Foresighting Future Workforce Needs in the Agri-food Sector – a pilot study on fresh produce packhouse skills for automation

Final Report

(July 2023)

Funding Partner | Project Partner | Project Partner | Technology Partner | Sponsor

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1.0 Executive Summary

1.1. Project Background

This report presents the process and outputs of a skills foresighting pilot exercise, which was undertaken to envision and identify the skills required within an automated fresh produce packhouse (FPP) environment of the future. The study was a collaborative effort between the University of Lincoln (UoL), the High Value Manufacturing Catapult (HVM-Catapult) and Manufacturing Technology Centre (MTC) under the sponsorship of the Gatsby Charitable Foundation. The Fresh Produce Consortium acted as industry sponsor, in recognition of their role as a key driver for change within the industry. The project's objective was to explore the foresighting of skills and undertake proof of concept trials to support industrial transition within the agri-food sector, in particular the adoption of robotics and automation technologies required for fresh produce packhouses. The project sought to: i) Provide a new case study for the foresighting methodology developed by Gatsby and HVM-Catapult; and ii) Lay out the foundations for future skills development programmes required by the sector.

1.2. Challenge and technological solution

Due to the combined impacts of Brexit, COVID and chronic workforce shortage, the UK agri-food sector is suffering a labour crisis characterised by a workforce shortage, skills deficit and loss, as well as perceived low wage and poor working conditions. The sector has been characterised by a high dependency on seasonal, low paid workers who often undertake manual jobs in challenging conditions. In recent years this agri-food sector has been challenged by high numbers on vacancies (500,000 estimated vacancies in 2021 (FDF, 2021), and increasing labour costs representing wage inflation of between 10 to 20% (Nye et al., 2021; House of Commons, 2022). As a result, the sector is urgently attempting to drive labour productivity through adoption of robotic and automation systems. These technology systems require a holistic systemic approach in which technologies around autonomous and non-autonomous robotics interact with other technologies such as machine vision and end effectors, data collection and management as well as control systems technologies and machine monitoring. These technologies will drive up workforce skills and salaries, however there is now emerging evidence that existing skills deficits in the current workforce are stifling this transition. Therefore, there is an urgent need to understand and underpin the skills required by current members of the workforce. In addition, more efforts are needed to define skills characterising new entrants that will support the workforce sectoral transformation towards automation (Illanes et al, 2018).

1.3. Approach and data management

This study applied a Foresighting methodology for skills and workforce developed by the HVM Catapult. The methodology uses a systematic approach that aims to be robust, scalable, and applicable across a wide range of manufacturing areas, sectors, and industries. The methodology involves two main activities. The first activity, called Step Zero, developed a shared understanding of the challenges and technical solutions for the automated FPP. These technological solutions formed the foundations of the second stage of the foresighting exercise. Implementation of Step Zero consisted of forty-one individual interviews with experts in the packhouse industry, categorised within three key groups: automation technology suppliers, packhouse industry users and educators.

Activity 2 comprised the application of the foresighting cycle. This covered five steps, which were implemented through six workshops and four online surveys with separate groups of automation technology suppliers, packhouse industry users/employers, and industry educators. The cycle involved preparatory actions to define stakeholders' scenarios and to select three job roles to focus in upon. The steps consisted of: i) the definition of organisational capabilities by robotic specialists, ii) the assignment of job roles proficiencies by users/employers, iii) the definition of future knowledge and skills statements by educators based on future individual capabilities, iv) the performance of an Artificial

Intelligence/Machine Learning analysis to identify gaps in the current Training and Education Provision, and, v) the elaboration of recommendations and how these translate into actions required to deliver upon an ambitious agenda to meet the future skills needs of automated FPPs.

1.4. Results, insights and Recommendations

The project generated process results and main topic insights which are summarised in this section. Recommendations based on both steps were also elaborated.

a. Results of the process

- The foresighting exercise generated a total of 1168 future Knowledge and Skills (K&S) statements for three job roles (technical operator, engineer, and advanced engineer) and two proficiency levels (experts and practitioners). These future K&S statements for packhouse automation were then mapped against 1010 current K&S statements of 325 Apprenticeship Standards existing in the Engineering and Manufacturing as well as Digital routes from the Institute for Apprenticeships & Technical Education (IFATE) using machine learning match and gap analysis. Due to the lack of IFATE particular standards to agri-food products packhouses, generic standards from the Engineering and Manufacturing (89%), and Digital route (11%). were used.
- The future K&S refer to six capabilities functions (Enterprise, Digital Thread, Design, Supply Chain, Product and Manufacturing & Production) and 25 capabilities domains identified as critical for the future of manufacturing that covers aspect of the enterprise management, . The major concentration of these capabilities appears on the Enterprise and Manufacturing & Production functions (63%) and the Engineer role (48%).

b. Insights on thematic findings

- The project generated evidence about the need to review/change current education provision in the context of systematic transformation of the FPP towards automation.
- Results demonstrate that existing occupational standards provide good coverage of what is needed in the future of technician roles (Technical Operator role (26% K&S gaps) but at higher-level Advanced Engineer role the coverage is less good (82% K&S gaps).
- There was a good match between some capability requirements at all levels, for example: "Statutory and Regulatory" capabilities associated to food security standards as well as "Manufacturing and Production Monitoring", which are relevant to both current and future states.
- Significant gaps were highlighted in capabilities most relevant to the future automated state, such as "Maintain / support vision systems and tools" and "Design / implement robotic systems and tools".

c. Recommendations

- To consider the development of both technical and non-technical skills within future education provision, to support the transition to automation in FPPs.
- To promote a multifaceted, flexible training and education provision to address twin challenges of educating new entrants whilst also developing the existing workforce.
- To review/change current education provision in the context of a system-wide transformation of the FPP sector to achieve automation by attending challenges within the sector.

1.5. Limitations

The pilot study focused on a generic FPP environment; from the point that the bulk product enters the process to when the packed product leaves (dispatch). Wider dependencies, such as creating the right financial environment to support automation, were outside the scope of this study. Future knowledge and skills gaps were identified with comparisons to the current Apprenticeship Standards (and some in progress) from the Institute for Apprenticeships and Technical Education (IFATE). However, the foresighting cycle did not cover other critical provision/schemes required to respond to the labour crisis, such as Continuous Professional Development and in-house training.

Contents

2.0 Introduction

This report presents the process and outputs of a skills foresighting pilot study undertaken by the Lincoln Institute for Agri-Food Technology (University of Lincoln (UoL)), supported by the Manufacturing Technology Centre (MTC), High Value Manufacturing Catapult (HVM-Catapult), and National Centre for Food Manufacturing (UoL). This pilot study aimed to determine the impact on future skill needs of automation within fresh produce packhouses (FPPs). The Fresh Produce Consortium were engaged as project sponsor due to its important role in the industry. Initially developed by HVM-Catapult with the support of the Gatsby Foundation, the Foresighting approach was extended and further piloted during the Department of Education (DfE) funded Emerging Skills Project. Further information about this approach can be found in Collier et al., (2020).

3.0 Project details: Challenges

The current labour crisis within the UK food chain, with 500,000 estimated vacancies in 2021 (FDF, 2021) out of 4.1 million roles in the sector (House of Commons, 2022), appears to be the major challenge of the FPP sector. The labour crisis with FPPs is a chronic problem in which shortages of local and overseas workforce and specific skills are combined with increasing labour costs representing wage inflation of between 10 to 20% (Nye et al., 2021; House of Commons, 2022). The FPP sector (which, for the purpose of this study comprises vegetables, fruits and ornamentals) has had a high dependency on seasonal and low-paid workers who undertake many manual jobs in challenging conditions. Recent disruptions created by post-Brexit trade and migration policies, Covid-19 and the Ukraine war build on long-term sectoral challenges (FDF, 2021; House of Commons, 2022). This has contributed to create perfect storms of food shortage that have affected UK fresh produce supply in 2022 and 2023[1] . Despite recent government actions providing 45,000 visas for 2023 for seasonal workers[2], this sectoral crisis requires short and long-term solutions to ensure the availability of seasonal employees (36%) as well as managerial/technical (23%) and supervisory (4%) occupations (Pye Tait Consulting, 2020).

A sectoral transformation is required to overcome various constraints that contribute to the FPP labour crisis (see details in Annex 1). Long-term challenges include aspects that currently characterise the sector, such as: i) low margins, short-term contracts and increasing input costs; ii) the time-dependent, seasonal, diverse, and dynamic nature of fresh produce; iii) increasing local and global demand for fruit and vegetables to contribute towards healthier diets; iii) a high degree of influence from stakeholders like retailers and policymakers; and iv) limited collaboration due to a competitive market environment. Long-term challenges also refer to FPP employment limitations created by the combined effect of UK population demographics and employment trends, changes in the migrant workforce in terms of skills base, as well as low staff retention in the sector due in part to a lack of clarity in career progression and working conditions. Moreover, there are challenges associated with current training and education provision in terms of gaps in visible progression pathways and an unmet need for flexibility within these schemes. The fact that a significant quantity of industry training occurs in-house (80%) with varying levels of transferability and training quality is also something that should be considered as it could reduce workforce flexibility (Pye Tait Consulting, 2020). Another element to consider is the current low uptake of 0.3% of apprentices/trainees (Pye Tait Consulting, 2020). One fundamental challenge remains namely transforming the perception of the FPP sector as having poor working conditions and little career opportunity to a more positive perception of career pathways with high quality and inclusive employment that makes FPPs an attractive sector for aspirational and ambitious workers.

[1] https://www.bbc.co.uk/news/64762429 (tomato shortage on March 2023

[2] https://deframedia.blog.gov.uk/2022/12/19/seasonal-workers-visas-for-2023/

It is widely accepted that automation can contribute towards mitigating these challenges by transitioning job roles and driving up workforce skills and salaries. However, whilst advances have occurred in automating some technologies used in FPPs, emergent technologies also need to be considered within any "roadmap" for whole-system training. Ultimately, integrated packhouse automation systems are required to move towards FPP automation. These systems consider the range between automated (repetitive task equipment) to fully autonomous robotic technologies. In addition, they require technologies for sensing (machine vision), acting (robotic arm end effectors), processing (data collection and management) and monitoring (control systems technologies and machine monitoring) (Figure 1). Future FPPs will require a wide range of complementary automation technologies that respond to the complexity of handling and the flexibility/ agility to cover multi-line and multi-product packing and processing processes (Figure 2).

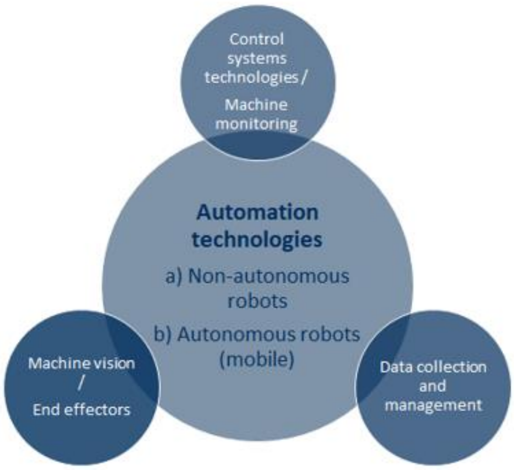


Figure 1. Integrated packhouse automation system.

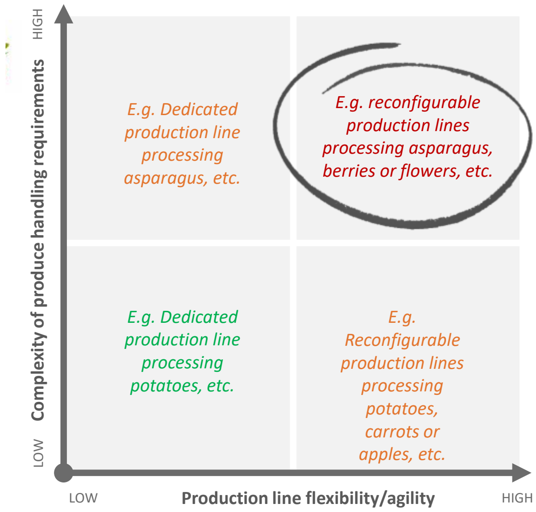


Figure 2. Automation technologies required for future fresh produce packhouses.

Several challenges are stifling the transition to the automation of FPPs. These include the need to adapt or develop robust automation technologies responding to FPP-specific requirements and, at the same time, improve/redesign packhouse infrastructure and the overall rural infrastructure where FPP are often located. It is necessary to increase capacity not only in the packhouses but also in the robotic sector and other stakeholders' support to meet increasing demands. There is a speed of change that is being imposed on the sector from outside, coupled with competition for employees across a number of sectors, which means that skills deficits in the existing packhouse workforce is a critical challenge. Therefore, there is an urgent need to understand and underpin the skills required by new workforce members in addition to upskilling existing staff. This study aims to contribute through its findings and in informing appropriate solutions.

4.0 Foresighting aims and objectives

Considering the challenges presented, the foresighting process aimed to identify the future knowledge and skills required by the FPP workforce to transition to automation, then to assess how the current education provision meets those requirements. This aim was achieved by addressing the following general objective: To explore the foresighting of skills and undertake ***proof of concept trials*** to support the ***industrial transition*** within the agri-food sector, in particular the ***adoption of robotics and automation*** technologies required for FPPs. In particular, the project:

i. Provided a **new case study** for the foresighting methodology developed by Gatsby and HVM-Catapult

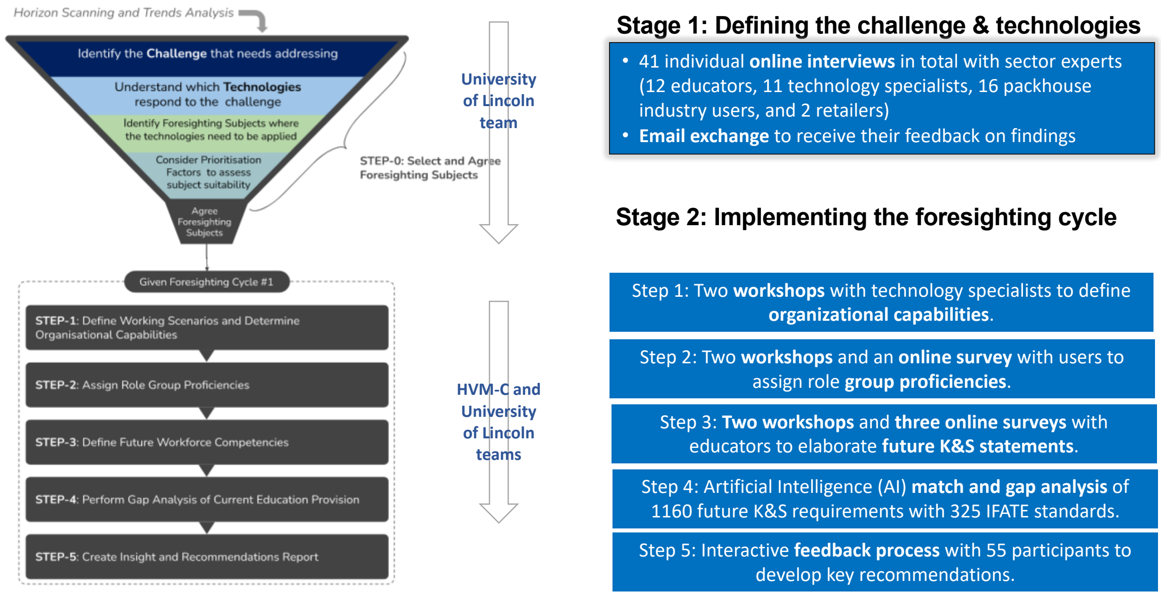
ii. Provided recommendations on **future skills** development programmes required by the fresh produce packhouse sector transition towards automation.

5.0 Approach and Data Management

The study applied the foresighting methodology developed by the HVM-Catapult to identify future workforce and skills (HVM-C, 2021). A detailed description of the process can be found in Annex 2. Figure 3 illustrates the different steps involved in this methodology. It also summarises how the process took place in this study. In general, there were two stages. The first stage, called Step Zero, developed a shared understanding of the challenges and technical solutions for the automated FPP. In an interactive approach, experts on the fresh produce sector were first interviewed, and later, findings were shared with them to seek agreement. Forty-one experts from the FPP sector were interviewed about sector challenges, technology contribution, and skills status.

The second stage refers to the different steps constituting the foresighting cycle. The cycle involved preparatory actions to define stakeholders' scenarios and to select three job roles to focus in upon. These three job roles were: a) Technical Operator (level 2/3 of qualifications) responsible of daily equipment operation, maintenance and repair); b) Engineer (level 3/4/5 of qualifications) responsible of overall automation operations and engineering processes), and Advanced Engineer (level 6/7 of qualifications) responsible for automation integration and design, technical and commercial leadership.

The first three steps consisted of activities with the three groups of sector experts (9 technology specialists, 8 packhouse operators and 19 educators) using online workshops and surveys to generate 1,160 future knowledge and skills (K&S) statements for three job roles (technical operator, engineer and advanced engineer) needed in automated fresh produce packhouses. In the fourth step the future K&S statements were analysed in a matching exercise called Map and Gap (M&G) against 1010 current K&S statements on 325 apprenticeship standards from the Institute for Apprenticeships & Technical Education (IFATE). These Apprenticeship Standards and Qualifications were used to compare the future K&S needs with the K&S standards of the current apprenticeship provision, mainly from the Engineering and Manufacturing (89%) and Digital route (11%). The last step consisted of an interactive feedback process sharing the main findings and recommendations with participants of the Fresh Produce Consortium Careers event that took place on the 16th of March of 2023.



Source:HVM-C (2021)

Figure 3. The HVM-Catapult Foresighting skills methodology (a) and its application in this study (b).

This study represents a proof of concept of the HVM-C methodology. Lessons from implementing this methodology have been integrated into following foresighting exercises in other sectors.

6.0 Results, insights and recommendations

This section describes process results, findings, thematical insights and recommendations.

6.1. Process results:

<u>Uneven distribution of Future K & S Statements by Organisational Capability and Job Role</u>

The distribution of the 1168 future knowledge and skills statements (FK&Ss) is unequal, as Figure 6 illustrates. An uneven allocation exists between the six organisational capability functions and the twenty-five capability domains. Future FPP automation skills were concentrated in Enterprise (35%) and Manufacturing & Production (28%) capability functions. The domain with most FK&Ss was Statutory/Regulatory (11%), due to the importance of food safety procedures. Manufacturing & Production Monitoring and Supply Chain are well represented too.

Figure 6. Distribution of FK&S per capability functions and domains

When disaggregating the data considering the three job roles (Technical Operator, Engineer, and Advanced Engineer), most of the FK&Ss are concentrated in the Engineer role (see Figure 7). Concerning the capabilities distribution, the general distribution shows the relevance of Enterprise and Manufacturing & Production function capabilities (Figure 8). The Statutory/Regulatory capability domain has a continuously higher number of FK&Ss across the Technical Operator and Advanced Engineer cases due to food safety relevance. However, Leadership, Manufacturing & Production monitoring, and Supply Chain become more critical for the Engineer job role (Figure 8).

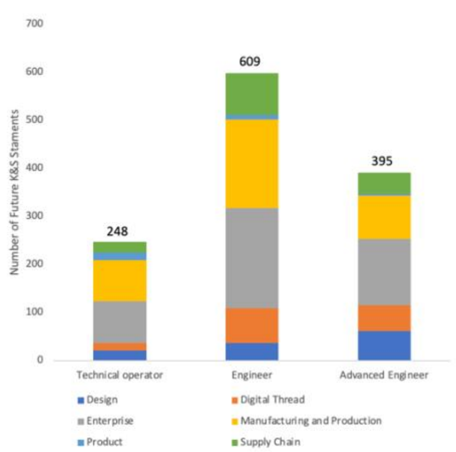


Figure 7. Distribution of FK&Ss per role

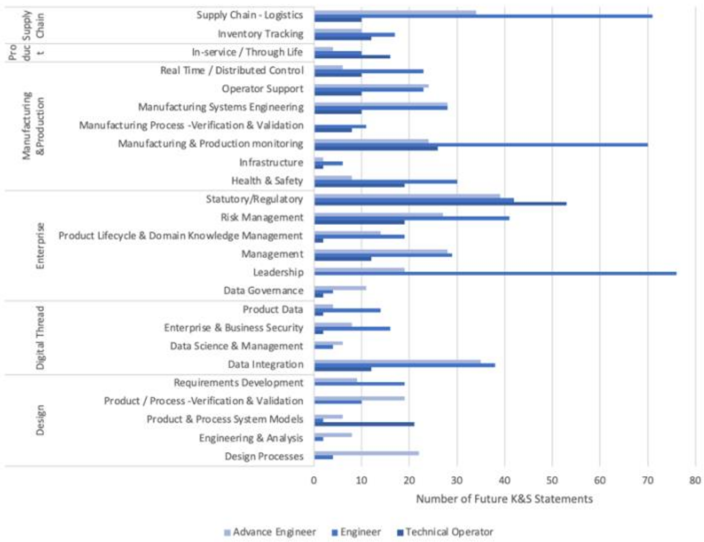


Figure 8. Distribution of FK&S statements per role and capability

6.2. Insights on thematic findings

<u>Gaps between the future and current knowledge and skills statements are greater as role levels increase (Advanced Engineer) based on the match / no match analysis</u>

Results showed fewer K&S gaps for the Technical Operator role (26%). In contrast, the highest number of gaps to be addressed are within the Advanced Engineer role (82%) (Figure 9).

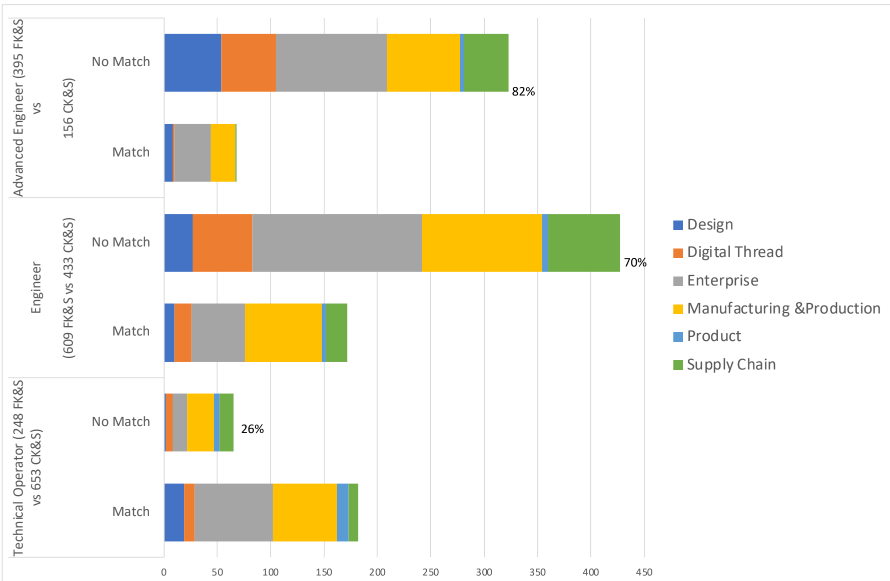


Figure 9. Match / No match analysis per role and capability

Furthermore, results show a good match between some capability requirements, e.g., Statutory and Regulatory (53%) and Manufacturing and Production Monitoring (51%). Nevertheless, relevant K&S gaps were identified in the Digital Thread (80%), Supply Chain (80%) and Design (70%) capabilities. No match existed for future K&Ss for Engineering Analysis and Infrastructure capabilities. K&Ss gaps also exist in capabilities identified by industry as the most relevant such as maintain / support vision systems and tools and design / implement robotic systems and tools. Table 3 presents examples of FK&Ss without a match (based on close AI association) with current Knowledge and Skills (CK&S) statements of the 325 Apprenticeship Standards tested.

Table 3. Example: FK&Ss without a match (close AI association) compared with current Standard Knowledge Skills (CK&S) Statements

Capability function	Capability domain	Future Knowledge and Skills statements without match
Design	Engineering Analysis	• Design **AI and robotics systems** for automation • Decide what **AI and machine learning** methods to deploy in new systems • Critique **AI and machine learning** algorithms for suitability in automation • Investigate multi criteria **modelling** and **simulation**
Digital Thread	Data Integration	• Analyse how you have supported and maintained **communication protocols**, systems and tools in your workplace • Choose appropriate **security standard** (and critique the appropriate standard if they cannot design or implement) • Summarise **information** required to be shared / what information is required / collected at each step of the supply chain stop
Enterprise	Leadership	• Facilitate **debate** on how automation will change **job roles with managers and workers** • Prioritize **tasks, duties, roles and explain the principles** change management. • Recommend **training programmes** which will be needed to support automation of Packhouses inc. training programmes for staff for Change Management to support technological automation
Manufacturing & Production	Infrastructure	• Design a system or tool for **autonomous intra-site logistics** • Build **systems** to enable **autonomous handling** of product across a packhouse site • Choose vision and **autonomous navigation systems** to enable robotic **handling** of product between steps in the supply chain
Product	In service through life	• Operate systems and tools used to calculate **carbon, energy, water and plastic (single use) use/impact** • Assess **production actions against shelf lives** and provide feedback • Select specific tools in order to complete a **maintenance repair procedure** on a specified item of machinery.
Supply chain	Inventory tracking	• Acquire data from **visual sensors** in different modalities and under different operating conditions • Choose appropriate **vision algorithm** for the specific environment/task and explain reasons for selection

Results from the fit/supply analysis indicate that currently, there are no standards that are good or fair candidates to adopt and adapt for responding to the FK&S statements defined in the foresighting exercise (see Figure 10). Standard ST0662 (Automation and controls engineering technician) appears as a poor candidate for adoption or adaptation for the Technician Operator and Engineer roles as it presents medium fit and surplus levels. In the case of an Advanced Engineer all the current standards present a low fit level.

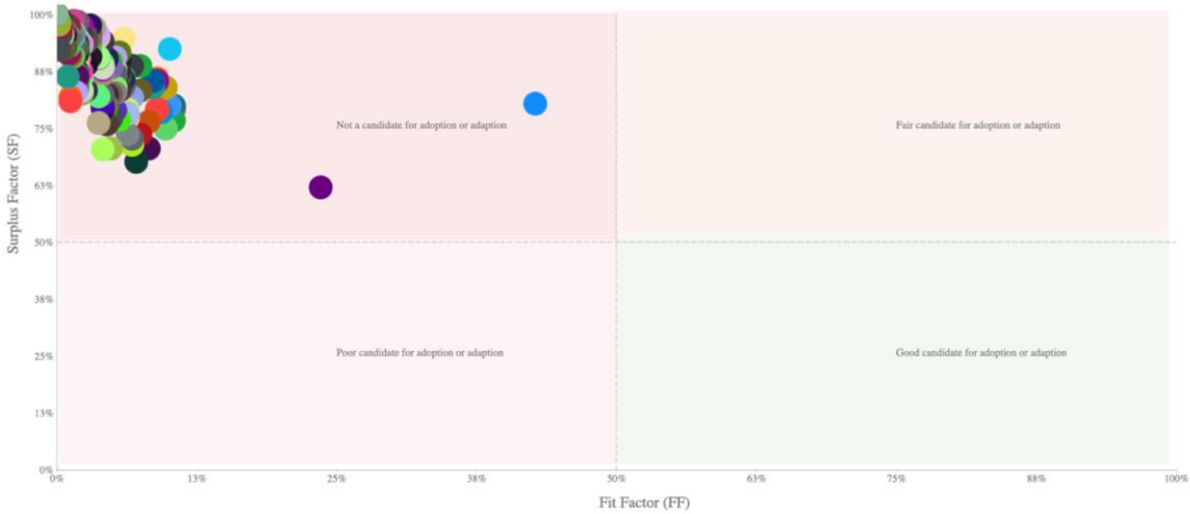


Figure 10. Fit & Surplus Matrix for the 325 Apprenticeship Standards tested

<u>The Foresighting approach can support Trailblazer groups in reviewing and developing Apprenticeship Standards through rapid identification of current K&Ss gaps</u>

This quantitative approach to identifying gaps in the education provision can become a tool that complements current schemes in which future training, and education schemes are developed. This is illustrated by the case of Apprentice Standard ST0023 for engineers, previously called Control Technical Support Engineer, which is now being developed as Control System Engineer. The foresighting approach demonstrates that the match percentage has increased in terms of the capability domains with the new standard (Control System Engineer) (see figure 11), i.e., the new Standard appears to encompass more of the FK&S requirements for this role, as defined by foresighting process.

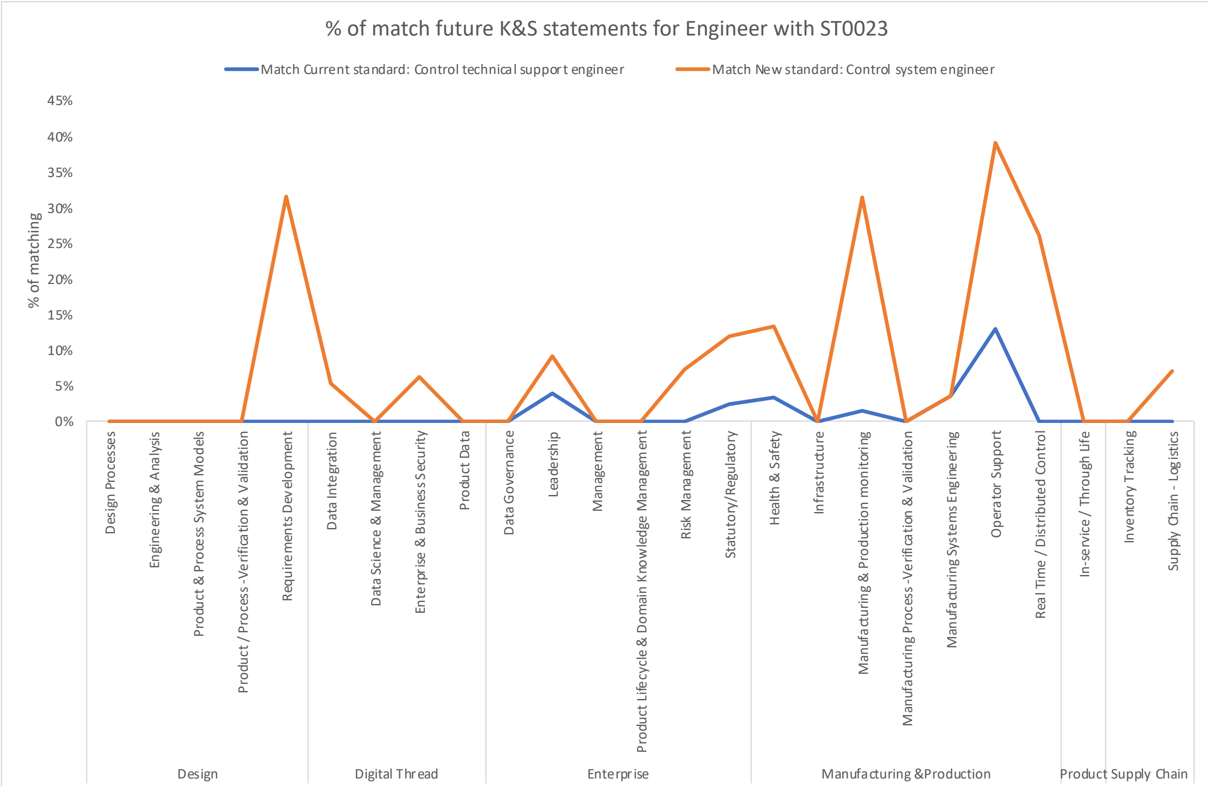


Figure 11. Match analysis of current and new version of standard ST0023

Nevertheless, as figure 11 illustrates, the matching percentage does not reach more than 35%, making evident the gap between the FK&S defined by the foresighting cycle and the Engineer job role. The new standard of Control system Engineer covers important gaps in requirements development (f.e. problem solving tools/techniques), manufacturing & production monitoring (f.e. assessment and monitoring techniques), and operation support capabilities domains (f.e. key performance indicators application). However, gaps exist in capabilities concerning technical (around cyber security and machine learning) as well as non-technical skills (such as teamwork/collaboration) that are crucial in the present and for the future of this position in fresh produce packhouse sector (Pye Tait Consulting, 2020). The prioritization of future K&S statements appears as an obligatory step for their potential use within education provision processes working with Trailblazer groups to discuss and agree on the statements that will be incorporated during the review or creation of new IFATE standards. Foresighting skills gaps do not only occur in the fresh produce agri-food sector (Pye Tait Consulting, 2020). It has been also reported as a concern for the engineering and manufacturing employers in the UK as applicants are missing both specialist technical and soft/teamwork knowledge and skills (IET, 2021).

6.3 Recommendations

a) Integrate both technical and non-technical skills in future education schemes to provide an appropriate workforce in an automated FPP

The study suggests that both technical and non-technical transferable skills, like "leadership", "project management", "teamwork," "project management", and "negotiation" will play a key role in the FPP industry to develop as "informed clients" and facilitate the transition towards automation. Technology supply companies will also have a role to play in this process through training and knowledge sharing. Non-technical skills were found to be a pre-requisite for the automation of the FPP both during the interviews and the review of relevant literature on automation (Bughin et al., 2018; Yusuf et al, 2020; Rawboon et al., 2021), as well as being signposted by the emphasis on the Enterprise domain.

A distinctive characteristic of the current FPP workforce referenced during interviews, is the predominantly lower academic attainment levels highlighting the need for basic skills in numeric literacy and English proficiency. These basic skills were not considered in this study, and they are normally overlooked in the development of current education and training provision.

b) Promote a multifaceted, flexible training and educational provision to address twin challenges of educating new entrants whilst also developing the existing workforce

The labour and skills shortages in the sector call for solutions in different facets of the current training and education provision (see figure 12). Solutions will necessarily involve enhancing *"on the job training", which* currently represents 80% of total sector training (Pye Tait Consulting, 2020). Solutions should also contemplate the key role of robotic suppliers in the training of both new and current staff. "Bitesized" training and education provision via short courses or top ups from CPD for upskilling low-academic levels workforce. These options will be critical for developing responsive, short-term solutions for the deficit in technical and non-technical skills, in conjunction with micro-credit courses from higher education provision.

These labour crisis challenges also call for a transformation of the current apprenticeship provision (with a low uptake of 0.3% of apprentices/trainees (Pye Tait Consulting, 2020) by increasing flexibility, responsiveness and relevance in the way standards are developed. Standards must also include transferable, generic non-technical skills that facilitate the high levels of mobility and turnover of the sector workforce. Moreover, the current push for automation also requires immediate action to raise awareness of the automation possibilities available and to facilitate cross-sector knowledge exchange within different industries in the fresh produce packhouse sector.

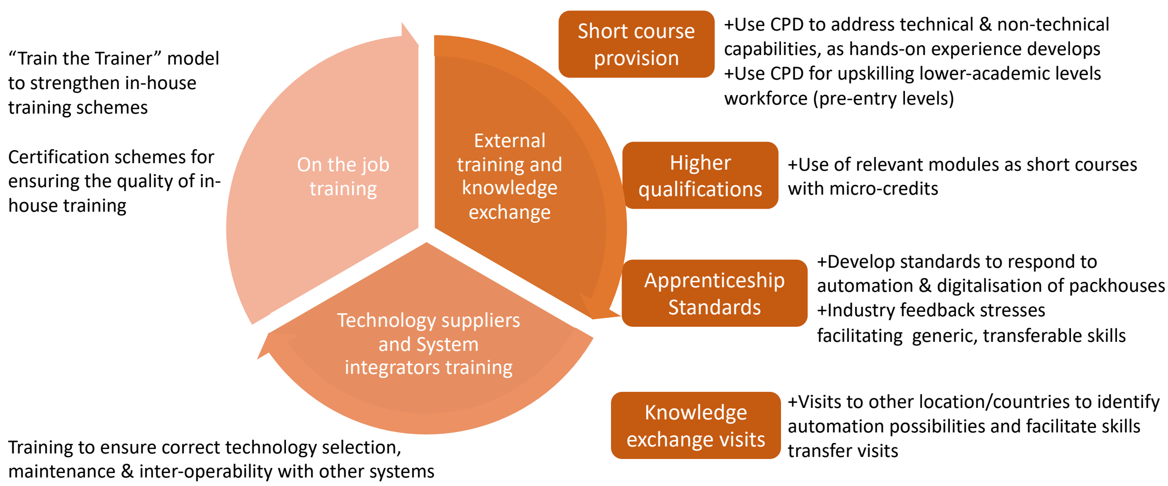


Figure 12. A multifaceted, flexible training and education provision for the fresh produce packhouse sector

c) Review/change current education provision as part of system-wide transformation of the FPP sector to achieve automation

Reviewing or changing the current education provision needs to be integrated into the systemic sectoral transformation that the FPP sector requires for automation (see figure 13). Tailor-made technologies, processes, and infrastructure changes are required to respond to the sector's particular challenges. There is also a need for support from the different value chain actors (like government and retailers) and collaboration within the sector. Particular attention should be paid to the agri-food and UK employment and workforce dynamic, as this will define the possibilities of the education schemes. For instance, to overcome challenges with the current schemes (Bootcamps in 2023), such as eligibility criteria (residence and language) and responsiveness for rapid skills provision update/turnover (5 to 7-8 years cycles) for all the levels, there will be the need to piloting new training and education provision schemes that could be non-accredited apprenticeships standards, tailored-made online teaching, or other short sharp training opportunities.

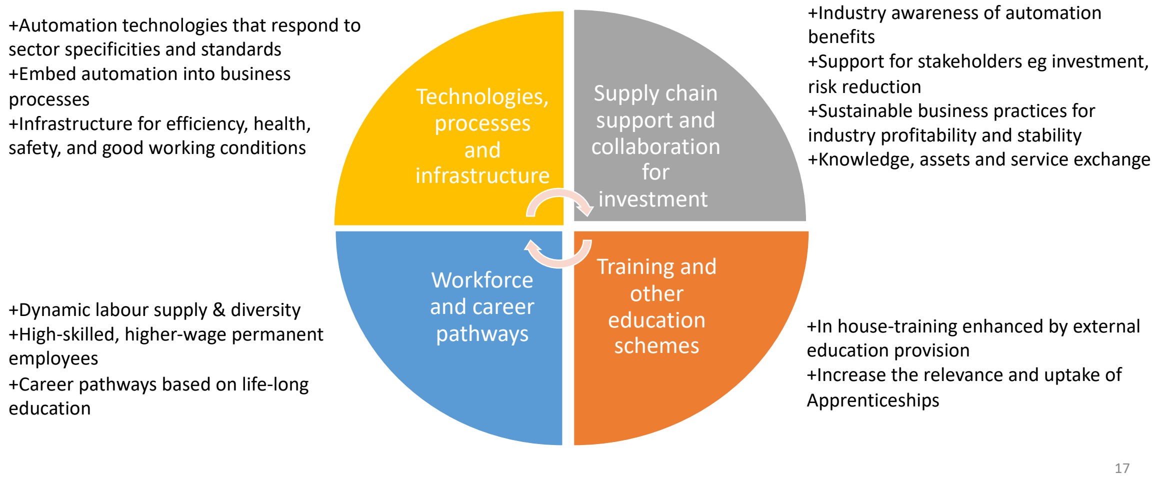


Figure 13. A system-wide transformation pathway for the FPP sector to achieve automation

7.0. Conclusion

The project generated evidence about the need to transform current education provision in the context of a systemic transformation of the fresh produce packhouse sector towards automation. The study focused on the knowledge and skills requirements for three job roles (Technical Operator (L2 &L3 qualifications), Engineer (L3 & L4 & L5 qualifications) and Advance Engineer (L5 & L6 qualifications)) as well as four capability functions and twenty-five capability domains that will be critical for the future automated fresh produce packhouses. Results demonstrated a good match between some capabilities associated with food safety ("Statutory and Regulatory") and "Manufacturing and Production Monitoring". Nevertheless, the study also identified technical and non-technical knowledge and skills gaps (K&S) in the current apprenticeship provision. These are fewer for the lower-level Technical Operator and more significant for the higher-level Advanced Engineer job. Further studies are required to identify the future training and education requirements for other crucial job roles for the packhouses as well as other stakeholders such as equipment suppliers, growers/farmers, and system integrators. Technology providers and system integrators will play a predominant role in facilitating skills transfer to the sector.

Participants highlighted the need to challenge several aspects of how education and training is currently provided. The apprenticeship scheme raised particular concern, and participants asked for increasing flexibility in how standards are developed to ensure that Apprenticeships remain responsive and relevant within a dynamic environment. Flexibility in education schemes is needed to adapt to current and future agri-food workforce particularities concerning their nationality, education levels, the high personnel turnover, and the rapid need for skills updates. Meeting training needs outside of the apprenticeship system will require resources to deliver the skills and capabilities needed in the automated environments of the future, given the need for existing workforce skills development and low take-up of Apprenticeships by the sector. More understanding and discussion are needed to define and implement actions to transition from a current concentration of in-house training towards a more distributed, multi-faceted training strategy that will attend twin challenges of educating new entrants while developing the existing workforce. This will mitigate initial bottlenecks in the supply of new entrants to the sector and the potential for movement between (highly automated) sectors to maintain a sufficiently high number of appropriately skilled workers within FPPs.

Transforming the current education provision to facilitate a smooth transition to fresh produce packhouse automation is vital to responding to the sector labour crisis challenge. This chronic challenge demands a system-based transformation of industry training and education provision to underpin a future fresh produce packhouse sector that is more sustainable, equitable and profitable. An integrated approach is needed to face the several challenges that contribute to the labour crisis in which training, and education provision efforts should be aligned with other actions in employment, stakeholder support and technology development. One fundamental challenge that requires further attention is transforming the negative and poor perception of the sector to a more positive perception of career pathways with high quality and inclusive employment that makes the fresh produce packhouse an attractive sector for aspirational and ambitious workers.

8.0. Reference

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Annex 1. Challenge of the Fresh Produce Packhouse (FPP) sector

1. **Challenge Title:**

Addressing the impact of reduced labour availability and increased wages in the fresh produce packhouse sector, whilst promoting efficiency.

2. **Challenge single sentence description:**

The labour challenges on workforce and skills' availability, and the increasing labour costs in the UK fresh produce packhouse are rooted in short and long-term systemic challenges around the agri-food system, employment, and education.

3. **Challenge description**

The current labour crisis of the UK food chain with 500,000 estimated vacancies in 2021 (FDF, 2021), appears as the major challenge of the Fresh Produce Packhouse (FPP) sector. This crisis calls for a major sectoral transformation that will not only respond to workforce and skills shortage and increasing labour costs; but also, to an increasing demand of fresh produce. Increased local demand stems from national and international trends towards healthier diets, lower environmental footprints, and greater resilience for future disruptions (National Food Strategy; 2021, FAO, 2017; Future, Food, and farming, 2011, The future of food, 2020).

The labour crisis in the FPP sector is a chronic problem that requires both short and long-term solutions to ensure the availability of both seasonal and permanent jobs (Nye and Lobley, 2021, Pye Tait Consulting, 2020). Recent disruptions build on long-term sectoral challenges (see Figure A1) to create a perfect storm that needs immediate responses which can also contribute to long term solutions (FDF, 2021). Failure to respond to this challenge is not an option as its impacts are directly affecting FPP business survival as a wide range of evidence from sector businesses and organisations show (evidence documents to the UK Parliament[3]). However, it is expected that the labour crisis would have a differential effect within the sector. For UK products with international competitors, this could imply making overseas packing and processing more attractive (EFRA, 2022). In products with a competitive advantage for local supply, this could promote the reduction of the number of FPPs towards further consolidation and automation.

A sectoral transformation is required to overcome a wide range of constraints that contribute to the FPP labour crisis (see details in the systemic transformation section of the graphic). Recent disruptions associated with Covid-19, the Ukraine war, and new post-Brexit trade and migration policies, call for a sector that is more resilient (Mitchell et al, 2020). Moreover, sectoral stakeholders need to implement the following structural transitions:

[3] Evidence of labour shortage in the UK agri-food sector written in 2021 by G's Fresh (LS006), Lea Valley Growers' Association (LS0020), the Ornamental Horticulture Roundtable Group (LS0021), the Fresh Produce Consortium (LS0038), the Cucumber Growers Association (LS0006), British Summer Fruits Limited (LS0017), and Lincolnshire County Council (LS0051)

Productivity growth through investment, including:

a. To move from a reliance on high numbers of low-skilled, low wage and temporary employees towards fewer, higher skilled, higher-wage and permanent jobs
b. To improve packhouse infrastructure to deliver more efficiency, sustainability, safety, healthy, and good working conditions
c. To invest and develop sustainable business practices in a sector characterised by low margins and short-term contracts

Investment in skills and workforce:

a. To transform the sector workforce from an ageing home workforce demographic and a reliance on migrant seasonal workers towards permanent dynamic labour supply reflecting equity, diversity, and inclusion
b. To promote the transition from unclear career progression and limited upskilling opportunities that create high turnover rates to a clear career pathway based on life-long education and progression and ensure employee retention
c. To transform the sector's perception away from the perception of poor working conditions to a positive perception of clear career pathways with decent and inclusive employment that makes FPP an attractive sector for aspirational and ambitious workers
d. To move from a high percentage of in work training to a hybrid range of provision (e.g. short courses through to apprenticeships) in which in house training is combined with external training programmes

Investment in partnership and collaboration:

e. To promote collaboration for knowledge exchange and assets and service sharing in a currently competitive and knowledge fragmented sector

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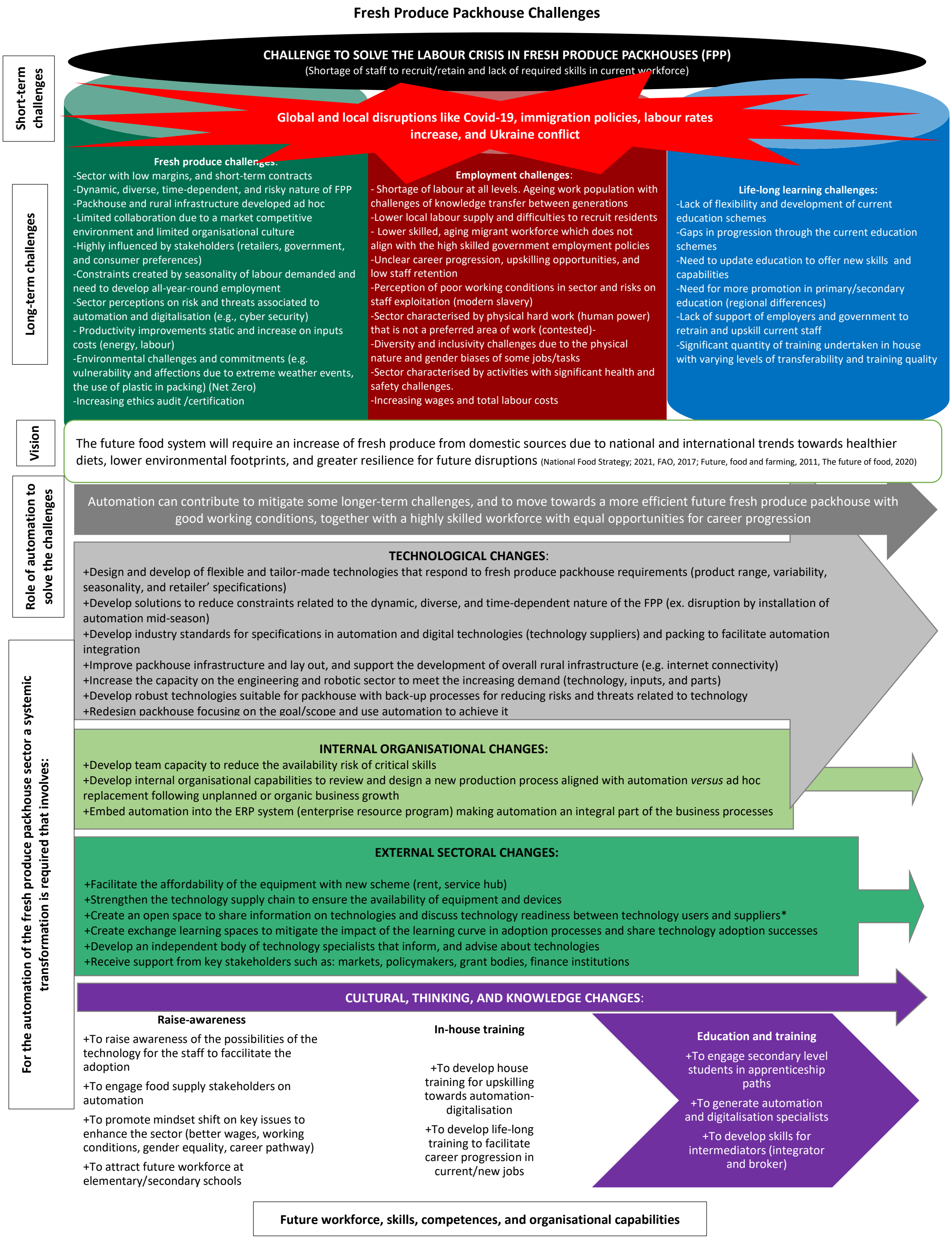
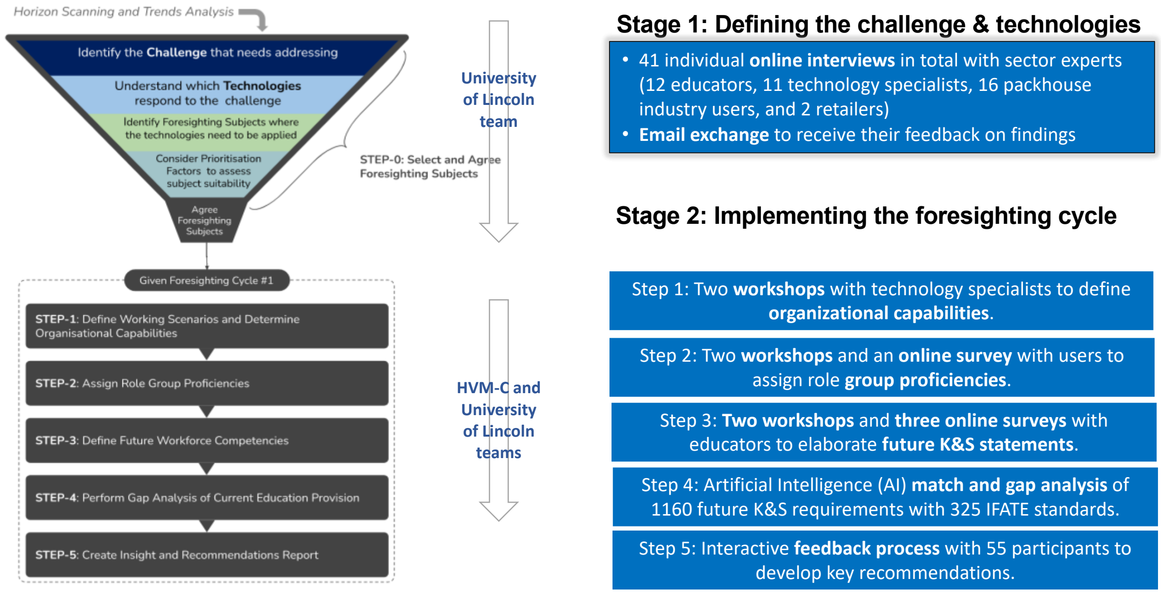


Figure A1. Challenges in the fresh produce packhouse sector

Annex 2. Detailed description of the approach and data management

The study applied the foresighting methodology developed by the HVM-Catapult to identify future workforce and skills (HVM-C, 2021). Figure 3 illustrates the different steps involved in this methodology. It also summarises how the process took place in this study. In general, there were two stages. The first stage was to select and agree on foresighting subjects (based on challenges and technologies). The second stage refers to the different steps constituting the foresighting cycle. As this study represents a proof of concept of the HVM-C methodology, we give a general description of the activity, and the approach used. We also share comments and discuss lessons learned on the implementation of the methodology and the outputs.



Source:HVM-C (2021)

Figure 3. The HVM-Catapult Foresighting skills methodology (a) and its application in this study (b).

1. Activity/Step 0. Select and Agree on Foresighting Subjects

This step covers the identification of challenges, and technologies that can respond to these challenges, as the basis for selecting technologies that will follow the foresighting cycle. We took an interactive approach in which first, experts on the fresh produce sector were interviewed, and later, findings were shared with them to seek agreement. Forty-one experts from the FPP sector were interviewed about sector challenges, technology contribution, and skills status. These experts specialise in education (12 educators), robotic technologies supply or advice (11 tech specialists), FPP industry (16 users), and commercialisation (2 retailers). Upon sharing the findings from this phase, we received feedback from 34% of interviewees who agreed with the problematisation of the challenge (labour crisis created by a workforce and skills shortage), the technology (automation) and the required systemic transitions for the FPPs' automation (for more details see Annex 1).

Lesson learnt: Our approach to interviewing sector experts and key stakeholders generated a broad view of the chronic challenges that the labour crisis represents to the FPP sector. This view requires a significant sectoral transformation, which involves solutions that are not limited to workforce and skills issues but also cover sectorial challenges concerning profitability, sustainability, and resilience. In addition, interviewees highlighted challenges concerning the negative perception of FPP sector and the mindset' shifts needed for the transition towards automation. However, these considerations, whilst acknowledged within the challenge, were outside the scope and methodological approach of the foresighting cycle (Activity 1).

5.2. Activity 1: Foresighting Cycle

The implementation of this cycle was undertaken under the guidance of the HVM-Catapult team, following a methodology that has been previously implemented in other sectors (Lanham et al., 2022). Preliminary steps were undertaken to inform the following decisions:

a. To focus on one foresighting cycle due to the integrated approach for FPP automation systems, involving five groups of technologies (see figure 1).
b. The scope chosen was packhouse automation for complex handling and flexibility/agility to cover multi-line and multi-product FPPs (see figure 2).
c. The definition and description of three job roles supporting the automation of the FPP were developed, as described in figure 4.

ROLE GROUP #1: Technical Operator
Typically those with Level 2/3 qualifications

Broadly aligns to the Engineering Council's ***Technical Operator - Eng.Tec:***

- Use engineering knowledge and understanding to apply technical and practical skills.
- Contribute to the design, development, manufacture, construction, commissioning, operation or maintenance of products, equipment, processes, systems or services.
- Accept and exercise personal and team responsibility.

ROLE GROUP #2: Engineer
Typically those with level 3/4/5 qualifications

Broadly aligns to the Engineering Council's ***Engineer - I.Eng:***

- Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.
- Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.

ROLE GROUP #3: Advanced Engineer
Typically those with level 6/7 qualifications

Broadly aligns to the Engineering Council's ***Advanced Engineer - C.Eng:***

- Use a combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology.
- Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems.
- Provide technical and commercial leadership. Level 6/7 – equating to Bachelors and Masters level qualifications.

Figure 4. Job roles selected for the foresighting cycle.

The foresighting cycle followed the next steps:

Step-1: Define Working Scenarios and Determine Organisational Capabilities

Scenarios: The definition of the working scenario describes the contribution of four supply chain stakeholders to automated FPPs that is described in detailed in Figure 5.

RTO, EQUIPMENT AND/OR SERVICE PROVIDERS	GROWERS/PRODUCERS
In the future, they will need to develop new tailor-made solutions to current and emergent problems in the sector, such as managing fresh produce with complex handling requirements via vision, handling, inspection, systems, etc.	In the future they will cater for more advanced packhouse requirements, such as digilisation of workflow processes, information and forecasting, as well as handling and delivery changes, etc.
FRESH PRODUCE PACKHOUSES	**SYSTEMS INTEGRATORS**
In the future, they will need to be able to define, specify, fund, commission and operate autonomous/non-autonomous automation systems (inc. vision, AI/ML, handling, inspection, etc) in order to process multiple production lines with complex handling requirements (in line with bespoke retailers/distributors requirements).	In the future, they will need to adapt proven technological solutions (from other sectors) to deliver Agri-tech solutions that are cost effective and meet the productivity and sustainability requirements.

Figure 5. Key stakeholders' future working scenarios for the case of the FPP automation.

Lesson learnt: Foresighting focus, scope and scenarios were presented during the workshops to contextualise the discussion and activities. Stakeholders' scenarios were used during the workshops with technologists to assign capabilities to supply chain actors. However, they were not actively considered in the following steps of the foresighting cycle, which limited their potential use and benefit. We consider that more work is needed around developing the scenarios and the reinforcing foresighting scope during the workshops, to ensure that participants think about the future, and its possibilities, rather than the current state.

Organisational capabilities: The definition of organisational capabilities involved two activities. There was an initial selection of 43 organisational capabilities, which were defined by the lead technologist as necessary to equip supply chain stakeholders to meet the workforce challenge. These organisational capabilities referred to the capability classification proposed by HVM-Catapult as part of the foresighting methodology. This classification defines six capabilities functions, and twenty-eight domains as starting points. The foresighting cycle excluded the following capability domains: Research application TRL 1-4, Model based product definitions, Process Simulation, and Supply Chain – Collaboration. In the end, six capability functions and twenty-five capabilities domains were selected (see Table 1). This classification covers technical skills associated with non-autonomous and autonomous systems, digitalisation, and data management, as well as control systems technologies and machine monitoring) (Figure 1). The classification contemplates non-technical skills such as leadership and management.

Table 1. Selected capability functions and domains based on HVM-Catapult

Capability Function	Capability Domain	
Design	Design processes Engineering and analysis Product and process system models	Requirements development Product / process – verification and validation
Digital Thread	Data integration Data science & management Enterprise & business security	Product data
Enterprise	Data governance Leadership Management	Risk management Statutory / regulatory Product lifecycle & domain knowledge management
Manufacturing and Production	Health and Safety Infrastructure Operator support Manufacturing and production monitoring	Manufacturing process - verification and validation Manufacturing systems engineering Real time/ distributed control
Product	In service through life	
Supply Chain	Inventory tracking	Supply chain logistics

The second activity defined key organisational capabilities through two workshops with technologists. The objective of the first workshop was to review the initial organisational capabilities with a wider group and to define the additional ones required to meet the challenge. It took place on the 10th of May 2022, and nine specialists in robotics technologies participated. The second workshop assigned the agreed organisational capabilities to the relevant supply chain actors and assigned the appropriate capability syntax (level of knowledge between define/devise, design/implement, use/apply or maintain/support) for each supply chain actor. It occurred on the 19th of May 2022 with the support of five expert technologists.

Lesson learnt: As organisational capabilities become the backbone to define future knowledge and skills statements (K&S), we feel that further discussion, with the inclusion of additional stakeholders, is required to select a robust set of organisational capabilities. Although with this classification it was possible to generate 1,160 future K&S statements, concerns were expressed by some of the workshop participants. around particularities of the fresh produce sector, such as the language challenge of migrant workforce. Participants also highlighted the relevance of non-technical skills such as teamwork, project management and negotiation. Furthermore, difficulties in understanding technical language were highlighted by participants at the users and educators' workshops. Due to these issues, we recommend including representatives from industry and education during the selection of organisational capabilities to enrich discussion, rather than relying solely upon input from technologists.

Step-2: Assign Role Group Proficiencies

This step involved two workshops with employers (users) to define the level of proficiency required for each of the three role groups and each given organisational capability. The first workshop took place on the 1st June 2022 with eight participants who individually allocated proficiency levels in an online survey tool. The second workshop occurred on the 10th June 2022 with the participation of seven users, who used their expert knowledge to review the proficiency levels allocation from the first workshop. At the end of the 2nd workshop, each participant completed the second survey tool to prioritise the top 3 organisational capabilities.

Lesson learnt: We received feedback from employers (users) referring to two aspects of the methodology. The first aspect refers to technical/format issues of the online survey tool. The second aspect considers process/capacity related to difficulty in understanding the language and wording used, as it was found to be too "engineering" focused or "academic". The process also relies on access to colleagues and staff to respond to the survey and is therefore limited by time constraints to undertake this process. We recommend that foresighting language should be made more accessible to all stakeholders. More time could also be built into the process for respondents to complete each survey. Building upon this idea, some participants also highlighted the potential benefits of collaboration and efficiencies that could be realised through group discussion and responding to the survey questions in a collective manner.

Step-3: Define Future Workforce Competencies

This step involved educators' participation in defining the required Knowledge and Skills (K&S) statements that meet the organisational capability needs. This work was progressed in two workshops, plus three online surveys between the workshops. In the first workshop on the 20th June 2022, nineteen educators received an explanation of the foresighting cycle and how to create the K&S statements using the online survey. Deadlines were given to respond the online surveys: i) Seven days to generate K&S statements, ii) Two days to review the responses of another participant, and iii) Five days to revise responses based on reviewers' comments. Fifteen educators completed the online exercise. This exercise generated a total of 1168 future K&S statements for three job roles (technical operator, engineer, and advanced engineer) and two proficiency levels (expert and practitioner).

The second workshop occurred on the 4th July 2022 with seventeen participants. The aim of this workshop was to review and confirm the map and gap analysis. However, the workshop was used to discuss participants' feedback, review the competencies and the standards, and explain the gap analysis and the mapping validation.

Lesson learnt: We received feedback from educators referring to three aspects of the methodology. The first aspect covers technical/format issues of the online surveys. It also covers limitations of the verbs provided, the multiplicity of functions, repetitions and overlaps, and biases in the vocabulary (weighted to skills rather knowledge). The second aspect considers process/capacity issues related to: the time required to answer the three surveys (more time required). Participants flagged the need for organisers to consider participants' background and educational specialisms for matching the development of future K&S, particularly technical/engineering capabilities. Finally, the third aspect refers to potential tensions between the foresighting method developing K&S statements *versus* other schemes like Trailblazer groups. Participants felt they would benefit from a collective creation of statements rather than developing K&S statements in isolation. Our recommendation is to discuss and agree on this process with educators to improve engagement/commitment and increase the potential application of the generated K&S statements.

Step-4: Perform gap analysis of the current education and training provision

The HVM-Catapult team implemented this step during July 2022. The future K&S statements were analysed in a matching exercise called Map and Gap (M&G) against 1010 current K&S statements on 325 apprenticeship standards from the Institute for Apprenticeships & Technical Education (IFATE) (see details in Table 2). These Apprenticeship Standards and Qualifications were used to compare the future K&S needs with the K&S standards of the current apprenticeship provision, mainly from the Engineering and Manufacturing (89%), but also from the Digital route (11%). During the foresighting exercise, two new versions of the standard (not accessible on IFATE webpages) were integrated into the exercise (standard ST0023 and standard ST0027).

Table 2. Summary of data used to perform the gap analysis

Data elements	**Value**
Capability business functions	6
Capability domains analysed	25
Business activity statement generate	170
Role group analysed (operator/engineer/advance engineer)	3
Proficiency levels analysed (expert/practitioner)	2
Future K&S Statement Generated	1168
Apprenticeship Standards Reviewed	325
Current K&S Statement Matched	1010

The Map and Gap (M&G) analysis uses machine learning to compare sentences and produce a **similarity score between 0 and 1**, where sentences with a similarity score of 1 are taken to be semantically identical. The process uses OpenAI's large language models and cosine similarity to calculate a similarity score for each pair of sentences. The M&G analysis generates a binary match / non-match result for each sentence comparison. The analysis also calculates a **fit-factor** and a **surplus factor** to provide quantitative measure (percentage) of how well or not an existing standard covers the future K&S statements (see details in Picker et al., 2022). The results of these analyses were accessible in a Power BI report developed by the MTC facilitating further exploration.

Lesson learnt: This step generates useful data for a quantitative comparison between future and current K&S statements. We only have a minor recommendation to integrate a data curation step before running this analysis to increase data accuracy and analysis reliability.

Step-5: Create Insights and Recommendations report

This step involved several activities. The first consisted of further data analysis of the K&S database to generate findings. The second activity was an interactive process of presenting these results to various key stakeholders, to identify insights and discuss recommendations. Several meetings took place during September and October of 2022 with the industry sponsor, lead educator, lead technologist, and the lead user to integrate their feedback into the analysis. Meetings occurred in October and November of 2022 to present and discuss results with the Steering Group and other key stakeholders. The product of these interactions was an executive report shared with fifty-five study participants for their feedback in January 2023. Feedback was received from three participants, who expressed their agreement on the current sector challenges. The industry sponsor indicated that findings were more useful for education and training providers than the industry as it focused on gaps in the apprenticeship provision but recognised the value of the collaboration between automation developers, employers, and educators to design new training, skills and education provision. Main project findings were presented on the 16th of March 2023 as part of the Fresh Produce Consortium Careers event. Final report elaboration occurred alongside these activities.

Lesson learnt: This step generated two lessons. The first lesson refers to communication of the study findings, as we received feedback concerning the difficulty of understanding technical terms and quantitative indicators (like the fit and surplus factors) compared to current sector language. The second lesson captures the challenge of incorporating insights from this quantitative approach to current schemes to develop curriculum, skills programmes and training. FPC as industry partner, indicated that it was challenging to engage in the process due to critical events that the industry was dealing with during this process. The engagement of educators in the activities was limited as several expressed concerns about the process and how this quantitative approach complements the current schemes of development, training and education provision. Although a general recognition of the value of this study was expressed, the project has a limited impact to inform the elaboration of the current training and education provision. We recommend that more efforts should be done in the context of this type of project to enhance the collaboration between educators, users, and technologists by increasing common understanding, common language (syntax) and creating spaces for agreements.

During this step of implementation, the relevance of the following study caveats became evident:

- The pilot study focused on a generic FPP environment, from when the bulk product enters (intake) to when the packed product leaves (dispatch). Therefore, wider dependencies, such as creating the right financial environment to support automation, were outside the scope of this study.
- A proportional sample of expert industry stakeholder, robotics and automation providers, packhouse operators and educators, contributed to the study. Results are subjective in part as they are based on their individual and collective knowledge and experience.
- Given that this pilot study was a proof of concept, the project did not consider all job roles within the FPP. Rather it focused on only three job roles chosen through the foresighting process. These roles were not readily recognisable for those participants who remained in the present rather than imagining the future.
- Future knowledge and technical and non-technical skills gaps were identified with comparisons to the current Apprenticeship Standards (and some in progress) from the Institute for Apprenticeships and Technical Education (IFATE). Other provision/schemes required to respond to the labour crisis, such as Continuous Professional Development, were not covered in the scope of this study.
- The HMV-Catapult foresighting methodology focuses predominantly on future knowledge and skills needed to support automation. However, the future state was not defined at the outset or consistently applied throughout the foresighting activities, which led to some confusion between future and current skills challenges. Both are important to discussing future skills, however only the future state was relevant to this study.
- The K & S gap analysis was a quantitative study, which did not rank future K & S statements according to relevance for the industry.
- This study acknowledges that Apprenticeships are only one aspect of addressing skills gaps. Other opportunities, such as short courses (CPD) and in-house training should be considered due to their relevance.