

ZENZIC[✓]

Barriers and Opportunities for Automation in UK Ports

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Contents /

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This document constitutes the Authors' review of evidence and highlights material findings from that review to date. It is a guidance document prepared by the Authors, who have sought to ensure the accuracy of the information contained herein as at March 2026. The review, together with any opinions, interpretations, summaries, findings, conclusions, and professional judgments expressed in this document, reflects the Authors' assessment of the facts and evidence available at the time of writing. These assessments are based on the application of research principles and professional judgment and involve subjective interpretation. As such, they are necessarily limited by the available data, scope of work, budget, and schedule.

This report and the supporting evidence do not, and are not intended to, anticipate all changes in conditions or circumstances that may occur after the date of issue or the provision of the underlying documentation. To the extent that more definitive conclusions are desired than those warranted by the currently available evidence, the conclusions stated herein are intended as guidance rather than a firm course of action, except where expressly stated otherwise.

Glossary /

Abbreviation	Term
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
ASDE	Automated / Autonomous Systems Development & Engineering
AV Act	Autonomous Vehicles Act 2024
BPA	British Ports Association
CAM	Connected and Automated Mobility
CAPEX	Capital Expenditure
CNI	Critical National Infrastructure
CVI	Coarse Visual Inspection
DBR	Desk-based Research
DP World	Dubai Ports World – port operator at London Gateway
DSA03-DMR	Defence Safety Authority Guide to Regulation of Maritime Autonomous Systems
EPI	Expert Panel Interview
HGV	Heavy Goods Vehicle
HSE	Health, Safety, and Environment
ISO	International Organisation for Standardisation

Abbreviation	Term
MAR Lab	Maritime Autonomy Regulation Lab
MASS	Maritime Autonomous Surface Ship
MCA	Maritime and Coastguard Agency
MOD	Ministry of Defence
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
R&D	Research and Development
ROI	Return on Investment
ROV	Remotely Operated Vehicle
SI	Stakeholder Interview
SME	Small and Medium-Sized Enterprise
TEU	Twenty-foot Equivalent Unit
TOS	Terminal Operating System
TRL	Technology Readiness Level
UKMPG	UK Major Ports Group
5G	Fifth Generation Mobile Network



Executive Summary /

Key Findings

Adoption of Connected and Autonomous Mobility (CAM) technologies in UK ports is shaped by complex physical, digital, regulatory, workforce, economic and environmental factors that present both barriers and opportunities.

Barriers & Opportunities for Automation in UK Ports

This study finds that the adoption of Connected and Autonomous Mobility (CAM) technologies in UK ports is shaped by a complex interaction of physical, digital, regulatory, workforce, economic and environmental factors, rather than by technology maturity alone.

UK ports operate in highly diverse, predominantly brownfield environments. This structural reality shapes the feasibility, cost and pace of automation, and differentiates the UK from international leaders characterised by large-scale, purpose-built greenfield terminals. As a result, automation in UK ports is more likely to progress through incremental, mixed-mode deployment rather than whole-terminal transformation.

While digital connectivity and data infrastructure are recognised as foundational enablers, gaps in connectivity, system integration and cybersecurity readiness constrain progress. These challenges are compounded by a fragmented regulatory landscape spanning land-side, waterside and on-road domains, creating uncertainty around safety assurance, liability and deployment beyond the port gate.

The introduction of CAM technologies in ports represents both a workforce transition challenge and a strategic opportunity. Concerns around job security, skills gaps and organisation change persist, particularly in a sector with strong unions and safety-critical roles. At the same time, automation can enhance safety, create higher-value roles and help address chronic labour shortages, provided workforce transitions are actively managed and supported.

From an economic perspective, the business case for port automation remains highly sensitive to upfront capital costs, operational disruption, asset utilisation and the ability to justify investment in heterogeneous, often low-margin environments. Although automation can deliver long-term operational efficiency and resilience benefits, uncertainty around return on investment remains

a significant barrier, particular for smaller and mid-sized ports with limited access to capital and economies of scale.

Automation and net-zero objectives are also increasingly interlinked. Electrified autonomous equipment, optimised operations and reduced fuel consumption can materially support port decarbonisation. However, these benefits can only be realised where ports have sufficient grid capacity and energy infrastructure to enable the transition.

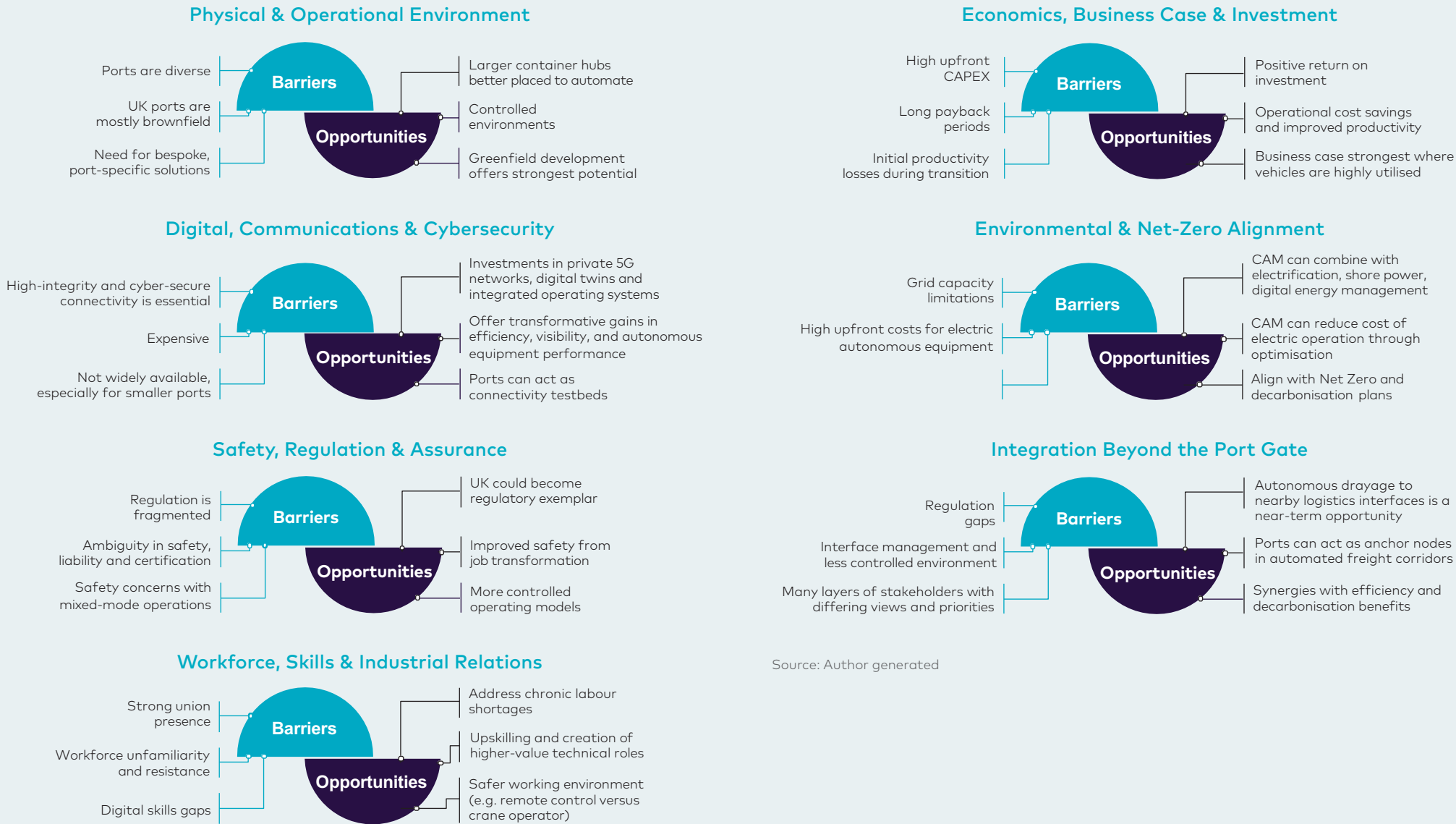
Extending automation beyond the port estate offers significant efficiency, economic and decarbonisation benefits. However, regulatory gaps and complex interfaces with public infrastructure currently limit the feasibility of end-to-end autonomous freight movements, constraining the ability to fully capture the benefits of automation across the wider supply chain.

While the UK is not currently a global leader in port automation, it has strong underlying capabilities from which to build. The UK has credible real-world exemplars of CAM deployment in ports, and automation has lagged primarily due to structural

and contextual constraints rather than a lack of technical capability. UK strengths in deploying mixed-mode automation within complex, brownfield environments represent a potential point of differentiation and a credible export opportunity, as many OECD ports face similar retrofit challenges.

From a supply chain perspective, the UK has a competitive edge at early technology readiness levels, notably in CAM software, AI, digital twins and R&D, rather than in hardware manufacturing. However, it faces increasing international competition and a fragmented domestic supply chain. There is a meaningful opportunity to strengthen the UK's global position by leveraging established and emerging strengths in software, data, robotics, analytics through cross-sector collaboration, provided this is supported by targeted government action.

Government intervention will therefore be essential to de-risk early deployment, enable the transition from trials to initial commercial operations, encourage port-to-port collaboration, accelerate innovation programmes and provide clearer regulatory pathways.



UK COMPETITIVE POSITION

- UK has strong foundations to become a global leader but currently lagging in adoption due to structural constraints, not lack of capability.
- UK aims to capture 10% of the global maritime autonomy market.
- International leaders: China, Singapore, the Netherlands, Nordics.

UK SUPPLY CHAIN

- **Strengths in TRL 1-4** (concept to early validation): CAM software, AI, digital twins and R&D.
- **Weaknesses in TRL 6-9** (applied validation to scaled deployment): UK lacks domestic manufacturing of automated port equipment.

CRITICAL ENABLERS OF GROWTH

- 1 Targeted government funding.
- 2 Strengthened collaboration and coordinated national strategy.
- 3 Enhanced maritime-specific automation/autonomy regulation.



Recommendations /

Without intervention, the UK risks remaining strong in pilots and R&D but weak in deployment, with economic benefits captured offshore.

Overall, the findings indicate that automation in UK ports is shaped less by technical limitations and more by physical, regulatory, economic and organisational constraints. While these barriers are challenging, they are coupled with clear opportunities to improve productivity, resilience, safety and decarbonisation outcomes. The UK's progress to date reflects the complexity of its port operating environments rather than a lack of capability, with notable strengths emerging in mixed-mode automation, digital solutions and early-stage innovation. Without targeted intervention, there is a risk that the UK remains strong in R&D, but weak in deployment, domestic value capture and supply-chain maturity.

Strategic implications

Three strategic implications emerge:

1. Scaled deployment is the most critical constraint: the critical challenge is moving from pilots to commercial deployment at scale. Public funding to

date has been effective in de-risking innovation but insufficiently targeted at supporting initial operational vehicles and the enabling infrastructure required to justify scaled deployment.

2. Mixed mode automation is the UK's most credible competitive niche: the UK is unlikely to lead in greenfield, fully automated port models as seen in parts of Asia. Instead, it has a realistic opportunity to lead in mixed-mode, brownfield automation, combining autonomous and manual operations within constrained environments, expertise that is increasingly relevant internationally.

3. Coordination and clarity are essential to unlock investment: greater collaboration between ports, clearer regulatory pathways and stronger alignment across government, industry and technology providers are required to reduce risk and crowd-in private capital.



Recommendations

To address these challenges, this study identifies the following priorities:

1. Rebalance public funding towards deployment and commercialisation: shifting public funding from R&D pilots towards early commercial deployment, particularly to support the scaling of initial fleets (such as autonomous HGVs and yard tractors) and enabling infrastructure.

2. Formalise and strengthen national collaboration: through mechanisms such as the UK Ports Automation Group, enabling structured knowledge-sharing and accelerated learning and a national voice to shape regulation, standards, and strategic funding asks.

3. Develop a more coherent, end-to-end regulatory approach for port automation: reducing fragmentation across land-side (HSE), waterside (MCA) and on-road (AV Act) domains, and embedding clearer port-specific safety and assurance standards.

4. Support workforce transition and skills development: ensuring automation delivers safer, higher-value roles and long-term operational resilience, with a focus on remote operations, fleet supervision, digital maintenance, and data/AI skills.

5. Leverage existing national strengths and cross-sector synergies: drawing on adjacent capabilities in vessel automation, AI, robotics, sensors, digital twins and CAM-related software, and the strengths of regional innovation clusters such as the Maritime Southwest cluster and Liverpool Sensor City.

Timely action will be critical to avoid falling behind in the transition to automation and to remain competitive with global leaders. Taken together, coordinated action would allow the UK to convert its strong digital and R&D capability into deployable, exportable solutions, strengthening productivity, resilience and alignment with net zero objectives across the UK ports sector.

Introduction /

The UK Port landscape

The UK has one of Europe’s largest and most diverse port industries, comprising around 120 commercial ports ranging from major deep-sea container hubs to specialised bulk terminals and smaller regional ports. In addition to these, the country has over 400 non-cargo handling ports and harbours, supporting fishing, leisure, and local connectivity needs. Freight activity is heavily concentrated, with the top 20 ports accounting for nearly 90% of total cargo volumes.

Ports vary significantly in scale, layout, ownership and cargo type. While deep-sea hubs such as Felixstowe, Southampton and London Gateway dominate container volumes, many regional ports also handle container or unitised traffic, including Tyne, Teesport, Liverpool, Bristol, Grangemouth, Belfast, Hull and Immingham. This diversity in port types, cargo flows and infrastructure strongly influences where automation is most feasible and where business cases are most compelling.

The UK port landscape is overwhelmingly brownfield, with only a handful of the country’s 120 commercial ports developed as true new-build greenfield sites in recent decades. As a result, over 95% of UK ports are characterised by legacy infrastructure, constrained development space and diverse operating models, which has important implications for automation feasibility

and deployment pathways and creates a need for retrofitted solutions and mixed-mode operations.

Overview of Automation, Autonomy and CAM

Automation refers to the use of technology to perform specific tasks with reduced human input. In ports, this includes systems such as remotely operated cranes, automated stacking cranes, automatic gate systems, and digital workflows that support more consistent and efficient operations. These systems follow defined rules but typically still involve human oversight.

Autonomy builds on automation by enabling systems to perceive their environment, make decisions and execute tasks with minimal human involvement. In port operations, this includes autonomous terminal tractors, autonomous trucks for internal container moves, driverless shuttles, automated yard equipment and self-navigating vessels. These systems rely on sensors, AI, communications and control technologies to operate safely and predictably in dynamic environments.

Connected and Automated Mobility (CAM) brings automation and autonomy together within a digitally connected environment. It refers to the wider ecosystem that links automated or autonomous equipment with enabling technologies such as private

5G, sensors, digital twins and integrated operating systems, allowing assets, infrastructure and control centres to communicate and operate in real time.

Automation use cases

Automation opportunities differ widely across port types and cargo flows. The strongest near-term business cases tend to be predictable, repeatable, and high-volume operational tasks, where technology is already maturing and early deployments demonstrate positive results.

Use cases with stronger business cases include autonomous terminal tractors and trucks for container movement within the port estate which are typically characterised by high-frequency, standardised flows with strong potential for cost savings and improved consistency and remotely operated or semi-automated cranes which have proven safety and productivity benefits in both quayside and yard operations.

Weaker business case include bulk handling operations where cargo flows are less predictable, equipment types are more specialised and utilisation varies. Bulk operations often require bespoke machinery and irregular movement patterns making automation more complex and harder to justify commercially.

Methodology /

WSP used a comprehensive five-stage process for the UK Ports Automation Study.

1. Data Gathering

A data gathering exercise was conducted, bringing together in-house knowledge through an Expert Panel, stakeholder engagement through interviews and desk-based research. Eight stakeholder interviews were conducted, and an evidence base of 20+ publicly available documents were reviewed.

2. Evidence Base

All information was consolidated into a consistent evidence base that underpinned our analysis.

3. Analysis

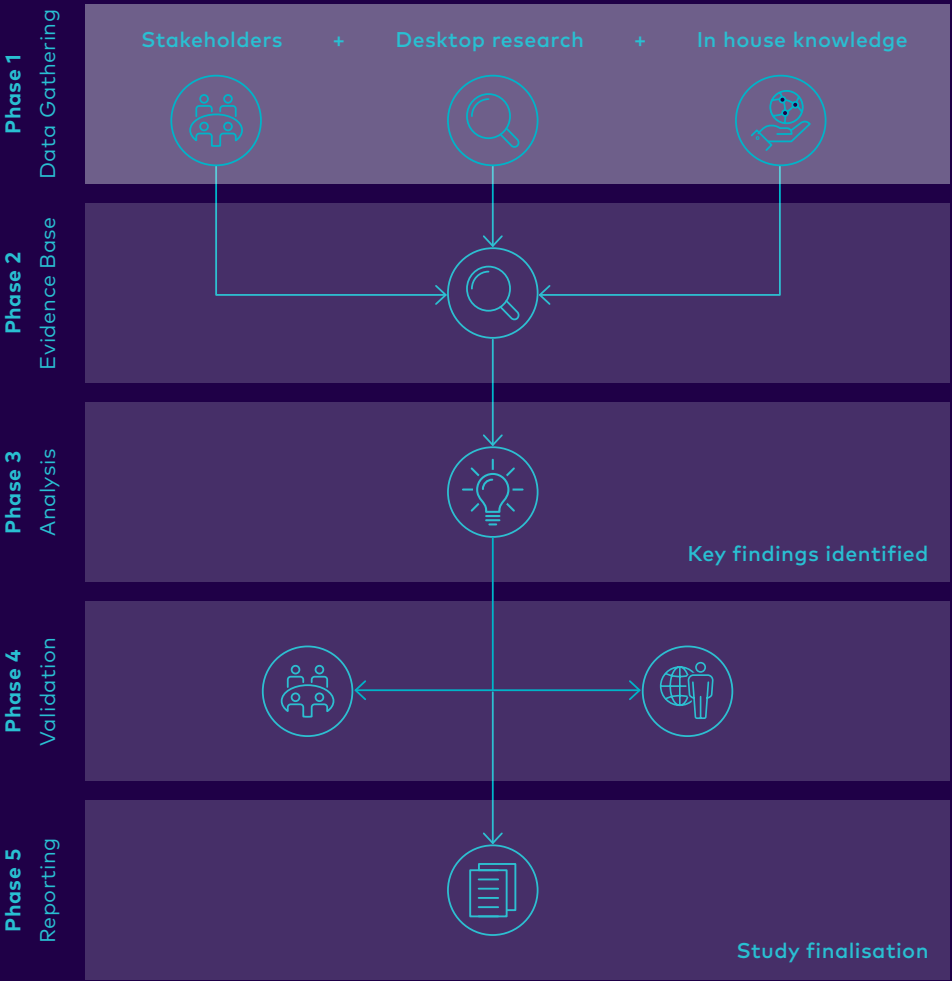
The evidence was analysed against seven key themes for barriers and opportunities and used to develop our initial findings.

4. Validation

The evidence was presented to Zenzic, the UK Ports Automation Group and our internal Expert Panel for challenge and validation.

5. Reporting

The findings were updated with insights from the validation phase, and a report finalised.



Source: Author generated

1. Key Barriers and Opportunities /

Physical & Operating Environment

UK ports operate in diverse, predominantly brownfield environments. This structural reality shapes the feasibility, cost and pace of automation, making operational context a critical determinant of deployment strategies for Connected and Autonomous Mobility (CAM).

Barriers

Heterogeneous and Brownfield Environments

UK ports vary widely in size, layout, cargo mix and operational models, making standardised automation solutions difficult to implement. Brownfield constraints, legacy infrastructure, ageing assets, limited land availability and complex traffic flows, restrict opportunities for large-scale system redesign. Greenfield opportunities offer the strongest potential for fully automated new-build terminals, but these opportunities are limited in the UK. Bulk handling operations are also more difficult to automate, as cargo flows are less predictable, utilisation varies and equipment types are more specialised.

Legacy Systems and Organisational Complexity

Many ports continue to rely on paper-based processes, siloed systems and variable data quality, limiting readiness for integrated digital and

automated operations. Divergent stakeholder interests and multi-layered governance structures slow decision-making and complicate automation planning.

Space and Infrastructure Limitations

Physical constraints, such as narrow operational corridors, mixed-use zones and limited development headroom, reduce the feasibility of segregated autonomous areas. Infrastructure gaps, especially connectivity and modernised assets, add further complexity.

Risk Aversion in Established Operations

Larger ports with stable, high-throughput operations tend to adopt conservative, incremental change to avoid operational disruption, lengthening the adoption timeline.

Opportunities

Mixed-Mode and Phased Automation Deployment

Ports can progressively introduce automation by converting targeted processes or equipment into “smart assets” enabling incremental, small-scale deployments before wider rollout. Mixed-use zones (manual and autonomous equipment operating together) also offer a pragmatic route for early adoption. Experience gained in mixed-mode brownfield ports is increasingly valuable internationally, as most OECD ports face similar retrofit constraints.

Controlled Operating Environments

Compared with public roads, port estates offer predictable, well-managed environments well suited for early CAM deployment, particularly for yard logistics and internal haulage. Large container hubs are structurally better placed to automate due to standardised flows.

Land and Waterside Opportunities

Automation potential exists across both landside (e.g., internal haulage, gate operations) and waterside domains (e.g., remote-operated cranes), though strategies will differ by function and environment.

Integration with Multimodal Operations

Remotely operated and autonomous equipment can support more efficient intermodal flows, particularly where ports interface with rail terminals, logistics parks or last-mile distribution nodes.



Key Insight: The diversity and brownfield nature of UK ports present challenges for full-scale automation but also carve out a distinctive opportunity: the UK can become a leader in mixed-mode, incremental automation solutions.

Digital, Communications & Cybersecurity

Digital connectivity, data infrastructure and cybersecurity are foundational enablers for CAM adoption. While UK ports increasingly recognise the value of digitalisation, gaps in connectivity, system integration and security readiness continue to constrain automation progress.

Barriers

Connectivity Limitations

Ports commonly face weak or inconsistent wireless coverage, physical obstructions, and limited availability of high-integrity digital infrastructure, restricting the reliability required for autonomous equipment. Interface management challenges, both between systems and zones, also hinder seamless communication between assets, operators and control systems.

Technology Immaturity and Rapid Change

While some trials are being carried out using 4G or satellite-based solutions (e.g. Starlink), scaling CAM will likely require investment in high-integrity private 5G networks, which although expensive, offer the reliability and low-latency performance needed for scaled autonomous equipment. Many CAM-enabling technologies remain immature or unproven, resulting in limited real-world trials, uncertainty around long-term performance, and difficulty selecting solutions in a rapidly

evolving landscape. Fast-paced AI and automation developments create hesitation among operators and public-sector procurers, who often default to established, lower-risk technologies.

Integration and System Complexity

Achieving end-to-end automation requires interoperability across diverse legacy systems, equipment suppliers and data formats, an area where current digital architectures are fragmented. Complex system-level integration (e.g., linking sensors, vehicles, terminal operating systems and connectivity layers) amplifies implementation risk.

Cybersecurity and Public Perception Risks

Growing cybersecurity threats and concerns over data integrity create barriers to deploying connected and autonomous systems at scale. Some ports are designated as Critical National Infrastructure, which has implications for cybersecurity, vendor choice, data sovereignty and risk appetite, particularly in the use of international suppliers.

Opportunities

Integrated Operating and Data Platforms

Ports can unlock significant efficiency gains through integrated operating systems, digital twins and shared data environments that enhance visibility, optimisation and predictive insights. Improved digital foundations support more consistent performance and enable scalable autonomous operations.

Synergies with Electrification and Modernisation

Investments in electrification often require upgraded grid, digital and communications infrastructure, creating opportunities to integrate CAM-ready systems into wider port modernisation programmes.

Digitisation of Legacy Processes

Replacing paper-based workflows with digital systems reduces errors, enables real-time data capture and improves operational resilience and efficiency. As high-quality datasets become more available, ports can adopt advanced analytics, machine learning and automated decision-support tools.

Ports as Digital Testbeds

UK ports such as Tyne, Thames Freeport (Port of Tilbury and DP World London Gateway) and Belfast Harbour are already acting as demonstrators for private 5G and advanced digital systems, providing replicable models for other ports and suppliers. The growing role of ports as data platforms strengthens opportunities for innovation, cross-sector learning and commercial partnerships.



Key Insight: Digital capability is a critical enabler of port automation. Addressing connectivity, data integration and cybersecurity risks will not only unlock CAM adoption but also drive system-wide efficiency and resilience across UK port operations.

Safety, Regulation & Assurance

Safety and regulatory clarity are fundamental prerequisites for deploying CAM technologies in ports. However, the UK’s current regulatory landscape is fragmented across land-side, waterside and on-road domains, creating uncertainty that slows investment and deployment.

Barriers

Fragmented and Emerging Regulatory Frameworks

Port autonomy sits at the intersection of workplace (HSE), maritime (MCA) and road (AV Act) regulation, with no unified framework to govern port-specific automated systems. This creates ambiguity around safety requirements, liability allocation and certification. Land ownership within port estates impacts which regulation applies (e.g. rail terminals may be classed as “on-road”), this limits the ability of ports to extend autonomous operations within port estates. The lack of alignment across authorities makes it difficult for operators to develop clear safety cases or progress from pilots to commercial deployment.

Safety Risks in Mixed-Mode Operations

Interfaces between autonomous systems, manual vehicles, pedestrians and public-access areas introduces complex safety challenges, including concerns about system behaviour in unpredictable

environments, and risks associated with mixed human-machine operations. Existing safety standards are believed to be more suited to CAM deployment in enclosed environments, resulting in challenges with adapting the standards to determine testing and commissioning approaches for port environments.

Technology Immaturity and Limited Assurance Pathways

Immature technology, limited trial data and inconsistent safety standards delay approval processes and erode operator confidence. The absence of clear test, validation and assurance frameworks increases perceived risk for both regulators and port operators.

Public and Workforce Perception Challenges

Concerns around autonomous accidents, liability, cybersecurity and loss of control feed public scepticism. Limited support frameworks and a lack of clarity on roles across the CAM ecosystem heighten resistance to change.

Opportunities

Improved Safety Through Automation

Automation offers potential for substantial reductions in incidents, including fewer fatal and serious accidents, by removing workers from hazardous operational zones. Stakeholders noted early evidence of improved safety performance where autonomous trucks have been trialled.

Remote-operation technologies can further enhance safety by reducing exposure to high-risk manual tasks.

Regulatory Leadership Opportunity for the UK

Ports are controlled environments with strong existing H&S cultures, ideal conditions for piloting regulatory sandboxes and developing port-specific safety cases.

Accelerating Assurance Through Trials and Demonstrators

Demonstrator projects (e.g., autonomous trucks, remote-operated equipment) help generate real-world safety data and build regulator confidence. Standardising processes for safety validation and quality assurance would reduce friction for scaling future deployments.

Greater Accessibility and Operational Control

Automation can enhance accessibility, improve traffic management, and enable more precise and predictable operations, contributing to safer port estates overall.



Key Insight: The UK has an opportunity to lead globally by shaping a coherent, end-to-end regulatory model for maritime autonomy.

Workforce, Skills & Industrial Relations

The introduction of CAM technologies in ports represents both a workforce transition challenge and a strategic opportunity. While concerns around job security, skills gaps and organisational change persist, automation can also enhance safety, create higher-value roles and help address chronic labour shortages.

Barriers

Workforce Resistance and Perception Challenges

Employees and unions often express concern over job displacement and loss of control, contributing to resistance to change. Workforce unfamiliarity with automation technologies and public concerns about safety create hesitancy around adoption.

Skills Gaps and Limited Digital Readiness

Significant gaps exist in digital, technical and automation-related competencies across the current workforce. This is driven by persistent shortages in traditional operational roles, including chronic HGV driver shortages and shortages in crane operators, which is compounded by an often-ageing operational workforce with significant retirement risk over the next decade. There is also a mismatch between the existing skills and those required for automation and digitalisation (e.g. remote

operators, digital maintenance); many port roles have traditionally been manual, creating a steep transition to new technology-enabled roles.

Uncertainty During Transition

Stakeholders highlighted concerns about redundancies, role changes and unclear career pathways as automation scales. The lack of clarity on responsibilities within the broader CAM ecosystem further complicates workforce planning.

Low Global Acceptance of CAM Technologies

Internationally, workforce acceptance of CAM remains limited, influencing perceptions among staff, unions and communities and slowing adoption in the UK port sector.

Opportunities

Upskilling and Workforce Development

Automation creates demand for higher-value technical roles, such as remote operators, fleet supervisors, data analysts and maintenance technologists, driving opportunities for structured upskilling. Approaches adopted in comparable industries (e.g., automotive manufacturing) demonstrate how reskilling can enhance job quality and satisfaction.

Improved Working Conditions and Safety

Automation reduces exposure to high-risk manual

tasks and enables safer, cleaner, more ergonomic working environments. Early examples (e.g., remote-controlled crane operations) show tangible improvements in working conditions and safety outcomes.

Addressing Workforce Shortages

Many ports face ongoing labour shortages and automation can help supplement limited staffing, particularly in repetitive or safety-critical roles. CAM can unlock more predictable operations, enhancing the attractiveness of port roles and supporting retention.

New Economic and Innovation Opportunities

The transition to CAM offers growth opportunities for UK SMEs, start-ups and service providers, particularly in software, training and human-machine interface solutions. Reskilling and redeployment can support more diverse job portfolios and future-ready port operations.



Key Insight: The primary workforce challenge is not large-scale job loss, but the pace of skills transformation. With structured upskilling, clear communication and early workforce engagement, CAM can create safer, higher-value and more resilient port jobs.



Economics, Business Case & Investment

The economics of port automation are highly sensitive to asset costs, operational disruption, and the ability to justify investment in heterogeneous, often low-margin environments. While stakeholders recognise the long-term operational efficiency and resilience benefits of CAM, uncertainty around ROI remains a major constraint, particularly for smaller and mid-sized ports.

Barriers

High Upfront Costs and Complex Business Cases

CAM deployment requires significant capital investment in equipment, digital infrastructure, and integration, which is difficult to justify where margins are thin and assets have long life cycles. Automation business cases are further complicated by operational diversity across UK ports and the bespoke solutions required in brownfield environments.

Uncertain Returns and Initial Productivity Impacts

Stakeholders reported ambiguity around achievable ROI due to limited UK deployment examples and early productivity dips during transition periods. Smaller and mid-sized ports face structurally weaker business cases due to limited economies of scale. Additionally, technology providers are sometimes perceived as overselling capability, adding scepticism and caution to investment decisions. The rapid speed of change in AI and automation also makes it difficult to commit capital without fear of technology obsolescence, increasing the perceived stranding risk for CAM.

Competitive Market Dynamics

UK ports primarily compete domestically rather than internationally, reducing incentives for collaboration. Reluctance to share data, lessons learned, or commercial insights constrains sector-wide learning and slows uptake.

Limited Public Funding and Support Mechanisms

Insufficient government support for scaling from pilots to early commercial deployment is seen as the critical gap in enabling operators to move beyond proof-of-concept. Large-scale automation is additionally hindered by funding limitations for enabling infrastructure such as electrification and connectivity.

Opportunities

Long-Term Cost Savings and Operational Consistency

Automation can reduce long-term labour, maintenance, and operational costs, while supporting more predictable throughput and reduced variability. Predictive maintenance, digital optimisation and consistent equipment performance can significantly improve asset utilisation.

Attracting Inward Investment and Enhancing Competitiveness

Automation supports ports and wider regional economic goals by improving efficiency, reliability, and logistic chain integration. Ports demonstrating early CAM successes can strengthen their strategic positioning and attract new commercial partnerships. Automation and AI are increasingly viewed as return enhancers by infrastructure

investors; however, investors may demand higher hurdle rates where technology is unproven, cash flows are exposed during transition and regulatory and labour risks are unresolved. Automation risk is typically priced as an execution and transition risk, rather than a technology risk.

New Revenue Streams and Service Models

CAM can enable new commercial offerings such as automated drayage, digital logistics services, and value-added data products. Ports adopting integrated digital and autonomous operations may tap into growing demand for automation-ready terminal services.

Strengthening Competitiveness Through Efficiency

Improved resilience, higher operational consistency, and better utilisation of terminal assets strengthen the business case, even if initial deployment requires structured, phased investment. Evidence from UK trials, such as autonomous trucks in Felixstowe, suggests positive returns and improved operational reliability at scale.



Key Insight: The key financial hurdle is moving from pilots to early deployment. Targeted investment, especially in initial fleets and infrastructure, would unlock stronger business cases and speed the pace of adoption.



Environmental & Net Zero Alignment

Automation and net-zero objectives are increasingly interlinked. Electrified autonomous equipment, optimised operations and reduced fuel consumption can materially support decarbonisation, but only where ports have the energy capacity and infrastructure to enable the transition.

Barriers

Grid Capacity and Energy Access Constraints

Ports face significant challenges in securing sufficient grid capacity to support widespread electrification and the deployment of autonomous equipment. Energy infrastructure upgrades are often costly and slow to deliver, creating a critical bottleneck for scaling electric autonomous fleets and associated charging infrastructure.

High Upfront Costs for Electric Autonomous Equipment

These constraints are compounded by the high capital cost of electric automated vehicles. Limited supply chain availability and long lead times also slows adoption. Many technologies are still in early stages of commercial readiness, increasing procurement and integration risks.

Competing Investment Priorities

Ports must balance investment across decarbonisation, digitisation, and operational modernisation. This creates difficult trade-offs, making it difficult to fund all initiatives concurrently. Ongoing supply-chain constraints, especially early-stage electric solutions, further restricts the pace of transition.

Value Chain Emissions

In addition, the manufacture of new electric and automated equipment carriers embodied carbon emissions. This can lead to short-term increases in Scope 3 emissions, even when significant operational Scope 1 & 2 emissions reductions are delivered over the asset lifecycle.

Opportunities

Strong Synergies Between Automation and Electrification

Automation can enhance energy efficiency through optimised driving patterns, reduced idling, and increased asset utilisation. Integrating electrified fleets with autonomous operations strengthens the business case for both technologies.

Support for Net-Zero and Emissions Reduction Goals

Automated operations can reduce fuel consumption,

shorten operating cycles and minimise emissions, supporting port decarbonisation strategies and compliance with future regulatory requirements. Stakeholders reported reduced fuel consumption and lower emissions from early trials and electrification initiatives. External studies suggest that automation-enabled electrification of port equipment can reduce operational CO2 emissions by approximately 20-40% at asset or terminal level, with additional single-digit reductions achievable through digital optimisation alone.

Smarter Energy and Charging Management

Automation also enables more predictable fleet movements, allowing ports to implement optimised charging strategies and reduce peak load stresses. Higher utilisation and targeted fleet deployment can reduce total equipment requirements, helping to lower both emissions and overall system costs over time.



Key Insight: Ports that invest in electrification and energy infrastructure early will be best positioned to deploy CAM at scale, unlocking both operational efficiency and measurable emissions reductions.

 Integration beyond the Port Gate

Extending automation beyond the port estate offers significant efficiency and decarbonisation benefits. However, regulatory gaps and complex interfaces with public infrastructure currently limit the feasibility of end-to-end autonomous freight movements.

Barriers

Regulatory Gaps at the Port–Public Interface

Autonomous movements beyond the port boundary face regulatory uncertainty, including restrictions under the Autonomous Vehicles Act 2024. These challenges intensify when autonomous vehicles interact with public roads, shared zones or mixed-use spaces, triggering more stringent safety, liability and compliance requirements.

Interface Management and System Integration Challenges

Regulatory challenges are compounded by the practical challenge of integrating autonomous port equipment with public-facing infrastructure (e.g., highways, depots, logistics parks). Effective operation requires robust digital, operational and safety coordination across multiple systems. System-level integration remains complex, especially in environments characterised by legacy infrastructure and diverse stakeholders.

Infrastructure and Stakeholder Complexity

Multiple operators, landowners and regulatory

bodies across a short geographic interface create fragmented decision-making and slow progress in the integration of automation beyond the port gate. Ports also noted limited control over external infrastructure, which constrains autonomous corridor development beyond the port estate.

Opportunities

Near-Term Autonomous Drayage

Despite the constraints, strong near-term opportunities exist for autonomous transport between ports and nearby depots, logistics parks and rail freight terminals, where travel distances are short and operational patterns are predictable.

Integration with Wider Transport Networks

Building on these early use cases, linking port automation with wider public transport systems and regional mobility (e.g., park-and-ride shuttles, remote parking, automated last-mile cargo routes) could unlock broader economic and social benefits.

Future Automated Freight Corridors

Over the longer term, ports can act as anchor nodes in emerging automated logistics corridors, enabling smoother, lower-emission freight flows across regional and national supply chains. Technology providers emphasise the potential for interoperable autonomous systems that operate seamlessly across multiple environments, provided regulatory and coordination challenges can be addressed.

Key Insight: Extending automation beyond the port gate remains constrained by regulation and interface complexity. However, short-distance autonomous drayage and controlled off-road corridors offer a practical, high-value pathway for early deployment.





2. UK Competitive Position /

CAM in Ports

UK Port automation lags due to structural constraints, not lack of capability.

UK Port CAM Market Context and Size

The Government has stated its ambition for the UK to be at the forefront of the global maritime autonomy industry, with analysis indicating the UK could capture 10% of a projected \$136bn market by the mid 2030s [DBR7]. Ports are inherently diverse, multi-stakeholder operating environments and stakeholders consistently expressed interest in advancing CAM in the maritime sector. However, deployment to date has remained limited relative to other sectors, most notably on-road logistics and passenger mobility, where levels of investment, regulatory clarity, and demand have driven faster progress.

Market analysis by the UK Automotive Council highlights the scale of this imbalance; the combined market size of on-road logistics and passenger CAM is expected to be more than three times larger than the off-road logistics market, which includes ports[DBR10]. This disparity is consistent with the distinctive barriers facing UK ports, including complex brownfield estates,

heterogenous operating environments and high upfront capital costs.

Despite these challenges, ports are highly controlled environments, shielded from many of the external variables that make on-road autonomy challenging. In principle this should it easier to automate ports from a safety and systems-integration perspective. The limited pace of deployment therefore reflects structural constraints rather than a lack of technical feasibility or capability.

UK Port Competitvity

There is significant competitive tension between UK Ports. Automation is viewed as a strategic and commercial differentiator, which can limit collaboration and create reluctance to share lessons, data or failures. However, extensive collaboration is already happening between UK Ports through industry associations such as the British Ports Association and UK Major Ports Groups on topics such as decarbonisation and policy. The emerging UK Ports Automation Group convened by Zenzic presents an excellent opportunity to bring together stakeholders to collaborate on the topic of port automation and collectively share knowledge key to aligning with progress in the on-road sectors.

Notable UK Case Studies

Despite there being a lag in CAM technology deployment within UK ports, there are multiple successful deployment examples and plans for future deployment.



Detail on the above case studies provided on the following page. This list is not exhaustive, but these examples were highlighted during the stakeholder engagement process.

Case Studies /

The UK is not currently a global leader in port automation, but it has strong foundations to become one, with credible standout exemplars of CAM in UK Ports already demonstrated.



Port of Felixstowe

- The Port of Felixstowe and its port operator Hutchinson Ports have implemented Europe's largest scaled deployment of 100 **autonomous trucks** in partnership with Westwell Technology. By the end of April 2026, all 100 will be on site at the port and there are currently 34 operational^[S15].
- These trucks focus on shipping, haulage, and interfaces with rail logistics and have been operating since June 2023. They are mixed modal and interact with hauliers and manual trucks when operating^[S15].
- The Port of Felixstowe confirm that there has been a positive return on investment from the introduction of these trucks^[S15].



Port of Tyne

- **5G Connectivity:** partnered with BT and Ericsson to deploy a private 5G network. Whilst this is not a necessity in the port currently, it enables the CAM transition^[S18].
- **External Drone:** deploying an external port drone to replace manual activities such as security patrols and infrastructure maintenance and surveys^[S18].
- **Autonomous terminal tractor trial:** announced in 2025, a trial of a fully autonomous terminal tractor and a secure mesh communication network. This was funded as part of the UK Pathfinder programme^[DBR11].
- **Robotic terminal truck trial:** back in 2023, a trial of a robotic terminal truck was developed by ANT Machines for the movement of containers within the port^[DBR12].



Belfast Harbour

- **Harlander Project:** joint government and industry funding to deploy a driverless shuttle to transport people through the harbour providing last mile connectivity. Whilst not connected to port operations, it is a positive use case for autonomous vehicles within a harbour environment^[DBR13].
- **5G Connectivity:** Belfast Harbour partnered with BT to install a private 5G network in the harbour estate. As outlined earlier in this study, connectivity is a key enabler of the CAM transition^[S13].
- **Automation initiatives** within container terminals, cargo terminals, ferry operations, logistics yards, and public transport integration. Successful pilots in both industry and public autonomy and plans for widespread adoption^[S13].



- **London Gateway:** operated by DP World, London Gateway has unmanned ship-to-shore cranes and automated stacking cranes. Their berth extensions offer a promising test case for further automation applications, and the port is soon to install an automated empty container handling system (BOXBAY Empty Superstack) in their new fully electric berth (Berth 4)^[DBR15].
- **Bathside Bay:** There is a proposal for a new port at Bathside Bay (Freeport East / Hutchinson Ports), which in the short term is intended to support offshore wind, but there may be potential for automation in the longer term via greenfield container terminal operations^[S11, DBR14].

Strengths & Weaknesses

UK experience in mixed-mode automation creates a viable niche which could present a unique export strength.

UK Versus International Peers

The most advanced progress in port automation is concentrated in Asia, particularly China and Singapore, as well as in parts of Northern Europe, notably the Netherlands and the Nordics. In these markets, automation has been enabled by large-scale greenfield port development, vertically integrated supply chains and sustained, long-term government investment. By contrast, the UK’s position reflects the market structure, rather than a lack of capability.

UK Operating Context and Opportunity for Mixed-Mode Automation

Most UK ports are characterised by brownfield development, constrained footprints and operational diversity. This makes retrofitting automation harder, riskier and more expensive than the purpose-built mega-terminals of Asia and Europe. These constraints limit the feasibility of large-scale, whole-terminal automation, but create a viable niche for incremental, mixed-mode automation which could present a unique export strength. In this context, automation is introduced in phases and must coexist with manual operations, presenting a different but potentially valuable pathway.

UK ports are already gaining valuable experience in the deployment of mixed human-autonomous environments at scale, including autonomous and manually driven trucks, remote-operated and manual cranes and phased deployment strategies. This operational experience represents a potential point of differentiation, particularly as most OECD ports globally face similar brownfield retrofit challenges. Demand for this type of expertise is increasing as markets such as the US, Canada and Western Europe seek to modernise existing port infrastructure. Given the high capital cost of developing new greenfield ports, retrofitting existing assets is typically more financially attractive. This creates an opportunity for the UK to establish a leading position in mixed-mode automation practice, provided it moves quickly to leverage the skills, experience and operational learning already embedded within its port operators.

UK Vessel Automation Expertise

UK leadership in automation is domain-specific, rather than broad. One notable strength is vessel automation, driven by the Ministry of Defence’s (MOD) progress and application of autonomous maritime systems. The DSA03-DMR, developed by the Defence Safety Authority, provides a framework for the regulation of maritime autonomous systems within MOD shipping activity. While this framework is not directly applicable to commercial ports, it provides a valuable foundation that could inform the development of wider regulatory approaches as automation expands within the port sector.

UK Weaknesses

The UK does not hold a significant lead in automated port hardware, crane development, or large-scale deployment when compared with international players. This reflects broader structural weaknesses in UK manufacturing capacity. The operating context of UK ports, characterised by smaller scale, limited greenfield development and the complexity of retrofitting legacy assets, further compounds these challenges by constraining demand for large-scale, standardised automation solutions.

Cost Considerations

Cost remains a decisive factor for UK and European ports. Operators often face a trade-off between lower-cost China-based OEMs with proven, large-scale deployment capability, and investment in UK or European OEMs that typically have more limited experience delivering automation at scale. This cost and technology maturity differential influences procurement decisions and shapes supplier decisions.

International Case Studies

International case studies presented in the following section illustrate the transformative potential of port automation. However, these examples should be interpreted with nuance in the UK context, as the scale, development model and enabling conditions underpinning many internation deployments are not always directly transferable. Nonetheless, they provide valuable insight into the future potential for maritime automation and the range of outcomes that could be achieved.

International Comparators

International case studies demonstrate the transformative potential of maritime automation.

Yangshan Port, Shanghai, China^[DBR16]



- Phase IV of Yangshan Port (greenfield site) claims to be the world’s largest single fully automated container terminal. Featuring 8 berths of 200,000 DWT and an annual throughput capacity of 6.3m TEUs.
- 145 AGVs, an intelligent terminal operating system, a digital twin system, fully electric powered with shore power coverage, and planned pilot programs for green fuel testing.

Port of Rotterdam, The Netherlands^[DBR18]



- Operated by APM Terminals on the man-made extension to the Port of Rotterdam, Maasvlakte II is a fully automated greenfield terminal.
- ~80% of crane movements are automated with remaining operations performed remotely, Portbase system, online booking systems for trucks and inland waterway vessel movements, integration with rail movements, and claims to be a zero-emission terminal.

Tuas Port, Singapore^[DBR17]



- Former greenfield site opened in 2022 with full targeted completion scheduled in the 2040s (21 berths planned in total). Tuas Port will have a handling capacity of 65m TEUs.
- Planned and existing automation opportunities include a vessel traffic management system, automated yard cranes, AGVs, remote control centre, and a private 5G network.

Port of Valencia, Spain^[DBR19]



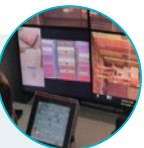
- Development of a private 5G network designed for high performance, mobility, wide coverage, strengthened device connectivity.
- 75% of the project’s funding was provided by the European Union, illustrating how government support can play a critical enabling role in overcoming key barriers to the adoption of maritime automation.

HHLA Container Terminal, Port of Hamburg, Germany^[DBR20]



- HHLA’s Hamburg container terminal (brownfield site) deployed ABB automation technology across 19 container blocks, including 57 automated stacker cranes.
- This is an example of successful deployment of automation in a brownfield site utilising European suppliers.

Norvik Container Terminal, Stockholm, Sweden^[DBR21]



- The Norvik Container Terminal is operated by Hutchinson Ports in Stockholm. It was a newly built port (greenfield site) opened in May 2020.
- The terminal has remotely operated quay cranes using HD cameras, hybrid-electric automated straddle carriers which can stack up to three containers high, fleet management system, and automated gate system.

Critical Enablers

Targeted government funding, increased collaboration, and strengthened regulation are critical enablers for UK competitiveness.

Critical Enablers for UK Leadership in Maritime Automation

Targeted Government Funding: There is a need to prioritise funding targeted towards port operators and focused on late-stage commercialisation, enable the UK technology providers to progress to higher TRLs and compete more effectively with international leaders. To date, government funding has been centred on de-risking pilots. While this remains important, the priority should shift towards operational deployment to justify the business case for scaled deployment and strengthen the UK’s overall global competitiveness.

Collaboration and Coordinated National Strategy: Encouraging sector-wide collaboration and aligning industry, academia and government will be crucial to avoid fragmentation and accelerate commercialisation. Without this, the UK risks remaining strong in R&D, but weak in deployment, with benefits captured offshore.

Regulation: the UK’s regulatory landscape for automation in port environments is highly fragmented. Responsibility is split across governing bodies and there is no singular framework for port-specific autonomous or automated systems. This creates regulatory grey zones which ultimately limit deployment potential. Therefore, the UK is well-positioned to shape an end-to-end regulatory framework for maritime automation that could act as an exemplar for global maritime standards.



3. UK Supply Chain Competitiveness /

The UK has a competitive edge in early technology readiness levels such as CAM software, AI, digital twins and R&D, not hardware.

UK Port automation lags due to structural constraints, not lack of capability.

Automation in UK Ports – Supply Chain Positioning
Evidence gathered in this study demonstrates that the UK has strengths at early technology readiness levels (TRLs) and weaknesses at later TRLs associated with deployment and scale.

Early TRLs (concept to early validation): The UK has a competitive edge in CAM software, AI, digital twins and R&D. UK CAM companies are internationally competitive, supported by world-class universities and strong R&D collaboration between Government, Industry and Academia. The evidence consistently highlights the importance of testbeds and demonstration environments in progressing early-stage technologies, with notable examples including Belfast Harbour and the Port of Tyne. In addition, the UK has strengths in aligned sectors including vessel automation, robotics, AI, and sensing, which can be leveraged into port automation applications.

Late TRLs (applied validation, deployment and scaled manufacturing): The UK lacks domestic manufacturing

capability for automated port equipment, with ports relying heavily on Chinese and European OEMs for autonomous trucks, terminal tractors, cranes and AGVs. This creates both vulnerability and opportunity; the UK can lead in software-defined autonomy, even where hardware remains imported. However, economic value capture occurs primarily through deployment at scale, not R&D alone, and continued late TRL weaknesses risk the benefits of scaled deployment, including job creation, economic growth and supply chain development, being captured offshore.

The UK also tends to experience challenges in scaling and commercialising technologies, which are sometimes compounded by gaps in enabling infrastructure such as connectivity and electricity capacity. As a result, the UK is unlikely to become a leader in late-stage TRLs at scale, particularly with respect to hardware manufacturing, without targeted investment to strengthen deployment pathways and supply chain capability. Investment focussed on the commercialisation and scaled deployment of UK technology providers would generate domestic economic benefits, strengthen operational learning, and improve long-term UK export potential.

Below are three examples of successful case studies demonstrating supply chain collaboration across UK ports.



- Port of Tyne**
- The Port of Tyne established their Venture Connect Programme to simulate inward investment and SME engagement.
 - In addition, working with Oxa (software development) and Terberg (hardware manufacturers). Retrofitting vehicles using Terberg and Oxa products.



- Port of Dover**
- The Port of Dover have been working with UK-based organisation Entopy, an organisation specialising in AI, data analytics and digital twin developments.
 - The Port of Dover have deployed digital twin technology for vessel and land side optimisation.



- Port of Felixstowe and Freeport East**
- Working with Westwell (technology provider, Shanghai-based) to provide automated trucks. In addition, working with New Zealand headquartered Ohmio (via Freeport East) to investigate the opportunity of autonomous bus services in the region with potential for connections with the port.
 - This is a good example of scaled deployment but with a heavy reliance on international players and limited opportunities for the UK supply chain.

International Competition

The UK faces tougher international competition in port automation, driven in part by fragmented domestic supply chains.

Automation in UK Ports – International Competition

A recurring theme of this study is that the structural context of UK ports differs materially from international leaders and is a key determinant of the UK’s ability to become a global leader in port automation. International competitors, particularly China, benefit from vertically integrated supply chains, spanning OEM manufacturing, hardware and software development. As a result, these players can offer end-to-end turnkey CAM solutions at scale and at lower unit costs, giving them a significant competitive advantage in large-scale port automation projects. European players benefit from well-developed manufacturing ecosystems and cross-border collaboration, enabling ports to source equipment and digital systems from regional suppliers. However, Europe remains behind China’s in the delivery of fully-integrated, low-cost CAM solutions at scale.

By contrast, the UK supply chain is more fragmented, constrained and dependent on international suppliers, leading to longer lead

times, increased integration complexity and reduced system-level control. This increases delivery risk and cost and ultimately makes it more challenging for the UK to compete with countries that possess stronger domestic supply chain capabilities.

Multiple stakeholders expressed support for strengthening supply chain sovereignty, reflecting the status of some UK ports as critical national infrastructure. Reliance on international suppliers, combined with broader public and political discourse, has contributed to concerns around geopolitical risk, with some European port operators opting not to pursue Asian turnkey solutions due to perceived reductions in control and heightened national cybersecurity considerations. At the same time, evidence from this study indicates that excluding international suppliers altogether, could constraint competitiveness, given their ability to provide mature, integrated and deployable automation solutions.

As such, implementing automation in UK ports remains complex, with engagement with international supply-chain leaders presenting both strategic challenges and opportunities that will need to be managed as deployment scales. The UK’s challenge is therefore not whether to engage internationally, but how to do so in a way that preserves resilience, value capture and long-term capability.

Zenzic Supply Chain Categories

Supply chain strengths and gaps have been assessed against the Zenzic Supply Chain Categories as established in the [June 2025 CAM Supply Chain report](#). This includes when themes were highlighted in expert panel interviews, stakeholder interviews and as part of desk-based research.

The following page provides a more detailed overview against each supply chain category.



Strengths & Weaknesses

The UK has a competitive edge in early technology readiness levels such as CAM software, AI, digital twins and R&D, not hardware.

Supply Chain Category	Definition	Examples (non-exhaustive)	Strengths	Gaps
Hardware	Physical equipment.	Port equipment, vehicles, Cameras, RADAR, LIDAR, onboard mapping hardware, sensors, controls, electronics and architecture.	• Small degrees of implementation across the UK.	• Manufacturing capability and cost competitiveness with leaders (e.g. China). • No UK OEMs for terminal tractors. • UK at prototype stage. • The European supply chain is also constrained.
Software	Digital applications and systems to facilitate automated functions.	Mapping, digital twins, path planning, control systems, connectivity, cybersecurity, human-machine interface, and data processing.	• Emerging technology providers and AI start-ups (e.g. Oxa), offering export strength. • UK-based developments in software stacks. • SME engagement in automation, AI and advanced connectivity.	• Application of UK software providers in large-scale deployment within the maritime space.
Engineering Services	Technical expertise to design, review, and validate automation solutions.	Vehicle or equipment design, process review, simulation and testing, security, infrastructure, and safety and auditing.	• Abundance of technical knowledge and experts in the maritime industry. • Strong engineering services consultancies.	• Technology constantly evolving. • Skills gaps.
Finance	Private or public funding to enable automation / CAM technologies.	Private sector (e.g. venture capital) and public sector (e.g. government funding).	• Financing bodies in abundance in the UK.	• Government funding to support transition with maritime focus.
Research Technology Organisation	Specialist institutions conducting research, testing and innovation.	Academia, research organisations, public sector research organisations, and catapults.	• Existing organisations: Zenzic, Connected Places Catapult • Strong link between academic, government, and industry. • Strong R&D capability in the UK.	• Alignment and collaboration on maritime automation. Zenzic convened 'UK Port Automation Group' to overcome this.

Supply Chain Category	Definition	Examples (non-exhaustive)	Strengths	Gaps
Test Services	Facilities enabling the testing of port automation equipment and solutions.	Controlled, semi-controlled, and public.	• Existing examples of test environments in the UK (e.g. Port of Felixstowe, Port of Tyne). • Ports are controlled environments.	• Mature test environments. • Incentives to trial and test within port environments. • Limited funding.
Tools	Simulations platforms, testing tools, development environments used to design, model, test and validate.	Simulation and testing tools.	• Technology providers such as Oxa's universal autonomy platform. • ~120 commercial ports in the UK which could act as unique test beds.	• Limited deployment support.
Operators	Organisations that deploy, run and manage automated systems in real-world applications.	Passenger transit, freight and logistics, last mile delivery, highway authority and personal mobility	• Limited UK experience.	• Homegrown operators of automated equipment. • Cost competitiveness and justifiable business case elements.
Insurance and Legal	Providers of insurance and legal services.	Including regulation and consumer testing.	• UK leader in insurance. • Development of DSA03-DMR Guide to Regulation of Maritime Autonomous Systems – MoD applications.	• Maritime specific standards and regulation. • Government policy.
Communications and data infrastructure	Digital foundations for automation equipment.	Data, web services, communication infrastructure, mapping and geospatial.	• Examples of private 5G networks implemented within the Port of Tyne. • Data analytics capability.	• Limited connectivity infrastructure at required scale. • Legacy infrastructure and paper-based systems.
OEM/ASDE	Organisations or build or develop automation equipment and systems.	Autonomous vehicles and automated equipment for use in ports.	• Limited UK experience.	• Manufacturing commonly still at pilot testing phase. • Challenges in scaling development.



Conclusions & Recommendations /

Future Outlook

The UK can build a competitive CAM supply chain by leveraging its digital strengths, with targeted government action.

Future Outlook

The findings of this study indicate that the UK has a meaningful opportunity to strengthen its global supply chain position in port automation by building on established and emerging strengths, most notably in R&D, software, AI, robotics, data analytics and cross-sector collaboration between industry, academia and government.

Several priority opportunity areas emerged:

- **Developing integrated terminal operating systems** that improve interoperability, predictability and optimisation across port operations, strengthening system-level performance and supporting scalable deployment.
- **Advancing AI-driven port applications** including perception systems, predictive maintenance, digital

twins and operational optimisation tools, where the UK already demonstrates strong technical capability.

- **Expanding pilot and demonstration programmes** for autonomous port equipment that accelerate commercial readiness, generate operational evidence, support the business case for scaled deployment and de-risk procurement for operators.
- **Leveraging wider UK expertise in adjacent advanced technology sectors**, such as vessel automation, robotics, data analytics, sensing (e.g. Liverpool's 'Sensor City'), alongside emerging innovation hubs (e.g. the South Coast marine autonomy cluster) to strengthen domestic capability and cross-sector spillovers.

Realising these opportunities will require targeted and sustained government support. Stakeholders consistently highlighted the need for public investment not only to de-risk pilots, but critically, to enable the transition from trials to early operational deployment. This includes encouraging port-to-port collaboration, accelerating innovation programmes and developing clearer, more coherent regulatory pathways. A shift

in funding emphasis from short-term R&D grants towards longer-term commercialisation and operational deployment support would enable the UK to build a more competitive, scalable and resilient supply chain, better positioned to capture value from domestic R&D.

Government commitment also presents a strategic opportunity to align supply chain development with the maritime sector's wider decarbonisation goals. Automation's close synergies with electrification, optimised energy use, reduced fuel consumption and improved operational efficiency mean that coordinated support could deliver both productivity gains and measurable environmental benefits, reinforcing the case for integrated investment and policy alignment.

Without a shift in focus from pilots to deployment, the UK risks remaining a strong innovator in port automation but a weak participant in value capture and global competitiveness.

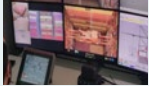
Sources of Information

File Name	Date of Source	Source Overview
EPI1	March 2026	Internal expert interview.
EPI2	March 2026	Internal expert interview.
EPI3	March 2026	Internal expert interview.
SI1	March 2026	Freeport East interview.
SI2	March 2026	Department for Business and Trade interview.
SI3	March 2026	Belfast Harbour interview.
SI4	March 2026	Connected Places Catapult interview.
SI5	March 2026	Hutchinson Ports interview.
SI6	March 2026	UK Major Ports Group interview.
SI7	March 2026	Oxa technology provider interview.
SI8	March 2026	Port of Tyne interview.
DBR1	April 2025	Zenzic: UK Connected and Automated Mobility Roadmap
DBR2	July 2024	Zenzic: Scaling up by 2035: Opportunities for the UK CAM sector
DBR3	June 2025	Zenzic: Maturing the UK CAM Supply Chain 2024/2
DBR4	June 2025	Zenzic: UK Connected and Automated Mobility Roadmap to 2035 – Opportunities for CAM. Why CAM?
DBR5	March 2024	Centre for Assuring Autonomy at the University of York: Building a Successful Maritime Autonomy Ecosystem
DBR6	Unknown	Connected Places Catapult: UK Ports of the Future A vision and roadmap
DBR7	Jan 2019	Department for Transport: Technology and Innovation in UK Maritime: The case of Autonomy

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DBR8	May 2018	UKMPG - UK major ports group: Port 2050 What could share the port of the future?
DBR9	2024	Connected Places Catapult: The Future of Communications as an Enabler at Ports
DBR10	April 2023	Confidential unpublished report: Department for Business and Trade and UK Automotive Council
DBR11	Aug 2025	Port of Tyne: News Article: NEAA and Consortium Launch Groundbreaking Autonomous Logistics Project at the Port of Tyne
DBR12	Nov 2023	Port of Tyne: YouTube Video: 5G Zero Emissions Robot
DBR13	Feb 2023	Belfast Harbour: Northern Ireland's first self-driving shuttle service coming to Belfast Harbour Estate thanks to £11 million joint government and industry funding
DBR14	Updated 2026	Freeport East Bathside Day: Hutchinson Ports: Freeport East Harwich - A New Offshore Wind Vision for Bathside Bay
DBR15	Unknown	DP World: London Gateway: ELECTRIFICATION & AUTOMATION
DBR16	Dec 2025	Yangshan Port, China: Presentation by China Harbour Engineering Company Ltd.: Practices and Insights from the Automation Upgrade of Yangshan Deep-Water Port Phase IV
DBR17	Updated 2026	Maritime and Port Authority of Singapore: Tuas Port: Tuas Port – A Smarter and Greener Port
DBR18	Updated 2026	APM Terminals: Our Terminals
DBR19	Updated 2024	Defence Safety Authority: DSA03-DMR Guide to Regulation of Maritime Autonomous Systems
DBR20	May 2024	ABB: ABB automation proves transformative at Hamburg's largest container terminal
DBR21	Updated 2026	Hutchinson Ports Stockholm: Our Terminal

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