonstration Intelligent Tillträdes-Kontroll –ITK för HCT fordon	Thomas Asp, Sten Wandel, Patrik Rydén	Link	2018

Ref	Title	Author	Link	Year
[28].	Designing a shared freight service intelligence platform for transport stakeholders using mobile telematics	Christoph Heinbach, Pascal Meier, Oliver Thomas	Link	2022
[29].	Development of E-Service Provision System Architecture Based on IoT and WSNs for Monitoring and Management of Freight Intermodal Transportation	Dalė Dzemydienė, Aurelija Burinskienė, Kristina Čižiūnienė, Arūnas Miliauskas	Link	2023
[30].	DIGITALA system - Digitalt förarstöd vid dispenstransporter	Magnus Andersson, Kristina Andersson		2024
[31].	Digitala system mobilitet och system - Förarlösa tjänster i Västra Skaraborg- En förstudie inom SMaRT-projektet	Håkan Burden, Mahdere DW Amanuel	Link	2021
[32].	Digitala system mobilitet och system - Transportdispenser	Magnus Andersson, Kristina Andersson		2024
[33].	Directive (EU) 2023/2661 of the European Parliament and of the Council of 22 November 2023	Official Journal of the European Union		2023
[34].	Directive (EU) 2010/40/EU of the European Parliament and of the council of 7 July 2010	Official Journal of the European Union		2010
[35].	Directive (EU) 2019/520 on the interoperability of electronic road toll systems and facilitating cross-border exchange of information on the failure to pay road fees in the Union	European Parliament, the Council of the European Union	Link	2019
[36].	eFTI regulation EUR-Lex - 4470291 - EN - EUR-Lex. Mapping and analysis of the legal framework necessary for the transition to electronic freight information	PWC, Tal Tech, TGS Baltic		2024
[37].	European Commission adopts new proposal on combining transport modes for more sustainable freight	European Commission	Link	2023
[38].	European Electronic Toll Service (EETS): Rolling plan for ICT standardisation	European Commission	Link	2021
[39].	European Modular Systems performances comparison in freight transport operations	Emilio Larrodé, Victoria Muerza	Link	2021

Ref	Title	Author	Link	Year
[40].	Evolution of Intelligent Access in Australia - A case study in stakeholder engagement	Gavin Hill, John Gordon	Link	2021
[41].	Fatigue activities in the Norwegian Public Roads Administration	Simen Hellgren Holtberget, Statens vegvesen Norwegian Public Roads Administration		2024
[42].	Final report on pilot for IA project allowing higher weight when roads are frozen			
[43].	Financing an accelerated shift to zero emission vehicles by deploying High-Capacity Transport with Intelligent Access by 2024	Ben Kraaijenhagen, Sten Wandel	Link	2023
[44].	FLUXNET Concept toolbox for logistics development	Robert Broesi, Tertius Hanekamp	Link	2018
[45].	FLUXNET Freight and Logistics Using eXtended Network Empowerment Tools	Robert Broesi		2015
[46].	FLUXNET Logistics in a multimodal context for robust infrastructures in vital regions	Robert Broesi, Tertius Hanekamp		2018
[47].	Fordonsflottans utveckling – Avancerade förarstödsystem och digitala tjänster	Peter Smeds - Trafikverket	Link	2025
[48].	Geofenced heavy trucks to protect bridges at crossings allowing higher weight on frozen roads	Kristina Andersson, Daniel Noreland, Jenny Lundahl, Anna Eriksson	Link	2023
[49].	Government invests £200 million to drive innovation and get more zero emission trucks on our roads	UK Department for Transport	Link	2023
[50].	HEAVYROUTE – Intelligent route guidance for heavy vehicles	Anita His, Damaris Omasits, Gunnar Lindberg	Link	2007
[51].	High capacity city transport with intelligent access - A Swedish case study of transporting excavated material	Fredrik Cederstava, Sten Wandel, Ann Segerborg-Fick, David Rylander, Thomas Asp, Sara Ranäng	Link	2022
[52].	How AI Is Improving Data Management	Thomas H. Davenport, Thomas C. Redman	Link	2022

Ref	Title	Author	Link	Year
[53].	How to decarbonise heavy-duty road transport? Results of a JRC workshop on Zero Emission Trucks	European Commission	Link	2021
[54].	HV Intelligent Access and e-waybills development in Estonia	T.Tõnts, M. Jurimaa, I.Nosach	Link	2016
[55].	HVTT15: Estonian VELUB system for more efficient and greener transport	Taavi Tõnts	Link	2018
[56].	HVTT15: FALCON IV: Validation of Smart Infrastructure Access Policy	K. Kural, F. Schmidt et al	Link	2022
[57].	Implementing tech and data-driven compliance	KPMG	Link	2024
[58].	Intelligent Access and geofencing - challenges and opportunities in Sweden	Sten Wandel, Thomas Asp	Link	2021
[59].	Intelligent Access pilot for special road transport	G. van Stekelenburg, N. Kneppers, R. Kusumakar	Link	2023
[60].	Intelligent Access Policy ensuring the right vehicle on the right road at the right time	Karel Kural, Elisah van Kempen, Ben Kraaijenhagen, Thomas Asp, Loes Aarts, Sten Wandel		2021
[61].	Intelligent Access Policy ensuring the right vehicle on the right road at the right time	Karel Kural, Elisah van Kempen, Ben Kraaijenhagen, Thomas Asp	Link	2021
[62].	Intelligent Access Program: Update on Heavy Vehicle Monitoring	Chris Koniditsiotis, Peter Girgis	Link	2010
[63].	Intelligent Access Program (IAP)	Transport Certification Australia	Link	2024
[64].	Intelligent Access Programme (IAP) - Overview of the IAP functional and technical specifications	Transport Certification Australia		2016
[65].	Intelligent Access, e-waybills and eFTI Developments in Estonia	Taavi Tõnts	Link	2023

Ref	Title	Author	Link	Year
[66].	Intelligent and smart access - a way to increase the benefits and ease the implementation of high capacity transport (HCT)	Jerker Sjögren	Link	2021
[67].	Intelligent Traffic Management Systems: A Lowdown of Software & Hardware Components	Volodymyr Zavadko	Link	2024
[68].	Intelligent transport systems — Station and communication architecture ISO/DIS 21217(en)	ISO	Link	
[69].	Intelligent Transportation Systems Benefits related to traffic congestion and safety can be limited by various factors	Elizabeth Repko - GOA - United States Government Accountability Office	Link	2023
[70].	Interconnectivity of Telematics Device with Other Systems Functional and Technical Specification	Transport Certification Australia		2021
[71].	Introduktion till Kunskapsunderlag Digitalisering av vägtransportssystemet	Ludwig von Werder, AFRY, Fredric Aldelind, AFRY, Jonna Bäckström, Peter Smeds - Trafikverket	Link	2024
[72].	Köproblem Kunskapsunderlag Digitalisering av vägtransportssystemet	Trafikverket	Link	2024
[73].	Kravspecifikation för Intelligent Tillträdeskontroll 74 ton	Thomas Asp, Sten Wandel, Magnus Olbäck, Sussi Miller-Tiedemann	Link	2016
[74].	Lessons learned from the pilot Intelligent Access for special road freight transport in the Netherlands	Marcel Otto, Loes Aarts	Link	2023
[75].	Management of Electronic Traffic Regulations (METR)	Transmitted by the expert from ISO/CEN	Link	2023
[76].	Ministry of infrastructure and Water Management	Government of the Netherlands	Link	
[77].	Mitigating traffic congestion: the role of intelligent transportation systems	Aaron Cheng, Min-Seok Pang, Paul A. Pavlou	Link	2020
[78].	National Highway Vehicle Regulator use of IA: IA Program (IAP)	National Highway Vehicle Regulator (Australia)	Link	

Ref	Title	Author	Link	Year
[79].	Normalisatie van aslastregistraties voor bijzonder wegtransport	Bas Hetjes	Link	2024
[80].	Overcoming Cross-Border Access Management Challenges	Eric Olden	Link	2024
[81].	Pilot Intelligente Toegang Bijzonder Wegtransport	Marcel Otto, Loes Aarts		2023
[82].	Proposal for a Directive of the European Parliament and of the Council	European Commission		2023
[83].	Public-Private Partnerships during COVID-19: time to ask some questions	Neven Ahmad	Link	2020
[84].	Quantitative Assessment of Intelligent Transport Systems for Road Freight Transport	Gideon Mbiydzenyuy	Link	2013
[85].	Regulation (EU) 2016/679: General Data Protection Regulation	European Parliament, the Council of the European Union	Link	2016
[86].	Regulation (EU) 2020/1056 on electronic freight transport information	European Parliament, the Council of the European Union	Link	2020
[87].	Regulations Commission Implementing Regulation (EU) 2019/1213 of July 2019	Official Journal of the European Union		2019
[88].	Report on the State of the EU Road Haulage Market	Johan Els	Link	2013
[89].	Results from CEDR - work done around Intelligent Access	Thomas Asp, Loes Aarts	Link	2023
[90].	Results from CEDR work done around intelligent access	Olivier Quoy, Thomas Asp, Loes Aarts		2022
[91].	Revealing mutual Relationships between Truck Platooning and Smart Hyperconnected Physical Internet Systems	Oliver Schauer	Link	2019
[92].	Self-driving vehicles set to be on roads by 2026 as Automated Vehicles Act becomes law	UK Department for Transport	Link	2024
[93].	SIM and the art of ITS communications	ITS (UK)	Link	2017

Ref	Title	Author	Link	Year
[94].	Smart loading zones. A data analytics approach for loading zones network design	Juan Pablo Castellon, Ivan Sanchez-Diaz, Jorge Gil	Link	2024
[95].	Strengthening Public-Private Cooperation with Civil Society	World Economic Forum	Link	2023
[96].	Synthesis Join CEDR - PIARC Webinar on Intelligent Access	CEDR, PIARC joint Webinar		2022
[97].	Telematics and Intelligent Access Program (IAP)	The National Heavy Vehicle Regulator (NHVR) - Branch of Australian Gov	Link	2024
[98].	The promising evolution of Intelligent Access: From Australia to Europe	Chris Walker, Alex Moulis et al	Link	2021
[99].	The UK's data protection legislation	UK Information Commissioner's Office	Link	2024
[100].	Three keys to accelerate the decarbonization of heavy-duty vehicles in the EU	Maria Xylia, Jindan Gong, Olle Olsson, Francis X. Johnson	Link	2021
[101].	Two decades of Intelligent Access in its birthplace of Australia - where we've been and where we're going	G. Hill, C. Koniditsiotis	Link	2023
[102].	Understanding Intelligent Access and policy transfer through social network analysis	Chris Walker, Alex Moulis	Link	2021
[103].	Upphinnandeolyckor - Kunskapsunderlag Digitalisering av Vägtransportssystemet	Trafikverket	Link	2024
[104].	U.S. National Blueprint for Transportation Decarbonization	US Environmental Protection Agency	Link	2024
[105].	EU Urban Mobility Observatory: UVARExchange project kicks off	European Commission	Link	2021
[106].	UVARBox: About UVAR Exchange	UVAR Box	Link	2021
[107].	CLOSER project	CLOSER	Link	2024
[108].				

Appendix C. Data gap analysis of data systems relevant to Intelligent Access

The pages below provide detailed summaries of the data systems and technologies that already exist that may provide useful data for an Intelligent Access implementation. Each summary provides a description of the system or technology, the data types involved, potential Intelligent Access applications the data may be useful for, an evaluation of the data against a set of gap criteria, and a commentary about the data gap.

Data system	Weight in motion (WIM) systems			
Description	These systems are created to control and weigh vehicles to increase transportation safety and reduce the damage caused by over-weighted vehicles. WIM systems can improve performance by eliminating stop times of trucks on static weight control systems. Applications of such systems include transport administration and enforcement. Poor enforcement of weight limits leads to additional costs in road maintenance and damage to infrastructure and the wider environment. Jacob and Feypell (2010) have identified the advantages of WIM systems and their importance for improving transportation operations. Their study showed WIM systems reduce the risk of accidents involving overweight vehicles, reduce damage to infrastructure such as roads and bridges, and lead to time savings for both truck drivers and police.			
Data types	Weight	Axle loads	Speed	Vehicle dimensions
	Vehicle class	Time		



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Applications of WIM systems include transport administration and enforcement

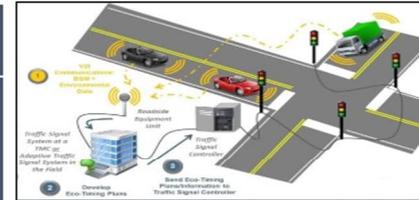
Gap diagram



Gap commentary

- WIM systems are highly reliable for detecting and processing real-time vehicle weight information.
- There have been several successful trials in North America and Europe with the data available and tested.
- WIM systems are expensive due to several factors related to their design, installation, operation, and maintenance. They can only be set up and monitored at specific points on the road network, therefore geographic coverage may be lacking.
- A critical gap would be cost, as WIM systems are specialised products which means there are fewer economies of scale in production which often leads to high costs in research and development to advance the technology.

Data system	Adaptive Signal Control Technology			
Description	A software system that uses detection technologies to automatically adjust the timing of traffic signals to work with changing traffic conditions. A central processor in the traffic signal controller evaluates data on traffic volume and speed and determines whether to adjust the traffic signal timing to improve traffic flow. Adaptive signal control technology in the controller then transmits the resulting signal timing adjustments to the traffic signals. The process repeats periodically—such as every few minutes—to keep traffic flowing smoothly.			
Data types	Traffic flow	Time	Distance	



Gap diagram



Gap commentary

- Adaptive signal control technologies use real-time data from traffic sensors and include self-diagnosing tools that can detect failures in traffic sensors or signals providing accurate and reliable data.
- These systems accumulate long-term data on traffic patterns, making historical data more mature and useful for predictive modelling.
- Initial installation of these systems may be expensive and require a higher up-front investment. These systems use highly complex datasets to deliver real-time adjustments.
- These systems are deployed in specific geographic areas offering targeted improvement often within urban areas, however, they are constrained by the existing road infrastructure and network in their location.
- Most systems process anonymised traffic data, avoiding personal data.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Adaptive Signal Control Technologies are becoming essential for improving mobility through smoothing traffic flows on the road network

Data system	Driver Behaviour monitoring and control systems			
Description	These systems analyse the speed and acceleration of drivers during transportation operations and provide feedback for improving driving skills. Such feedback leads to reduced fuel consumption and results in more eco-friendly transportation. It also supports transportation resource management: using technologies for improving the concentration of drivers leads to a reduction in accidents and to an improvement of the safety of operations (see Marell and Westin, 1999).			
Data types	Speed	Acceleration and braking	Cornering	Engine metrics
	Fuel	Idling time	Distance	Behavioural events



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Driver behaviour monitoring and control systems can optimise vehicle use and improve driver safety

Gap diagram



Gap commentary

- These systems can understand specific driver behaviour and convert this information into early warnings, alerts, and precautionary measures to safeguard drivers in real time. These systems accumulate long term data through patterns and monitoring.
- These systems can relay information from either the driver or a central monitoring system to help improve driving efficiency and optimise vehicle usage.
- The data is available and growing with increased usage of such types of data in newer vehicles.
- Some users may not appreciate the data being recorded and used for enhancement. This would require methods to anonymise the data collected.

Data system	Delivery Space Booking Systems			
Description	These systems allow the space for parking to be booked for a specific vehicle to load or unload freight during a specific time window. Such systems are useful in urban areas where space is at a premium, as well as at transport terminals. These systems contribute to the environmental and efficiency/effectiveness by eliminating the wasted time spent searching for parking spaces. Teodorovic and Lucic (2006) discussed the need for intelligent parking booking systems and have proposed strategies for designing such systems. According to their study, the application of these systems reduces the total number of vehicle trips during a specific time (improving environmental performance) and maximises the utilisation of parking space (enhancing the efficiency of transportation infrastructure).			
Data types	Time	Capacity	Volume and weight	Vehicle details
	Cargo details			



Gap commentary

- These systems can be accurate and reliable in improving the efficiency of transportation by maximising the utilisation of parking spaces.
- These systems can be utilised in urban areas with space limitations therefore the system has high geographic coverage and can cover large locations.
- The cost of these systems may increase depending on the intelligent application and scale of use. A larger urban area could mean complexities in setting up and monitoring the system. The data for these systems are growing and will help shape improved versions in the future.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Delivery space booking systems can help improve efficiency, security and reduce congestion in busy urban areas.

Data system	Vehicle Identification Systems (VIS)			
Description	Information such as the type and class of vehicles, their registration numbers and other identification information is used in different transportation operations for transportation resource management. Such information is also used by authorities for controlling the security of transportation operations. License plate recognition is an important research area in transportation and has been broadly studied in the last two decades (Thome et al., 2011).			
Data types	Identifiers	Descriptive details	Ownership	



Gap diagram



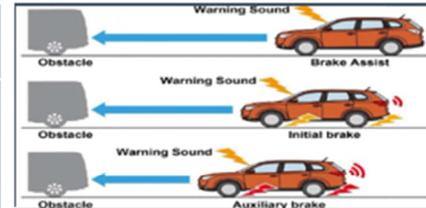
Gap commentary

- Vehicle Identification Systems work efficiently and are highly accurate.
- These systems can track the positioning of vehicles, identifying how long they stay in a specific geographic location while covering a large quantity of vehicles.
- These systems can be expensive to install and maintain, especially across large areas.
- The systems can pick up information from number plate registration, which may have some data privacy concerns. However, these registrations are normally anonymised to avoid any direct personal information being exposed.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route-planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Vehicle identification systems play a key role in enhancing security, efficiency, and automation in various industries such as transportation, logistics, parking management and toll systems

Data system	Crash Preventing Systems (CPS)			
Description	Technologies such as sensors are used in these systems to reduce the probability of collisions. For example, sensors installed on a car can warn drivers when they get close to an object. Another kind of crash preventing system can detect objects and provide information regarding the probability of incidents by measuring the distance between vehicles via the transportation infrastructure. If a pedestrian jumps in front of a vehicle a signal is sent to the vehicle and leads to the prevention of a collision. Systems for the detection of pedestrians at night are an example of this group. Tsugawa et al. (1997) have described how the structure of intelligent vehicle/highway systems (IVHSs) increases transportation safety. Moreover, Chira-Chavala and Yoo (1994) have demonstrated that the application of cruise control systems leads to a reduction in the number of traffic incidents.			
Data types	Speed	Acceleration and braking	Cornering	Engine metrics
	Fuel	Idling time	Distance	Behavioural events



Gap diagram



Gap commentary

- CPS constantly track the vehicle's surroundings and geographic data as well as using sensors to understand its surroundings accurately. They work well in high-traffic environments and locations with many variables. However, these systems can be over cautious and activate when they may not necessarily be needed, although work effectively in worse cases.
- This type of data is growing and has been around for over 10 years. In terms of setup costs, these systems can be higher depending on their specifications and needs.
- The data from CPS allows for the analysis of multiple variables, however integrating data from various sensors can be technically complex.

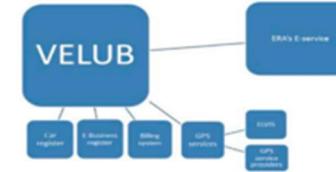
Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

Crash-preventing systems focus on aiding driver safety during travel

Data system	VELUB System			
Description	A digital solution to help road owners and police monitor abnormal heavy vehicle movements in Estonia. It is a cloud monitoring platform, that is currently in the live testing phase. VELUB developers are working towards a system that can be used in Europe for longer and/or heavier vehicles, to monitor trucks and protect other road users most effectively. In the Estonian state, the 52t timber transport project saves 10 million EUR/y and 20% CO ₂ , NO _x . In the future, road and bridge infrastructure can be protected even more once the VELUB System is online. The potential application to the rest of the world could save billions per year in cost (Euro).			
Data types	Temperature	Time	Economical dimension	Dimensions
	Weight			

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset-management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource-management	Traffic-control	Vehicle-parking	Fuelling-/charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

The VELUB system is primarily focused on aiding abnormal heavy vehicle movements. It is currently being trailed in Estonia, with future applications for the rest of the world.



Gap diagram



Gap commentary

- The VELUB system is currently in its live testing phase and, therefore lacks sufficient data to be understood fully. The trial is being built into bigger systems which is hoped to grow in scale.
- There are critical gaps in cost, complexity, and maturity of data type: This data is still in the early stages, and although it covers the whole of Estonia, geographically there are limitations with how widely the data can be used and applied to other countries. The potential for worldwide usage is promising, however further data is required to prove this claim.

Data system	Closed Circuit Television (CCTV)			
Description	CCTV involves video monitoring systems placed along roadways or intersections that transmit video for real-time viewing for uses such as identifying signal outages or incidents. Closed circuit television cameras are tied into a transportation management centre's network so that staff can view the video feed. Some cameras always show the same view, while others can be panned, tilted, or zoomed to get multiple views of the same roadway.			
Data types	Cameras	Recording devices	Transmission	Storage solutions
	Viewing and monitoring			



Gap commentary

- CCTV cameras are accurate and reliable in what data they produce with high clear-definition video footage. The data is available and can be tracked back to the year 1942.
- The data is in video form which can lead to complexities in extracting information from the data. Sometimes the data could be subjective depending on the perspective, angle, or positioning of the system.
- There may be privacy concerns with personal data collected from the recordings and its usage.

Intelligent access applications

Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling-/charging
Driver support	Infrastructure support	Environmental management	Fleet management

CCTV can be used for security, surveillance, traffic management, transportation aids and monitoring

Data system	Connected Vehicles			
Description	Connected vehicle technologies enable the exchange of safety messages among vehicles and the roadway infrastructure. Connected vehicle technologies use short-range radio signals. Vehicles equipped with transceivers send and receive messages with other vehicles, infrastructure, or mobile devices. Transportation infrastructure equipped with roadside transceivers can receive messages from and send messages to local vehicles to, for example, provide information to drivers about road surface conditions or the time remaining for a green traffic signal.			
Data types	Data transmission	Distance	Fuel efficiency	Time



Gap diagram



Gap commentary

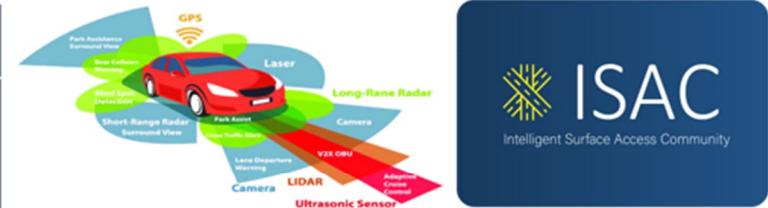
- CV are reliable and accurate in communicating information across the transport network to road users
- CVs have been around since 1996
- CV has connectivity capable of spreading across the road network nationwide
- The cost of CVs can vary with some sophisticated systems being more expensive while other basic systems are integrated for less outlay

Intelligent access applications

Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Connected vehicles work to communicate with transport infrastructure to keep road users safe, alert and aware of any live changes to the network

Data system	Detection Technologies			
Description	Various devices detect vehicles and other users of the road on a roadway, potentially including pedestrians and cyclists. Detection technologies include inductive loops and video detection systems (i.e., cameras). Inductive loops are coils of wire embedded in the pavement; an electric current changes when vehicles pass over them. Video detection systems mounted above intersections identify the presence of vehicles, count or classify them, and/or measure their speed. These devices transmit traffic information to traffic signal controllers that may be programmed to adjust the timing of traffic lights.			
Data types	Optical technologies	Radar technologies	Sonar technologies	Infrared technologies
	Magnetic technologies	Chemical sensors	Biological sensors	Acoustic technologies



Gap diagram



Gap commentary

- These systems are reliable under different environmental conditions offering high levels of accuracy and contactless identification
- They scan and analyse large quantities of traffic data making them valuable for intelligent access. These systems have been widely adopted with data formats and processes maturing over time.
- Most detection systems have low operating costs once installed, offering longer-term savings.
- Some detection technologies can provide complex data sets, which analyse traffic flows, vehicle types, and pedestrian movements.
- These systems are often deployed in specific high-priority areas. Rural or underdeveloped areas may miss out.
- Most systems collect anonymised data, minimising privacy concerns.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Detection Technologies are used to help improve traffic management, security, and overall system efficiency

Data system	Dynamic Message Signs (DMS)			
Description	Electronic road signs used to inform travellers of incidents, travel times, detours, or special events. Dynamic message signs may connect to a transportation management centre, from where the signs can be operated remotely, or they may update messages automatically based on traffic data. For example, software may process information on travel speeds from detection technologies and then automatically post travel times for a particular corridor.			
Data types	Display technologies	Communication technologies	Control systems	



Gap diagram



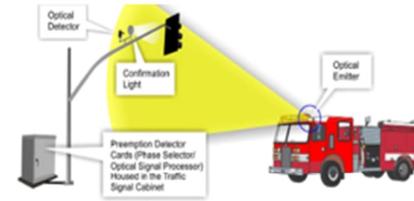
Gap commentary

- DMS can display highly accurate, context sensitive information such as parking availability, travel time or toll rates.
- The signs operate using real time data from traffic management systems ensuring they can constantly display relevant information to drivers and pedestrians.
- DMS have been used for a long time and rely on constantly uploaded data. The systems pull information from a variety of sources such as traffic cameras, road sensors and weather monitoring systems, displaying them in a form which is easy to understand.
- DMS have higher initial setup costs but can lead to longer term cost savings by reducing the need for manual traffic management.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental-management	Fleet-management

Dynamic Message Signs are a valuable tool for improving traffic management and communicating live up to date information to road users

Data system	Emergency Vehicle Pre-emption Systems (EVP)			
Description	Devices that alter planned traffic signal timing to give green lights to emergency vehicles going through intersections. Equipment aboard an emergency vehicle emits a signal detected by devices at intersections. Software interprets the information and directs the traffic signal controller device to, for example, keep the light green until the emergency vehicle has passed through. (This type of system can use connected vehicle technology.)			
Data types	Distance data	Time data	Performance metrics	Sensor data
	Traffic flow data			



Gap diagram



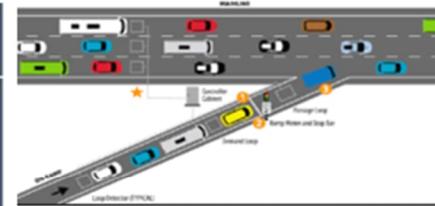
Gap commentary

- EVPS are designed to be reliable and accurate in reducing the disruption to overall traffic flow while prioritising emergency vehicles.
- EVPS constantly communicate with traffic signals providing real-time data on the location and status of emergency vehicles, allowing intelligent access systems to react instantly. This type of data is high in maturity with long-term data collected proving its effectiveness.
- EVPS generate complex data related to traffic flow, vehicle speed, and signal timing which can lead to difficulties in interpreting data.
- EVPS are commonly deployed at major junctions along emergency routes, however, EVP's may not store rich data in rural areas. ~~which may not display data in rural areas.~~

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed-compliance	General-compliance	Vehicle-tracking	Route planning
Resource-management	Traffic control	Vehicle-parking	Fuelling/charging
Driver support	Infrastructure support	Environmental-management	Fleet-management

Emergency Vehicle pre-emption systems can enhance road safety, reduce emergency response times, and improve traffic flow

Data system	Ramp Meters		
Description	Traffic signals on freeway on-ramps that regulate the frequency of vehicles entering freeway traffic. Detectors placed on the onramp and on the freeway feed data on traffic conditions into a ramp meter controller that uses this information to determine how to time the signals allowing waiting vehicles to enter the freeway. By introducing the traffic at a controlled rate, ramp meters help reduce congestion, improve traffic flow, and enhance safety on highways.		
Data types	Traffic flow and control	Performance metrics	



Gap diagram



Gap commentary

- Ramp meters are reliable for real-time traffic during peak hours, although less useful during off-peak hours.
- Ramp meters are connected to the road network and the data that's gathered is readily available for analysis, although there will be less data available in low traffic volume areas.
- The historical data collected from ramp meters allows traffic management systems to refine metering algorithms and predict future traffic conditions.
- Ramp meters have high installation costs but offer relatively low cost for traffic management, by avoiding major infrastructure investments and managing the current traffic flows.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Ramp Meters can optimise vehicle access to highways, enhance road safety, and improve the overall efficiency of traffic management

Data system	Road Weather Information Systems (RWIS)			
Description	Systems that process information from environmental sensor stations along a roadway to alert traffic managers or the public about hazardous conditions. Multiple environmental sensors along a roadway measure conditions such as visibility or humidity. Software processes and communicates this information to transportation management centres to help with decision-making. In an advanced road weather information system, the software may automatically take certain actions, such as displaying a reduced speed limit on a dynamic message sign during hazardous conditions.			
Data types	Environmental measures	Pavement conditions	Temperature measures	Infrastructure measures
	Traffic flow data	Ramp metering control data	Queue management data	Congestion data



Gap diagram



Gap commentary

- RWIS integrate data from multiple sensors ensuring the overall assessment of road conditions is constantly monitored and highly accurate.
- RWIS provide a continuous stream of data making real-time weather and road condition information available for traffic management. This type of data has been collected and analysed since 1861.
- The initial cost of installation is high with widespread geographic coverage needed. Regular maintenance is required where sensors are exposed to extreme weather conditions.
- The data is built from many variables and can require advanced algorithms to analyse.

Intelligent access applications			
Heavy-vehicles	Abnormal-loads	Dangerous-goods	High-capacity-vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle-tracking	Route-planning
Resource-management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet-management

RWIS can improve road safety by allowing traffic management systems to make informed decision about speed limits, road closures, and vehicle access during adverse weather conditions

Data system	Critical infrastructure management system (CIMS)			
Description	CIMS involves the monitoring, maintenance, and protection of essential facilities and systems, such as transportation networks, power grids, water supply, communication systems, and bridges. These infrastructures are crucial for the functioning of society and their security and resilience are vital. Bridge Operators use the processed data for the bridge effect calculation to decide if the bridge is in danger of being damaged. In case of severe damage (safety) risk the bridge operator can display a warning to truck drivers and advise them to either reduce their speed or increase vehicle separations.			
Data types	Geospatial data	Time	Date	Performance and condition metrics
	Risk and impact metrics			



- ### Gap commentary
- CIMS are designed for high reliability, with precise monitoring and full control.
 - Data from access points, sensors and control systems ensures comprehensive coverage of critical assets
 - Many critical infrastructure systems have been operational for long periods resulting in mature data sets that can forecast usage patterns and maintenance needs.
 - CIMS require regular updates, sensor replacements, and network maintenance leading to ongoing costs that may increase over time.
 - Integrating data from multiple infrastructure sources can be complex and requires sophisticated data processing systems.

Intelligent access applications

Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Critical Infrastructure Management ensures that access to critical assets is controlled, monitored, and optimised to enhance security operational efficiency and system resilience

Data system	Intelligent Route Guidance Systems (IRGS)			
Description	IRGS provide route planning based on processed data on the current traffic situation, from the traffic management centre. The traffic situation and a suite of effect models (e.g. emission model, fuel consumption model, bridge and road damage index) are the basis for the route planning service provider to offer route planning, including specialist planning for HGVs, routing and HGV monitoring to logistics companies. Navigation service providers can use the data to offer a navigation service to logistics companies.			
Data types	Real time traffic data	Historical traffic data	Weather data	Road network data
	Routing algorithms	GPS	Telematics and sensors	User interfaces and visualisation



Gap diagram



Gap commentary

- IRGS are highly reliable due to their ability to adapt to real-time traffic data and can provide accurate turn-by-turn navigation.
- IRGS pull data from a wide range of sources and have been in use for many years, resulting in mature highly refined datasets.
- Implementing and integrating IRG systems for large scale or citywide developments can be costly, including the cost of continuous maintenance of the data sources.
- The complexity of data from multiple sources, as well as the volume of data generated by traffic monitoring systems, can increase the technical complexity of these systems.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

IRG systems ensure that vehicles are directed efficiently, enhancing traffic flow, reducing congestion, and improving access to restricted or high priority areas

Data system	Accident Warning Information Systems (AWIS)			
Description	AWIS provide accident information to nearby vehicles to enable the reduction of the effect of accidents, for example queue build up, chain accidents, fire, and rear end collisions (found to make up to 13.5% of accidents in Sweden in 1999 (Biding and Lind, 2002)). Freeway incident warning systems have shown that travel times could be reduced by 21% (Birst and Smadi, 2000) and fuel and delays by up to 3% and 7%, respectively (Wunderlich et al., 1999).			
Data types	Display technologies	Communication technologies	Sensor data	Control systems
	Time data	Distance data	Speed data	



Gap diagram



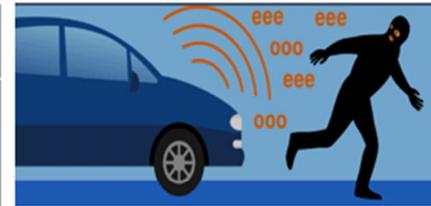
Gap commentary

- AWIS are designed to provide real time accident alerts and pull data from multiple sources.
- AWIS have been implemented and used for over 10 years providing mature reliable data that can be used to improve system performance.
- Installation and maintenance of the AWI systems can be expensive, especially in regions with limited existing infrastructure, however these systems can lead to long-term cost savings for road authorities.
- The data collected by AWIS can be complex, requiring advanced algorithms to analyse it. With so many potential data sources there is a risk of overload making it difficult to prioritise or filter.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

AWI systems help reroute traffic, improve emergency response times, and enhance overall road safety

Data system	Theft Alarm and Recovery Systems (TARS)			
Description	TARS provide real-time location and status information about stolen goods and vehicles to the goods owner, traffic and transport managers and other legitimate stakeholders. They combine real-time monitoring, automated access control, geofencing, and advanced tracking to detect theft, initiate recovery efforts, and improve security infrastructure. These systems play an important part in preventing unauthorised access and accelerating the recovery of stolen assets, making them an essential feature for vehicle management, urban planning, and law enforcement.			
Data types	Detection data	Alarm data	Surveillance data	Access control data
	Recovery tracking data	Emergency response data		



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

TARS can enhance security and recovery capabilities for both vehicles and infrastructure. Crucial for vehicle management, urban planning, and law enforcement

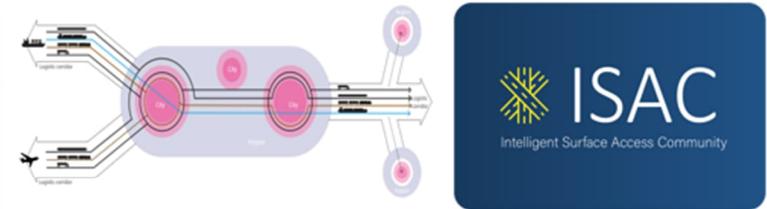
Gap diagram



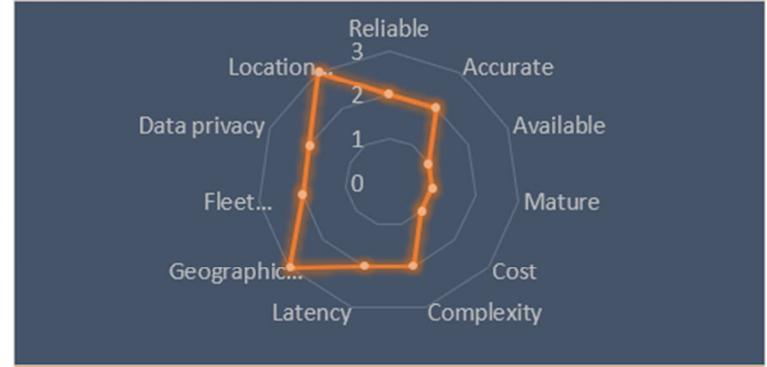
Gap commentary

- TARS are highly reliable in detecting unauthorised access based on the quality of hardware and the robustness of network connectivity
- TARS is typically accurate however may be affected by false alarms through minor vibrations or mechanical issues
- The TARS have low latency and can cover locations with GPS being able to cover fleets.
- This type of data is easily accessible and tracked back with historical evidence.
- The cost of such systems can be regarded as a critical gap in this case as the hardware, connectivity, and system integration can be expensive

Data system	FLUXNET infrastructural spatial model			
Description	FLUXNET is a project developing transport models focussed on optimising or adding terminals, infrastructure and modes on three different scales. Logistic oriented development (LOD) is a suite of tools for improving the use of the spatial infrastructural system for transport and logistics. The models focus on terminals, modes, and infrastructure. To achieve an integrated approach towards logistics, land-use and infrastructure planning, the FLUXNET study is exploring the potential benefits of integrating multimodal transport networks, liveability, and spatial planning.			
Data types	Infrastructure data	Planning data	Spatial planning data	



Gap diagram



Gap commentary

- The FLUXNET model is a valuable instrument for a planner to improve logistics-related planning issues.
- When the model is applied to a specific geographical region, the principles are valuable in finding opportunities for improving spatial and network performance (mobility, living quality, environmental quality, etc).
- The test bed applications show logistics is an increasingly important topic. On the regional scale, logistics face new challenges posed by circular economies and the rise of XXL warehouses. However, based on the testbeds there is little development among planning authorities to guide these developments. One of the critical gaps is the cost for optimising all components (Terminal, modes and infrastructure).

Intelligent access applications

Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

An example is the test bed Lombardy-Mortara Rail Terminal an electrified intermodal terminal

Data system	Transport Order Handling Systems (TOHS)			
Description	TOHS provide real-time order information sharing between the goods owner, transport manager, driver, and other parties, as well as feedback when the orders are satisfied. TOHS are a critical tool used in logistics, transportation, and fleet management to manage and track orders, vehicle movements, and delivery statuses. They streamline the process of assigning, monitoring, and fulfilling transport orders across fleets, helping companies optimise their logistics operations.			
Data types	Order processing	Dispatch management data	Route planning data	Tracking and visibility data
	Communication and notifications data	Documentation and compliance data	Returns and claims management data	



Gap diagram



Gap commentary

- TOHS work well to automate access management, prevent unauthorised access, and provide insights into fleet operations reliably.
- TOHS data is available in real time, accurately displaying information such as order status, delivery schedules, and vehicle locations. The data is well established in industries such as logistics, shipping, and retail making it mature and reliable.
- TOHS can be costly especially for large scale operations which include software licensing, integration development and ongoing maintenance. However, the system can save costs in labour and improve operational efficiency.
- Data privacy concerns must be carefully managed, particularly in large or sensitive operations.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling/charging
Driver support	Infrastructure support	Environmental management	Fleet management

TOH systems aim to streamline access control, improve operational efficiency, and enhance security across transport and logistics.

Data system	Transport Resource Optimisation Systems (TROS)			
Description	TROS attempt to optimise overall resources including road infrastructure, vehicle capacities, vehicle trips, so that the optimisation of subsystems (e.g. routing, driver planning) may not negatively affect other systems such as road maintenance. By optimising various aspects of fleet management, including vehicle allocation, route planning, driver schedules, and fuel consumption, TRO systems help companies reduce costs, improve operational performance, and enhance service levels.			
Data types	Fleet management data	Drive management data	Route optimisation data	Load optimisation data
	Scheduling and planning data	Real-time monitoring data	Data analytics and reporting data	



Gap diagram



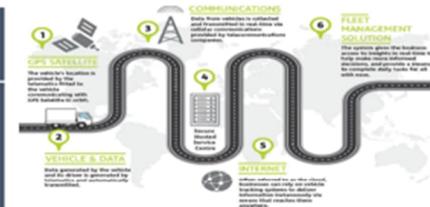
Gap commentary

- TROS are highly reliable and provide accurate predictions for optimisations particularly in route planning, fuel efficiency, and vehicle utilisation. The systems can adapt to real time data efficiently.
- TROS generate a large amount of data in real time and have been used in logistics and transportation making it a mature and well-understood technology.
- The initial implementation of a TRO system can be costly, but it will reduce operational expense through optimisation.
- The systems can be complex with a need to break down multiple variables simultaneously. Also managing the system requires specialised expertise and real time monitoring with regular adjustments to ensure optimal performance.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling/charging
Driver support	Infrastructure support	Environmental management	Fleet management

TRO systems help to reduce costs, improve operational performance, and improve service levels.

Data system	Vehicle Follow-up Systems (VFS)			
Description	VFS collect and analyse vehicle performance-related data including empty mileage, fuel consumption and vehicle status, then reports such data to different stakeholders such as fleet owners and vehicle inspection agencies. The system also allows for monitoring compliance with pre-set routes and schedules, optimising resource allocation, and improving the overall transparency of fleet operations.			
Data types	Real time GPS tracking data	Telematics data	Maintenance data	Driver performance data
	Route deviation data	Fuel consumption data	Incident reporting data	



Gap diagram



Gap commentary

- VFS are reliable and accurate as the data collected is precise and real-time. However occasional GPS inaccuracies or delays in data transmission could lead to minor discrepancies in vehicle tracking.
- VFS tracking data is well established and standardised making it highly mature and reliable, often used in logistics, transportation and security.
- The implementation of VFS can incur significant costs although it will offer long term savings in use.
- VFS systems are less complex than other fleet management systems but require strong technical infrastructure to manage data flow between tracking devices.
- They have a large geographic area coverage and can cover a large array of fleets.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless-cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

VFS can improve access control, security, and operational efficiency.

Data system	Route Guidance Systems (RGS)			
Description	RGS provide information relevant to specific corridors related to, for instance, zebra crossings or school children, as well as helping the infrastructure owners influence the use of a given route. Studies have shown they result in a reduction in travel times under average congestion conditions for all vehicles (Wunderlich, 1998). RGS focus on specific route information allowing vehicles to reroute in response to changing conditions such as traffic jams or road closures. RGS enhance the ability to manage access control based on route adherence, optimise traffic flow, and reduce congestion.			
Data types	Route information	Traffic data	Weather data	Geospatial and mapping data
	Road condition data			



Gap diagram



Gap commentary

- RGS are reliable in providing real-time route recommendations and updates based on traffic conditions, road closures, and other factors. They typically use GPS data, traffic feeds and predictive analytics to provide high accurate routes.
- Route guidance data is mature with widespread usage and has the potential of AI-driven predictive route planning in future developments
- RGS systems are not complex and are designed for geographic mobility allowing a large amount of available data to be relayed at very low latency.
- Managing the sensitive data requires compliance with regulations like GDPR although the route data is typically less sensitive than other vehicle or personal data.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

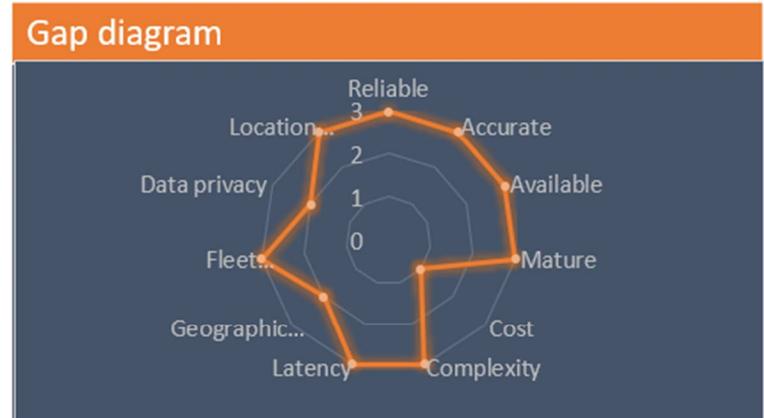
RGS helps reroute vehicles in response to changing conditions like traffic jams or road closures

Data system	Road User Charging Systems (RUCS)			
Description	RUCS (electronic toll collection) collect charges related to the use of road infrastructure based on location, time, road type and vehicle type. Many such systems are anticipated in Europe (Kageson and Dings, 2000). Trials have led to a reduction in traffic growth (5%), vehicle trips (8%) and empty trips (20%) (Elvika et al., 2007). Congestion control schemes in Stockholm (related to but different from an RUC) have led to reduced traffic (10 to 15%), shorter queue time (30 to 50%), lower emissions (2.5%) and fewer accidents (5 to 10%), (Broaddus and Gertz, 2008) as well as 16% less congestion (Algers et al., 2006).			
Data types	Vehicle identification	Usage data	Location and movement data	Tolling and pricing data
	Compliance and enforcement data	Environmental and traffic data		



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

RUCS can be used to manage and regulate vehicle entry into specific zones, such as low-emissions zones, highways, or urban areas, based on vehicle type, route, and time of day.



- Gap commentary**
- RUCS use GPS, RFID, and ANPR technologies to identify vehicles and charge them accurately. These data formats are well established, providing mature data.
 - The cost of implementing and maintaining these systems is substantial due to the need for infrastructure for example; toll booths, ANPR cameras, and transaction processing systems. Managing this data can be complex and requires constant monitoring.
 - Whilst RUCS are highly mobile across defined zones they are limited in where the infrastructure is in place.
 - Managing the privacy and security of vehicle location and payment data is critical, requiring encryption, secure storage, and strict access control to prevent data breaches.

Data system	Real Time Track and Trace of Goods System (RTTS)			
Description	RTT provides information such as speed, location and status of goods to goods owners, transport managers and other stakeholders, that can enable tracking of such goods if necessary. RTTS systems monitor and provide real-time updates on the location and status of goods in transit.			
Data types	Speed data	Location data	Temperature data	Humidity data
	Shock data	Acceleration data	Shipping data	



Gap diagram



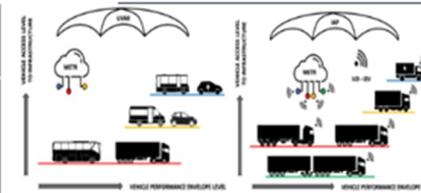
Gap commentary

- RTTS are highly reliable using GPS and RFID sensors to track the location and condition of goods in transit. However, the accuracy of these systems may be compromised in environments with poor GPS signals.
- RTTS data is well established in industries like logistics, supply chain management, and manufacturing providing mature data.
- The cost of implementing RTT systems can vary based on the scale and technology used. While the upfront investment is high, there are benefits in long-term cost savings.
- RTT systems involve a certain level of complexity due to the need for sensors, software platforms, and real-time data analysis.
- Ensuring the privacy and security data generated by RTT systems is essential, especially in high-value or sensitive goods sectors where data breaches could have significant consequences.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle-parking	Fuelling/charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

RTTS can optimise resource allocation, streamline access control, ensure regulatory compliance, and respond swiftly to disruptions

Data system	Urban Vehicle Access Regulation (UVAR) IA policy			
Description	<p>The idea of intelligent vehicle access is supported by the European Parliament through recent preparatory action called Urban Vehicle Access Regulation (UVAR). The emphasis is to establish a form of a traffic management system that regulates access to specific urban areas and locations. Access is conditional upon a vehicle type, age, or emission category for a specific time of the day or day of the week, for example as practiced in the NORDICWAY project.</p> <p>UVAR provides a feasible approach to facilitate the deployment of the new generation of road freight vehicles whilst ensuring operational safety and compatibility with the infrastructure and the environment.</p>			
Data types	Average daily traffic	Lane and/or bridge width	Accident history	Cornering space and road slope
	Policy makers / Planners and owners	Low-speed manoeuvrability	Dynamic stability	Environmental impact



Gap diagram



Gap commentary

- UVAR is an Intelligent Access policy aimed at ensuring the right vehicles are on the right roads at the right times.
- The UVAR pilot programme aims primarily at enhancing urban mobility, similar to the approach of intelligent Access policy. It can be upscaled and adapted for road freight transport.
- The established enforcement technologies that will be used are highly reliable with good accuracy. Although the policy is relatively new the data that is being used is mature given it takes information from previously trialled and tested methods such as traffic management systems.
- A critical gap would be cost. Significant investment in infrastructure and enforcement systems is needed, although this could be offset with revenue from charges and penalties.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

UVAR ensures improvements in urban living environments, more flexible traffic management that is highly effective and beneficial for clean mobility.

Data system	Mobile Telematics Systems (MTS)			
Description	Transport objects are presently equipped with radio frequency identification (RFID), sensor-tracking devices, and telematics units enabling IoT services to optimise transport operations (Fargu Harson et al. 2021). As a result, the objects gain intelligent characteristics encompassing identification, localisation, communication, sensing, or logical functions and enable innovative IoT services in supply chain management (Atzori et al. 2010).			
Data types	Geospatial data	Time and data	Performance metrics	Environmental conditions



Gap diagram



Gap commentary

- MTS provide reliable data from GPS, vehicle diagnostics, and mobile devices. They provide precise data on vehicle and driver behavior.
- MTS data is well established from widespread use in fleet management and logistics, ensuring smooth integration with Intelligent Access systems.
- Costs are moderate with lower upfront costs compared to more complex systems.
- The complexity of the data is moderate with systems requiring real-time data analysis and coordination of multiple inputs.
- MTS may have sensitive data that requires robust security and privacy measures to protect vehicle and driver data, particularly in regions with strict regulations.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless-cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route-planning
Resource management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

MTS can optimise traffic management, enhance safety, and regulate access based on driver behaviour, vehicle performance, and environmental factors

Data system	On-board Safety and Security Monitoring Systems (SSMS)			
Description	SSMS help the driver to constantly monitor the vehicle and its contents without manual checks. These systems continuously track and monitor vehicle conditions, cargo status, and safety parameters in real time. This allows drivers and fleet operators to ensure compliance with safety regulations, such as temperature control for refrigerated products, tire pressure, or cargo security, without manual inspections.			
Data types	Sensors and cameras	Alert systems	Temperature monitoring	



Gap diagram



Gap commentary

- SSMS provides reliable monitoring of vehicle and cargo conditions, though occasional issues such as sensor malfunctions may affect performance.
- The systems can be highly accurate with precise tracking of safety and security components such as temperature, pressure, and vehicle health.
- SSMS systems are well-established in sectors like food transport, pharmaceuticals, and hazardous materials, ensuring stable data for Intelligent access integration.
- SSMS can be costly, with investment in sensors, monitoring systems, and software integration, though long-term savings through improved safety are likely.
- There is a need for robust security and compliance with privacy regulations due to the tracking of valuable / regulate goods.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

SSMS can provide real-time safety data that informs access decisions, ensures compliance with safety standards, and reduces the risk of accidents or cargo damage

Data system	Pay as You Drive Systems (PYDS)			
Description	PYDS provide location-related information to insurance companies to help reward drivers according to risk attitudes and exposure and reinforce good driving (Azudrive-PYD, 2013). Studies show a reduction of 10% in mileage and fuel consumption and 15% in total collisions (Litman, 1997). PYDS encourages safer driving by offering financial incentives for lower-risk behaviour			
Data types	Distance	Speed	Time	Driving events

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

PYDS can optimise road use, improve traffic management, and enhance safety while supporting personalised access controls based on individual driving patterns



Gap diagram



Gap commentary

- PYDS can have reliable tracking of driver behaviour and location, though occasional signal loss or inaccuracies may occur in remote areas.
- The data collected tends to be accurate with precise data on speed, braking, and acceleration, though certain environmental factors may affect GPS accuracy.
- PYDS data is well established with data formats and standards used in the insurance industry, ensuring stable and reliable data for intelligent access integration.
- The costs for PYDS are moderate with affordable upfront costs for telematics devices or mobile apps, though intelligent access integration may increase overall costs significantly.
- PYDS requires strong data protection and privacy measure due to the detailed tracking of driver behaviour and location.

Data system	Remote Monitoring Systems (RMS)			
Description	RMS allow dispatchers and fleet owners to continuously track the status and location of vehicles in real time. These systems provide valuable data on vehicle conditions, driver behaviour, and route progress, which can be leveraged in Intelligent Access (IA) applications to optimise access control, traffic flow, and fleet operations.			
Data types	Fault prediction	Fault detection and repair	Weight data	Dimension data



Gap diagram



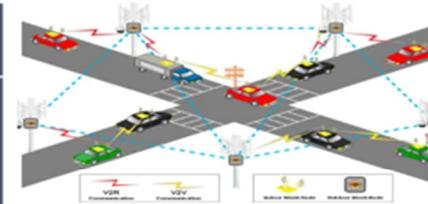
Gap commentary

- RMS can be reliable with real-time tracking of vehicle location and performance, though connectivity issues in remote areas may reduce reliability.
- RMS uses precise data on vehicle status and movements, though GPS signal interference may cause occasional inaccuracies in remote areas.
- The data used is well established, providing mature data for Intelligent access integration.
- RMS can have high costs, specifically in telematics hardware and data platforms, although long term benefits in fleet efficiency and safety can justify the cost.
- RMS can have widespread adaptation in commercial fleets, ensuring broad data availability for intelligent access applications.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

Remote monitoring intelligent access systems can ensure vehicles meet operational requirements, improve route planning, and enhance safety

Data system	Road Hindrance Warning Systems (RHWS)			
Description	RHWS provide real-time information about road obstacles, traffic jams, construction zones, and other disruptions. These systems also offer suggestions for avoiding delays and rerouting vehicles in real-time to optimise travel times.			
Data types	Hindrance data	Severity and impact	Weather conditions	Traffic data



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

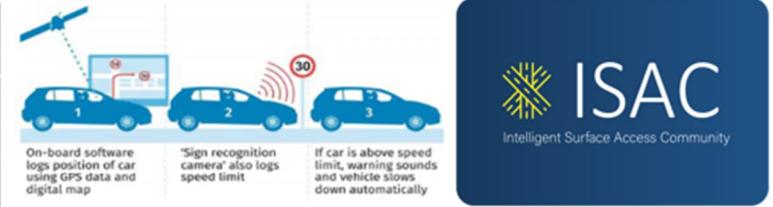
RHWS contribute to improved traffic efficiency, reduced congestions, and enhanced road safety, especially in high traffic environments

Gap diagram



Gap commentary

- RHWS are reliable at detecting major road hindrances although occasional delays or technical issues may affect data reliability. They can detect major road disruptions although smaller or temporary obstacles may sometimes be missed.
- RHW systems are not as mature as other telematics, however they are evolving as sensor and traffic monitoring technologies advance.
- While there is a significant upfront cost for sensors and real time data infrastructure, this can be offset by long term savings from reduced congestion and improved safety.
- RHWS focus on traffic and road conditions, involving data with lower sensitivity concerns, though privacy concerns may arise if combined with other telematics data.



Gap diagram



Gap commentary

- ISAS are reliable at monitoring speed based on GPS and onboard systems, though reliability may be affected by GPS inaccuracies in certain areas.
- Speed limit data is well established and standardised ensuring mature data whilst readily available on ISAS.
- ISAS are simple in design allowing for easy data analysis. However they may increase in complexity across different geographic regions with varying speed limits.
- ISAS collects detailed data on vehicle location, speed, and driver behaviour, raising potential privacy concerns. This data must be carefully managed to comply with privacy regulations, especially when shared with third parties like insurance companies or enforcement agencies

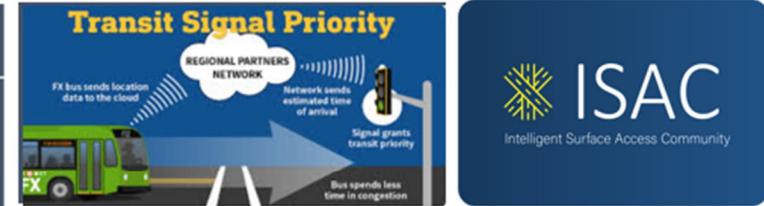
Data system	Intelligent Speed Adaptation Systems (ISAS)			
Description	ISAS provide dynamic information about the current speed limit that can lead to a reduction in collisions and in fuel consumption, with trial results in Sweden showing an estimated reduction of 20 to 30%, if all cars were equipped with an ISA system (SRA, 2009b). ISAS helps ensure that vehicles comply with speed limits by providing real-time speed information and enforcing limits through warnings or direct vehicle control.			
Data types	Speed data	Traffic data	GPS data	Geographic

Intelligent access applications

Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route-planning
Resource-management	Traffic control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

ISAS help to improve road safety, manage traffic flows, and ensure compliance with speed regulations in specific zones, such as residential areas, school zones, or highways

Data system	Transit Signal Priority Systems (TSPS)			
Description	TSPS adjust normal traffic signal timing to give priority to public transit vehicles (e.g., buses). A device aboard the bus sends a signal picked up by a detection device along the roadway. These data feed into a software system that determines whether to extend a green light for the bus to cross the intersection. This type of system can use connected vehicle technology.			
Data types	Transit vehicle delay	Travel time savings	On-time performance	Intersection clearance time



Gap diagram



Gap commentary

- TSPS are generally reliable when well-integrated with traffic signal controllers. Reliability may decrease if there are communication issues between buses and roadside devices.
- TSP are designed to be highly accurate at detecting an approaching transit vehicle and calculating optimal timing to extend. In some rare instances errors may arise if sensors misidentify vehicles.
- The data is immediately available and is well established making it mature data. The integration of connected vehicle technology and growth of smart cities has further developed the maturity of TSPS.
- Implementing TSPS can be costly due to investment in roadside detection infrastructure, communication systems and traffic signal upgrades. However, the long-term benefits can offset the initial up-front costs.
- TSPS collect location and signal data avoiding privacy concerns.

Intelligent access applications			
Heavy-vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

TSPS can help reduce delays, improve transit reliability, and streamline traffic flow in busy traffic environments

Data system	eCall system (ES)			
Description	eCall reduces the time taken to locate and rescue victims of a collision as well as the vehicle and its contents. It reduces the total cost related to incidents by preventing the deaths and reducing incident severity and waiting time. Trials in Stockholm suggest the incident cost reduction potential to be between 5 and 15% (SRA, 2005). Users include drivers, road traffic inspectors, rescue agencies, accident statistic agencies, local authorities and goods owners.			
Data types	GPS data	Location data	eCall network	



Gap diagram



Gap commentary

- ES are highly reliable, activating automatically in the event of a crash or severe incident. However, reliability can be affected in remote areas with weak coverage.
- The data generated by ES is available in real time and has been in use in many parts of Europe, where it is mandatory in all new cars.
- ES are relatively inexpensive to implement in modern vehicles, as they leverage existing vehicle sensors and communication infrastructure.
- ES operate with minimal complexity and are mostly automated, they are designed to work across geographic areas although in extremely remote areas with no cellular coverage there may be limitations.
- ES collect sensitive data, including vehicle locations, time of incident, and potentially passenger information. Ensuring data that is collected is exclusively for crash response is crucial in mitigating privacy concerns.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure-support	Environmental-management	Fleet-management

ES can improve emergency response times, enhance traffic management after incidents and contribute to road safety by providing accurate information to authorities, traffic managers and insurance companies

Data system	Advanced Driver Logs Systems (ADLS)			
Description	ADLS record various time-based activities for HGV drivers and help the driver avoid driving under the influence of external factors such as alcohol, which has been shown to account for up to 16% of driver incidents in 2008 (HeavyRoute, 2010b). ADLS are digital records that track drivers' hours, vehicle usage, and driving behaviour. They are typically integrated with electronic logging devices (ELDs) mandated for commercial drivers in many regions. These logs help ensure compliance with regulations, such as driving hours limits, and provide insights into driver performance and vehicle health.			
Data types	Trip data	Vehicle performance	Driver behaviour data	Safety and compliance data
	Environmental data	Communication data	Location and time data	Fuel and emissions data



Gap diagram



Gap commentary

- ADLS reliability depends on the consistency of the data captured by the vehicle. They can capture accurate data since they automatically log hours of service, vehicle speed, etc which reduces the potential for human error compared to traditional paper logs.
- The data is available and has been used in regulated industries such as trucking where electronic logging devices are mandatory. The data generated is standardised and mature making it easy to integrate across different systems.
- While there are up-front costs and maintenance costs, the long-term benefits of compliance, reduced paperwork and improved fleet management often outweigh the expenses.
- The data is typically used for regulatory compliance and operational efficiency and privacy protections are often in place to ensure data is safe

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

ADL systems improve fleet management, enhance road safety, and enable monitoring of driver activity, contributing to more efficient transport and logistics operations

Data system	Infrastructure Repair and Maintenance Systems (IRMS)			
Description	Information from IRMS provides real-time information on the status and maintenance history of infrastructure. These systems allow for preventive maintenance, which has been found to potentially reduce maintenance costs by 25% (Hammarstrom and Yahya, 2000). IRMS provide real-time monitoring and historical data on the status and maintenance of infrastructure, such as roads, bridges, tunnels, and other transport-related assets. These systems support preventive maintenance strategies, potentially reducing costs by optimising repair schedules and minimising unexpected failures.			
Data types	Asset data	Inspection and monitoring data	Maintenance repair data	Environmental data
	Safety and compliance data	Predictive maintenance data	Performance data	Resource allocation data



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey-time-reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

IRMS play a key role in maintaining infrastructure reliability, improving safety, and reducing downtime. Authorities can prioritise repairs and manage traffic disruptions more effectively

Gap diagram



Gap commentary

- IRMS relies on sensors, inspection records, and condition-based monitoring to provide reliable data on infrastructure health. Reliability may be affected by sensor malfunctions, data inaccuracies, or unforeseen environmental impacts.
- These systems provide highly accurate insights into current and future maintenance needs of roads, bridges and tunnels.
- Some infrastructure (older assets) may not have comprehensive maintenance histories, affecting the completeness of data.
- The initial implementation of IRMS can be costly across large infrastructure networks. However, these costs are offset by long-term savings achieved through preventative maintenance.
- These systems require complex integration of sensor networks and analytics especially in large geographically dispersed infrastructure.

Data system	Geofencing / Geo-tracking (GEO)			
Description	GEO provides control support for areas of interest such as corridors, military areas, incident areas, parking areas and tunnels without using physical barriers. Users include vehicle fleet owners, infrastructure owners, gate operators, vehicle parking operators, and loading / unloading units. GEO refers to the creation of virtual geographic boundaries using GPS or RFID technology, allowing software to trigger a response when a device or vehicle enters or exits a defined area.			
Data types	GPS data	Location data	RFID data	



Gap diagram



Gap commentary

- GEO relies on well-established GPS and RFID systems, making it highly reliable for tracking and controlling access in defined zones. Data availability may be limited in areas with poor GPS signal or intermittent connectivity, though GEO systems are generally robust in most environments.
- Implementing GEO systems is relatively cost-effective, especially when leveraging existing GPS or RFID infrastructure. Costs can vary depending on the size of the geofenced area, the level of accuracy required and the need for additional hardware.
- GEO systems are relatively simple to implement in small-scale and well-defined areas, with low latency rates providing accurate real time data.
- GEO systems collect location-based data which raises privacy concerns however, the focus on spatial data can mitigate some of these concerns.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote-clean-vehicles
Journey time reliability	Congestion	Asset-management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle-parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

GEO is utilised for various purposes, including regulating access to restricted areas, managing traffic in specific zones, and optimising logistics and fleet management

Data system	Information on Truck Parking Systems (ITPS)			
Description	ITPS provide parking related information in real-time to drivers and facility owners. Similar systems have been reported with about 1% to 2% reduction in parking location time (Lindkvist et al., 2003) and 9% in travel time (SAIC, 2007). ITPS provide real-time information on the availability of parking spaces for trucks, particularly in rest areas, logistics hubs, and along highways. These systems are important for improving road safety, ensuring regulatory compliance with mandatory rest periods, and optimising logistics operations.			
Data types	Parking availability data	Location and mapping data	Facility data	Reservation and booking data
	Occupancy and forecasting analytics	Compliance and regulatory data	Safety and incident data	Parking usage and efficiency data



Gap diagram



Gap commentary

- ITPS are reliable with sensors and real time data providing accurate information on parking space availability, though sensor malfunctions may occur.
- The data is available, although not as mature, and gaps may arise in regions with less parking infrastructure or fewer monitoring systems.
- ITPS can be complex depending on the mix of hardware and software required for operation but can be automated once systems are in place.
- The systems has good coverage in urban areas and along motorways, but challenges can arise in rural or less- developed regions.
- ITPS have minimal privacy concerns related to parking occupancy data, though protection of personally identifiable information is still required.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document-processing	Seamless-cross-border	Emissions	Promote clean-vehicles
Journey-time-reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic-control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental-management	Fleet management

ITPS enhance route planning, reduce the risk of parking violations, and mitigate the challenges associated with parking scarcity, especially in high traffic areas

Data system	Remote Declaration Systems (RDS)			
Description	RDS enable the declaration of information to be transferred electronically at places such as gates, control stations, and loading/unloading stations reduce delays. RDS are used to declare shipments, vehicle details, and other relevant data remotely, reducing congestion at busy entry points and ensuring smoother, faster, and more efficient processes.			
Data types	User identification data	Declaration data	Item or cargo data	Tax and duty data
	Shipment and transportation data	Compliance and regulatory data	Payment data	Security and risk data



Gap diagram



Gap commentary

- RDS are typically very reliable, as they are based on established digital communication and automation technologies.
- The accuracy of RDS is high, as it eliminates the possibility of data entry errors.
- The data generated by RDS is highly mature, given that electronic data interchange has been standard practice in logistics and transportation for decades.
- RDS systems have moderate costs for software and hardware; the long-term cost savings are significant.
- Once configured, RDS are largely automated, requiring minimal oversight, though initial setup and integration may require technical expertise.
- RDS are increasingly being adopted by fleets, particularly those engaged in high volume logistics operations.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

RDS enhance the efficiency of logistics and transport by automating exchange, minimising manual checks, and ensuring regulatory compliance

Data system	Staff Monitoring Systems (SMS)			
Description	SMS track employee activities, presence, performance, and compliance with safety regulations in real time using technologies including GPS, biometric data, RFID, and software-based monitoring tools. These systems play a crucial role in ensuring that workers in logistics, transportation, and warehousing follow prescribed routes, meet operational guidelines, and maintain safety standards. SMS collect information related to health, fatigue, and other matters, about hauler company staff for staff administration (seen as the most expensive resource) and control, for example, by police and labour unions. It is different from ODM and DP in that it focuses on company-wide staff and the company's legal obligations.			
Data types	Time and attendance data	Performance metrics	Behavioural data	Surveillance data
	Communication data	Employee feedback		



Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

SMS improve the efficiency of operations, enhances security, ensures regulatory compliance, and optimises resource allocation by providing timely insights on staff performance and location

Gap diagram



Gap commentary

- SMS provide accurate real time data on staff movements and activities, making it easier to monitor compliance and ensure safety.
- SMS generally offer high accuracy, especially when using biometric authentication and GPS tracking.
- The data collected by SMS is becoming increasingly mature, with well-established standards for location tracking, biometric information, and activity monitoring.
- SMS collect highly sensitive information, such as biometric data, personal location tracking, and performance metrics, which raises privacy concerns. Ensuring compliance with data protection regulations such as GDPR and maintaining secure communication and storage protocols is essential.

Data system	On-Board Mass (OBM) Systems			
Description	These systems allow for the digital collection of axle mass measurements, which are combined with vehicle position data to provide richer insights into vehicle movement, load, and configuration. This data is used to manage compliance with road transport laws and to improve road safety and infrastructure management. For example, in Finland, there is a mandatory display of actual axle loads in the driver cabin. Additionally, some compliance mechanisms involve reporting position and weight data with or without IDs for statistical purposes or independent audits. Higher assurance levels include independent certification of on-board equipment and oversight of telematics providers, where data is valid in court.			
Data types	Vehicle position data	Vehicle mass data	Vehicle dimension data	Vehicle load / axle load data
	Vehicle speed data	Geospatial data	Load distribution data	Telematics data



Gap diagram



Gap commentary

- OBM systems are integrated with telematics and geofencing technologies to provide real-time data on vehicle weight and load distribution providing accurate and reliable readings.
- These systems help ensure compliance with weight regulations, preventing overloading and reducing the risk of infrastructure damage.
- OBM systems must generate data records following the OBM system functional and technical specifications. The importance of data integrity and authenticity in the communication between the telematics devices and the OBM system is vital. The integrity code ensures data is transmitted accurately and has not been tampered with during transmission.
- OBM systems can introduce complexities due to hardware requirements, integration with vehicle systems, and communication with IA platforms. Variations in vehicle types and load characteristics can add to this further.

Intelligent access applications			
Heavy vehicles	Abnormal loads	Dangerous goods	High-capacity vehicles
Document processing	Seamless cross-border	Emissions	Promote clean vehicles
Journey time reliability	Congestion	Asset management	Safety
Speed compliance	General compliance	Vehicle tracking	Route planning
Resource management	Traffic control	Vehicle parking	Fuelling / charging
Driver support	Infrastructure support	Environmental management	Fleet management

OBM systems are used to check compliance with road transport laws and improve road safety and infrastructure management. They can also provide logistics managers with ways to optimise load distribution.

