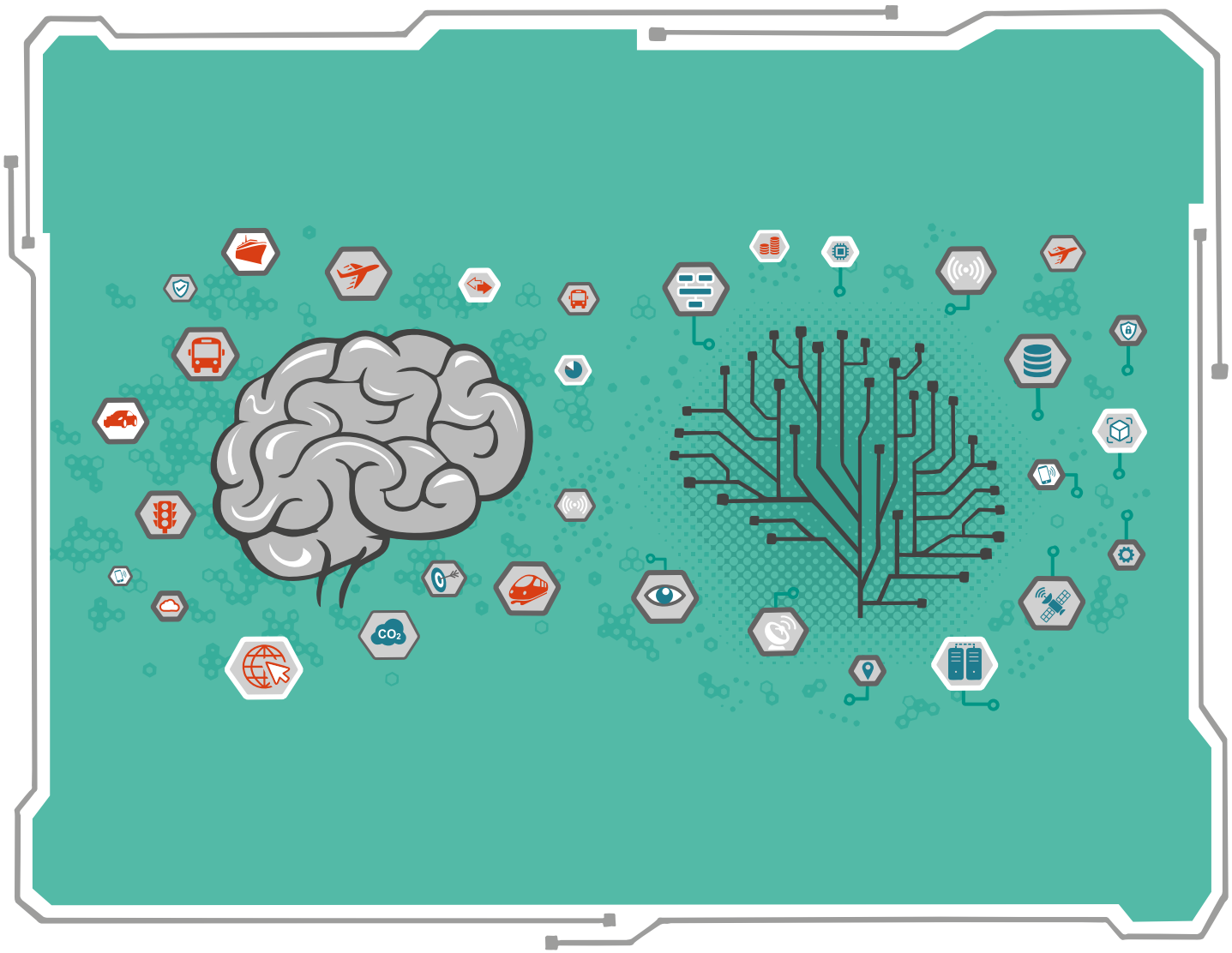
THE FUTURE OF TRANSPORT

BRIDGING THE GAP

Overcoming the Barriers to AI Adoption in Transport



PPR2060

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Our colour key (below) **connects the key insights from the 8 key barriers** (pages 7–21) **to the 5 key opportunities to transform transport by overcoming these barriers** (pages 23–28)**.**

1. Establishing clear governance and regulation
2. Balancing innovation and data protection through collaboration
3. Enhancing technical skills and expertise
4. Building public confidence in AI adoption
5. Ensuring investment in infrastructure to support innovation and impact

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FOREWORD

"There is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things."

Niccolò Machiavelli *(1513) The Prince, Ch. 6.*

I am reminded of Niccolò Machiavelli's warning that people and organisations don't like change. Of course, this is true some of the time, in some circumstances, and for some people. It is also true that there are a reasonable number of us, often the majority, who when helped with the adoption process, embrace learning, and thrive through discovering new and innovative ways to improve our world and live our lives.

The use of Artificial Intelligence in transport will become more prevalent. In my opinion, the choices we now face must focus on taking on the 'perilous conduct' of leadership in this space. Specifically, how will we enable the best AI solutions to be adopted at scale? The alternative is to be passive and watch on, as AI inefficiently and undemocratically integrates into the journeys we make, impacting accessibility, efficiency, choice, safety, cost, and data privacy and security. This passive option is unattractive, not least because it carries much greater risks to our economy, communities, and environment.

The motivation to act is therefore clear. AI represents a significant opportunity to enhance mobility for everyone and to mitigate the unacceptable levels of harm caused by today's transport systems – every day in the UK about 400 people are killed or injured on our roads and transport accounts for a third of all carbon dioxide emissions.

This work builds on a growing body of accredited literature, which describes the challenges and obstacles that many in the transport sector experience when it comes to introducing AI-driven solutions. These barriers are technical and non-technical (organisational, societal, economic and environmental) in their origin, requiring diverse system-wide perspectives to be able to solve the wicked problem of improving the adoption of AI in transport.

Bringing together a diverse group of over 60 stakeholders from across the AI and transport ecosystems, this work co-created a cross-sectoral approach for overcoming the barriers to the adoption of AI in transport. Having this strong foundational understanding and broad consensus on the nature of these barriers enabled stakeholders to collaborate, and through industry led workshops explore and develop practicable solutions.

This brings me back to Machiavelli's leadership point. All those who contributed to this activity should be rightly proud of their collective achievement. Because of their input, five key opportunities have been identified to drive the change that would be necessary to improve the adoption of AI in transport. The power behind these recommendations is that they set a direction and give the public, private and academic sectors a common framework.

However, achieving fundamental change and overcoming existing and perceived barriers to the adoption of AI will be an ongoing mission. I am delighted to endorse this report's call for further coordinated effort across the transport industry to create an AI ready ecosystem within the transport sector, because by working together we can realise the benefits.

Prof. Richard Cuerden
Director, Safety Advisory and TRL Academy
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EXECUTIVE SUMMARY

The integration of Artificial Intelligence (AI) in the transport sector presents a significant opportunity to enhance efficiency, safety, and sustainability. Yet, AI adoption faces several barriers that hinder its full potential, including technical and non-technical challenges. These challenges contribute to a fragmented data landscape, slowing innovation and limiting AI's transformative potential. To address these issues, a structured approach to overcoming these barriers is needed. This study aims to identify key barriers to AI adoption in the transport sector and to propose actionable solutions that will support AI integration in the UK transport network.

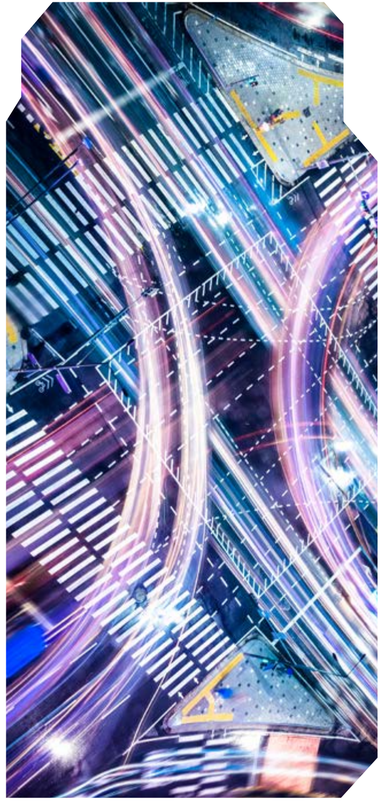
To achieve this, the study employed a mixed-methods approach, incorporating an extensive literature review and two industry-led workshops where experts from across the UK transport sector, academia, and AI providers participated. The literature review identified 12 key barriers, categorised into technological, organisational, societal , economic and environmental and cross-sectoral collaboration themes. The first workshop, held at TRL's Smart Mobility Living Lab in London, brought together industry stakeholders in the transport sector to refine and prioritise these barriers based on real-world experiences. Some of the initial barriers identified were found to overlap and were merged, resulting in a condensed final list of eight barriers.

These eight barriers were then explored in greater depth during a second workshop, which was held at the Transport AI Conference in Manchester. Participants engaged in collaborative discussions, further refining the list of key barriers and developing a set of strategic recommendations to address these challenges. The findings of this study provide a practical strategy to accelerate AI adoption in transport. Stakeholders identified five key opportunities to drive change:

1. Establishing clear governance and regulation
2. Balancing innovation and security through collaboration
3. Enhancing technical skills and expertise
4. Building public confidence in AI adoption
5. Ensuring investment in infrastructure to support innovation and impact

These recommendations highlight the need for a coordinated effort across the transport industry to create an AI-ready ecosystem, ensuring that AI can effectively support a future efficient, safe and sustainable transport system.

NAVIGATING AI ADOPTION



Enabling the Future of UK Transport

The UK transport sector is at a critical crossroad, as other industries rapidly advance in leveraging AI to meet customer demands. Today's modern transport network faces an opportunity to revolutionise mobility in the largely untapped world of AI. Integrating AI into our daily travel is not just an option – it is a necessity to efficiently tackle today's significant levels of emissions, persistent congestion and safety concerns.

Imagine a transport system where AI is embedded at the heart of every journey, where predictive algorithms anticipate and mitigate congestion before it happens, re-routing traffic for optimal flow. Envision a world where trains self-diagnose and self-repair, minimising delays and maximising efficiency. Picture a road network serviced by autonomous vehicles for personal and commercial use, communicating in real-time to streamline traffic management, update road users on roadworks and ultimately enhancing safety. Certainly, this sounds ambitious.

> The successful delivery of meaningful change is made possible when we collaborate and adapt to overcome the challenges before us.

The integration of AI in transport faces numerous barriers that must be understood and addressed to fully unlock its potential. Data is often confined to silos, algorithms are fragmented and human oversight prohibits accelerating our industry to the next level. AI can help us to move beyond outdated legacy systems and give us the confidence to fully incorporate machine learning in our decision making. However, are we prepared for the ethical dilemmas that may arise? Who is accountable when an AI-driven vehicle makes a critical decision? How can we ensure fairness and prevent algorithmic bias from sustaining existing inequalities?

> In an increasingly interconnected world how can we safeguard data and give passengers the confidence to embrace AI in their daily travel?

These questions must be addressed head-on, not ignored, as we navigate the advancement of AI in the transport sector. The time for incremental adjustments has passed. The industry stands at a pivotal juncture, demanding a fundamental transformation to move from a reactive model, to one that is proactive and predictive. By embracing opportunities for change and implementing AI, the transport sector has the potential to revolutionise mobility, redefining how people and goods move. This shift can directly address the evolving needs of passengers and freight customers alike, enabling a smarter, more adaptive and future-ready transport system.

Rewriting the Roadmap

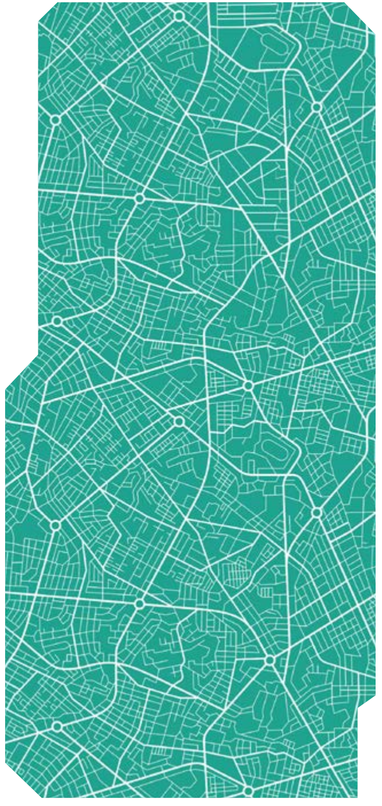
Each day, AI is integrated into various aspects of our lives. For instance, AI-driven systems provide real-time updates on bus and train occupancy, instantly notifying us of delays and allowing us to make informed travel decisions. Even parking has become more efficient, with the ability to reserve spaces in advance being introduced, eliminating the frustration of searching for a vacant spot. Traffic signal systems are able to dynamically adapt to congestion levels, facilitating an efficient journey. If a bus is full, AI can promptly detect overcrowding in real time and direct passengers to an alternative vehicle, ensuring a more comfortable and efficient journey. As intelligent transport system solutions continue to evolve, their potential to optimise mobility is becoming increasingly evident.

> While AI is increasingly becoming a part of our daily journeys, its widespread adoption continues to encounter significant challenges.

Despite these advancements, some scepticism persists within the industry. Many remain attached to traditional habits or question the extent to which AI-driven systems can truly enhance our travel experiences. Issues related to data discoverability, privacy, security, and ethical considerations contribute to hesitation among transport users. Organisational resistance, legal and monetary constraints, and a lack of leadership further impede progress. Transport data remains fragmented without a culture that fully understands and values such data, despite developing technical expertise and strong incentives for investment.

> Existing barriers to the adoption of AI in the transport sector hinder innovation and limit the potential of AI to transform mobility.

What will the future of transport look like? Envision a world where AI goes beyond mere assistance, but anticipates, adapts, and refines itself to meet our needs before we even realise them. A seamlessly intelligent transport system that allows us to embrace a reality where hesitation fades, trust grows, and technology propels us towards a safer, more efficient, and sustainable future. The journey to AI-driven transport is just beginning. To reach this vision, we must first confront the barriers standing in our way. This paper explores these challenges in greater depth.



FROM THEORY TO PRACTICE

Methods Overview

This report follows a structured approach to identifying and analysing barriers to AI adoption in transport. It incorporates insights from academic literature with industry expertise gained through two interactive workshops. The first workshop confirmed and prioritised the barriers, while the second explored the barriers in more depth to identify potential solutions.

A growing body of literature focusing on the barriers to AI adoption across many sectors underscores the critical role that overcoming these barriers has in unlocking the benefits of AI. To establish a solid technical foundation for this work, scientific and grey literature were both reviewed, including research reported in non-academic publications, policy papers and industry white papers. Barriers to AI adoption were identified from this research and categorised into four key themes:

1. Technological barriers
2. Organisational barriers
3. Societal, economic and environmental barriers
4. Cross-sector collaboration.

Following the literature review, an interactive cross-industry workshop was convened at TRL's Smart Mobility Living Lab in London, bringing together key transport stakeholders. These included representatives from the Rail Safety and Standards Board (RSSB), Railway Industry Association (RIA), Rail Delivery Group (RDG), Partners, Confederation of Passenger Transport (CPT), Transport for London (TfL), Local Council Roads Innovation Group (LCRIG), Research Institute for Disabled Consumers (RiDC), Alan Turing Institute (ATI), UK Research and Innovation (UKRI), London Legacy Development Corporation (LLDC) and several independent industry experts.

This workshop began with an interactive presentation summarising key findings from the literature review, which identified **12 preliminary barriers to AI adoption**. Participants were invited to engage with the findings through digital interaction tools, enabling them to prioritise barriers relevant to their specific domains. The group was then divided into two discussion panels, where they explored:

- **How each barrier manifests in different transport sectors.**
- **Examples of specific projects where these barriers had been encountered.**
- **Prioritisation of barriers based on impact and feasibility of resolution.**

A key outcome was the finding that some of the initial barriers identified were found to overlap, and so these were merged to result in a condensed final list of eight barriers. The discussions provided real-time insights into industry perspectives, refined the AI adoption barriers and informed the focus of a second workshop.

The second workshop took place at the Transport AI Conference in Manchester, where 65 experts attended from across the transport industry, including rail, road, maritime, aviation, and urban mobility. Stakeholders came from a diverse range of organisations, including public transport authorities, consultancies, research institutions, and AI solution providers. This ensured a broad scope of perspectives and expertise, enriching discussions on AI adoption challenges. Eight tables were formed to facilitate focused conversations on AI adoption challenges, with each table focused on one of the eight identified barriers.

This session adopted a World Café approach, where some participants remained at a table while others rotated to contribute fresh perspectives. The structure stimulated a dynamic exchange of ideas, fostering collaboration across industry sectors. The workshop objectives were to validate and refine the shortlist of **8 key barriers to AI adoption** and explore the root causes of each barrier. The output was to identify potential solutions and opportunities for overcoming these barriers. To facilitate this, three key questions were deliberated by workshop attendees in regard to the barrier on each table:

- **What are your experiences with the root causes of your barrier?**
- **What does a future transport system look like to you with your barrier removed?**
- **What actions should the transport sector take to overcome your barrier and achieve this future transport system?**

For each identified barrier, stakeholders provided valuable insights, outlining practical concerns and offering recommendations tailored to the address the specific challenges faced by organisations implementing AI. Following a thorough review of all discussions and suggested actions, the recommendations were grouped into broader thematic categories to ensure a structured and consistent approach. This process resulted in the identification of five overarching opportunities for action to overcome these barriers to AI adoption. By highlighting these opportunities, a clear and actionable roadmap was created that reflects the real-world priorities of stakeholders, ensuring that AI can be successfully integrated into transport systems through practical, industry-driven solutions.

DATA DISCOVERABILITY AND QUALITY

Definition: AI in transport faces challenges with using fragmented and often inaccessible data due to proprietary restrictions which creates a lack of standardisation. This limits access to reliable, fair and ethical data AI-driven data and applications.

Literature Review

Given the nature and the sheer volume and heterogeneity of data generated within the transport ecosystem, data encompasses diverse formats. Across all modes, including road, rail, air, and maritime, data is multifaceted, from sensor readings and traffic flow data to passenger information and maintenance logs. As highlighted by the UK Government Digital Service report1, this fragmented data landscape makes it difficult to identify and access the specific datasets needed for particular AI applications.

Transport data often resides in multiple public and private databases (e.g., bus operators, train operating companies, local authorities). Gaining a consolidated dataset is difficult, particularly when commercial interests or privacy concerns limit data sharing. Thus, emphasis is placed on the need for standardised data formats and common data platforms to facilitate data sharing and interoperability across different stakeholders.2 Research has shown that the lack of standardised data governance frameworks and metadata schemas hinders the discoverability of relevant datasets.3 This lack of discoverability translates to increased time and resources spent on data acquisition and preprocessing, significantly slowing down the AI development lifecycle.

Root Causes

- Lack of centralised data management making it difficult to locate, access, and integrate data for AI applications.
- Incomplete, outdated, or inaccurate data leads to poor data quality and undermines the reliability of AI models.
- An unbalanced number of uniform data formats and metadata are challenges that limit the scalability of AI solutions.

Case Study

Traffic Regulation Orders (TROs)

Despite its purpose to serve cities and counties with regulations to observe road safety, congestion and local air quality, how this is enforced with AI remains unclear.

Currently deployed by over 150 local authorities across the UK these regulations are often non-digitised and vary in formats. This makes it challenging to anticipate and understand how to improve our road network. For instance, without access to high quality and timely data (particularly quality rich data), providing real-time updates for road closures remains delayed, hindering route optimisation for logistics companies, causing delivery delays and increased fuel consumption.4

In other words, urban transport systems that can benefit from AI adoption currently suffer from fragmented data-sharing frameworks, particularly in smaller cities.5 Hence there is a need for centralised protocols and funding to ensure equitable access to AI capabilities. Without such a national framework in place, real-time traffic information operators cannot dynamically optimise routes, leading to inefficiencies.

1

How do we discover what data is available and how this can be accessed? We must create a clear pathway on how we manage data ownership, data aggregation issues and data usage effectively.

2

Legacy systems and outdated contractual agreements restrict access to critical data. This challenges users when requesting permissions in particular aggregated data from various sources.

3

There is a need to recognise and specify key data requirements early on in the planning stages of AI projects. By identifying the purpose of the data, organisations can condense large data volumes of information into actionable insights.

4

National Data Library: Stakeholders agreed that a more open collaboration between academia, industry, and the public sector is needed. Offering standardised access to open source data allows users to locate required information in one place, accelerating innovation.

5

Improve communication between systems. By standardising the data format systems across the transport sector, such as rail and road, better passenger experiences can be developed.

6

Maximise data use by taking a multi-faceted approach to explore the technical, organisational, and financial considerations. Can we incentivise commercial enterprises to share data points?

INFRASTRUCTURE FOR AI INTEGRATION

Definition: Transport systems currently lack the physical and digital infrastructure needed to support real-time AI deployment. Integrating AI with current frameworks and legacy systems is not only costly, but also complex. This leads to an ineffective deployment of AI at scale.

Literature Review

Development of AI in transport systems requires robust infrastructure to support data sharing and real-time applications. This includes the systems and processes needed for collecting, storing, processing, and managing the vast amounts of data required. AI-based transport systems often rely on real-time communication and connectivity to function effectively. This includes networks and technologies that facilitate the exchange of data between vehicles, infrastructure, and control centres.[6] Reliable and high-speed connectivity is therefore crucial to deploying applications such as AVs, smart traffic management, and optimising EV charging based on user demand and connected infrastructures.[7]

The transport industry's reliance on real-time data processing necessitates high-speed seamless connectivity via 5G networks and Internet of Things (IoT) infrastructure. However, the fundamental network infrastructure to support these technologies must be present in both urban and rural areas, as without this the industry faces challenges due to limited broadband coverage. Beyond these challenges, unauthorised persons and persistence of that access is a significant challenge for AI integration in transport infrastructure. Cyber security concerns and the reliance on IoT devices and interconnected systems increases vulnerabilities to cyber-attacks, data breaches, and unauthorised access.[8] These threats can disrupt critical services and compromise the safety and efficiency of AI systems.[9]

Root Causes

- Conflicting communication networks between software and hardware due to rapid advancements in technology causes development to lag.
- Since AI systems require vast amounts of data, and organisations often struggle with inadequate data storage solutions, risks such as data breaches and unauthorised access represent key root causes.
- Outdated legacy IT infrastructure and systems are often incompatible with modern AI technologies, making integration difficult and slowing down adoption.

Case Study

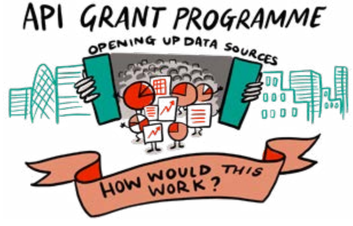
Maritime Autonomous Surface Ships (MASS)

Infrastructure gaps are not confined to road transport but expand to other sectors like maritime as a barrier to adopting Maritime Autonomous Surface Ships (MASS). These independently operated ships require remote control centers and operational control for each level of autonomy, necessitating upgrades to port infrastructure and along maritime routes. However, many ports and maritime hubs still depend on traditional logistics frameworks, limiting seamless integration. Key infrastructure challenges include insufficient 5G/6G coverage for real-time AI-driven decision-making, and outdated docking and refuelling stations suggesting a lack of port readiness.

However trials such as those concluded with Yara Birkeland, were often disrupted due to poor digital infrastructure, such as unreliable communication networks, which delay real-time decision-making for route optimisation and cargo transfers.[10] For MASS to thrive, governments and industry stakeholders must invest in smart ports, AI-compatible traffic management systems, and real-time data-sharing networks.

1

The need for interplay between software development and on-field operatives emerged as a critical area for improvement to enhance data utility.

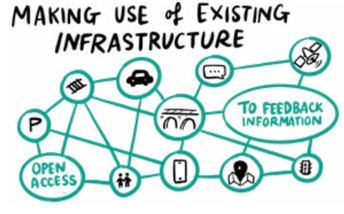


2

Cyber security is a significant challenge, as reliance on (IoT) devices, V2X and interconnected systems continue to expose a higher risk of encountering cyber threats.

3

Physical barriers, such as access to advanced connectivity (i.e. 5G and 6G), must be accessible and balanced for all geographic regions to allow road and rail sectors to offer AI functionality without compromising on passenger data use concerns.



4

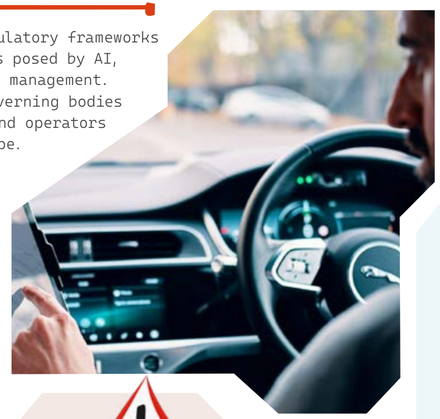
Should organisations allow open access to certain data points which could enable us to make better use of existing infrastructure?

5

Stakeholders suggest that the rate at which we develop and expand our infrastructure can be achieved by capital revenue splits and exploring the most beneficial case for businesses to adopt.

REGULATION AND GOVERNANCE

Definition: Outdated or fragmented regulatory frameworks often fail to address the unique challenges posed by AI, such as accountability, liability, and risk management. This results in inconsistencies between governing bodies (national, regional and local), suppliers and operators leading to a disjointed governance landscape.



Literature Review

Legal frameworks within the transport sector have been described as outdated, particularly in logistics and public transit.[11] The lack of harmonised governance models creates a legal vacuum that leaves stakeholders uncertain about compliance requirements.[12] For instance, the European Union's General Data Protection Regulation (GDPR) imposes strict data privacy requirements, which can conflict with the data-intensive nature of AI systems used in transport.[13] This regulatory ambiguity discourages investment and slows down the deployment of AI-driven solutions.

AI governance remains a key issue due to organisational and technological barriers that hinder data control and liability attribution for AI-driven decisions. In the rail sector for instance, outdated legal frameworks and fragmented governance slow AI adoption. RSSB is working to align the Rail Technical Strategy with the Whole Industry Strategic Plan (WISP), yet sector-wide gaps in liability, data sharing, and compliance remain. Tools like the Managing Disruption Toolkit and climate risk modelling require clear data ownership and harmonised contracts. Modernising these frameworks is critical to enabling AI-driven solutions that improve safety, sustainability, and operational resilience.[14] This lack of clear policies on data ownership, privacy, and usage rights limits AI adoption.

Root Causes

- Rapid development of AI technologies often out paces the creation of clear and consistent regulations
- The lack of standardised frameworks such as universally accepted governance standards creates ambiguity, making it difficult to implement AI responsibly
- Stringent data protection laws (such as GDPR and DPA 2018) create data privacy and security concerns.

Case Study

Regulation and Governance Challenges in Autonomous Vehicle Deployment

Autonomous Vehicles (AVs) are advancing rapidly, with OEMs integrating technologies that offer self-driving solutions. However, a key issue that impedes its implementation is how we address the accountability and liability frameworks for these technologies. This creates regulatory inconsistencies that complicate deployment for suppliers and operators.

This lack of consistency for suppliers and operators results in in varying safety, testing, and operational requirements across jurisdictions. This regulatory patchwork makes it difficult for manufacturers to produce AVs that comply with all requirements, increasing costs and delays.

A study by Sheffield Hallam University in 2024 highlights the urgent need for harmonised governance structures to support AV integration[15]. They identified that, for cities at the forefront of connected and automated vehicles, growth is underpinned by proactive policy making to support these vehicles. Hence, establishing clear national and international standards would streamline compliance and provide legal clarity for liability in AV-related incidents.

1. Stakeholders emphasised how using "all" data available to enable AI-driven innovations is challenged with concerns over data privacy, ownership, and competition. It became apparent these sensitivities create resistance to sharing data across stakeholders, hindering the creation of unified and interoperable AI systems that could enhance transport services.

2. AI is a broad subject area that requires clear and rigid governance. At present, the lack of collaboration and coherence hinders decision makers from leveraging their understanding to provide solutions faster.

4. Solving this barrier opens up faster progress to integrate AI in transport in a manner which is bounded by structural governance and strategy on how AI can be used and what levels of passenger data can be utilised.

3. Existing tension surrounding data usage, particularly regarding commercial sensitivity, is driven by a lack of harmonised regulations across different governance levels.

5. Consistency between government sources will allow for Transport strategy groups and local authorities to collaborate on future transport systems.

6. Priority roadmaps and consistent forms of communication will provide stakeholders with the mechanisms and tools needed to share data between private and public organisations, offering more flexible and adaptable regulatory frameworks.

SKILLS AND WORKFORCE READINESS

Definition: At present there is a shortage of skilled professionals with the technical expertise in developing, deploying and maintaining AI-driven systems. Resistance from within traditional transport sector industries,where concerns about job displacement exist, increase resistance to a future AI-enabled transport system.

Literature Review

The transport sector faces significant challenges in adopting and scaling AI-driven solutions due to a persistent skills gap. The transport industry traditionally relies on manual and operational skills, leaving it ill-prepared for the data-driven demands of AI technologies. This skills gap is further compounded by the rapid pace of technological advancement, which outstrips the ability of educational institutions and training programs to keep up.[16] As a result, organisations struggle to recruit and retain talent with essential expertise in network systems, data engineering, machine learning, and AI ethics, which hinders progress on projects on solutions that could enhance efficiency and safety.

This shortage of technical capacity often forces organisations to rely on costly external expertise, making AI integration unsustainable in the long term. Reports from the CIHT and other studies emphasise the need for cross-modal training programmes and partnerships between academia and industry to address these gaps and build a workforce capable of adapting to AI-driven workflows.[17]

Beyond technical skills, workforce readiness is also hindered by cultural resistance to change. Many employees in the industry are sceptical of AI technologies, fearing job displacement or increased complexity in their roles. Without effective change management strategies and clear communication about the benefits of AI, organisations face significant challenges in fostering a culture of AI dependency.

Root Causes

- The industry currently faces a lack of AI literacy and technical expertise making it difficult to manage AI effectively.
- There is a gap in accessible, high-quality training programs to upskill the current workforce, leaving employees unprepared to work with or alongside AI systems.
- There is a mismatch between education and industry needs, causing fears of role redundancies leading to a lack of motivation to engage with AI.

Case Study

Bridging the skill gap in the transport industry

The UK is believed to be facing a significant skills gap, with a shortage of engineers and AI specialists needed to maintain and regulate vehicles equipped with Advanced Driver Assistance Systems (ADAS). With projections indicating that by 2030, 44% of UK cars will incorporate such systems, this necessitates a workforce that is skilled and trained to ensure we continue to operate safe roads and highways.[18]

At present however, there is a lack of structured, widely recognised training programmes tailored to AI in transport and this in turn has resulted in limited awareness among operational staff about the practical use cases and benefits of AI, leading to resistance or underutilisation. Transport for West Midlands (TfWM) have identified a need for approximately 60,000 new workers over the next 15 years to support the region's transport infrastructure, including roles in digital and AI sectors.[19]

However, without sustained investment in education and training, the adoption of AI in the UK's road transport sector may continue to be impeded by this critical skills shortage.

1. Many organisations lack the necessary technical expertise to utilise the full potential of AI, which hinders their ability to integrate solutions effectively. As such there is a strong need for cross-sector leadership to direct and guide organisations through this transition.

2. There is a need to accommodate and account for a learning curve phase to the adoption of AI, for which decision makers should factor in the additional cost and time needed to exercise this.

3. Sourcing skilled professionals is challenging as most train in the public sector but pursue work opportunities in the private sector due to remuneration. Retaining talent is vital in creating the necessary workforce to implement AI effectively.

4. Develop training that targets all levels of AI literacy and all applications for AI-based systems. These training initiatives should be designed to upskill and equip employees with the tools and understanding needed to operate and manage AI systems, reducing dependencies on outsourcing activities.

5. Senior leaders have a responsibility to discuss the use of AI within the workforce and the positive impact this can have when carrying out daily tasks. Employees should be supported and reassured of the benefits of AI to tackle stigmas surrounding redundancies. Fostering an open-minded workforce culture where learning and developing is encouraged will help retain skilled professionals within the sector, thus accelerating AI implementation.

6. Risks, such as cyber security risks, may arise when inexperienced employees utilise AI software, such as ChatGPT and Gemini within the workforce. Focusing on capability development across the workforce can mitigate the risk of data breaches and security issues.

DECISION-MAKING AND ACCOUNTABILITY

Definition: AI-related decision-making requires clear accountability frameworks. Uncertainty on who is responsible for the actions of an AI-based system, particularly following a mistake, limits the ability of organisations to make informed, ethical, and transparent decisions, resulting in a reluctance to deploy AI at scale.

Literature Review

Effective decision-making and accountability are critical for the successful adoption of AI in transport systems. Senior leaders, decision-makers, and project managers must possess foundational AI knowledge to ensure informed, transparent, and ethical deployment of AI technologies. Without such literacy, organisations risk failing to align AI applications with public expectations, ethical standards, and regulatory frameworks.

Research has shown the need for decision-makers to address human and social factors, such as trust and resistance to automation, while leveraging AI's potential for economic and operational improvements.[20] Leaders equipped with AI knowledge are better positioned to communicate benefits, mitigate public concerns, and establish accountability frameworks for AI implementation.

Root Causes

- Lack of clear accountability framework can create a challenge in assigning responsibility when errors occur.
- The absence of legal and ethical understanding makes it difficult to validate AI decisions, build public trust, and ensure safe data management.

Case Study

GATEway Project

TRL conducted a review to understand public perception and acceptance of driverless micro-transit vehicles in the GATEway project in Greenwich.[21] Passenger experiences were analysed, focusing on safety, satisfaction, and willingness to pay for such services. While participants were generally open to the technology, a critical concern emerged: What happens if something goes wrong? This highlights the need for clear accountability and robust decision-making frameworks.

A key lesson learned from the trial was that participants felt more comfortable with a safety operator present, indicating hesitancy in fully relying on AI decisions. The lack of a clear liability model created reluctance among regulators and insurers, as uncertainty over responsibility in case of system failure posed a major barrier to widespread adoption. Furthermore, the project highlighted the necessity of clear policies on human intervention and liability assignment, as regulatory and ethical considerations remain central to building trust in AI-driven transport. These findings reinforce the successful deployment of AI-driven solutions. While the technology holds significant promise, its successful deployment depends on establishing well-defined accountability structures and a transparent regulatory framework to ensure both public confidence and operational safety[25].

1. Stakeholders stressed the importance of strengthening organisational leadership in AI, ensuring that leaders and decision-makers have the necessary knowledge and expertise to confidently guide AI adoption and integration.

2. Stakeholders highlighted why we need to foster a cultural shift, transitioning from risk-averse and blame-focused mindsets towards a more open, experimental, and proactive approach that encourages innovation and continuous improvement.

3. How can AI truly transform transport safety if systems remain siloed? Collaboration across different transport sectors is key. By enabling connected solutions, AI tools can be seamlessly integrated, ensuring that data flows efficiently between vehicles, infrastructure, and traffic management systems to create a more adaptive and intelligent transport network.

4. Stakeholders found that bureaucracy and uncertainty over AI implementation decisions results in multiple unnecessary approvals and a reduction in the efficiency of the AI innovation process.

5. Stakeholders proposed that creating dedicated offices or teams can guide cross-sectoral AI implementation in an informed and structured manner.

6. Stakeholders suggested the government should recycle AI solutions—rather than reinventing them, the sector should prioritise reusing existing AI tools where possible to accelerate adoption.

PUBLIC TRUST AND SOCIAL ACCEPTANCE

Definition: Widespread scepticism about AI reliability, safety, and fairness, combined with the lack of extensive real-world testing, can impact public trust and acceptance of AI-enabled transport systems, preventing solutions from deploying at scale and benefiting society.

Literature Review

Public fearfulness around AI privacy in smart cities, particularly in mobility and governance systems, have been debated as key public concerns towards AI use.[21] Extensive collection of personal data, and its potential mismanagement, raises concerns about surveillance and trust, leading to resistance to AI adoption. To address this, continuous public engagement and transparent data practices, including explainable AI, strong privacy regulations, and ethical frameworks should be considered to build trust and acceptance.

Furthermore, social resistance to adopting AI technologies is often driven by fear of job loss, lack of understanding, and apprehension toward workplace changes. This resistance is not only seen among frontline workers but also among senior staff members, who may prefer established methods and resist investing time in learning new AI-based systems. This is due to lack of clear communication and well-defined AI strategies, where employees often assume the worst-case scenario, further deepening their reluctance to adopt.

Recently, Great Britain implemented AI in MOT testing, using a data-driven approach to enhance efficiency, target resources more effectively, and maintain high safety standards. Currently each year there are 66,000 testers conducting 40 million MOT tests across 23,000 garages in Great Britain, with a team of 300 examiners auditing garages across the country.[23] AI-driven insights now analyse data, identify patterns, detect anomalies, and focus inspections where they are needed most, improving compliance monitoring and regulatory oversight, whilst also reducing unnecessary resource use. However, concerns arose about workforce displacement during this process, signalling the need for transparency when adopting AI-systems at scale.

Root Causes

- Public trust in AI is low because people are unsure whether it is safe, fair, or reliable. Lack of real-world testing and unclear accountability makes them worry about biased decisions.
- Misconceptions and fear of the unknown result in public concerns that AI could replace jobs or change their roles in ways they do not understand. Limited AI training and knowledge make this fear worse.
- Some senior staff prefer traditional ways of working and see AI as disruptive. Without a clear AI strategy and proper training, adoption remains slow.

Case Study

Bus Open Data Service (BODS)

The Bus Open Data Service (BODS), launched in 2020 under the Bus Services Act 2017, aimed to improve bus travel in England by providing open access to timetable, real-time vehicle location, and fare data.[24] It uses standards such as TransXChange (timetables), SIRI-VM (real-time tracking), and NeTEx (fares). Key milestones included deadlines for operators to publish this data between 2020 and 2023. Despite its benefits, BODS has been criticised for excluding accessibility information, affecting passengers with disabilities. This resulted in distrust from vulnerable passengers from using public buses due to the lack of accessibility data in real-time systems, which caused missed connections and reduced travel independence.

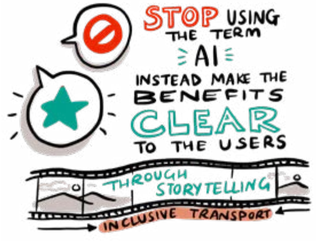
The findings indicate that good communications, along with AI literacy and awareness, is becoming increasingly important to improve public trust and social acceptance. Without transparency and clear regulations, scepticism may continue grows hindering AI adoption timelines.

1 Stakeholders highlighted that the transport sector has struggled to convey AI's potential in a way that resonates with the public, with operators and strategic leaders driving misunderstandings and mistrust.

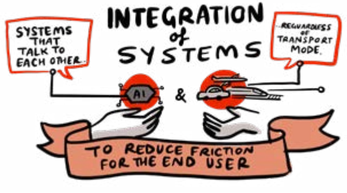
2 Discussions with stakeholders revealed that AI in transport requires changes in how trust is communicated. The lack of effective communication employed by the media on AI's benefits and implications has contributed to scepticism.

3 Stakeholder feedback indicated passengers welcome the use of digital methods to improve their journey experience. How can we replicate the same confidence through implementing AI without compromising on trust and the service delivered?

4 It has been suggested by stakeholders to stop using the term "AI" without context: Many people react negatively to the term "AI" due to misconceptions about its impact. Instead, clearly communicate AI's benefits to the user by explaining how it improves efficiency, safety, and convenience.



5 Stakeholders emphasised that AI adoption should be presented in a way that highlights how it benefits transport, rather than replacing jobs.



6 Transport networks should focus on creating AI systems that work together seamlessly, rather than implementing isolated solutions. Ensuring AI is seamlessly integrated and provides real value will help reduce resistance from both the public and industry professionals.

COST TO IMPLEMENT

Definition: Adopting AI in transport requires substantial investment, with the returns on this investment largely unknown, making the implementation of AI-driven solutions risky for public transport agencies and operators. This could limit AI-enabled benefits to those who can afford to invest, reducing access and widening the data-divide gap.

Literature Review

AI has the potential to enhance efficiency and reduce costs in the transport sector, but economic barriers hinder widespread adoption. AI-driven predictive maintenance has been demonstrated as a cost-saving tool in multi-modal transport, yet high upfront costs and technical barriers necessitate tailored financial models.[25] Public sector funding constraints further slow digital infrastructure upgrades and AI adoption, while limited digitalisation in port logistics reduces supply chain efficiency.[26] Economic challenges also stem from fragmented systems. Long-term cost savings can be achieved from digital transformation, but this requires harmonised policies and shared funding.

Investment incentives and public-private partnerships are critical to overcoming these obstacles. At present, high costs are associated with digital and physical infrastructure, as well as the increasing cost of power for supply and cooling.[27] AI can also support sustainability goals while cutting costs, as demonstrated by the AI-powered EV Charging Initiative, which uses predictive algorithms to optimise energy use and costs.[28] Similarly, AI-driven traffic management can ease congestion and reduce costs, but high infrastructure costs also hinder the adoption of advanced technologies like autonomous vehicles and Intelligent Transport Systems.[29] Addressing these economic challenges requires innovative business models, sustainable funding, and strategic investments to balance costs and cost savings to unlock AI's full potential in transport.

Root Causes

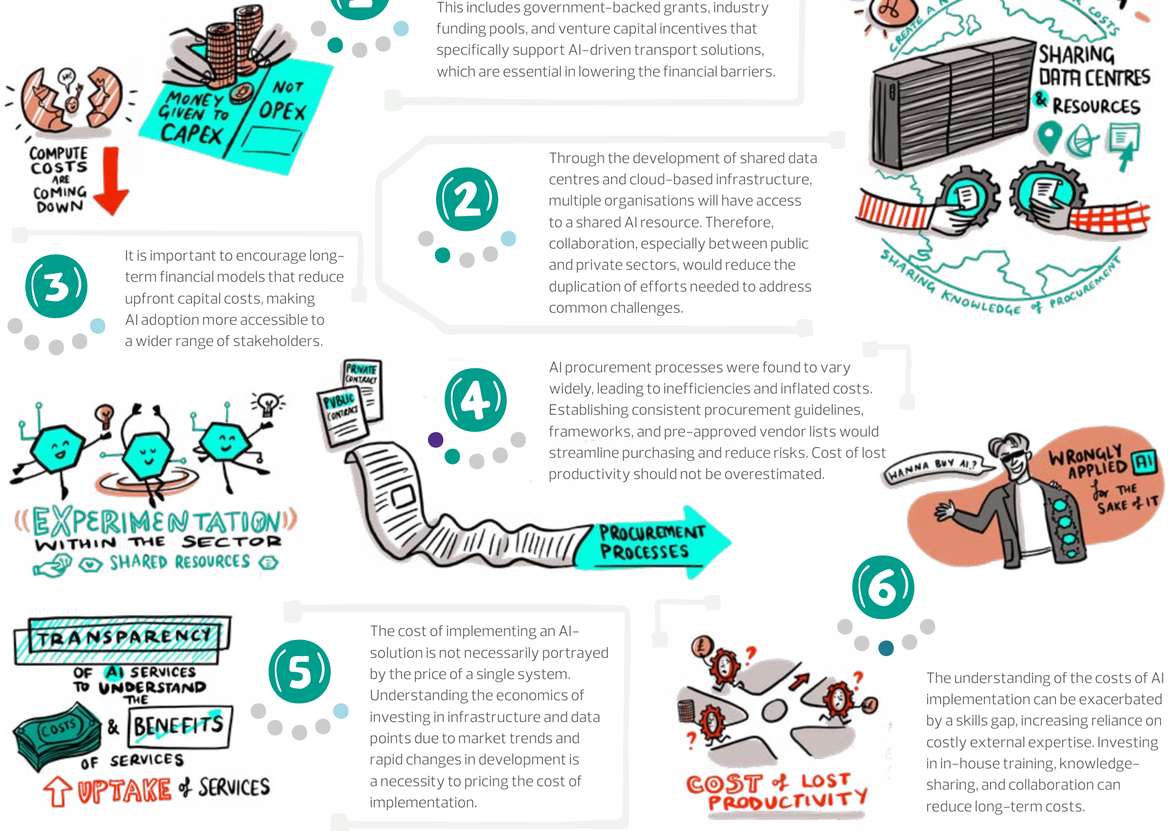
- Investment costs and funding gaps encompass the procurement of advanced hardware and software necessary for AI implementation. It also includes the substantial costs associated with hiring or training a specialised workforce to manage these technologies.
- AI systems heavily rely on vast amounts of high-quality data. The processes of collecting and managing this data can be extremely costly, especially when dealing with varied data sources and formats.
- Not being clear on what data is required and instead sourcing AI driven data before finalising the end goal.

Case Study

EV Charging Deserts

Electric vehicles (EVs) are widely recognised as a key solution for reducing carbon emissions and fostering sustainable transportation. However, the high capital cost of establishing EV charging stations has emerged as a significant barrier to mass adoption, especially in areas with limited access to funding or investment . Rural areas are therefore at risk of becoming "charging deserts" as commercial viability for private investment is questionable due to higher connection costs and lower demand.[30]

A key challenge in these areas is the high cost of grid connections and installation. Unlike urban centres, where population density ensures frequent use of charging stations, rural locations experience lower demand, making it difficult for investors to recover costs. As such the AI benefits that can be introduced through EV charging such as predicting demand and grid management may remain restricted to those who have access to financial resources.



ENVIRONMENTAL IMPACTS

Definition: While AI-driven transport solutions can reduce the impact of transport operations on the environment, the computational systems necessary to do so consume significant amounts of energy and water. Sustainable AI models are therefore needed in the drive to mitigate the impact of the transport sector on the environment.

Literature Review

The environmental impact of AI on commuting is complex and has resulted in a notable rise in worldwide energy usage with high levels of greenhouse gas (GHG) emissions. Research consistently pointing to the massive energy consumption of training and running AI models, particularly large language models.[31] This increase poses a twofold challenge: addressing the escalating computational requirements while reducing environmental effect. Further challenges associated with mitigating the direct and indirect environmental impacts has meant computing AI poses significant environmental repercussions. Direct impacts such as resource consumption are primarily negative in nature and are associated with using vast amounts of; energy demand, raw resources and water to power and cool data centres that process and compute data.[32] Indirect impacts are those which stem from applications of AI such as smart grid technology or digital twin simulation. Nonetheless efforts are needed to measure how we advance AI processing and hardware without leading to increased levels of electronic waste, increased levels of GHG and over-extraction of raw materials.

AI applications, including route optimisation, fuel efficiency improvements, and support for green mobility initiatives have the potential to significantly reduce carbon emissions, enhance air quality, and promote eco-friendly transport options. AI-powered route optimisation has been shown to significantly reduce CO_2 emissions, especially in congested urban areas.[33] However, realising these benefits depends on robust infrastructure, regulatory frameworks, and efficient data-sharing mechanisms.

Root Causes

- AI systems, particularly those used for complex tasks like autonomous driving and real-time traffic management, require vast amounts of computational power. This translates to substantial energy and water resource consumption by data centres, leading to increased environmental impact.
- Resource intensity of hardware production involves the extensive extraction process of rare earth minerals, which contributes to environmental degradation,
- Rapid advancements in AI technology are leading to frequent hardware upgrades, resulting in a growing volume of electronic waste.

Case Study

AI-Powered Route Optimisation in Maritime Shipping

Maritime shipping is a major contributor to global CO_2 emissions, projected to reach 5% by 2050 without intervention. One effective solution is AI-powered route optimisation, which analyses real-time data to identify the most efficient travel paths. Studies show this can reduce fuel consumption and CO_2 emissions by up to 10%, lowering costs and environmental impact.[34]

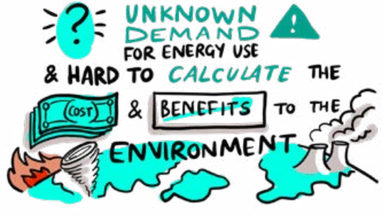
Traditional navigation relies on static planning, leading to inefficiencies and excessive fuel use. AI-driven systems dynamically adjust routes based on weather, ocean currents, and congestion, optimising efficiency. To maximise these benefits, industry leaders and policymakers must invest in digital infrastructure and regulatory support. Without strategic adoption, shipping will continue to face inefficiencies and rising emissions. AI-powered route optimisation presents a scalable solution for a greener, more efficient maritime sector.

1 There is a need to focus on climate-conscious and sustainable AI deployment strategies to minimise environmental and ecological harm.

2 It should be ensured that AI-driven systems calculate and consider the impact of energy requirements, emissions, ecological harm and waste before adoption.

3 Resource-sharing models are required to balance demand for data centre resource to avoid using unnecessary energy.

4 Stakeholders raised the question of "Are we over relying on nuclear energy as our source?" We should be inspired to solve how we can meet the growing processing demands of AI by utilising the cleanest energy sources and reducing the need to extract rare earth minerals.



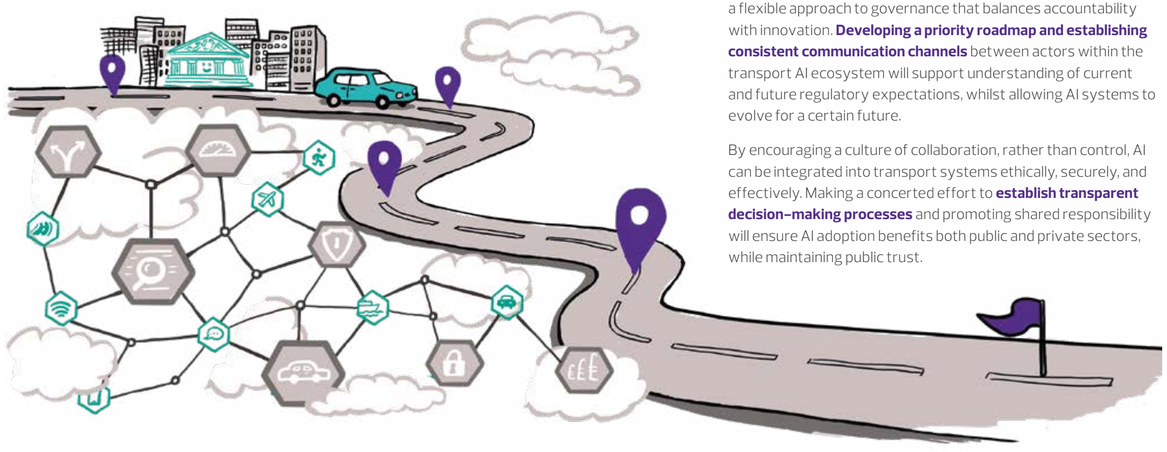
5 There is a need to assess AI's resource consumption and its impact on achieving net zero goals. Improper disposal of e-waste can release hazardous substances into the environment, posing risks to ecosystems.

Five key opportunities to transform transport as we know it

OPPORTUNITY 1

Establishing clear governance and regulation

Unclear rules, lack of responsibility, and business concerns make it challenging to implement AI in transport and highlight the need for clear and consistent AI governance frameworks. These issues were discussed under Regulation and Governance, Data Discoverability and Quality,and a structure for AI Integration.



Establishing a clear and consistent AI governance framework that fosters collaboration and removes regulatory uncertainty is a necessity for the transport sector. A lack of harmonised regulations, unclear responsibilities, and commercial sensitivity are major barriers to AI adoption in transport. **Creating a structured, coordinated and continuously evolving approach to AI governance**, both nationally and locally, will enable decision-makers at all levels to more effectively implement AI solutions.

Data privacy, ownership, and competition concerns currently make it difficult for private and public organisations to share information transparently. This slows progress and prevents the development of unified and interoperable AI systems. Consistency and cooperation across the sector must be promoted and enabled, **with effective governance practices collaboratively and openly shared.**

Instead of an overly rigid framework, action should be focused on a flexible approach to governance that balances accountability with innovation. **Developing a priority roadmap and establishing consistent communication channels** between actors within the transport AI ecosystem will support understanding of current and future regulatory expectations, whilst allowing AI systems to evolve for a certain future.

By encouraging a culture of collaboration, rather than control, AI can be integrated into transport systems ethically, securely, and effectively. Making a concerted effort to **establish transparent decision-making processes** and promoting shared responsibility will ensure AI adoption benefits both public and private sectors, while maintaining public trust.

OPPORTUNITY 2

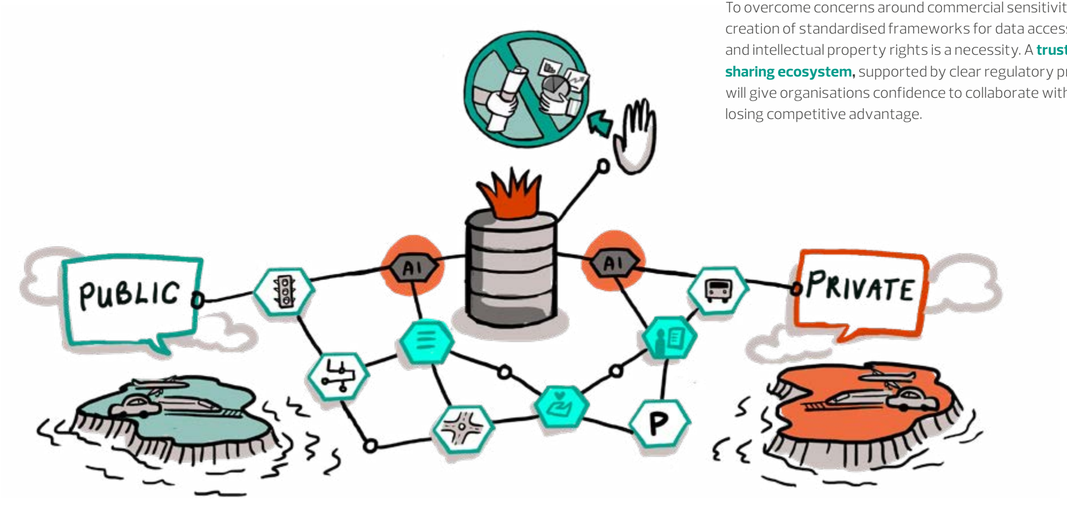
Balancing innovation and data protection through collaboration

The challenges of data sharing, resource collaboration, and AI infrastructure are key barriers to AI adoption in transport. These issues emerged in discussions on Data Discoverability and Quality,Infrastructure for AI Integration, and Regulation and Governance.

Many transport organisations operate in isolation, restricting their access to essential data, knowledge and AI-ready resources. Commercial partnerships are required to improve data discoverability, resource sharing, and AI infrastructure development. While solutions exist that address this challenge, these channels should be better harnessed by all to **bridge the gap in public and private sector cooperation.**

Shared data centres and AI resources must be developed as national assets to allow both the public and private sectors to access computational power and high-quality datasets without duplication of effort and cost. Public-private investment should be incentivised to develop shared AI infrastructure, such as a National Data Library, to reduce the costs and increase efficiency of AI solutions across the sector.

To overcome concerns around commercial sensitivity, the creation of standardised frameworks for data access, security, and intellectual property rights is a necessity. A **trusted data-sharing ecosystem,** supported by clear regulatory protections, will give organisations confidence to collaborate without fear of losing competitive advantage.



OPPORTUNITY 3

Enhancing technical skills and expertise

Workforce culture, leadership, and technical skills limit the adoption of AI in transport. These challenges were raised in discussions on kills and Workforce Readiness, Decision-Making and Accountability, and Public Trust and Social Acceptance.

A proactive learning culture, leadership engagement, and workforce training must be encouraged to embed AI skills across the public and private sectors. **A national AI skills strategy should be introduced**, and local delivery mechanisms put in place, to ensure the UK workforce – from senior leaders to frontline workers – have the knowledge and confidence to work with AI-driven systems.

To bridge technical skill gaps, **collaboration with industry, academia, and training providers** to share technical data analysis skills, AI literacy, and ethical AI considerations will enable employees to work alongside AI systems effectively rather than viewing them as a threat.

Strong leadership is crucial for AI adoption. **Promoting AI literacy at the executive level** must be considered to ensure senior leaders understand the potential, risks, and implementation strategies for AI. A lack of leadership engagement often results in slow decision-making, risk-averse behaviour, and missed opportunities for AI-driven innovation.

Fostering a supportive work culture and promoting AI adoption through transparency, employee engagement, and reskilling opportunities will strengthen acceptance. Employees need to see AI as a tool that enhances their work rather than replaces it. The **early implementation of good change management practices**, such as open communication, clear role transitions and training, will ease resistance and create a workforce that embraces AI as an enabler of progress.

OPPORTUNITY 4

Building public confidence in AI adoption

Gaining public trust and tackling widespread uncertainty about the benefits of AI, its negative impacts and perceived risk towards workforce displacement is a key opportunity for enabling AI adoption in transport. These discussions were put forward in Public Trust, Social Acceptance, Skills and Workforce Readiness.

Transport providers and technology developers must **transparently and clearly communicate the benefits arising from AI solutions,** rather than simply regurgitating the term 'AI' or other jargon which can alienate users. By clearly explaining the positive impacts the AI solution will deliver, customers become more understanding of how it will be experienced in daily travel.

Coordinated public awareness campaigns and user-friendly guides are essential stepping-stones to demystifying AI use cases to the end user. The industry must work together to demonstrate how AI brings value to customer travel aspirations, or to support those in the industry working with it. Cross-sector consistency in messaging can be the trigger for much-needed cultural and attitudinal shifts.

While there is a need to integrate systems to reduce friction, policy makers should implement robust data protection measures that ensure compliance with privacy regulations to alleviate concerns. **The public will need assurance that their data is being responsibly and securely handled**. Sensitively communicating how the risks of data security and protection have been ethically managed is critical to building confidence.

Mechanisms for **enabling public involvement to collaboratively design and implement AI systems** will be vital to building public trust in AI. Transport operators and AI developers should consult with a broad and representative range of stakeholders throughout the life-cycle of an AI product. They should provide clear, accessible information, such as how their AI systems are designed to function, their decision-making processes, and the steps they have taken to ensure physical and digital risks are appropriately managed.

OPPORTUNITY 5

Ensuring investment in infrastructure to support innovation and impact

The need to balance investment in physical and digital infrastructure with the intended operational benefits and environmental impacts can be both a driver and barrier to innovation for AI in transport. These challenges were raised in discussions on cost of Implementation, Infrastructure for AI Integration and Environmental Impacts.

A key challenge to the adoption of AI in transport is overcoming the actual, and perceived, costs and impacts of AI solutions throughout their value chain. To enable this, **an evidence-based approach for evaluating the value chain impact of AI solutions** must be developed. Bridging this evidence gap will empower organisations to undertake impact analyses and have greater certainty when developing business cases for implementing any future AI solution.

A focus on **securing targeted AI innovation funding through public-private partnerships** is crucial for sharing the investment burden, bridging resource and expertise gaps and accelerating AI solutions for social benefits. Collaboration between policymakers, local authorities, the private transport sector, and AI developers alleviates financial burdens and delivers pilot projects. Tax incentives, grants, or subsidies can encourage transport organisations to invest in AI solutions and make adoption more financially viable.

The opportunities for utilising exisiting physical and digital infrastructure cost-effectively should be explored to better leverage these assets for the benefit of future AI applications. To enable this, **a national AI infrastructure registry should be developed to** improve the discoverability and utilisation of these assets and collaboratively accelerate the early adoption of AI in transport.

Longer-term national and local capital infrastructure programmes that focus on **modernising physical and digital infrastructure** are required to ensure the UK transport sector remains at the forefront of the global race in developing AI-driven transport applications. It was recognised that, although we have not yet fully exploited existing physical and digital infrastructure, enhancements in capacity will certainly be needed in the future with increased adoption of AI solutions in transport.

It is vital to **develop AI solutions that aim to mitigate their impact on the planet.** These must align with net-zero strategies by using clean energy to power data centres and by minimising ecological damage. Strategies such as resource-sharing models to minimise our carbon footprint should be considered as a collaborative measure that results in reducing the impact of AI solutions.

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Statement of Authorship

This report was prepared by TRL researchers Dr Phil Martin, Dr Omar Jamal, Dr Sanaz Bozorg, Tejal Khullar, and Dr Robin Workman. All authors were responsible for the conceptualisation, research, and writing of this report. This included designing the report structure, designing and facilitating the workshops, analysing workshop discussions, synthesising key findings, and drafting the final document.

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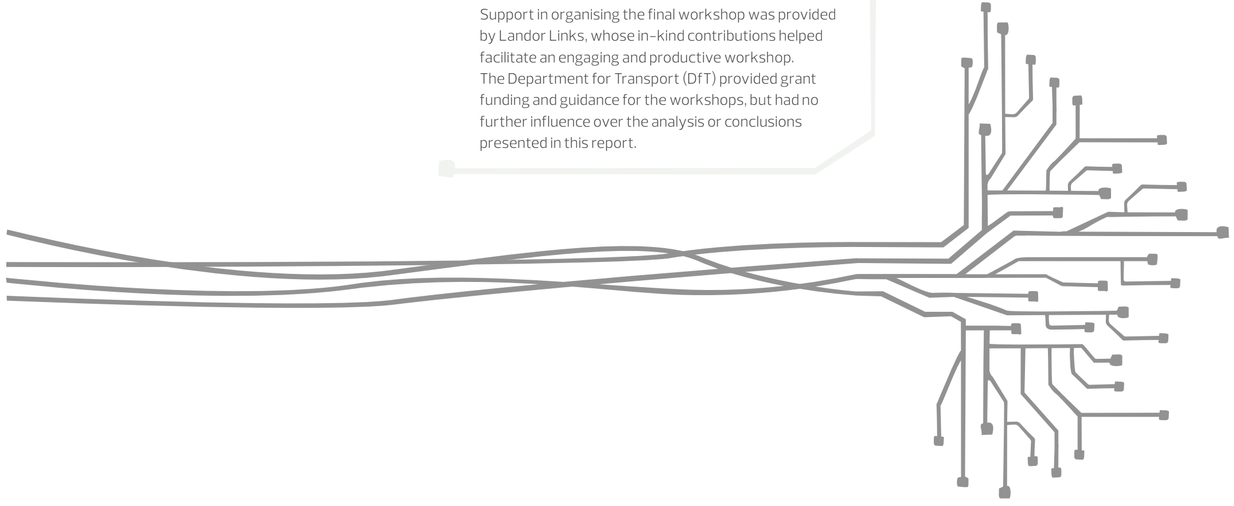

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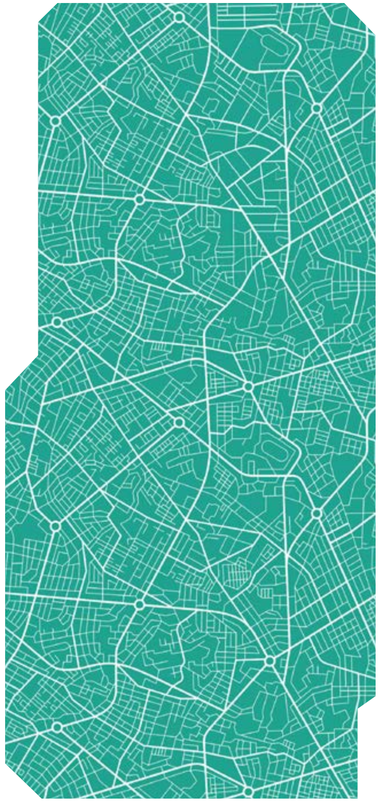

TRL THE FUTURE OF TRANSPORT

AI in transport offers significant potential for efficiency, safety, and sustainability, but its adoption faces challenges that must be overcome to unlock its potential. Following an extensive literature review and discussion of AI use in transport across two industry-led workshops, eight technical and non-technical barriers were identified as key areas needing attention. These findings were developed into five strategic opportunities for the sector: establishing clear governance and regulation, balancing innovation and data protection through collaboration, enhancing technical skills, building public confidence, and ensuring infrastructure investment to drive impact. Collaborative action on these opportunities can help create an effective AI-ready ecosystem to modernise our transport network.

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