Workforce Foresighting Hub

Enhancing Cyber-Physical Resilience for Remote Crane Operations in Ports

Workforce Foresighting Hub findings report in collaboration with the Connected Places Catapult.

Date: 21/08/2025

CATAPULT Connected Places

Acknowledgements

The Workforce Foresighting process integrates data from the following international data sets:

IfATE – Institute for Apprenticeships and Technical Education, England

ESCO – European Skills, Competencies, Qualifications & Occupations, EU

ONet – Occupational Networks Online, USA

In accordance with licence and publishing requirements of these organisations for the use of their data sets, the Workforce Foresighting Hub team states that –

The method and process used in the Workforce Foresighting process is under development and there may be errors and omissions in the data provided.

This report was produced following workshops undertaken February – June 2025 using the data set and tools available at that time.

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Executive Summary

This report examines workforce challenges facing UK ports as they adopt remote-controlled crane operations and Digital Twin technology. Conducted by Connected Places Catapult with the Workforce Foresighting Hub, the study reveals a critical mismatch between emerging job requirements and current training provision.

Workforce foresighting identifies skills needed for tomorrow's jobs, ensuring education systems prepare workers for new technologies and industrial growth. This study maps future workforce needs and recommends actions to close identified gaps.

The Challenge

UK ports face a digital transformation paradox: while remote crane operations promise efficiency gains and safety improvements, they expose critical infrastructure to cyber threats. Traditional crane operators, skilled in hands-on work, must now master digital systems and cybersecurity protocols: a shift from physical expertise to technological literacy.

Without targeted intervention, the sector risks operational disruption, compromised safety, and cascading vulnerabilities across maritime supply chains. The stakes are high: ports handle 95% of UK trade by volume and contribute over £7.7 billion annually to the economy[[1]]. Digital Twin technology emerged as the optimal response. These virtual replicas of physical crane systems enable real-time monitoring, predictive maintenance, and risk-free training environments. Unlike traditional approaches, Digital Twins simultaneously address operational efficiency and security concerns[[2]].

The technology integrates with existing Remote Control Operation Systems while serving as a cybersecurity testing platform[[3]]. This dual functionality bridges the gap between traditional operational expertise and emerging technological requirements.

The transformation is substantial: Digital Twin market is forecast to grow 40% year-on-year[[4]], cybersecurity roles are among the top 15 fastest-growing globally through 2030[[5]], and we estimate that over 60% of current crane operators need retraining. This creates both challenge and opportunity: significant upskilling requirements alongside new career pathways in industrial cybersecurity, simulation engineering, and remote operations management.

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[1] Source: Maritime UK.
[2] Source: Port Technology.
[3] Source: MDPI.
[4] Source: Fortune Business Insight.
[5] Source: World Economic Forum, The Future of Jobs Report 2025.

Participants and stakeholders

Employers	Educators	Technologists
Richard Holland – Transport Accelerator: Maritime, (Connected Places Catapult)	Mohammad Hammoudeh - Manchester Metropolitan University	Mark Robinson – Chrome Angel
Brian Bishop - Data People Connected Limited	Maria Papadaki – University of Warwick	Ryan Protheroe – Midlands Cyber Cluster
Charles Hall - Neva Group	Mastaneh Davis - Roehampton University	Evan Jones – Complete Cyber
Filippo Sanzeni – Connected Places Catapult	Abdul Khalique - Liverpool John Moores University	Carol Lo – University of the West of England
	Olamide Jogunola - Manchester Metropolitan University	Xicheng Li – University of Glasgow
	Afshin Mansouri – Brunel University	Sebati Ghosh – University of York

Table 1: Participants and stakeholders

Key Findings

Ports will shift from implementation-focused roles toward design and enterprise functions, requiring capabilities in system architecture, data governance, and strategic technology planning. Cross-functional integration becomes essential as IT, operations, and compliance teams must collaborate on cyber-physical systems.

Still, a systematic mismatch exists between future job requirements and current training provision. Of 31 Future Occupational Profiles we identified, only one, Predictive Maintenance Specialist, shows good compatibility with existing standards. From our analysis, three career levels emerge:

- **Senior**: encompass strategic and architectural functions, including Cyber-Physical Resilience Engineer, System Security Engineer, Zero Trust Architect, and Regulatory Compliance Specialist. These positions demand advanced expertise in system design, strategic security planning, and regulatory navigation while maintaining deep operational awareness of port-specific requirements.

- **Mid-level**: focus on specialised technical implementation, including Predictive Maintenance Specialist, Virtual Modelling Specialist, Simulation-Based Training Specialist, and Remote Access Engineer. These roles bridge strategic vision with operational execution, requiring sophisticated technical skills combined with a practical understanding of port operational environments.

- **Junior**: provide entry pathways through roles such as Remote Crane Operator, Cybersecurity Training Specialist, and Data Analyst. These positions establish foundational competencies while offering progression pathways toward more specialised functions within the cyber-physical security ecosystem.

Most roles show "low" compatibility with existing apprenticeships and qualifications. Critical gaps include junior-level entry pathways and senior cybersecurity positions, suggesting

current infrastructure lacks fundamental components for cyber-physical security competencies.
To explore the full dataset, occupational profiles, and capability mappings, access the interactive foresighting visualisation tool:

🔗 Workforce Foresighting Visualisation Tool[6]

Actions Required

1. **Convene a Working Group**: Include Connected Places Catapult, Innovate UK, IfATE, port operators, universities, and technology providers to validate findings and coordinate development.

2. **Validate Job Profiles**: Test Future Occupational Profiles against real-world demands and employer feedback to ensure training investments target genuine needs.

3. **Appoint a Skills Champion**: Designate leadership to drive capability development and maintain momentum across multiple stakeholders.

4. **Implement Phased Action Plan**:
    - *Short-term*: Develop CPD modules for critical gaps; identify transferable skills from defence and manufacturing
    - *Mid-term*: Update apprenticeship standards; create new qualifications; implement modular course changes

5. **Plan Future Foresighting**: Extend analysis to autonomous vessels, port AI systems, and broader maritime cybersecurity.

Without coordinated action, UK ports risk technological marginalisation. The workforce will lack skills to operate, secure, and maintain advanced systems – compromising operational resilience and national competitiveness.

Success requires unprecedented coordination across education, industry, and policy domains. The choice is stark: coordinate comprehensive action now or accept competitive decline in a sector vital to UK economic prosperity and security.

Digital transformation waits for no one. Competitor nations are already advancing maritime cyber-physical capabilities. The UK must act decisively to maintain its maritime leadership position.

[6] Workforce visualisation tool https://hvmcatapultforesighting.retool.com/embedded/public/e869283b-4b8a-437c-973e-64ab292e5b87?token=08d982f00dfda7ab00d046dedc0377d8&_environment=production

1 Introduction

1 Introduction

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1.1	Background to Workforce Foresighting
1.2	Workforce Foresighting - Process Overview
1.3	Foresighting vs Forecasting
1.4	Introducing the Visualisation Tool

1.1 Background to Workforce Foresighting

The report "Manufacturing the Future Workforce" (Collier et al., 2020) recommended the Skills Value Chain as an approach to avoid shortfalls in workforce capabilities relating to future innovations (see Figure 1). This is the genesis of the workforce foresighting programme, which is sponsored by Innovate UK and delivered through the Innovate UK Catapult Network.

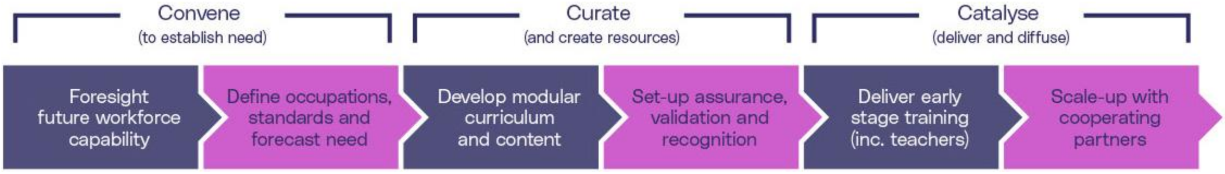

Figure 1: Figure 1: The Skills Value Chain

The first step of the skills value chain is to "Foresight future workforce capability": This calls for technology, industry, education, and training partners to convene using government as a focal point, to "foresight and articulate future skills need, standards and qualifications associated with emerging technologies" (Collier et al., 2020).

1.2 Workforce Foresighting - Process Overview

The core of workforce foresighting is convening three groups of relevant specialists to conduct structured, Delphi-style, facilitated workshops to capture and discuss the set of organisational capabilities that will be required to respond to and exploit technology innovation.

Organisational capabilities are captured using a bespoke classification that has been developed by the Workforce Foresighting Hub. The classification uses a structured common language to enable cross sector and cross centre collaboration and integration of data. Additionally, the classification enables data from a number of other national and international open-source workforce datasets to be integrated through the same common language. The data is held in a cloud based "data-cube" that is dynamically growing as each workforce foresighting cycle adds to the shared data relating to future workforce capabilities.

Using cutting edge AI and Large Language Model data tools, the data-cube is used to undertake detailed analysis to 'map' future workforce capability requirements against the current education and training provision to identify where existing provision can be used and where new provision, CPD or qualifications are required.

As an agile development project, the Workforce Foresighting Hub team are constantly evolving and improving the detailed workshop process and workshop approach, but always consists of the following stages:

Considering – Clarifying the Challenge to be met (the 'what' and the 'when') and collating solutions (the 'how') as foresighting topic suggestions align with strategic priorities
Identifying – Gain clarity and consensus about the solutions to be put forward – make the case for foresighting
Preparing – The convening of specialists and scheduling of workshops
Carrying out – Run foresighting workshops with experts, collate and analyse data

Communicating – Insights, findings and recommendations gathered from all research in report
Causing action – The driving of action based on the recommendations (promoting progress down the rest of the skills value chain) built on the findings and recommendations of foresighting

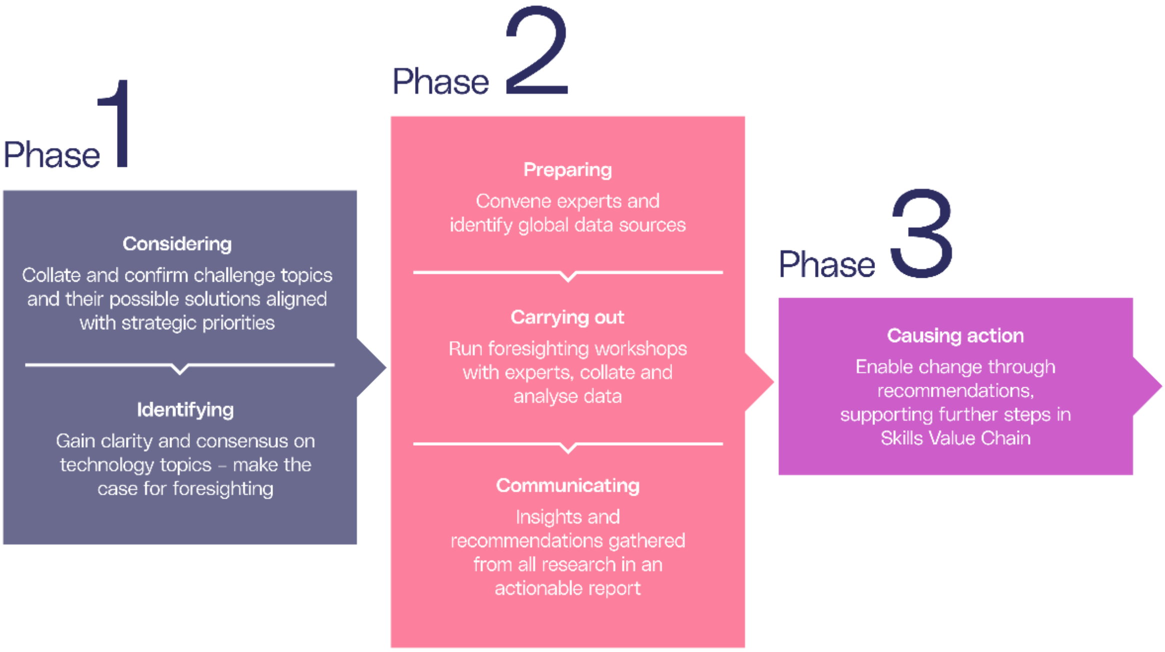

Figure 2: The workforce foresighting process

1.3 Foresighting vs Forecasting

Although this study is focussed on workforce foresighting (capabilities required) it is important to keep in mind parallel findings from forecasting (required capacities and numbers).

Forecasting, alongside foresighting, provides vital input to the sector, feeding into recruitment and development targets for employers, and consideration of economic class sizes and recruitment targets for educators. However, it is beyond the scope of the foresighting study to carry out independent forecasting, and as such readers should refer to referenced studies for detail on forecasting.

1.4 Introducing the Visualisation Tool

The Workforce Foresighting Hub's Visualisation Tool is a powerful, innovative system, which will enable the reader to explore and analyse foresighting data to determine the capabilities required for future roles. Links throughout this report make it easy to identify existing standards which meet the needs of these future roles and pinpoint where new standards are necessary to develop a skilled workforce equipped to adopt new technologies.

The data is generated by the foresighting cycles, integrating the expertise of technologists/domain specialists, employers and educators. The data informs the development of future curriculums and course content as determined by the action plan. Using AI tools validated by human oversight, and by linking to external data sources, the tool identifies differences at the level of occupation/role as well as detailed changes required to help update/refresh knowledge, skills and behaviours thus delivering insights for learners, providers, creators and assurers of skills.

Detailed instructions on how to use the Visualisation Tool can be found in the appendix E (**E Visualisation links and Illustrations**).

Data Capture Overview [7]

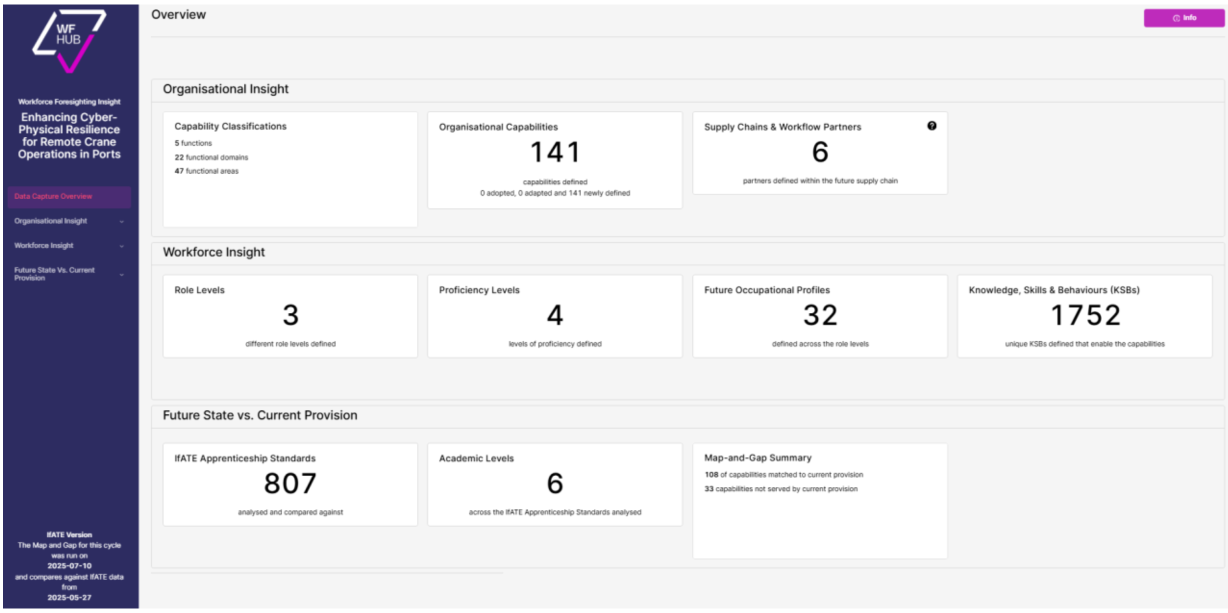

Figure 3: Data capture overview example

[7] Data capture overview https://hvmcatapultforesighting.retool.com/embedded/public/e869283b-4b8a-437c-973e-64ab292e5b87?_environment=production&token=08d982f00dfda7ab00d046dedc0377d8

2. Aligning the Challenge and Solutions with national priorities

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Section	Title
2.1	Positioning and context of national challenge
2.2	Potential and prioritised technology solutions to the challenge
2.3	Workforce Foresighting for Chosen Prioritised Technology Solutions
2.4	Current and predicted scale of technology deployment in UK

2.1 Positioning and context of national challenge

The UK Government has positioned maritime innovation and infrastructure resilience as strategic priorities under Innovate UK's Strategic Delivery Plan (2022–2025)[[8]]. These documents create clear policy backing for the technological transformation already reshaping UK ports.

Remote-controlled crane operations deliver on multiple national objectives simultaneously. Enhanced cyber-physical security strengthens critical infrastructure protection, a national security imperative. Digitising transport and logistics systems boosts economic competitiveness while automation contributes to net-zero targets through operational efficiency. Stronger port resilience secures both domestic supply chains and international trade flows.

The Maritime 2050policy paper[[9]] explicitly calls for UK leadership in shipping, automation, and cybersecurity across port operations. This creates both opportunity and obligation: ports must develop workforce capabilities that can implement and maintain advanced technological systems while ensuring operational security.

The numbers justify strategic workforce investment. UK ports contribute over £7.7 billion annually to the economy and support more than 100,000 jobs directly and indirectly. More critically, they handle 95% of the country's trade by volume, making workforce capability development a matter of economic security, not just operational efficiency.

The sector faces a generational shift that creates both challenge and opportunity. Traditional roles emphasising physical presence and hands-on expertise are giving way to hybrid digital-technical positions requiring new competency combinations: data management, systems integration, and cyber resilience protocols. This transition offers natural entry points for advanced training while potentially reducing resistance to technological change.

Digital Twin platforms and Remote-Control Operation Systems (RCOS) represent a paradigm shift, rather than an operational enhancement. These integrated systems enable real-time simulation of routine operations and threat scenarios, comprehensive predictive maintenance with anomaly detection, and advanced remote training environments for risk-free workforce development. As these technologies become fundamental operational tools, the sector needs new professional categories that transcend traditional boundaries. Cyber-Physical Resilience Engineers and Simulation-Based Training Specialists exemplify professionals operating at the intersection of engineering expertise, data science capabilities, and cybersecurity protocols.

This evolution demands adaptive workforce strategies that accommodate rapid technological change while maintaining operational continuity. Virtual simulation capabilities create unique training opportunities that accelerate skill development and reduce traditional learning risks. However, realising these benefits requires coordinated training infrastructure development that bridges traditional expertise with emerging competencies.

Research and practical implementation evidence substantiate the cyber-physical security transformation framework across multiple dimensions. Port Technology International research[[10]] reveals the dual nature of remote crane deployment: substantial operational benefits in efficiency and safety alongside emerging risk profiles requiring sophisticated

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[8] Source: UK Innovation Strategy and Innovate UK Action Plan.
[9] Source: Maritime 2050: Navigating the Future.
[10] Source: The Journal of Ports and Terminals.

management. While technological benefits are significant, realising them safely demands workforce capabilities extending far beyond traditional operational competencies.

Siemens Xcelerator[[11]] implementations provide real-world validation of RCOS integration with Digital Twin technology for enhanced crane operations. These implementations confirm that technological capabilities exist to support advanced cyber-physical security operations while highlighting the critical importance of developing appropriate workforce competencies.

This convergence of research evidence and practical validation creates a robust foundation for workforce development initiatives, confirming that technological transformation is both inevitable and achievable with appropriate human capability development. Success requires coordinated attention to both technological deployment and workforce capability building, with particular emphasis on developing integrated competencies that bridge traditional operational expertise with emerging cyber-physical security requirements.

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[11] Source: Driving Crane Performance Through Data.

2.2 Potential and prioritised technology solutions to the challenge

The foresighting cycle used a systematic methodology to evaluate and select technology solutions for cyber-physical resilience challenges in remote crane operations.

Our initial scoping engaged diverse stakeholders to propose candidate technologies aligned with sector needs and Innovate UK's Digital & Technologies objectives. This broad consultation ensured proposed solutions addressed genuine operational needs rather than theoretical possibilities.

Following that, a validation workshop series leveraged expertise from industry practitioners, academic researchers, and technology specialists to assess technical feasibility, operational relevance, and workforce implications. This multi-perspective approach balanced technical capability with practical implementation challenges.

After that, we mapped the capabilities of each technology's potential impact on organisational functions and workforce roles. This process identified solutions that could deliver operational benefits while creating manageable workforce transition pathways.

Finally, our selection criteria prioritised technologies based on scalability potential, risk mitigation capabilities, and alignment with national maritime policies. This framework ensured selected technologies supported both immediate improvements and long-term transformation.

Chosen Technology and Justification

Digital Twin Technology emerged as the optimal solution for its unique ability to address multiple cyber-physical resilience challenges simultaneously. The technology enhances operational efficiency while strengthening security protocols across interconnected systems.

Digital Twins enable comprehensive modelling of routine operations and cyber threat scenarios, providing visibility into potential vulnerabilities before they appear in real environments. This shifts security from reactive measures to anticipatory resilience planning.

The technology creates safe environments for operator training and cybersecurity testing, eliminating traditional training risks while enabling skill development across complex scenarios. This proves valuable for developing cyber-physical security competencies without disrupting critical infrastructure during learning.

Real-time monitoring and anomaly detection extend beyond traditional maintenance to encompass system health assessment, cybersecurity threat detection, and operational efficiency optimisation. Proven integration with existing Remote Control Operation Systems, demonstrated through Siemens' RCOS platforms cited above, confirms implementation feasibility while minimising disruption to current frameworks. This capability will drive rapid scaling across UK ports between 2025 and 2030.

Current State and Supply Chain Impact

Most UK ports currently rely on manual or semi-automated crane systems with limited remote capabilities, creating substantial scope for Digital Twin advancement while highlighting urgent workforce development needs.

- The transformation creates cascading effects across operational domains:
- Crane Service Providers must adopt digital maintenance protocols and simulation capabilities to remain competitive
- Port Operators need new roles spanning data governance, regulatory compliance, and remote operations management
- Systems Integrators will lead Digital Twin deployment and legacy system integration
- Cybersecurity Consultants become essential for resilience engineering and threat modelling
- Regulatory frameworks require updating remote and autonomous operations while maintaining safety standards

Timing Considerations

Short-Term (2025-2026): Pilot deployments of Digital Twin platforms across selected UK ports. Concurrent development of CPD modules addresses immediate workforce upskilling while apprenticeship standards begin incorporating cyber-physical security competencies.

Mid-Term (2027-2030): Comprehensive Digital Twin implementation across major UK facilities alongside new occupational profiles and qualification frameworks. Simulation-based training expands sector-wide, ensuring systematic workforce development supporting sustained technological advancement.

2.3 Workforce Foresighting for Chosen Prioritised Technology Solutions

Digital Twin Technology is the strategic focal point for workforce foresighting, selected for its capacity to address operational efficiency demands and cyber-physical resilience requirements in remote crane operations.

The technology provides real-time simulation of crane operations and threat scenarios while enabling predictive maintenance and anomaly detection across integrated environments. Safe training environments eliminate traditional learning risks while accelerating competency development.

This technology directly supports Innovate UK's Digital & Technologies impact domain and aligns with national strategies for infrastructure resilience and maritime innovation. The cycle was titled: **Enhancing Cyber-Physical Resilience for Remote Crane Operations in Ports.**

This title encapsulates the strategic focus on securing and optimising digitally enabled port infrastructure through advanced simulation and monitoring technologies while emphasising the critical importance of developing workforce capabilities that can effectively manage complex cyber-physical security challenges across integrated operational environments.

2.4 Current and predicted scale of technology deployment in UK

UK ports show fragmented Digital Twin and Remote-Control Operation Systems deployment – early-stage pilots and isolated use cases rather than systematic integration. Most crane operations remain manual or semi-automated, with digital technologies serving monitoring rather than control functions.

Digital maturity varies dramatically across facilities. Major ports like Felixstowe and Southampton explore automation while smaller ports lag significantly. This creates opportunities for rapid advancement but challenges for systematic workforce development across diverse environments.

Cyber-physical security integration remains limited in operational technology environments – precisely the gap Digital Twin deployment addresses. Workforce readiness is low, with traditional roles dominant and minimal exposure to simulation-based or remote systems. Digital Twin and RCOS deployment create transformation across port supply chain layers:

- Crane Service Providers must shift from traditional maintenance to predictive protocols, simulation-based diagnostics, and remote servicing that integrates digital monitoring with physical operations.
- Port Operators face organizational restructuring requiring new roles in data governance, regulatory compliance, and remote operations management that bridges traditional expertise with technological capabilities.
- Systems Integrators see increased demand for complex integration services connecting Digital Twin platforms with legacy systems while ensuring operational continuity and enhanced security.

- Cybersecurity Consultants assume critical responsibilities for securing remote access and industrial control systems, requiring specialized cyber-physical security expertise in maritime environments.
- Regulatory Bodies must update compliance frameworks for remote and autonomous operations while maintaining safety standards across evolving implementations.

Each transformation creates both opportunity and obligation: ports that move decisively gain competitive advantage while laggards risk obsolescence in an increasingly automated maritime environment.

3. Findings and Results

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Section	Title
3.1	Methodology and Findings
3.2	Step One – How will the Supply chain change - Organisational Changes
3.3	Step Two – How will the Workforce change - Occupational Changes
3.4	Step Three – How the current Education provision meets the future need - Highlighted Changes to Future Provision

3.1 Methodology and Findings

Summary information is provided with a narrative based on the underlying data which is also provided using bespoke visualisations to enable greater insight and access to detail. The report is aligned to the needs of those responsible for workforce planning – employers, educators, and skills providers.

Step One – How will the Supply chain change - Organisational Changes

Exploration of organisational changes provides insights into how organisations will need to adapt their current capabilities to implement the solutions that respond to the challenge addressed by the foresighting project.

Typically, organisational changes will also require the adoption of new capabilities and a change in the distribution of these capabilities across supply chain partners. The change in capabilities within an organisation as well as their supply chain partners will determine the changes knowledge and skill changes required by the role groups within the workforce of each Supply Chain partner.

Step Two – How will the Workforce change - Occupational Changes

A set of 'Future Occupational Profiles' (FOPs) is produced by the foresight process that demonstrates how current occupations may need to change in the future. FOPs are generated using a combination of attributes from the underlying capability classification and from data collected in the workshops. The FOP generation algorithm works to group capabilities into logical sets reflecting role levels, function, proficiency and capability similarity. As part of the foresight process the generated FOPs are reviewed, revised and distilled by the Employer group. The agreed set of FOPs are then compared with selected current education provision; the default reference is the set of Institute for Apprenticeships and Technical Education (IfATE) apprenticeship standards; to assess which current training and education provision could be used in the future. Two bespoke metrics - match and surplus - are used to evaluate the alignment of current provision with the set of FOPs proposed. Summaries are presented of the key findings related to each Supply Chain partner.

Findings are aimed at both Employers, and Education and Training Providers, and identify matches and gaps in future training needs compared with current provision to guide further detailed investigation.

Step Three – How the current Education provision meets the future need - Highlighted Changes to Future Provision

The report identifies suggested changes to education and training provision – principally apprenticeship standards that will deliver the knowledge, skills and behaviours required by future occupations. In some cases, this will include the development of short courses and continued professional development (CPD) to upskill the current workforce to meet future needs. Additionally, foresighting outputs can be used to develop programmes, qualifications, and apprenticeship standards for new entrants to the workforce joining via apprenticeship, taught qualification, or other training programme.

The insight and data in this part of the report are primarily aimed at educators training providers, apprenticeship standards bodies and awarding organisations. Combined with insight arising from the Supply Chain capability changes, the provision insight offers an effective way for employers to identify training opportunities that align to their future needs.

3.2 Step One – How will the Supply Chain change - Organisational Changes Insight

Organisation functions

Organisation functions

The Workforce Foresighting process uses an information architecture built on five functional areas which are common to any business:

Design	The function of an organisation that focuses on activities relating to product, service or solution design.
Implement	The function of an organisation that focuses on activities relating to producing / making / providing its products or services.
Logistics	The function of an organisation that focuses on activities relating to procurement, delivery, materials, or services necessary for operations – service / manufacturing, etc.
Support	The function of an organisation that focuses on activities relating to users, in-service support, repair / maintenance, recycling, end of life disposal.
Enterprise	Core functions of an organisation - e.g., strategic planning, leadership and management, human resources, digital backbone and data systems, integration of relevant statutory / regulatory requirements and compliance.

The functional structure is developed to levels of detail that enable the foresight process to reference external data sets including ONET (US) Occupational Information Network [[12]], ESCO – European Skills, Competences, Qualifications and Occupations[[13]], IfATE (UK) Institute for Apprenticeships and Technical Education[[14]] .

The five root functions comprise around 40 domains which are broken down to around 140 functional areas. The architecture is used to position ~ 25,000 capability statements which are the building blocks used in the workforce foresight process. Each capability statement has several attributes - some are static and reflect the position of the capability statement in the architecture, whilst others are dynamic and are assigned values through a cycle and set of workshops.

[12] ONET - Occupational Information Network - https://www.onetcenter.org/
[13] ESCO - European Skills, Competences, Qualifications and Occupations - https://esco.ec.europa.eu/en
[14] IfATE – Institute for Apprenticeships and Technical Education - https://www.instituteforapprenticeships.org/

The data architecture is implemented in a bespoke ‘data-cube’ which underpins the foresight process, workshops, and enables extensive use of LLM and AI tools. Additionally, a key feature of the data-cube is that the data from each foresight topic cycle is added into the data set and can then be used, where relevant, in future cycles. This ensures that the capabilities of the system are dynamic and up to date.

Identifying the Future Supply Chain Capabilities

The following charts and graphs summarise the changes in the set of capabilities that will be required by the supply chain (Supply Chain involved in production) in the future. The pie-charts reflect the distribution of capabilities across the five functions of the capability classification. The future state data is captured in three technology focused workshops. The current state data is derived from information collected on apprenticeship standards used across current supply chain partners. sector. This latter information is not as detailed as that produced by the workshops but is indicative and used to provide a point of comparison.

These initial pie charts summarise the changes that will be required by the whole supply chain, across the five functions. The analysis reveals a significant shift in organisational capabilities, with Design and Enterprise functions experiencing overall relative increases while Implementation shows a corresponding decrease. Notably, the Enterprise function now commands a 24% share of organizational focus, reflecting the sector's evolution toward more strategic and systems-oriented roles as ports embrace cyber-physical technologies.

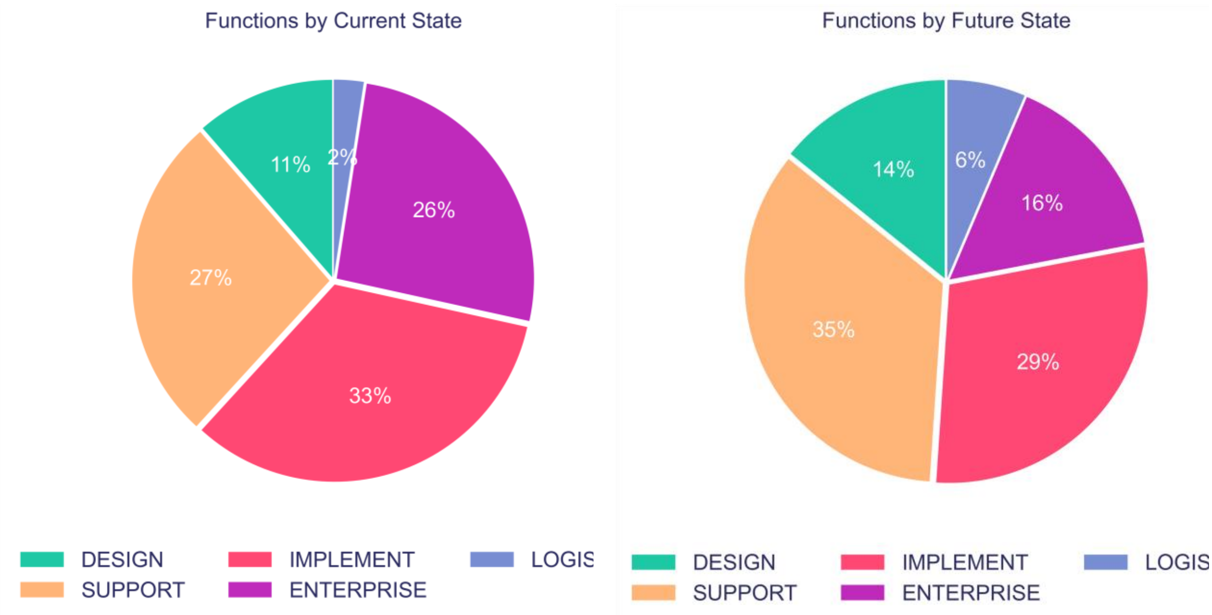


Figure 4: Current and Future – Whole Supply Chain - Capability Function Distribution %

Whilst the information on current and future Supply Chain capabilities is useful to indicate relative changes, factors such as volume of activity will also determine which functions may have greater future significance.

The graphs that follow show the distribution of capabilities assigned at domain level within the five main functions for this cycle. These graphs provide insight into the relative importance of each domain for the screen sector in the future.

Design Domains

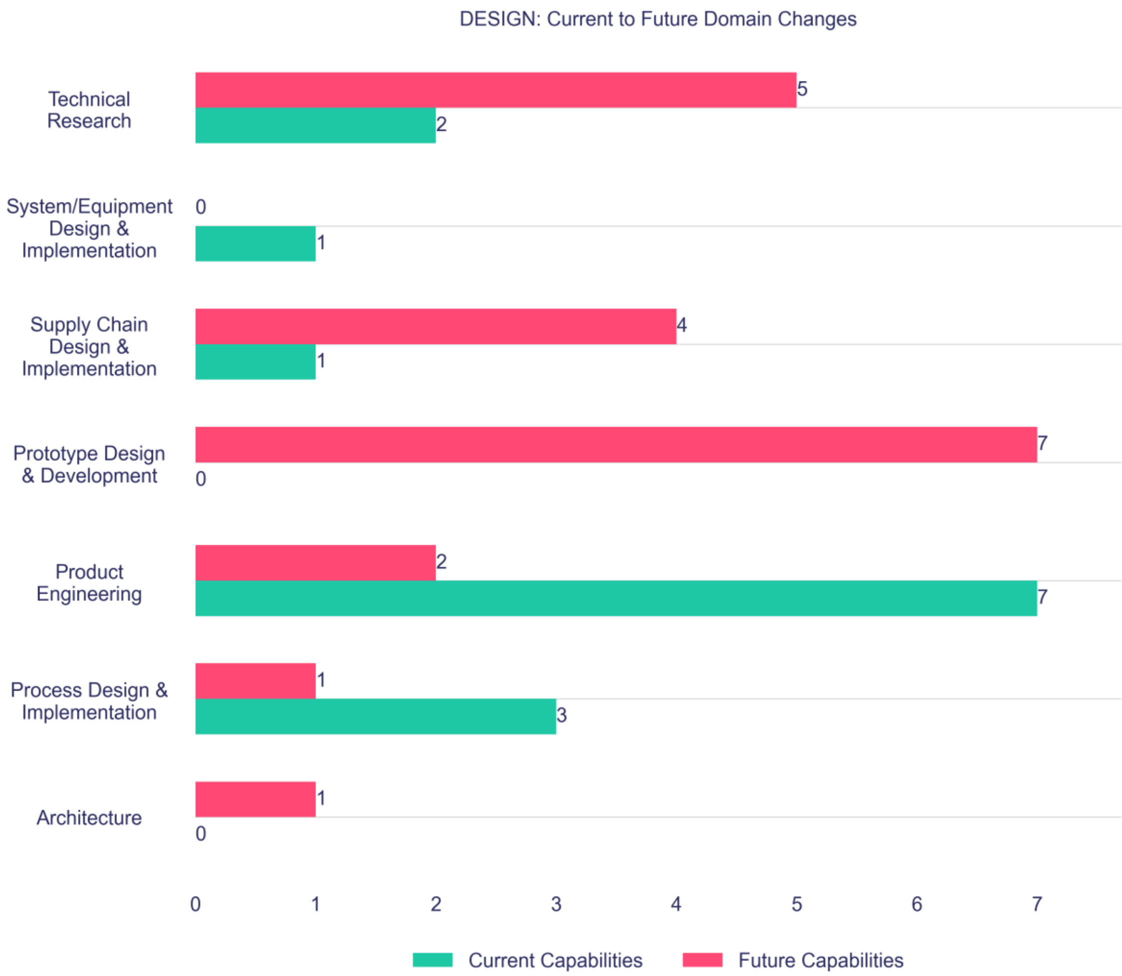


Figure 5: Design Future Domain Spread of Capabilities

The design function has the **highest number organisational capabilities with 46 out of a total of 131 capabilities for this cycle**, reflecting the cycle focus of AI in image asset creation. At domain-level, the highest number of capabilities exist within the process design and implementation domain. These include capabilities to model processes or develop processes. The second highest is in prototype design and development with a high requirement for the design of systems and applications, rather than physical prototypes.

The current / future comparison for Design reflects the foresighted transition to an increase in new products, engineering, and evaluation ahead of the development and implementation phase.

Enterprise Domains:

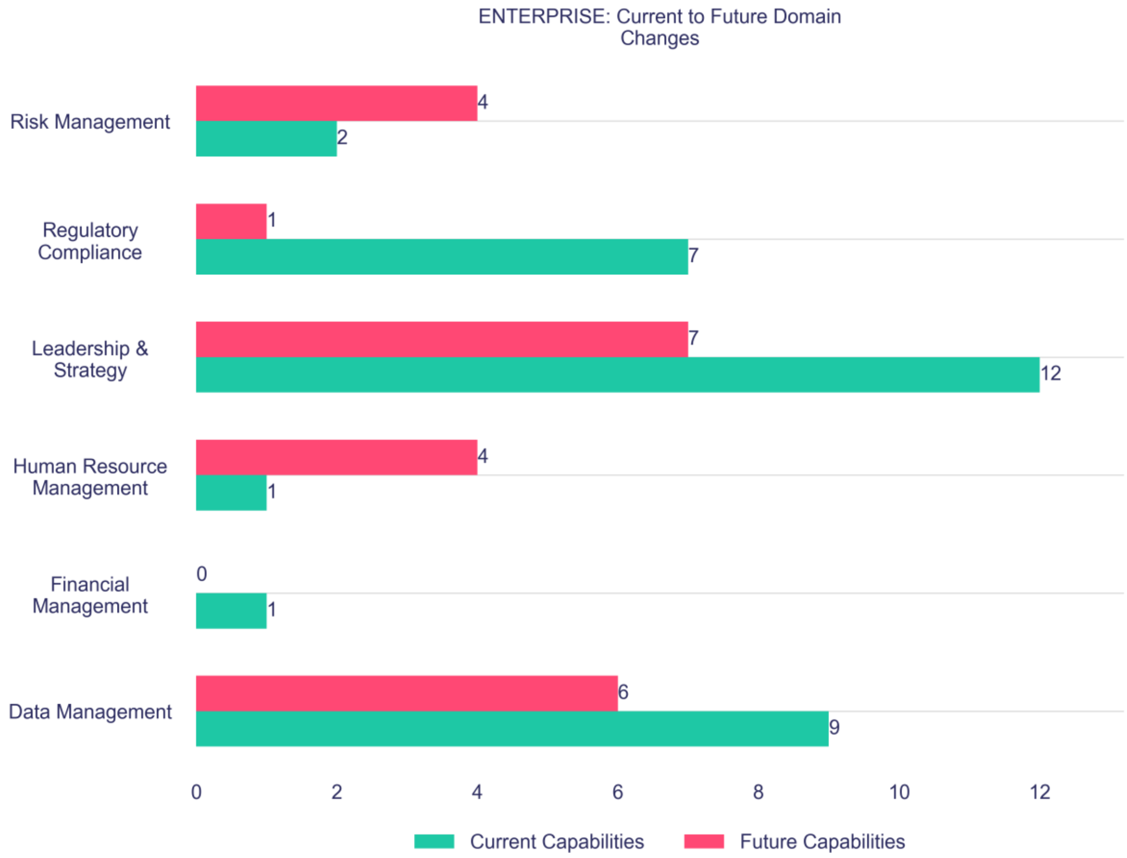


Figure 6: Enterprise Future Domain Spread of Capabilities#

Second highest ranking is the enterprise function with 31 capabilities out of 131. Most capabilities sit in the Data Management domain; focusing on areas such as performing data analysis; data storage design and evaluating data quality. Capabilities in the domain of leadership and strategy include identifying new business partnerships for this emerging technology; identifying business threats and opportunities; and evaluating environment impact. Regulatory compliance capabilities also feature in this function including coordinating compliance activities and monitoring compliance and regulation changes.

The current / future comparisons in the Enterprise area show the increased need associated with a maturing and competitive regulated market and the need to increase human resources.

Implementation Domains

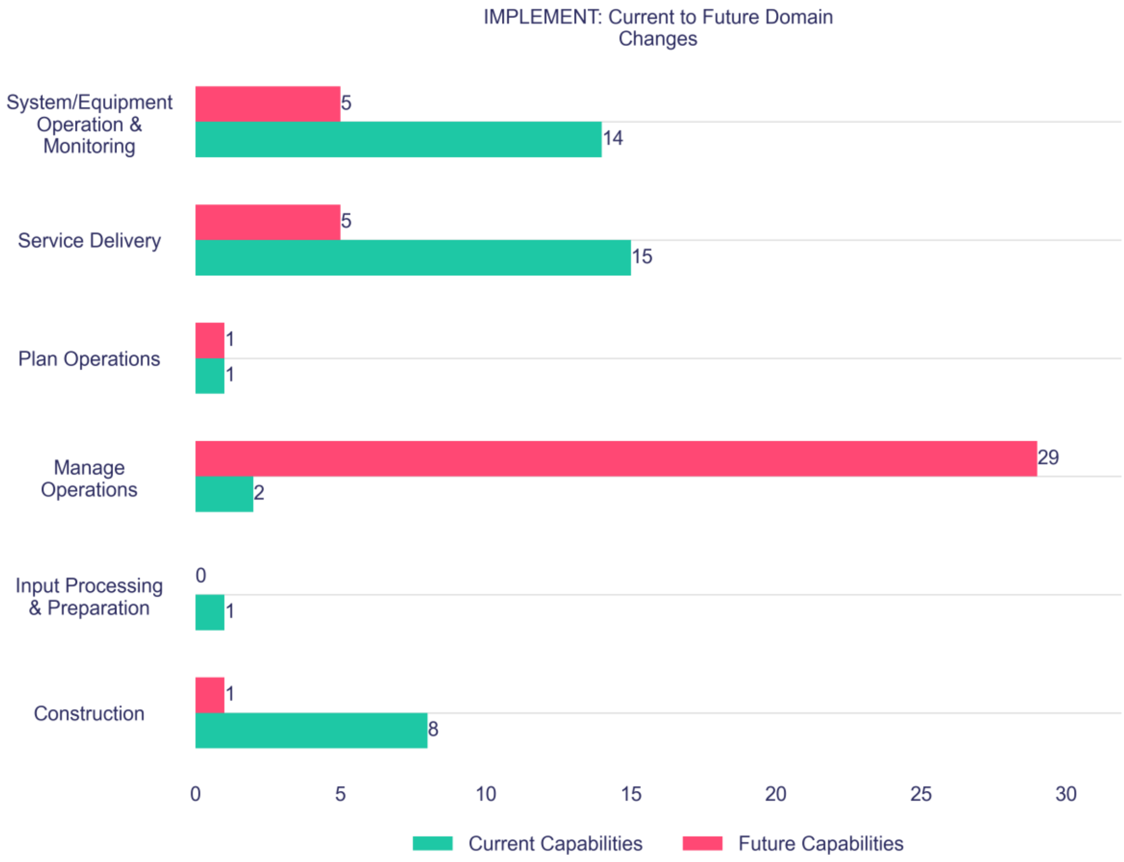


Figure 7: Implementation Future Domains Spread of Capabilities

Of the 131 cycle capabilities for the cycle, 28 sit in the 'implement' function with most operating in the service delivery domain in areas such as creating and processing digital media; analysing and verification of information; planning and scheduling of services; and communicating and translating information. Closely behind are system and equipment monitoring and manage operations.

The current / future comparison of implementation functions reflects the changes associated with greater adoption and product sales volume.

Logistics Domains

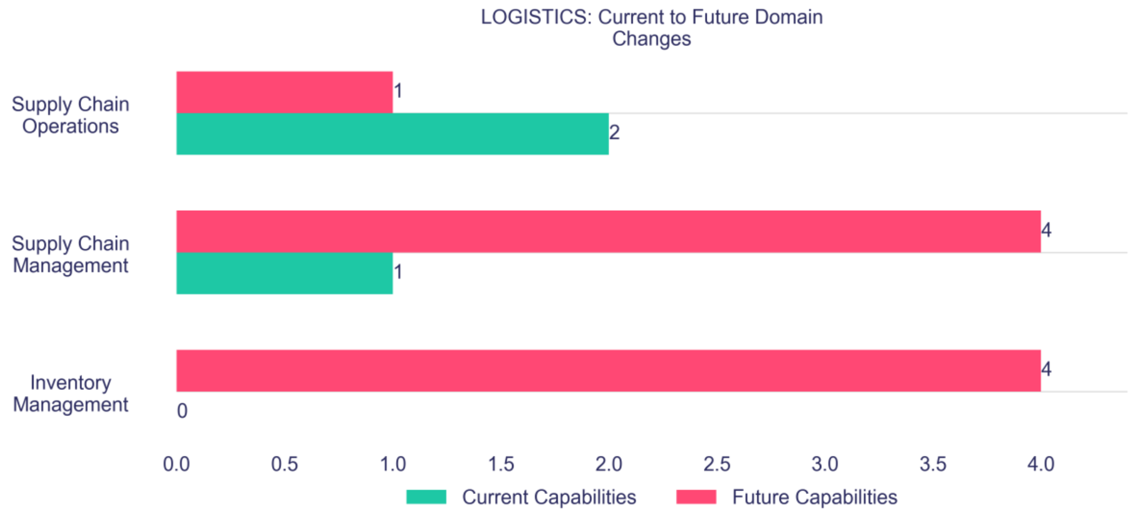


Figure 8: Logistics Future Domains- Future Spread of Capabilities

Only 5 capabilities out of 131 sit in the logistics function, reflecting the cycle focus on AI in image asset creation. Of those five capabilities, they operate in the functional areas of identifying and working with suppliers; monitoring inventories; coordinating logistics; and providing transport services.

The current and future comparison for logistics is as expected for organisations gearing up to work at a higher scale of production.

Support Domains

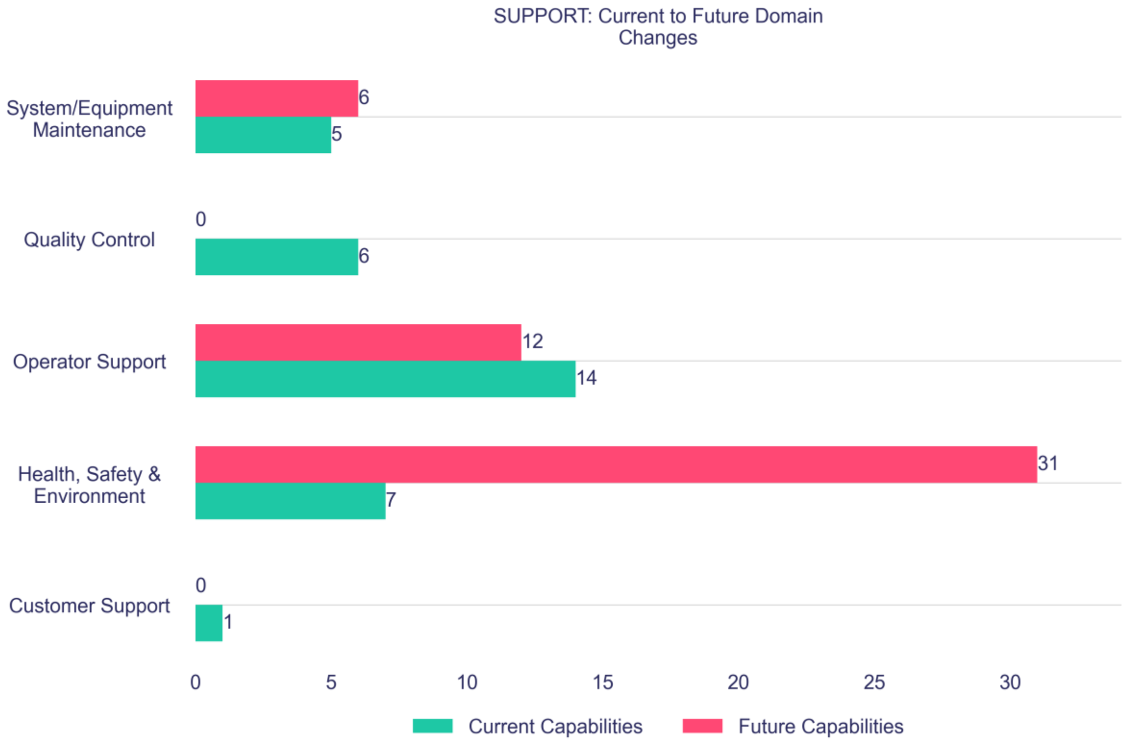


Figure 9: Support Future Domains - Future Spread of Capabilities

The 'support' function has **21 capabilities of the 131 for the cycle**, with the Operator Support domain being the highest. This included capabilities in areas such as designing and configuring support systems and operating support systems

The current and future support comparison reflects the current prominent levels of Health and Safety – the reduction in proportions may be due to omissions during the data gathering and analysis.

Visualisation Instructions organisational capabilities

Visualisation Data Link	What is it and what can it be used for?
Organisational Capabilities [15]	The page provides details of the capabilities required by each supply chain partner and the supply chain as whole. The information is presented using the Capability Classification Framework, Design / Implement / Logistics / Support / Enterprise and can be interrogated and then exported to suit specific user requirements and interest. The information provided also identifies capabilities supported by existing provision, and also where there may be gaps that require new development to support to equip the future workforce.

[15] Organisational Capabilities hvmcatapultforesighting.retool.com/embedded/public/f56f84e9-8ab8-414f-aa1a-0b42ab5c71df?_environment=production&token=08d982f00dfda7ab00d046dedc0377d8

3.3 Step Two – How will the Workforce change

Occupational Change Insight

Insight into occupational change uses the understanding of how capabilities will change across business functions (section 3.2, **Step One – How will the Supply Chain change - Organisational Changes Insight**) to inform proposals for how occupations and their associated skills set for each supply chain partner may need be revised to reflect change for each role level within that partner.

Supply Chain partner organisation types

The workforce foresighting process recognises that different partners in a Supply Chain will require appropriate capabilities, and these are determined and agreed in the initial workshops. In this cycle, the following Supply Chain partners were identified and then used during participant workshops and data analysis to determine the organisational needs:

Table key: Supply chain partners

- Crane Service Providers
- Port Operators
- Software & Systems Integrators
- Transport Operators (Vessels, Rail, HGVs)
- Cybersecurity Consultants & Suppliers
- Regulators CP

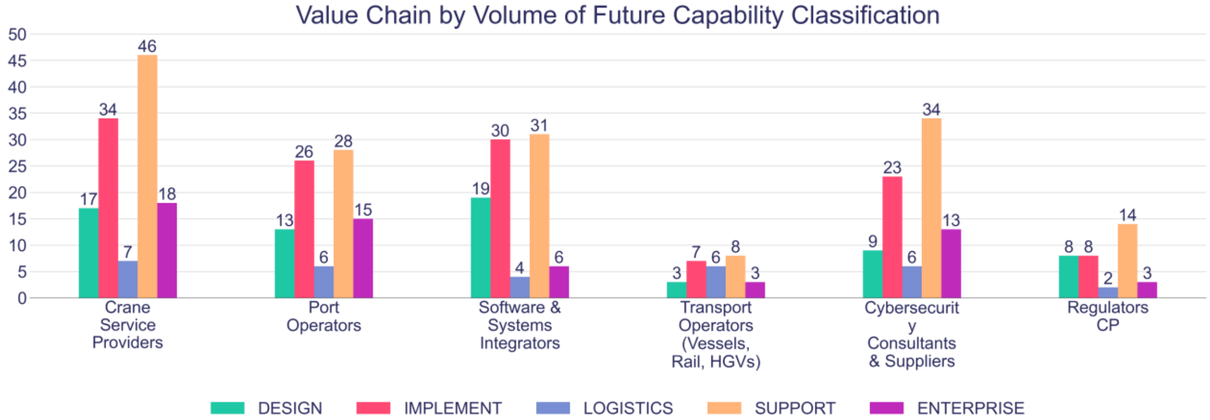


Figure 10: Distribution of Functions across each Supply Chain Partner

The graph illustrates the distribution of capabilities by function across the Supply Chain Partners. These capability sets are used to form the set of Future Occupational Profiles within each role level.

Visualisation Instructions supply chain capabilities

Detailed instructions on how to use the Visualisation Tool can be found in the appendix E (**E Visualisation links and Illustrations**).

Visualisation Data Link	What is it and what can it be used for?
Supply Chain Capabilities	This page provides an overview of the identified capabilities at a Supply Chain Partner level. By selecting/deselecting each Supply Chain Partner you can review the capabilities identified as required in that area of the Supply Chain. This can be used to generate organisational capability profiles for each area of the Supply Chain to help prioritise and focus the acquisition of new capabilities that will be required in the future. It can also be used to generate combined organisational profiles, where an organisation may be involved in more than one area of the Supply Chain.

Role Levels

The foresighting process uses the concept of Role Levels to represent future occupations. Utilising this approach acknowledges that the workforce is not homogeneous, there will be varying levels of proficiency required across a workforce and qualifications and training may be aligned/require different types of vocational or academic qualifications. Additionally, the role level approach seeks to avoid presuming that the future workforce will be operating at a different level to the current state.

Proficiencies

Each of these role levels will require proficiency that reflects their role and the needs of each Supply Chain Partner. The foresight process uses a three-point scale to capture and differentiate the proficiencies required. This information is used both in the generation of the Future Occupational Profiles, and to assist the definition of training needs identified. Within the workforce foresight process proficiency is defined as:

Awareness (A) - Has a foundational knowledge of tools, technology, techniques relevant to sector, industry, or organisation. Sufficient comprehension to know where to seek further information/details as necessary for a particular issue.

Practitioner (P) - Has the ability to apply and use independently a tool, system, or process. Understands the implications, consequences, and impact for their role/function. A Practitioner knows what key actions are required and in what context.

Expert (E) - Has detailed knowledge of process, system, tool, or technology. Can support others and identify improvements required for a process, system, or tool. An Expert can implement improvements personally or direct and guide others.

During the workshops participants applied their insight to assign proficiency for each role group to each capability. Individual responses were aggregated by the system to arrive at a consensus.

A summary of the distribution of required proficiency for the role levels in this cycle are:

Proficiency	Senior Level	Mid-Level	Junior Level
Awareness	14	8	34
Practitioner	91	80	18
Expert	198	166	18

Table 2: Proficiency Profile by Role Levels

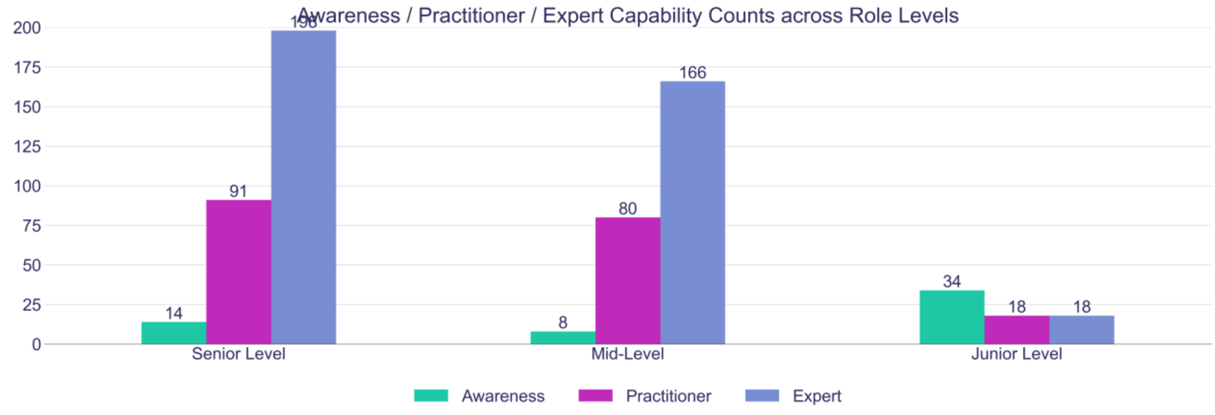


Figure 11: Proficiency details by Role Level

Future Occupational Profiles

FOPs are used to describe and suggest occupations, or roles, that may be required in the future and provide a framework to indicate capabilities and related duties. They can be used to review the impact on current roles and the adaptation that may be required in the future.

Educators can review current apprenticeship standards against the requirements of the FOPs and interpret which need to be changed to fill the gaps between the current and future state.

Employers can consider existing apprenticeship standards and make a judgement on adapting an existing apprenticeship standard to upskill their workforce to meet the requirements of a particular FOP.

FOPs and indicative skills need

Combining proficiency with the identified FOPs, the following graphs indicate the priority needs across the supply chain for each Role Group to deliver future capabilities.

Senior Level Role Level FOPs:

In this cycle the Senior Level role level was defined as occupations and roles requiring Level 6 qualifications or apprenticeships.

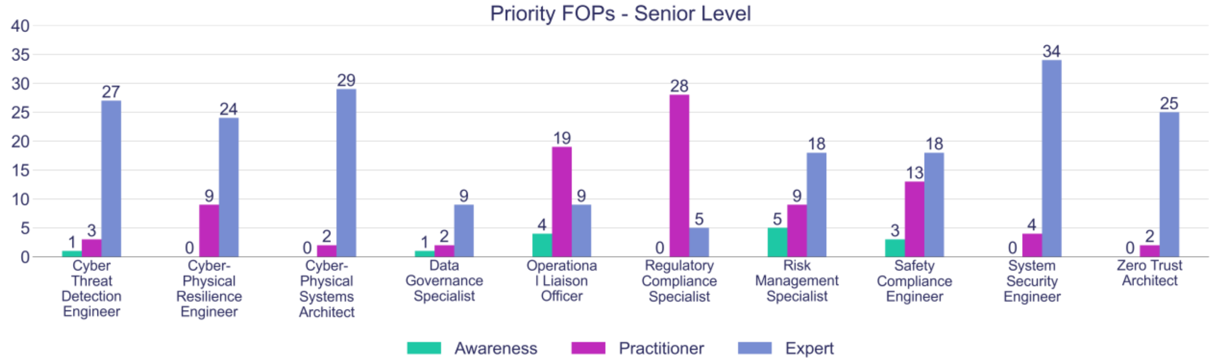


Figure 12: Priority FOPs - Senior Level Role Level

Mid-Level Role Level FOPs:

In this cycle the Mid-Level role level was defined as occupations and roles requiring Level 4 qualifications or apprenticeships.

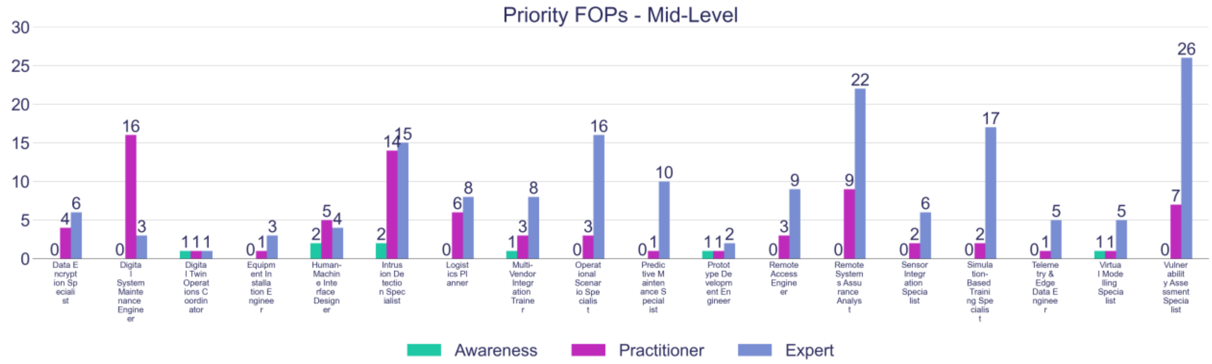


Figure 13: Priority FOPs - Mid-Level Role Level

Junior Level Role Level FOPs:

In this cycle the Junior Level role level was defined as occupations and roles requiring Level 1 qualifications or apprenticeships.

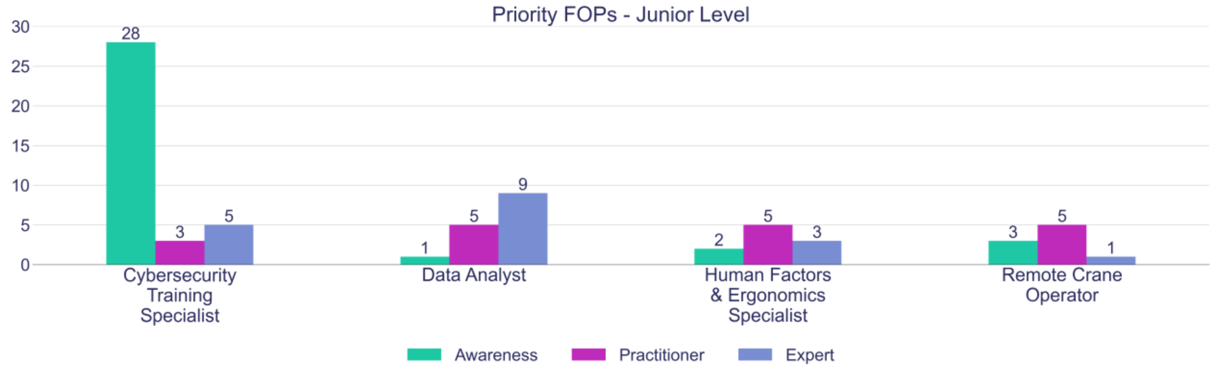


Figure 14: Priority FOPs - Junior Level Role Level

Visualisation Instructions FOP Matrix

Detailed instructions on how to use the Visualisation Tool can be found in the appendix E (**E Visualisation links and Illustrations**).

Visualisation Data Link	What is it and what can it be used for?
FOP Matrix [16]	This page provides a detailed breakdown of future occupational profiles that could be required in the future workforce. These were generated using a combination of attributes collected through the workshops and an algorithm. These suggested profiles were then reviewed and ratified by small groups of employers who were able to add/remove capabilities and uprate/downrate proficiency levels required. You can view all the FOPs in a role level by selecting one (or more) of these from the drop down. This will then allow you to select the FOPs aligned to that role level. The populated table allows you review and compares different FOPs within or across role levels. You can view the capabilities in each FOP and the assigned proficiency levels.

[16] FOP Matrix https://hvmcatapultforesighting.retool.com/embedded/public/f99a913f-8827-4730-8893-d618d489bc84?_environment=production&token=08d982f00dfda7ab00d046dedc0377d8

3.4 Step Three – How the current Education provision meets the future need

Highlighted Changes for Future Provision

The Workforce Foresighting process has developed two metrics to quantify the alignment between a FOP and a current standard or qualification:

> **Fit** – expressed as a %, it is a measure of the proportion of a FOP that is covered by an existing standard or qualification.
>
> **Surplus** – expressed as a %, it is a measure of the not relevant material in an existing standard that is not required for a FOP.

An ideal existing qualification or standard would have a high fit and low surplus – this implies good coverage of the FOP but with little material that is not relevant to the FOP. Conversely a poor candidate would have a low fit and high surplus. Using these two metrics it is possible to quantitively evaluate, rank, and compare a range of existing provisions against a set of FOPs describing future needs.

Our interpretation is represented by a simple nine-box model to position the suitability of a given current occupational standard to a future occupational profile:

Factor scores

Fit Factor	Fit score	Surplus Factor	Surplus score
0 - 32%	1	81-100%	1
33-65%	2	51-80%	2
66-100%	3	0 - 50%	3

Table 3: Suitability Grid

(Multiplying the Fit score by the Surplus score gives a Suitability Grid score of 1-9 as below)

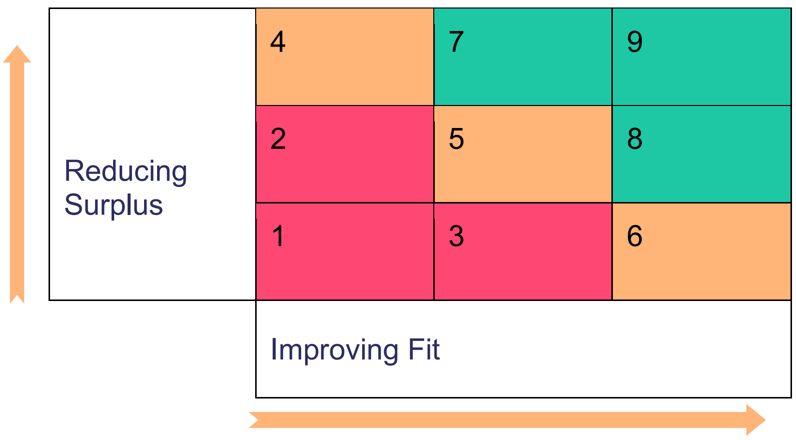


Figure 15: Fit Factor scores and Suitability Grid

Using this score and indicated 'RAG status' the following interpretations can be made:

High Suitability – 7,8,9 – for standards that have good coverage of FOPs.
Represents good candidates from current apprenticeship standards used as the basis of development to meet FOP requirements and inform elements of short course and CPD provision.

Some Suitability– 4,5,6 – for standards that have only partial coverage of FOPs.
These are likely to require extended work to meet FOP requirements, further review of the data may be necessary. They are likely to contain some useful information to inform elements of short course and CPD provision.

Low Suitability – 1,2,3 – for standards that have poor coverage of FOPs.
These are unlikely to be adaptable to meet future needs but may contain some useful information to inform elements of short course and CPD provision, which can be assessed using the data visualisation tools.

FOP findings compared with current standards

Using the approach described above and applying the ‘RAG’ scores to each FOP indicating the suitability of current apprenticeship standards selected from the IfATE set, the following table begins to identify areas of action and concern for the provision of future skills for each Supply Chain Partner to respond to the challenge.

Supply Chain Partner - Crane Service Providers

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Cyber-Physical Resilience Engineer	Low
Senior Level	System Security Engineer	Low
Mid-Level	Digital System Maintenance Engineer	Low
Mid-Level	Equipment Installation Engineer	Low
Mid-Level	Human-Machine Interface Designer	Low
Mid-Level	Multi-Vendor Integration Trainer	Low
Mid-Level	Predictive Maintenance Specialist	Good
Mid-Level	Remote Access Engineer	Low
Mid-Level	Sensor Integration Specialist	Low
Mid-Level	Simulation-Based Training Specialist	Low
Mid-Level	Telemetry & Edge Data Engineer	Low
Mid-Level	Virtual Modelling Specialist	Some
Junior Level	Cybersecurity Training Specialist	Low
Junior Level	Remote Crane Operator	Low

Table 4: Supply Chain Partner - Crane Service Providers

Detailed breakdown:

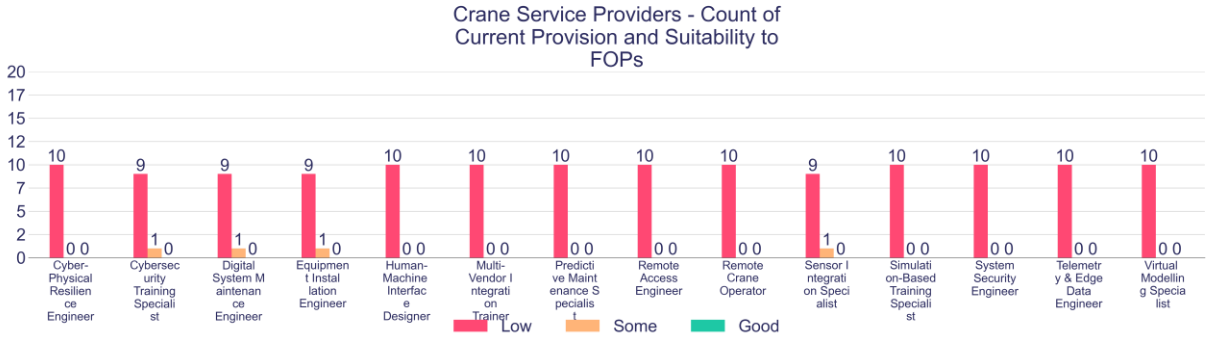


Figure 16: Suitability Summary - Crane Service Providers

Supply Chain Partner - Port Operators

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Cyber-Physical Resilience Engineer	Low
Senior Level	Data Governance Specialist	Low
Senior Level	Operational Liaison Officer	Low
Senior Level	Regulatory Compliance Specialist	Low
Senior Level	Risk Management Specialist	Low
Senior Level	Safety Compliance Engineer	Low
Mid-Level	Logistics Planner	Low
Mid-Level	Operational Scenario Specialist	Some
Mid-Level	Simulation-Based Training Specialist	Low
Junior Level	Cybersecurity Training Specialist	Low
Junior Level	Data Analyst	Low
Junior Level	Human Factors & Ergonomics Specialist	Low
Junior Level	Remote Crane Operator	Low

Figure 17: Supply Chain Partner - Port Operators

Detailed breakdown:

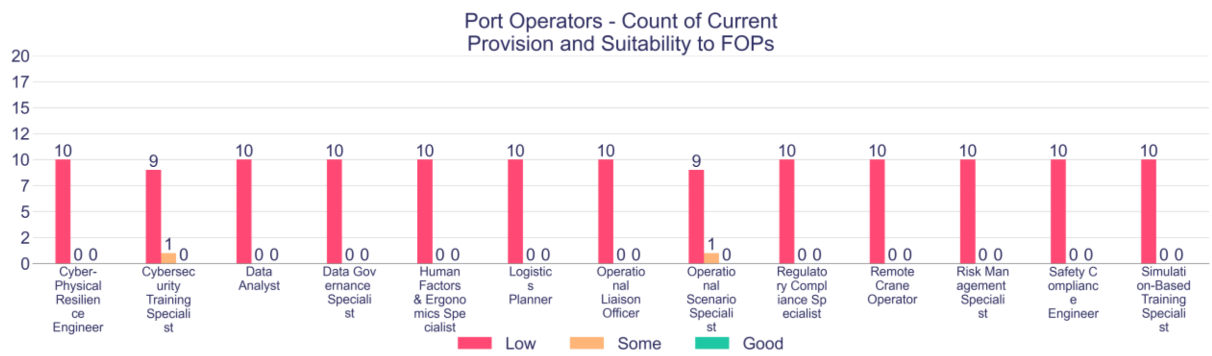


Figure 18: Suitability Summary - Port Operators

Supply Chain Partner - Software & Systems Integrators

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Zero Trust Architect	Low
Senior Level	Risk Management Specialist	Low
Senior Level	Cyber-Physical Systems Architect	Low
Senior Level	Cyber-Physical Resilience Engineer	Low
Senior Level	Cyber Threat Detection Engineer	Low
Senior Level	System Security Engineer	Low
Mid-Level	Vulnerability Assessment Specialist	Some
Mid-Level	Virtual Modelling Specialist	Some
Mid-Level	Telemetry & Edge Data Engineer	Low
Mid-Level	Simulation-Based Training Specialist	Low
Mid-Level	Sensor Integration Specialist	Low
Mid-Level	Remote Systems Assurance Analyst	Low
Mid-Level	Prototype Development Engineer	Low
Mid-Level	Predictive Maintenance Specialist	Good
Mid-Level	Multi-Vendor Integration Trainer	Low
Mid-Level	Intrusion Detection Specialist	Low
Mid-Level	Human-Machine Interface Designer	Low
Mid-Level	Equipment Installation Engineer	Low
Mid-Level	Digital Twin Operations Coordinator	Low
Mid-Level	Digital System Maintenance Engineer	Low
Mid-Level	Data Encryption Specialist	Low
Mid-Level	Remote Access Engineer	Low
Junior Level	Data Analyst	Low

Figure 19: Supply Chain Partner - Software & Systems Integrators

Detailed breakdown:

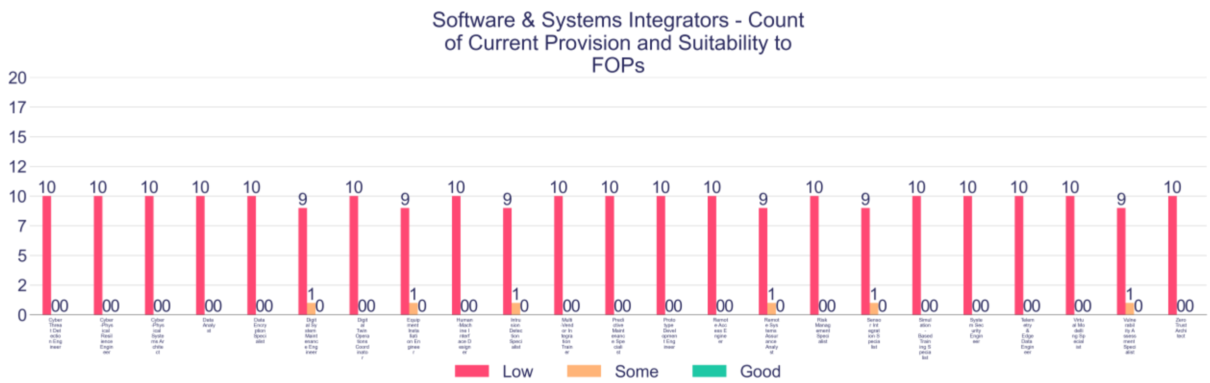


Figure 20: Suitability Summary - Software & Systems Integrators

Supply Chain Partner - Transport Operators (Vessels, Rail, HGVs)

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Operational Liaison Officer	Low
Mid-Level	Logistics Planner	Low
Junior Level	Cybersecurity Training Specialist	Low
Junior Level	Human Factors & Ergonomics Specialist	Low

Table 5: Supply Chain Partner - Transport Operators (Vessels, Rail, HGVs)

Detailed breakdown:

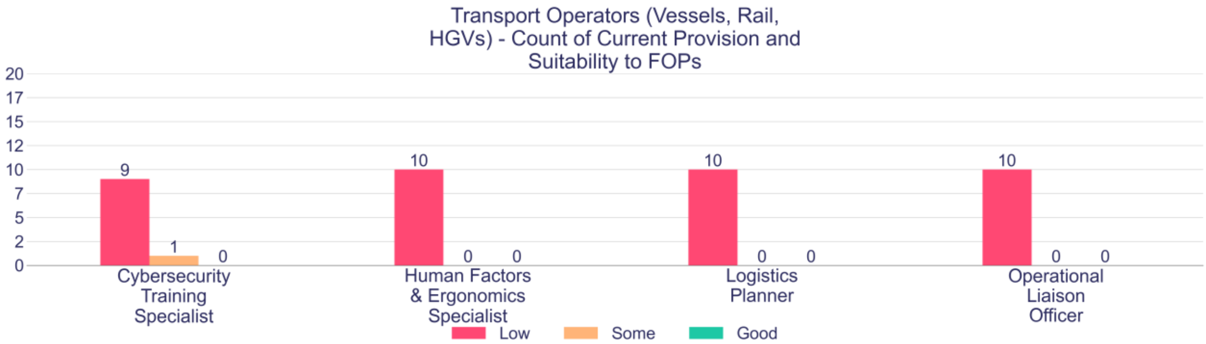


Figure 21: Suitability Summary - Transport Operators (Vessels, Rail, HGVs)

Supply Chain Partner - Cybersecurity Consultants & Suppliers

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Cyber Threat Detection Engineer	Low
Senior Level	Cyber-Physical Resilience Engineer	Low
Senior Level	Cyber-Physical Systems Architect	Low
Senior Level	Regulatory Compliance Specialist	Low
Senior Level	Risk Management Specialist	Low
Senior Level	System Security Engineer	Low
Senior Level	Zero Trust Architect	Low
Mid-Level	Data Encryption Specialist	Low
Mid-Level	Intrusion Detection Specialist	Low
Mid-Level	Operational Scenario Specialist	Some
Mid-Level	Remote Systems Assurance Analyst	Low
Mid-Level	Simulation-Based Training Specialist	Low
Mid-Level	Vulnerability Assessment Specialist	Some
Junior Level	Cybersecurity Training Specialist	Low

Table 6: Supply Chain Partner - Cybersecurity Consultants & Suppliers

Detailed breakdown:

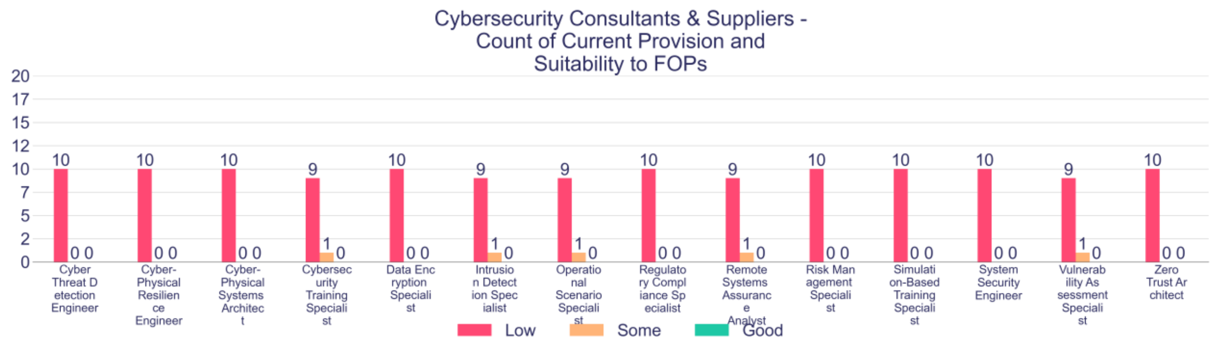


Figure 18: Suitability Summary - Cybersecurity Consultants & Suppliers

Supply Chain Partner - Regulators CP

Role Level	Selected Future Occupational Profiles	Current Suitability Summary
Senior Level	Data Governance Specialist	Low
Senior Level	Operational Liaison Officer	Low
Senior Level	Regulatory Compliance Specialist	Low
Senior Level	Safety Compliance Engineer	Low

Table 7: Supply Chain Partner - Regulators CP

Detailed breakdown:

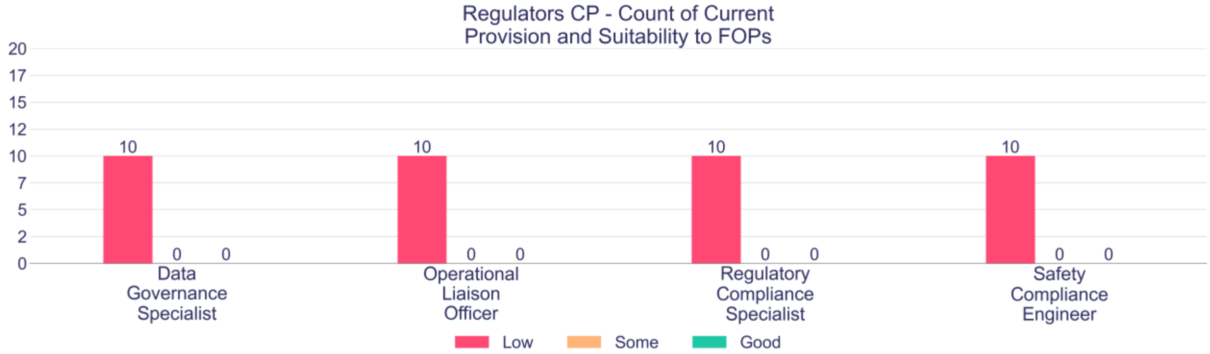


Figure 22: Suitability Summary - Regulators CP

Visualisation tool links and descriptions

Visualisation Data Link	What is it and what can it be used for?
FOP Detail	This page allows you to review a specific Occupational Profile, including the capabilities contained within it and the Knowledge, Skills & Behaviour (KSB) tags associated with the capability. You can select an individual Role Level and linked FOP in the two available dropdowns. The table in the lower section of the page will then be populated with all relevant capabilities. The search control above the table allows you to filter content of any of the columns of data. A key piece of functionality in this table is the presence of the KSB tags associated with the capabilities.
Future KSBs Summary	This page provides a view of the complete set of capabilities within the cycle along with all of the associated KSB tags which are linked to them. It is, essentially, the superset of all details displayed on the Fop detail page. This is used to: • To review the identified Knowledge, Skill and Behaviour tags for a given capability, to support development of future education and learning material. • To review the requirements from a capability level, rather than a role level/occupational profile grouping.
Capabilities Matched to Current Provision	This page allows you to review and compare individual capabilities against 'Duty' statements in an Apprenticeship / Occupational Standard. You can select individual capabilities to review their specific matches. These matches are shown in the bottom panel, including the Standard, the Level and the Duty Statement this is matched to. You can filter in several ways to focus your review: • By the Capability Classification Framework (left-hand panel). • By capabilities that **are** served by the reference mapping framework – the default is Institute for Apprenticeships and Technical Education (IfATE) provision. • By capabilities that **are not** served by the reference mapping framework, e.g., IfATE provision – these are capabilities required in the future that may require new/bespoke training and CPD materials to be developed to upskill/re-skill the workforce.

Visualisation Data Link	What is it and what can it be used for?
	This page can be used to identify where existing provision may exist across the broad spectrum of Apprenticeship standards, and not just within a narrow range of sector-specific Standards. The data also allows you to identify where provision may already exist to support specific capabilities.
Fit & Surplus Factors	This page allows you to review the 'Fit' and 'Surplus' of Prototype Future Occupation Profiles (FOP) against existing training provision e.g. Institute for Apprenticeships and Technical Education (IfATE). It is possible for the 'Fit' and 'Surplus' comparison to total over 100%, as they are two separate calculations based on a two-way comparison.
Fit & Surplus Matrix	This page is a visual representation of the 'Fit and Surplus Factor' insight. You can visually review 'Fit' and 'Surplus' of Prototype Future Occupation Profiles (FOP) against existing training provision e.g. Institute for Apprenticeships and Technical Education (IfATE). This can help you identify which provision may align strongest, or which may require adaptation, to provide the suitable provision fit for each future role. It will help you focus in on which provision to focus your attention for analysis.
FOP Capability Matches	This page allows you to view the matches between Capabilities and Institute for Apprenticeships and Technical Education (IfATE) Duty Statements. Clicking the arrow next to a number in the 'Matches' column will open a popup with more detail for each Capability. Each capability also includes Knowledge, Skill and Behaviour Tags, to support with scaffolding future education provision. You can review individual Prototype Future Occupational Profiles (FOPs) or review all FOPs under a Role Level, to give a more holistic view of Capabilities and Matches Where a future capability has been matched to existing provision (currently, by default, IfATE apprenticeship standards) it is possible to interrogate the data and identify specific statements in standards that align to enable identification of existing training materials and activities that could be used or adapted to meet future requirements. This can be used to review the capability requirements for Role Levels and FOPs, from Job / Occupation level through to Knowledge, Skill and Behaviour level

Table 8: Visualisation tool links and descriptions

4. Conclusions and Next Steps

4. Conclusion and Next Steps

4	Conclusions and Next Steps
4.1	Summary of Key Insights
4.2	What this means for Industry and the Workforce
4.3	What this means for Education
4.4	Recommended next steps

4.1 Summary of Key Insights

The foresighting analysis reveals a structural failure in the UK workforce development that threatens the port sector's digital transformation. Of 31 Future Occupational Profiles identified, only one – Predictive Maintenance Specialist – achieved a "Good" suitability rating against existing IfATE standards.

The misalignment spans all career levels, from entry positions to senior strategic roles. Most profiles scored "Low" or "Some" suitability, demonstrating that current qualification frameworks lack foundational components for cyber-physical security competencies.

The implications are stark. The sector faces compressed timelines for developing educational pathways that bridge traditional operational expertise with technological competencies while maintaining operational continuity. Existing professionals need entirely new competency sets, not enhanced versions of current capabilities.

Most critically, success demands cross-sector collaboration transcending traditional boundaries. Future-proofing the workforce requires coordinated action across educational institutions, technology providers, regulatory bodies, and operational stakeholders – reflecting the interdisciplinary nature of cyber-physical security challenges.

The training inadequacy proved more comprehensive than anticipated, revealing fundamental gaps across all professional development levels. Low suitability ratings for foundational roles expose a critical absence of entry-level pathways into digitally enabled port operations. This creates workforce pipeline bottlenecks that could persist for years without intervention.

More concerning: complete absence of standards for high-complexity senior roles, including Cyber-Physical Resilience Engineer, System Security Engineer, and Zero Trust Architect. These positions carry strategic importance for sector security and resilience, yet current educational infrastructure provides no development pathways. This senior-level gap threatens leadership deficits cascading across organisational transformation.

Particularly striking was inadequate support for simulation and Digital Twin roles – the technological core of the chosen cyber-physical security approach. Despite growing relevance across industrial sectors, the current provision fails to address these capabilities, suggesting broader inadequacies in the UK technical education infrastructure.

Without immediate comprehensive intervention, the sector confronts a widening skills gap that could compromise the safe deployment of remote and autonomous technologies. The implications extend beyond operational efficiency to basic capability for managing cyber-physical systems integration.

The foresighting process engaged a strategically diverse ecosystem providing comprehensive perspectives across workforce development challenges. Industry leaders from Port of Tyne, Neva Group, and Data People Connected contributed operational insights, grounding theoretical frameworks in practical realities.

Educational institutions – University of Warwick, Manchester Metropolitan University, and Brunel University – provided critical perspectives on curriculum development capabilities and constraints while identifying pathways for rapid qualification enhancement.

Technology experts from Chrome Angel, Midlands Cyber Cluster, and Complete Cyber ensured workforce development recommendations reflect genuine technological requirements rather than theoretical constructs, providing insight into skills transferability and emerging competency requirements.

Cross-sector discussions revealed a paradox: widespread challenge recognition coupled with insufficient coordinated action. This disconnection between awareness and implementation highlights the need for formal coordination mechanisms to translate shared understanding into systematic intervention.

Trade association involvement, industry council participation, and skills working group coordination prove essential for transitioning from insight to implementation. Workforce transformation complexity demands institutional collaboration extending beyond traditional boundaries to encompass the full ecosystem influencing development outcomes.

Success depends on maintaining stakeholder momentum while establishing clear accountability frameworks, ensuring coordinated action across institutional domains. The foresighting process created a collaboration foundation; the challenge lies in sustaining and directing that collaboration toward comprehensive workforce transformation supporting the UK port sector's transition to secure, efficient cyber-physical operations.

The convergence of stakeholder recognition, analytical clarity, and strategic urgency creates unprecedented opportunity for workforce development reform. However, realising this opportunity requires immediate transition from insight to coordinated action across educational, industrial, and policy stakeholders.

FOP suitability to selected education provision

The below table counts the number of IfATE standards by suitability score for each FOP. For the purpose of this report, we've utilised the suitability grid to highlight the top IfATE standards that support each FOP. The table identifies if they have low, some or high suitability and colour-coded their overall suitability.

Role Level	Primary Supply Chain / Supply Chain Partner	Future Occupation Profile	Overall Suitability RAG
Senior Level	Crane Service Providers, Port Operators, Software Systems Integrators, Cybersecurity Consultants Suppliers	Cyber-Physical Resilience Engineer	Low
Senior Level	Crane Service Providers, Software Systems Integrators, Cybersecurity Consultants Suppliers	System Security Engineer	Low
Senior Level	Port Operators, Cybersecurity Consultants Suppliers, Regulators CP	Regulatory Compliance Specialist	Low
Senior Level	Port Operators, Regulators CP	Data Governance Specialist	Low
Senior Level	Port Operators, Regulators CP	Safety Compliance Engineer	Low
Senior Level	Port Operators, Software Systems Integrators, Cybersecurity Consultants Suppliers	Risk Management Specialist	Low
Senior Level	Port Operators, Transport Operators (Vessels, Rail, HGVs), Regulators CP	Operational Liaison Officer	Low
Senior Level	Software Systems Integrators, Cybersecurity Consultants Suppliers,	Cyber Threat Detection Engineer	Low
Senior Level	Software Systems Integrators, Cybersecurity Consultants Suppliers	Cyber-Physical Systems Architect	Low
Senior Level	Software Systems Integrators, Cybersecurity Consultants Suppliers	Zero Trust Architect	Low
Mid-Level	Software Systems Integrators	Digital Twin Operations Coordinator	Low
Mid-Level	Software Systems Integrators	Prototype Development Engineer	Low
Mid-Level	Crane Service Providers, Port Operators, Software Systems Integrators, Cybersecurity Consultants Suppliers	Simulation-Based Training Specialist	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Digital System Maintenance Engineer	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Equipment Installation Engineer	Low

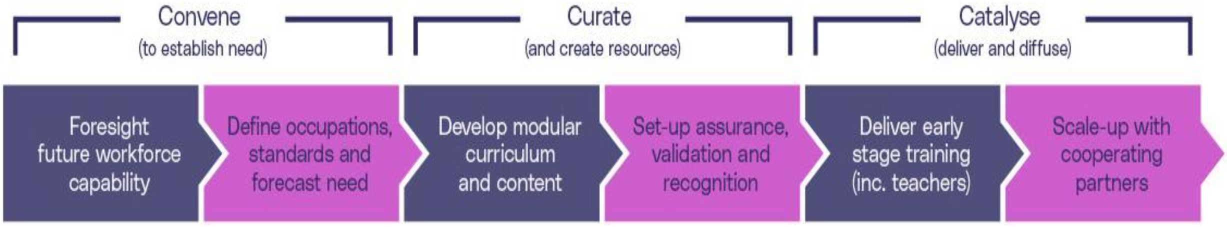
Role Level	Primary Supply Chain / Supply Chain Partner	Future Occupation Profile	Overall Suitability RAG
Mid-Level	Crane Service Providers, Software Systems Integrators	Human-Machine Interface Designer	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Multi-Vendor Integration Trainer	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Predictive Maintenance Specialist	Good
Mid-Level	Crane Service Providers, Software Systems Integrators	Remote Access Engineer	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Sensor Integration Specialist	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Telemetry Edge Data Engineer	Low
Mid-Level	Crane Service Providers, Software Systems Integrators	Virtual Modelling Specialist	Some
Mid-Level	Port Operators, Cybersecurity Consultants Suppliers	Operational Scenario Specialist	Some
Mid-Level	Port Operators, Transport Operators (Vessels, Rail, HGVs)	Logistics Planner	Low
Mid-Level	Software Systems Integrators, Cybersecurity Consultants Suppliers	Data Encryption Specialist	Low
Mid-Level	Software Systems Integrators, Cybersecurity Consultants Suppliers	Intrusion Detection Specialist	Low
Mid-Level	Software Systems Integrators, Cybersecurity Consultants Suppliers	Remote Systems Assurance Analyst	Low

Table 9: IfATE standards by suitability score for each FOP

4.2 What this means for Industry and the Workforce

Collective Action

Foresighting has been developed to provide insight and the detailed information required to enable action by relevant stakeholders but is the first step of the Skills Value Chain. Collective action will be required by all stakeholders to ensure that the changes identified by foresighting – to the supply chain, the workforce and education provision are implemented.



UK port employers must coordinate immediate and long-term responses to cyber-physical security workforce challenges through unprecedented collaboration across the sector.

The most urgent priority involves investing in Continuing Professional Development targeting simulation technologies, cybersecurity protocols, and remote operations management, precisely the areas showing the biggest skills gaps in current provision. Simultaneously, employers should recruit from manufacturing and defence sectors for senior roles where transferable skills already exist, creating structured transition pathways that recognise prior learning while adding essential port-specific training and regulatory compliance knowledge.

Employers must engage proactively in curriculum development across all education levels, ensuring emerging programmes incorporate the cyber-physical security competencies identified through foresighting analysis. This includes promoting hybrid roles that combine engineering, data science, and cybersecurity expertise to attract technology professionals who haven't previously considered maritime careers. Success requires coordinated sector awareness campaigns highlighting sophisticated technological challenges and career advancement opportunities within digitally transformed port operations.

Effective coordination demands establishing cross-functional working groups that address system integration challenges extending beyond individual organisational boundaries. These groups must align workforce planning with technology deployment timelines, ensuring competency development delivers qualified professionals when implementations require them rather than discovering gaps after deployment. The interconnected nature of cyber-physical security challenges requires coordinated responses across the entire supply chain: from crane service providers and port operators to systems integrators and cybersecurity consultants.

By taking these coordinated actions, the UK port sector can secure a skilled workforce capable of supporting the safe, efficient, and resilient deployment of remote and autonomous technologies. This will reinforce the sector's alignment with Innovate UK's **Digital & Technologies** impact domain and strengthen its global competitiveness.

4.3 What this means for Education

Educational transformation represents the greatest challenge and opportunity for enabling the UK port sector's cyber-physical security transition. Rather than wholesale restructuring, strategic targeted interventions can bridge skills gaps while maintaining educational efficiency and industry responsiveness.

The modular enhancement approach emerges as an optimal strategy, enabling institutions to respond rapidly to capability gaps while leveraging existing infrastructure rather than developing entirely new programmes. Electrical and mechanical engineering disciplines provide essential foundations that can be strategically enhanced rather than replaced, supporting systems integration, predictive maintenance, and remote operations management core to cyber-physical security.

Systems integration and simulation engineering represent the most critical enhancement areas, requiring targeted modules addressing Digital Twin technologies, cyber-physical systems management, and threat modelling protocols. These bridge traditional engineering with emerging technological requirements, creating integrated competencies reflecting the interdisciplinary nature of modern port operations.

Module development opportunities include electrical engineering covering advanced telemetry and sensor integration, mechanical engineering emphasising predictive maintenance and cyber-physical system integration, and systems integration modules addressing Digital Twin coordination and multi-vendor platforms. Existing standards for power transmission, maintenance, and manufacturing technicians offer accelerated pathways through strategic enhancement of proven pedagogical frameworks.

Advanced competency requirements in cyber-physical resilience engineering and zero trust architecture demand sophisticated approaches leveraging research capabilities alongside industry expertise. PhD sponsorships and industry collaborations provide mechanisms for developing senior-level expertise while creating knowledge transfer pathways between academic research and practical implementation.

Academia requires fundamental shifts from traditional consultation to ongoing collaborative partnerships encompassing curriculum co-development, research alignment, and continuous validation against evolving operational requirements. Foresighting working group participation maintains educational relevance while contributing academic expertise to sectoral transformation planning.

Success demands institutional agility, enabling rapid response to capability gaps while maintaining quality and coherence. Collaborative research integration across institutions, industry partners, and technology providers creates comprehensive capability development, leveraging diverse expertise while ensuring implementation relevance. This strategic alignment with Innovate UK's Digital & Technologies domain positions educational institutions as critical partners in achieving national objectives while creating sustainable competitive advantages for UK port operations.

4.4 Recommended next steps

The comprehensive roadmap for the UK port sector workforce readiness constitutes a strategic transformation framework, positioning the sector as a global leader in cyber-physical security implementation. With competitor nations already advancing maritime cyber-physical capabilities, coordinated action is urgent.

Future Occupational Profiles provide systematic foundations for addressing capability deficits and skills evolution across digital transformation timelines. These comprehensive competency frameworks guide educational development, recruitment strategies, and organisational capability building rather than serving as simple job descriptions. Industry standards must leverage FOP frameworks, ensuring revised requirements reflect genuine operational needs while maintaining progression pathways from entry-level through advanced expertise. Apprenticeship standards revision for emerging roles – Cyber-Physical Resilience Engineer, Simulation-Based Training Specialist, Digital Twin Operations Coordinator – creates sustainable workforce pipelines reflecting sophisticated competency requirements.

Short-term actions require cross-stakeholder collaboration across educators, awarding bodies, and employers for curriculum co-development and coordinated delivery, maximising efficiency while ensuring quality. The focus on design, simulation, and lifecycle activities reflects fundamental shifts from implementation toward enterprise functions requiring integrated competencies spanning traditional disciplinary boundaries. Strategic recruitment from manufacturing, defence, and related sectors offers immediate opportunities for critical capability gaps, particularly senior positions where traditional training timelines create unacceptable delays.

Mid-term actions demand systematic integration of prioritised Future Occupational Profiles across apprenticeship standards, vocational qualifications, and higher education programmes, ensuring coherent progression pathways rather than fragmented development. Modular implementation approaches enable accelerated industry responsiveness while avoiding delays in comprehensive course redesign, allowing institutions to leverage existing strengths while building new competencies.

Educators must establish continuous assessment and feedback systems through ongoing IfATE standards review with employer stakeholders, maintaining alignment with evolving operational requirements. Strategic CPD course development identifies enhancement opportunities and fundamental requirements, enabling strategic resource allocation across concurrent capability-building initiatives.

The dissemination framework requires working group establishment for comprehensive action plans and systematic sharing of insights across industry, educational, and policy networks. Regular FOP review processes ensure workforce development frameworks remain aligned with emerging technological capabilities rather than becoming static representations. Without systematic implementation, the UK port sector faces technological marginalisation, compromising operational capabilities and strategic maritime positioning. Workforce capability gaps create cascading vulnerabilities across operational technology systems, cybersecurity protocols, and supply chain management, extending to national economic security. Immediate coordinated action remains essential for securing UK leadership in maritime operations while building adaptive workforce capabilities for continuous evolution in increasingly sophisticated cyber-physical environments.

Appendix

Appendices

Title
A List of Participants
B Cycle timeline
C Access to output data - link and authorisation
D Glossary - common language
E Visualisation links and Illustrations

A List of Participants

Industry Participants	Skills Participants	Technology Participants
Richard Holland – Transport Accelerator: Maritime, (Connected Places Catapult)	Mohammad Hammoudeh - Manchester Metropolitan University	Mark Robinson – Chrome Angel
Brian Bishop - Data People Connected Limited	Maria Papadaki – University of Warwick	Ryan Protheroe – Midlands Cyber Cluster
Charles Hall - Neva Group	Mastaneh Davis - Roehampton University	Evan Jones – Complete Cyber
Filippo Sanzeni – Connected Places Catapult	Abdul Khalique - Liverpool John Moores University	Carol Lo – University of the West of England
	Olamide Jogunola - Manchester Metropolitan University	Xicheng Li – University of Glasgow
	Afshin Mansouri – Brunel University	Sebati Ghosh – University of York

Table 10: List of Participants

B Cycle timeline

Workforce Foresighting cycle started the Carry Out phase in February 2025. The Carry Out phase concluded in July 2025. The Findings report was prepared following the data validation period and published in September 2025.

C Access to output data - link and authorisation

The following text/data has been automatically generated using cycle data – Delete this notice before publishing

Data Capture Overview [17]

[17] Data capture overview https://hvmcatapultforesighting.retool.com/embedded/public/e869283b-4b8a-437c-973e-64ab292e5b87?_environment=production&token=08d982f00dfda7ab00d046dedc0377d8

D Glossary - common language

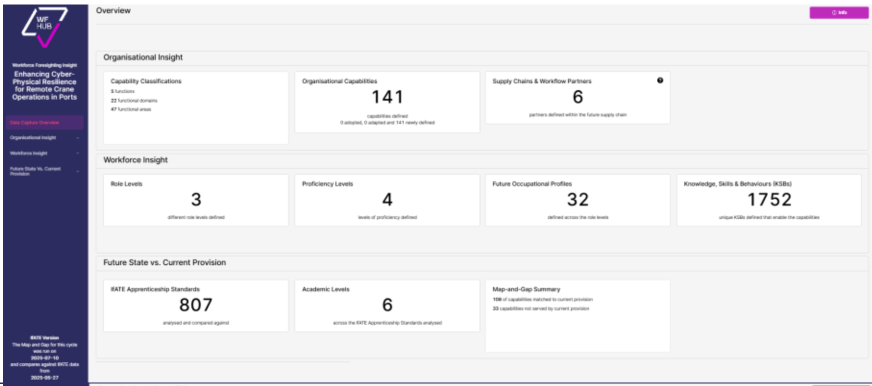
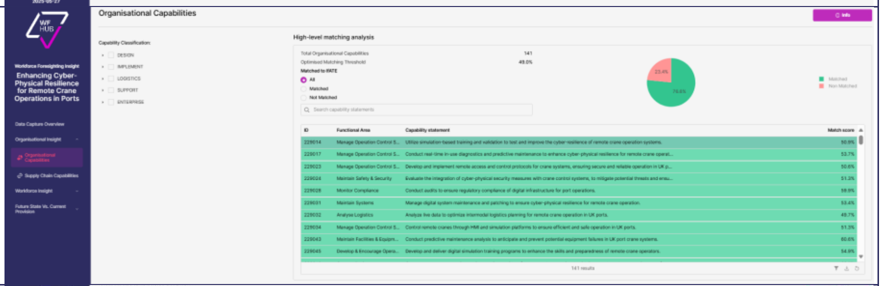
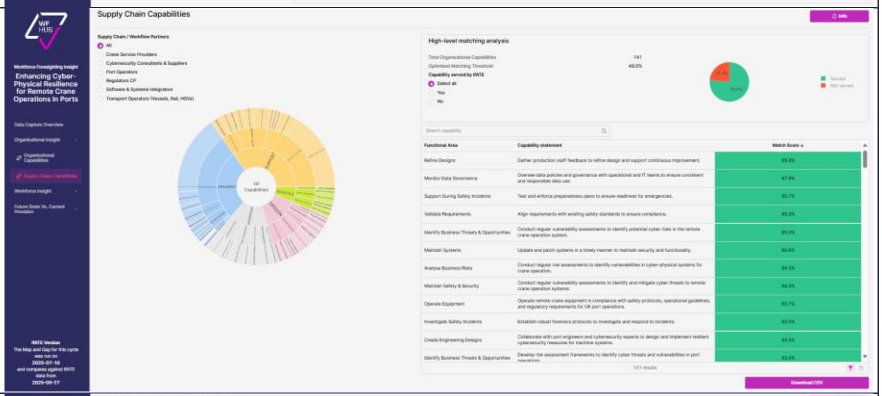
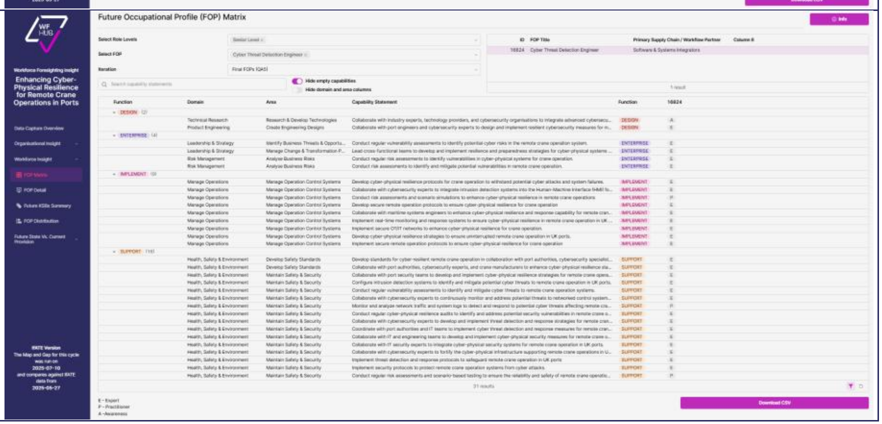
Term	Definition
Impact Domains	Innovate UK domains used as Strategic Categories to assist setting and monitoring priorities
National Challenge (Industry / Sector / Region)	A recognised technological or socio-political threat or opportunity for which there is consensus that workforce action is necessary
Challenge Response	Specific intervention aimed at the challenge
Capability (Organisation)	The collective abilities, and expertise of an organisation to carry out a function, because provision and preparation have been made by the organisation
Capability Classification	Classification provides a common, structured vocabulary to define capability
Capability Statements	Description of the depth and nature of each capability within an organisation
Capability Syntax	Common language to describe each capability application within organisation type
Competencies (Workforce / Individual)	‘Proficiency, aptitude, capacity, skill, technique, experience, expertise, facility, fitness related to capability
Competency definition 'KSBs' (Knowledge, Skills and Behaviours)	Knowledge, Skills, and Behaviours are the elements used to express the required competencies for each Role Group
Competency Domain	Used during foresighting analysis to provide focus on existing and emerging competency needs
Delphi Process	Foresighting takes a Delphi approach which has come to represent consulting expert opinion. (Harking back to the Delphic Oracle of ancient Greece)
Foresight Cycle	Set of workshops, analysis and reporting that implements the Foresight Process for each subject
Foresight Process	A series of activities which are convened to understand future competence needs, the opportunities available and actions required to deliver the right skills at the right time and place
Foresighting Champion	An individual nominated within a new user organisation of foresighting to facilitate and lead the use of foresighting processes and tools with the support of the Project Team
Foresighting Subject	The application of specific technologies in the context of a given challenge and which are candidates for foresighting
Future Competency Set	The KBS output from the Educator workshop for each Role Group
Map and Gap Analysis	A combined expert and automated process that maps the Future Competency Set against a selected reference framework
Organisation Type	Simple description of nature of organisation for which capability is required
Proficiencies	Proficiencies differentiate the degree of competencies required from differing Role Groups to support capabilities
Project Sponsor	Typically, a stakeholder in the challenge being successfully met who requires information to under-write plans to act

Role Group	Role groups are a collective of roles that exist in a typical manufacturing business / industrial sector
Syntax	The way in which a statement is phrased to ensure reliable, repeatable and meaningful interpretation
Technologies	The technology that could be used to address the challenge
Working Scenario	To provide further context in relation to the subjects and used to position participants thinking during the detailed identification of future capabilities
Workshops	Online sessions used to undertake each step in the foresight process
Roadmaps	Sector, Industry, Regional view of emerging opportunities and their market entry
Participants	Technologists, Educators, Employers

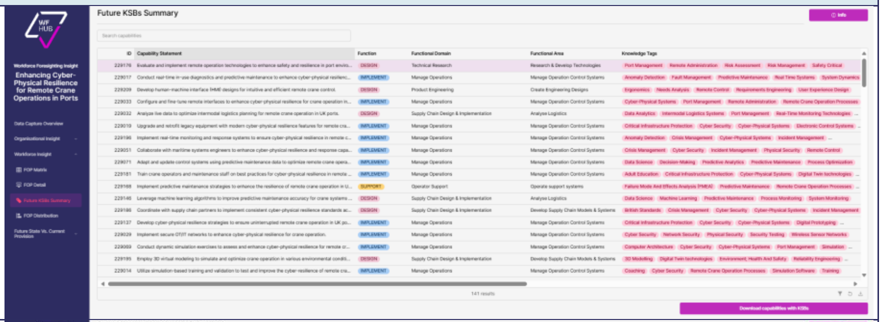
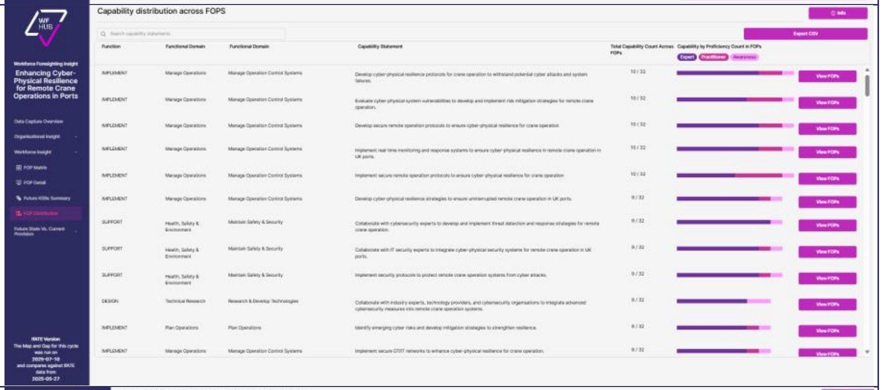
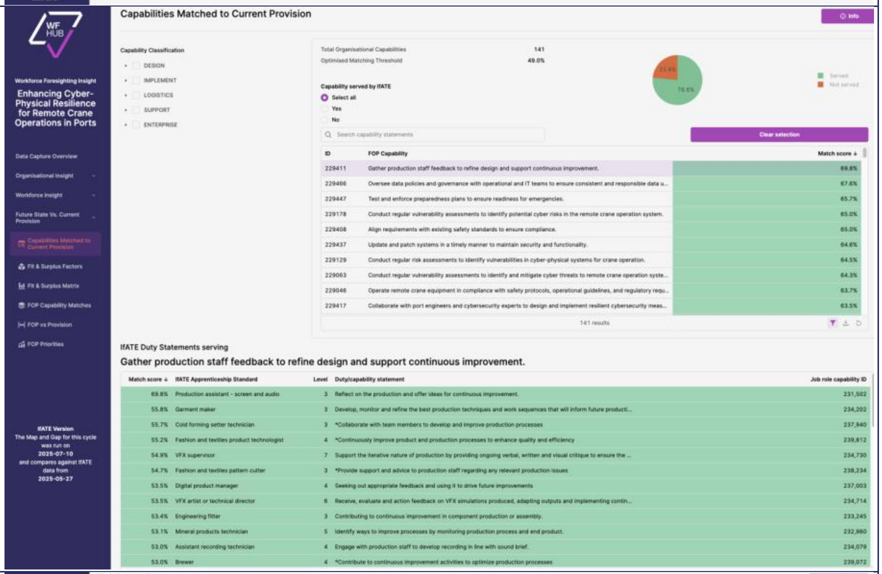
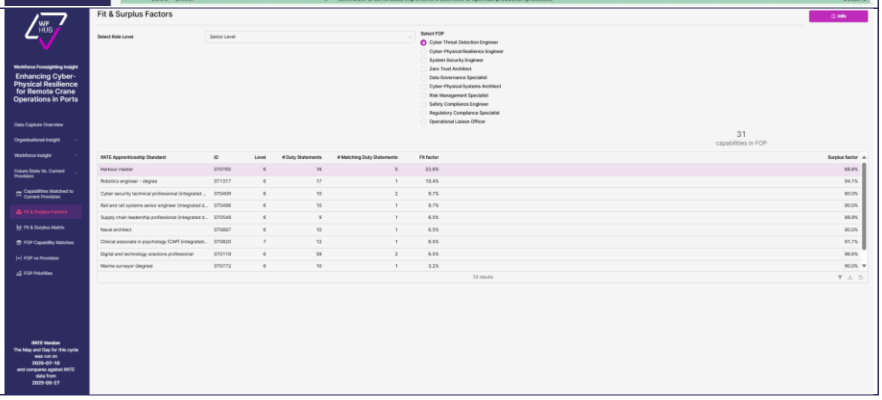
Table 11: Glossary - common language

E Visualisation links and Illustrations

Images are not cycle specific and just for guidance purposes

Link to Visualisation	View of data
Data Capture Overview	
Organisational Capabilities	
Supply Chain Capabilities	
FOP Matrix	

Date: 21/08/2025
Report version 1.0
WF Template Report Content version 2.0

Link to Visualisation	View of data
Future KSBs Summary	
FOP Distribution	
Capabilities Matched to Current Provision	
Fit Surplus Factors	

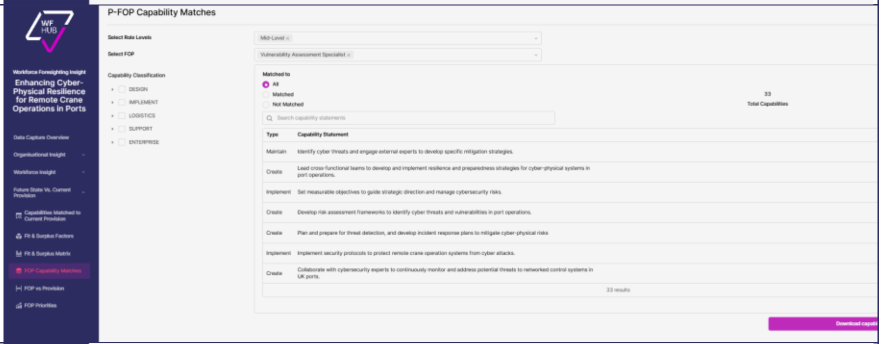
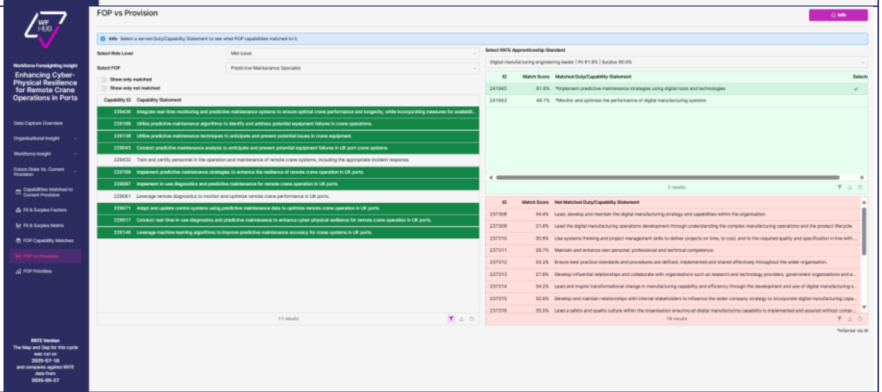
Link to Visualisation	View of data
[Fit Surplus Matrix]()	
[FOP Capability Matches]()	
[FOP vs Provision]()	
[FOP Priorities]()	

Table 12: Visualisation links and Illustrations